ISSN 1847-2001 (Print)
ISSN 1848-2295 (Online)

Central European Conference on Information and Intelligent Systems

CECIIS



28th International Conference 2017

Organized by:
University of Zagreb
Faculty of Organization and Informatics

September 27th - 29th, 2017
Varaždin, Croatia

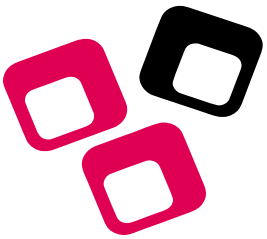
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ISSN 1848-2295 (Online)

UDC 004:007

University of Zagreb
Faculty of Organization and Informatics

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Publisher
Faculty of Organization and Informatics, University of Zagreb
Pavlinska 2, HR-42000 Varaždin, Croatia

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CECIIS Proceedings have been indexed in the following databases: INSPEC, ProQuest (SciTech Premium Collection, ProQuest Technology Collection and ProQuest Adavanced Technologies & Aerospace Database).

ISSN 1847-2001 (Print)
ISSN 1848-2295 (Online)

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Preface

During the twenty-eight-year period of the annual conference, the Central European Conference on Information and Intelligent Systems (CECIIS) has become one of the most important conferences in the area of applied information science in Central Europe. International participants, program committee and reviewers were a prerequisite for referring the Conference's Proceedings to prominent bases. The conference and accompanying events are certainly the most significant scientific event organized by the Faculty of Organization and Informatics at the University of Zagreb.

The main aim of CECIIS is to foster the cooperation among researchers involved in the development and application of methods and techniques in the field of information and intelligent systems. These Proceedings of CECIIS 2017 contain 38 scientific papers that were double-blind peer reviewed by two independent reviewers and approved by the international Program Committee within eight research tracks: Data and Knowledge Bases, Education and Learning Analytics, Emerging Trends in ICT, ICT Entrepreneurship and Innovation, Intelligent Information Systems, Quality of Software and Services, Software Engineering, Strategic Planning and Decision Making. The poster and presentation section for students is also a part of CECIIS, with student poster abstracts published separately on-line. After the conference, the selected papers will be further reviewed by two independent international reviewers with the possibility of being extended and included in the Journal of Organizational and Information Sciences (JIOS), the international scientific journal published by the Faculty of Organization and Informatics.

The special value of this year's conference is featured by outstanding invited lecturers, researchers who have left a deep mark in the scientific and professional areas they deal with. Within the CECIIS 2017 the following three invited lectures were presented:
Bran Selić (Malina Software Corp., SAD), On the Engineering of Software-Based Systems for the 21st century;
Sokratis K. Katsikas (NTNU - Norwegian University of Science and Technology, Norway), Security and Privacy Challenges in Intelligent Information Systems.

Furthermore, several parallel events were held:
e-Schools Day - presentations and workshops of the project "e-Schools: Establishing a System for Developing Digitally Mature Schools (pilot project)";
presentation of projects e-Schools, DIGITRANS and CRISS;
Workshop on Data Analysis;
as well as CECIIS 2017 conference sponsors' events.

An important part of the CECIIS 2017 conference is the panel discussion entitled "Academy-Industry Cooperation: Applied Research in ICT", which has brought together prominent researchers, managers of major ICT companies and policy makers. We would like to express kindly gratitude to all the authors, presenters, reviewers, session chairs, attendees, organizers of parallel events and, above all, our invited speakers for their contributions. We acknowledge that the organizational and supporting assistance and hosting of the Faculty of Organization and Informatics was crucially important for the overall success of the Conference. We would like to extend our appreciation to the Program and Organizing Committee members.

Finally, we are most grateful to all our industrial partners and sponsors for their support.
We believe that inside these covers you will find relevant and interesting papers in the field of information and intelligent systems. We also look forward to your participation in one of many CECIIS conferences to come.

September, 2017

On the behalf of the
Program and Organizing Committees

Vjeran Strahonja and Valentina Kirinić

Data and Knowledge Bases

Marko Horvat
A Brief Overview of Affective Multimedia Databases

Dražena Gašpar, Mirela Mabić, Tihomir Krtalić
Integrating Two Worlds: Relational and NoSQL

Slavica Kordić, Sonja Ristić, Milan Čeliković, Vladimir Dimitrieski, Ivan Luković
Reverse Engineering of a Generic Relational Database Schema Into a Domain-Specific Data Model

Ivan Srdić, Gordan Gledec
Contextual Spellchecking Based on N-grams

A Brief Overview of Affective Multimedia Databases

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Abstract. *Multimedia documents such as videos, images, sounds and text inevitable stimulate emotional responses which can be measured. These documents are stored in dedicated affective databases along with descriptive metadata such as emotion and semantics. The landscape of multimedia databases for elicitation and estimation of emotions is very diverse. The databases are continuously employed in many areas such as psychology, psychiatry, neurosciences and cognitive sciences in studies of emotional responses, anxiety, stress, attention, cognitive states and in brain research. Their data models are also being increasingly used in computer science for sentiment analysis, multifaceted search in multimedia retrieval and automated recognition of emotions. Because of their growing relevance, it is important to compile a concise overview of the most important multimedia databases for stimulation and estimation of emotions. The aim of the paper is to help domain experts to find more easily the optimal database for their research, and others to quickly familiarize themselves with this area. The overview lists 24 most recent and frequently used affective multimedia databases, which jointly contain 126,805 emotionally-annotated multimedia documents, and describes their quintessential properties.*

Keywords. affective computing, multimedia, databases, emotion stimuli, emotion estimation

1 Introduction

Even though not immediately apparent all multimedia documents provoke emotional reactions of different intensities and polarities (Coan & Allen, 2007). Human-computer interfaces allow users to observe pictures, video clips, generated graphics, read text or listen to sounds, music and human voices which all, deliberately or inadvertently, modulate their emotional states (Brave & Nass, 2003). This spontaneous cognitive process has many practical applications in cognitive sciences, psychology and neuroscience (Frantzidis et al., 2010). Affective multimedia is also very important for various computer science domains such as affective computing and human-computer interaction (Palm & Glodek, 2013). Combined with sufficiently immersive and unobtrusive visualization hardware such as Head Mounted Display (HMD) or high-resolution television sets in low-interference ambient affective multimedia databases provide a simple, low-cost and efficient means to scientifically study emotional impact (Villani & Riva, 2012). Overall, the scope of emotion-related research is growing and, accordingly, the importance of these databases is steadily increasing.

Multimedia documents with annotated semantic and emotion content are stored in affective multimedia databases. Apart from digital objects these databases contain meta-data about their high-level semantics and statistically expected emotion that will be induced in a subject when exposed to a multimedia document. The semantics is annotated manually by researchers and emotions are estimated in controlled experiments with human subjects.

The paper provides a short overview of the most important contemporary affective multimedia databases containing video, general pictures, pictures of faces, audio and text. It is impossible to list all databases in a short format since new ones are continuously being developed. Further, many are either small or not publicly available and constructed for specific experiments.

2 Properties of affective multimedia databases

Contemporary affective multimedia databases are not relational databases or complex structures for massive storage of multimodal data. In fact, they are simple repositories of audio-visual multimedia documents such as pictures, sounds, text, videos etc. with described general semantics and emotion content. Two distinct features differentiate affective multimedia databases from other multimedia repositories: 1) purpose of multimedia documents and 2) emotion representation of multimedia documents. Multimedia documents in affective multimedia databases are explicitly aimed at inducing or stimulating emotions in

exposed subjects. As such they are usually referred to as stimuli. All multimedia documents (i.e. stimuli) in affective multimedia databases have specified semantic and emotional content. Sometimes they are accompanied with specific meta-data such as elicited psychological or neurological signals. Importantly, these databases are still very difficult to build, use and maintain (Horvat, Popović & Ćosić, 2013).

Affective multimedia databases are created by different groups of researchers and usually shared freely for scientific and educational purposes (Bradley & Lang, 2000). The databases are standardized which allows them to be used in a controllable and predictable manner (Horvat, Bogunović & Ćosić, 2014). With affective multimedia databases the process of emotion stimulation is not stochastic, unpredictable or singular but articulated, controlled and comparable to the scientifically established practices. An important consequence of the standardization is that the emotion elicitation effects can be measured, replicated and validated by different research teams. Before standardized affective multimedia databases have been developed researchers had to create unique stimuli sequences for each emotion experiment. Stimuli used in one laboratory were rarely used by other laboratories. Attempts at recreating the same experimental materials from descriptions in the literature were time-consuming, difficult and prone to errors. Therefore, the development of affective multimedia databases represents a significant improvement in the study of emotions, behaviour and cognition.

The most cited affective repository for emotion elicitation is The Pictures of Facial Affect (POFA) (Ekman & Friesen, 1975). The Nencki Affective Picture System (NAPS) (Marchewka et al., 2014) together with its domain expansions The Nencki Affective Picture System discrete emotional categories (NAPS BE) (Riegel et al., 2016) and The Erotic subset for the Nencki Affective Picture System (NAPS ERO) (Wierzba et al., 2015) are the newest large general repositories. Examples of typical stimuli from some of the datasets are shown in Fig. 1.



Figure 1. Exemplar visual stimuli from four repositories. From top to bottom and left to right: NAPS (Marchewka et al., 2014), The International Affective Picture System (IAPS) (Lang, Bradley & Cuthbert, 2008), The Military Affective Picture System (MAPS) (Goodman, Katz & Dretsch, 2016), The NimStim Face Stimulus Set (Tottenham et al., 2009).

The following sections describe in more detail semantic and emotional models used in contemporary affective multimedia databases.

2.1 Semantic models

Affective multimedia databases have very simple semantic models. The stimuli are described with mutually unrelated keywords from unsupervised glossaries. Most often only a single keyword is used to describe a document. Moreover, lexical variations and synonyms are often used for description of similar concepts. Some databases organize documents in several semantic categories such as “people”, “objects”, “landscape”, “faces” etc. However, semantic relations between different concepts, and documents which they describe, are left broadly undefined. For example, in the IAPS a picture portraying an attack dog can be tagged as “dog”, “canine” and “hound”, “attack”, “attackdog” and “attack_dog”. Pictures displaying people are described with singulars and plurals such as “man” and “men” or “woman” and “women”. Natural language processing methods and more sophisticated knowledge representation schemes are necessary to improve information performance from affective multimedia databases (Horvat, Vuković & Car, 2016). Document retrieval is possible only with lexical relatedness measures since there are no criteria to calculate semantic similarity between concepts in query and document metadata descriptions (Horvat, Vuković & Car, 2016). More expressive and formal semantic models are not possible without modification of database multimedia descriptors and introduction of appropriate knowledge structures (Horvat, Bogunović & Ćosić, 2014; Horvat et al., 2009). As was already experimentally shown, the inadequate semantic descriptors result in three negative effects which impair stimuli retrieval: 1) low recall, 2) low precision and high recall or 3) vocabulary mismatch (Horvat, Bogunović & Ćosić, 2014; Horvat, Vuković & Car, 2016).

2.2 Emotion models

Documents in affective multimedia databases are described with at least one of the two emotion models: categorical and dimensional (Peter & Herbon, 2006). The dimensional model, which is also called Circumplex model of affect (Posner, Russell & Peterson, 2005) or Pleasure Arousal Dominance model (PAD) (Mehrabian, 1996), is founded on theories of emotion which propose that affective meaning can be well characterized by a small number of dimensions.

Dimensions are chosen on their ability to statistically characterize subjective emotional ratings with the least number of dimensions possible (Bradley & Lang, 1994). These dimensions generally include one bipolar or two unipolar dimensions that represent positivity and negativity and have been labelled in various ways, such as valence or pleasure. Moreover, usually included is a dimension that captures intensity, arousal, or energy level. In computer models these dimensions are described with two orthogonal vectors called valence and arousal which form a two-dimensional cartesian space. The length of the vectors, i.e. dimensional emotion values or normative ratings, are real numbers between 1.0 and 9.0. Such model is simple and easy to represent in digital systems.

In contrast to the dimensional theories, categorical theories claim that the dimensional models, particularly those using only two dimensions, do not accurately reflect the neural systems underlying emotional responses. Instead, supporters of these theories propose that there are many emotions that are universal across cultures and have an evolutionary and biological basis (Ekman, 1992). Which discrete emotions are included in these theories is a point of contention, as is the choice of which dimensions to include in the dimensional models. Most supporters of discrete emotion theories agree that six primary emotions exist: happiness, sadness, surprise, anger, fear and disgust. Basic emotions can be represented as areas inside the valence-arousal space. Their exact shape and location are individually dependent and have a developmental trajectory throughout a person's lifetime (Posner, Russell & Peterson, 2005). Dimensional and categorical theories of affect can both effectively describe emotion in digital systems but are not mutually exclusive. Some repositories already incorporate both theories of emotion – per example (Riegel et al., 2016). Annotations according to both theories are useful because they provide a more complete characterization of stimuli affect.

It has been experimentally proven that visual stimuli from the IAPS produce different responses in skin conductance, startle reflex, breathing and heart rate depending (Bradley et al., 2001a; Bradley et al., 2001b; Kukolja et al., 2014). Relationship of EEG signals to emotion phenomena is being intensively investigated (Wu et al., 2010). Recently new open-access toolboxes are being developed to simplify deep analysis of physiological time-series such as ECG and EEG (Jovic et al., 2016).

3 Catalogue of affective multimedia databases

The landscape of affective multimedia databases is very diverse. Mainly the databases are pictorial and small. A substantial number of databases are used rarely while some larger databases are employed frequently. To avoid negative effects of habituation emotion should be induced with visually and auditory different stimuli, but with the same or compatible semantics (Coan & Allen, 2007). Because of this reason researchers often employ the largest affective multimedia databases which are adequately diverse. Smaller databases with fewer different stimuli are employed only for small-scale or domain research where the lack of stimuli variety is less important.

The catalogue of affective multimedia databases is in Table 1. Apart from the POFA (Ekman & Friesen, 1975), the most important affective picture repository is The International Affective Picture System (IAPS) (Lang, Bradley & Cuthbert, 2008). Other significant databases are: The Geneva affective picture database (GAPED) (Dan-Glauser & Scherer, 2011), NAPS (Marchewka et al., 2014), NAPS BE (Riegel et al., 2016), NAPS ERO (Wierzba et al., 2015), as well as DIsgust-RelaTed-Images (DIRTI) database (Haberkamp et al., 2017), Set of Fear Inducing Pictures (SFIP) (Michałowski et al., 2017), MAPS (Goodman, Katz & Dretsch, 2016), Besançon Affective Picture Set-Adolescents (BAPS-Ado) (Szymanska et al., 2015), LIRIS-ACCEDE (Baveye et al., 2015), Geneva faces and voices (GEFAV) database (Ferdenzi et al., 2015), Child Affective Facial Expression Set (CAFE) (LoBue & Thrasher, 2014), Affectiva-MIT Facial Expression Dataset (AM-FED) (McDuff et al., 2013), Emotional Movie Database (EMDB) (Carvalho et al., 2012), DEAP: A Database for Emotion Analysis using Physiological Signals (Koelstra et al., 2012), NIMH Child Emotional Faces Picture Set (NIMH-ChEFS) (Egger et al., 2011), Radboud Faces Database (RaFD) (Langner et al., 2010), NimStim Face Stimulus Set (Tottenham et al., 2009), CAS-PEAL Large-Scale Chinese Face Database (Gao et al., 2008), International Affective Digitized Sounds (IADS) (Bradley & Lang, 2007a), Affective Norms for English Texts (ANET) (Bradley & Lang, 2007b), Karolinska Directed Emotional Faces (KDEF) (Lundqvist, Flykt & Öhman, 1998), Japanese Female Facial Expression (JAFFE) Database (Lyons et al., 1998) and, finally, Affective Norms for English Words (ANEW) (Bradley & Lang, 1999).

Altogether, there are 3 video databases (VID), 7 picture databases (PIC), 8 picture face databases (FAC), 1 video and face database (FAC VID), 1 video and sound face database (FAC VID SND), 2 with text (TXT) and 1 database only with sounds (SND). The stimuli are annotated with the discrete emotion model (DIS) or with the dimensional model (DIM), or both (DIM DIS). IAPS and IADS stimuli were originally annotated only with valence and arousal values but later emotion norms were also added (DIS*).

Table 1. The list of the most often used collections of audio-visual stimuli sorted from the newest to the oldest.

Name	Modality	Emotion	Stimuli No.	Published
DIRTI	PIC	DIM DIS	300	2017
NAPS/NAPS BE	PIC	DIM DIS	1,356	2014-2016
SFIP	PIC	DIM	1,400	2016
NAPS ERO	PIC	DIM	200	2015
MAPS	PIC	DIM	240	2015
BAPS-Ado	PIC	DIM DIS	93	2015
LIRIS-ACCEDE	VID	DIM	9,800	2015
GEFAV	FAC VID SND	DIS	111	2014
CAFÉ	FAC	DIS	1,192	2014
AM-FED	FAC VID	DIS	242	2013
EMDB	VID	DIM	52	2012
DEAP	VID	DIM	120	2012
GAPED	PIC	DIS	730	2011
NIMH-ChEFS	FAC	DIS	482	2011
RaFD	FAC	DIS	536	2010
NimStim	FAC	DIS	672	2009
CAS-PEAL	FAC	DIS	99,594	2008
IAPS	PAC	DIM DIS*	1,182	1997-2008
IADS	SND	DIM DIS*	111	1999-2007
ANET	TXT	DIM	60	1999-2007
KDEF	FAC	DIS	4,900	1998
JAFFE	FAC	DIS	213	1998
ANEW	TXT	DIM	3,109	1999
POFA	FAC	DIS	110	1976-1993

Some datasets had multiple revisions in the designated time frame. Annotations are explained in the text above. The newest repository is DIRTI being published in 2017, the largest is CAS-PEAL with 99,594 pictures of 1,040 individuals, and the most expressively annotated is NAPS/NAPS BE/NAPS ERO as single linked corpora. As can be seen facial expression databases, or face databases, are the most numerous modality among affective multimedia databases. they are employed in emotion elicitation, these databases are also often used in computer vision for face recognition and face detection. For a more detailed overview of these databases consult (Gao et al., 2008). The presented catalogue is not exhaustive, nevertheless it includes the most frequently referenced databases. Additional lists of affective multimedia databases which may be used for emotion estimation can be found in (Baveye et al., 2015; Zeng et al., 2009; Gao et al., 2008).

4 Conclusion

In this article we have presented a compact catalogue of affective multimedia databases. In total, 24 repositories were listed containing 126,805 documents of different modalities. The principal purpose of these databases is to provoke emotional reactions in a predictable manner. Their multimedia content is described with the dimensional or discrete emotion model, or sometimes both.

The wider field of affective multimedia databases research provides several interesting directions for investigation and development. Most importantly, these databases should be interlinked and become more practical through multifaceted queries combining semantics, emotion and other available metadata. Construction of new repositories must be facilitated, as well as creation of personalized stimuli sequences. Introduction of structured data sources has already shown promising results in document retrieval quality (Horvat, Grbin & Gledec, 2013). Knowledge discovery of integrated data could provide statistically significant indicators of hidden relationships between semantics and emotion (Horvat, Popović & Ćosić, 2012). Looking even further into the future, truly multimodal corpora containing haptic and olfactory stimuli are likely to be developed. Eventually, interactive virtual reality stimuli will become common-place.

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Integrating Two Worlds: Relational and NoSQL

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Abstract.*NoSQL databases emerged as a response to the Big Data challenges generated because of extensive use of Internet and Web applications. However, not all problems are the Big Data problems. Transaction-oriented problems still can be better-solved using relational databases, while NoSQL databases are better solution for the Big Data demands. Because the users want to analyze this data together, the integration of relational and NoSQL databases becomes necessity.*
The authors discuss two approaches to data integration between relational and NoSQL databases: native and hybrid solutions explained on the example of integration transactional data from Oracle databases with data stored in MongoDB.

Keywords. NoSQL, relational databases, native solution, hybrid solution, Oracle, MongoDB.

1 Introduction

Over the last ten years, the challenges related to the Big Data phenomenon have been the main driving forces behind NoSQL database development. There are many different and unclear definitions of the Big Data term. Usually, the definitions are related to domains and use different numbers of Vs to explain the Big Data. Firstly, the Vs refer to data volume, velocity and variety (Lanely, 2001). In 2016 IBM added veracity, while Microsoft added variability and visibility. However, these definitions are focused on data itself, not on the using the data as a tool for resolving business problems. That is the reason why Wu, Buyya, and Ramamohanarao (2016) in their definition of the Big Data started from the business view and use three aspects: data domain (searching for patterns), business intelligence domain (making predictions) and statistical domain (making assumptions). They understood that the purpose of data is to gain hindsight (i.e., metadata patterns from historical data), insight (i.e., a deep understanding of issues or problems), and foresight (i.e., more accurate predictions in the near future) in a cost-effective manner (Wu, Buyya, & Ramamohanarao, 2016). The development and practical implementation of both, NoSQL and relational databases, is showing that they were right. Today, after more than 10 years of development and use of NoSQL databases, it is clear that neither everything is good in NoSQL nor everything is so bad in relational databases. Not all problems are the Big Data problems, so transaction-oriented problems still can be better solved by using relational databases, while NoSQL databases are better in resolving the Big Data demands. But, the real problem is the fact that when business perspective of data is in questions, there is no always clear boundary between transactional and the Big Data requirements. Namely, database users are not interested in technical details about their data (about type of database, storage methods, database server, etc.), they just want to analyse their data together, regardless of whether the data are stored in relational or NoSQL databases. Business users are looking for patterns in their data, they need better insight of data in order to make better decisions and ensure further development and survival of their organizations in globalized, dynamic and turbulent world. Users' requirements related to data analysis through business intelligence (BI)tools have forced vendors of both, relational and NoSQL databases, to look for solutions that will enable them to integrate data stored in relational with data stored in NoSQL databases. Most of NoSQL vendors have recognized the necessity to provide support for Structured Query Language - SQL (Hive Query Language – HQL, Cassandra Query Language – CQL, Cypher, etc.) in order to attract more experienced developers and users, to enhance usability and programmer efficiency, and to provide easier integration with BI and analytical tools. On the other hand, most of relational databases vendors offer support for JSON (JavaScript Object Notation). The JSON is primarily used as data interchange format between a server and web application. It enables storing of JavaScript objects as text, avoiding complicated parsing and translations (JSON, 2017). When applications use JSON data stored in NoSQL database, it is their responsibility to ensure data integrity, but native support for JSON by relational databases means that these databases provide use of JSON together will all of the benefits of relational databases (transactions, indexing, declarative queries, etc.).

In this paper, the authors discuss two approaches to data integration between relational and NoSQL databases: native and hybrid solutions. These solutions are explained on the example of integration transactional data from Oracle databases with data stored in MongoDB.

2 Relational and NoSQL databases integration

The integration of relational and NoSQL databases is one of the possible solutions that can ensure that users get the best of the both worlds, high scalability and availability of NoSQL databases and transactions, integrity and standardization (SQL) of relational databases. During last few years different approaches, all with the same goal to ensure data integration and/or migration from relational and NoSQL databases, have arisen. Developing of Bridge Query Language (BQL) as a tool for interface standardization (Curé, Hecht, Le Duc & Lamolle, 2011) was one of the approaches. Atzeni, Bugiotti, and Rossi (2012) proposed the *"SOS (Save Our Systems) platform"* as a common API for interface standardization. Some authors (Rocha et al., 2015; Stanescu, Brezovan & Burdescu, 2016, Nikam et al., 2016) proposed frameworks for mapping relational data to NoSQL databases, while others (Liao et al., 2016) developed data adapters for querying and transformation between relational and NoSQL databases. The different approaches related to relational and NoSQL databases integration can be summarized as:

1. Native solution,
2. Hybrid solution.

A native solution is based on the standard database drivers and ways how the business layer communicates with a specific database. Since data is stored in both, relational and NoSQL, databases in order to use it together it is necessary to integrate it somehow. This integration is implemented on the business layer. When data is extracted from the databases (relational and NoSQL), it is linked and converted into format adequate for its use on the user (business) layer. If data is storing in a database (either relational or NoSQL), it is the responsibility of the business layer to prepare it to storage and to store it in the specific (relational or NoSQL) database.

A hybrid solution is based on development of additional layer that enables SQL communication between business and data layer. It means that developers can use familiar SQL patterns on the business layer, but they must employ new layer for translating these patterns into the NoSQL programming interface in order to enable communication with the NoSQL database.

It is easier to explain and understand these two solutions if concrete examples are presented. In preparing the examples the authors started with requirement for integration of data about university's teaching staff stored in relational (Oracle) database with data about their publications (papers, chapters, books, etc.) stored in NoSQL database (MongoDB). Namely, in this example, data about teaching staff is part of university's information system based on transactional (relational) database, in this case Oracle database. Storing data about teachers' publications is new application, developed lately, and it requires storing a lot of pdf documents and images. That is the reason why MongoDB is used for storing this data. Namely, MongoDB performs extremely well in working with such types of data. MongoDB uses GridFS based on two collections within the database: one for storing metadata about the file, and another for the file itself where the file is broken down into small pieces called chunks. Thanks to this file system organization, neither the number of files nor their size is limited. Also, it is easier to access specific parts of large files by extracting respective chunks, which makes MongoDB very fast in storing and extracting data of any type. Figure 1 shows user's requirement and how data used in the examples is stored.

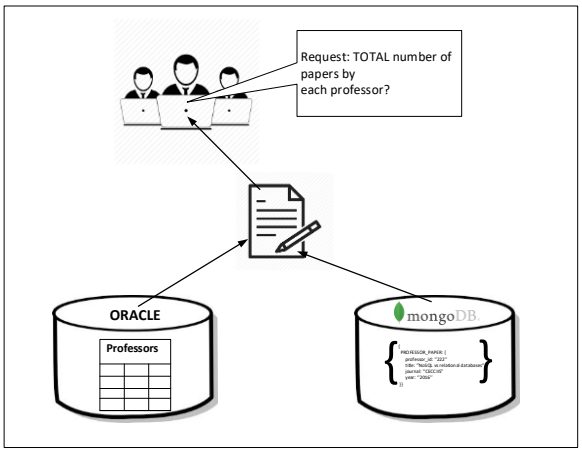


Figure 1. User's requirement and data storage

2.1 Native solution

The native solution for the requirement presented in Figure 1 involved the use of native drivers for communication with Oracle and MongoDB. In order to answer on question how many papers was published by each teacher, it is necessary to integrate data about teaching staff from Oracle database with data about publications from MongoDB. In native solution this integration is implemented on the business layer. In the presented example, REpresentational State Ttransfer(REST) Web services, the Java programming language and the Java EE 7 framework were used. Although it is common to use JPA (Java Persistence API) for work with relational data when using this technology, in this case that was not possible because JPA lack the functionality of working with multiple data sources.

Because of that, access to Oracle database was ensured through the JDBC (Java DatabaseConnectivity) driver, while the Java MongoDB driverwas used to access the MongoDB database. Since it is not possible to map the results of queries from the MongoDB database with Java objects directly, the authors decided to use the open-source library Gson. Gson Java library performs conversion in two directions: converting Java objects into their JSON representation or converting JSON string to an equivalent Java object.

In presented example, relational table of professors (teaching staff) and MongoDB collections of publications need to be linkedin order to get the required data. A native driver was used as the connector for an individual database. Therefore, the use of native drivers eliminates the possibility to make queries that would be performed on Oracle and MongoDB databases at the same time. The problem of linking databases and extracting the data was solved through the following steps:

- Data about teaching staff (professors) were stored in relational database (Oracle) and for access was used Oracle JDBC driver. The method *List<Professor>getProfessorList()*was used for retrieving data about teaching staff (Figure 2).
- Java MongoDB driver was used for access to MongoDB where publications were stored. All publications were retrieved by the method *List<ProfessorPaper>getProfessorPaperList()* (Figure 3).
- The method *ProfessorPaper getProfessor PaperById(String id)* returns all publications by professor (for a submitted professor's id) (Figure 4).
- Upon retrieval, the data are linked by a key (id).
- Linking results in an object of the class *ReportModel* (Figure 5). It contains data about professors and the total number of publications by each professor while the result is a Java object that is passed to the report engine that uses it to generate the expected report.

```
public List<Professor> getProfessorList()throws BusinessException, SQLException {
      Connection conn =null;
      PreparedStatement preparedStatement =null;
      String selectSQL ="SELECT ID,TITLE, FIRST_NAME, LAST_NAME, UNIVERSITY_ID,
FACULTY_ID FROM PROFESSOR";
      List<Professor> professorList =new ArrayList();
try{
         conn = dataSource.getConnection();
         preparedStatement = conn.prepareStatement(selectSQL);
         ResultSet rs = preparedStatement.executeQuery();
while(rs.next()){
            Professor professor =null;
            professor =new Professor();
            professor.setId(rs.getBigDecimal(1));
            professor.setTitle(rs.getString(2));
            professor.setFirstName(rs.getString(3));
           professor.setLastName(rs.getString(4));
            University university = universityService.getUniversityById(rs.getBigDecimal(5));
            BigDecimal fac = rs.getBigDecimal(6);
            Faculty faculty = facultyService.getFacultyById(fac);
            professor.setUniversity(university);
            professor.setFaculty(faculty);
            professorList.add(professor);}
}catch(SQLException ex){
thrownew BusinessException("Error fetching professor!");
}finally{
if(conn !=null){
            conn.close();
}
if(preparedStatement !=null){
            preparedStatement.close();}}
return professorList;}
```

Figure 2. The method for retrieving data about teaching staff

```
public List<ProfessorPaper> getProfessorPaperList(){
      MongoCollection collection = mongoClientProvider.getMongoCollection("professorPaper");
      MongoCursor<Document> cursor = collection.find().iterator();

if(cursor !=null){
         String cursorString = util.cursorToString(cursor);
         GsonBuilder gsonBuilder =new GsonBuilder();
         Gson gson = gsonBuilder.create();

         List<ProfessorPaper> list = gson.fromJson(cursorString,new TypeToken<List<ProfessorPaper>>(){
}.getType());
return list;
}else{
returnnull;}}
```

Figure 3. The method for retrieving all publications by professor

```
public ProfessorPaper getProfessorPaperById(String id){
      MongoCollection collection = mongoClientProvider.getMongoCollection("professorPaper");
      Bson filter = eq("_id", id);
      Document document =(Document) collection.find(filter).first();

if(document !=null){
         String json = document.toJson();
         Gson gson =new Gson();
         ProfessorPaper ecoTest = gson.fromJson(json,new TypeToken<ProfessorPaper>(){
}.getType());

return ecoTest;
}else{
returnnull;}}
```

Figure 4. The method for returning the total number of publications by professor

```
public List<ReportModel> getNumberOfPaperByProfessor()throws BusinessException, SQLException {
      List<Professor> professorList;
      professorList=professorService.getProfessorList();
      List<ReportModel> reportList =new ArrayList();

for(Professor professor : professorList){
         Long count = professorPaperMongoService.getCountByProfessorId(professor.getId());
         reportList.add(new ReportModel(professor, count));
}
return reportList;}
```

Figure 5. The class ReportModel

2.2 Hybrid solution

A hybrid solution involves development of additional layer that enables SQL communication between business and data layer. Namely, work with data stored in relational databases is based on the unique standard of the SQL. SQL implementations vary slightly among relational database vendors. Acceptance of the standard by different relational vendors has allowed integration of various databases, and brought the developer community to a situation that it is almost the immaterial which relational database product they use. As opposite, development of the NoSQL market has brought a huge number of solutions that offer various data organization models and data management APIs. This diversity of programming languages and interfaces for work with data in the NoSQL databases makes the huge challenge in finding appropriate solution for integration relational and NoSQL databases. That is the reason why the SQL has been seen as powerful

solution for the problem of integration relational and NoSQL world (Lawrence, 2014).

In their paper, Vilaça et al. (2012) present the DQE (Distributed Query Engine) as a platform to execute SQL queries on NoSQL databases, while keeping their data-model scalability and flexibility. DQE represents a strong concept that will combine said scalability and flexibility of NoSQL schemas with the expressiveness of SQL. Further, they show how simple key-value operations and the associated data model can be mapped into SQL structures, and describe a full implementation of the model on the HBase database using Apache Derby's query engine.

Lawrence (2014) considered DQE-like solutions to connect the relational and NoSQL worlds, and found a solution in SQL, which provided a theoretical foundation for the system called Unity. Unity is a generalizable integration and virtualization system based on SQL interface. According to Lawrence (2014), the key features of the Unity are:

- It uses a SQL query processor and optimizer that include support for push-down filters and cross-source hash joins.
- It has a SQL dialect translator that brings different SQL dialects of relational-database vendors to the same form.
- It has a SQL-form to NoSQL APIs translator, and operators not supported by native NoSQL database APIs are performed using the Unity virtualization engine.
- It offers mapping of SQL functions into appropriate forms supported by various vendors of relational and NoSQL databases.
- It provides data virtualization allowing queries and joins across relational and NoSQL data sources.

Unity offers compatibility with existing SQL solutions and new ones being developed by the developer community, based on the SQL standard. At the same time, it offers the possibility of using the appropriate dataorganization philosophy that meets the needs and requirements that applications bring to developer teams. Unity offers an answer to growing needs of web applications for simultaneous use of NoSQL and relational systems.

Unity also offers a kind of extension of the NoSQL system, by implementing unsupported operators through its virtualization engine. It seems that this architecture allows use of the best of the two philosophies, using the interface most appropriate for most of the developer community.

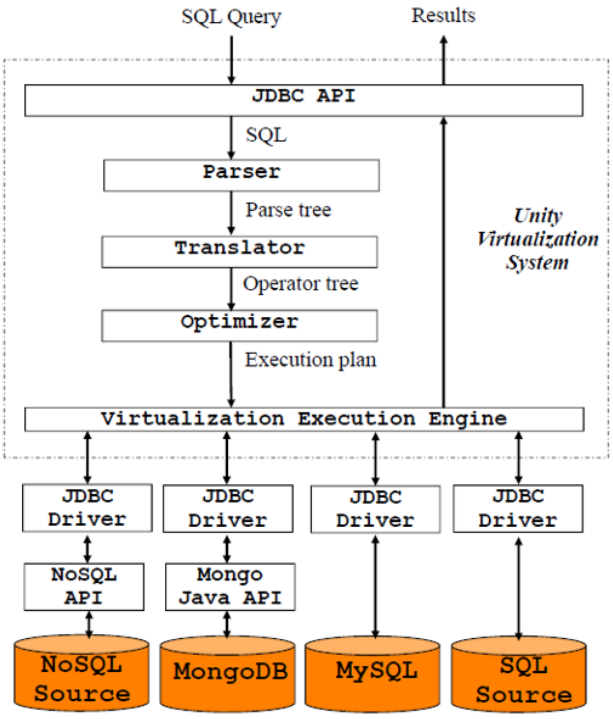


Figure 6. Unity architecture (Lawrence, 2014)

Presently, Unity is available as a commercial product on the market of JDBC drivers. It supports Oracle, MySQL, SQL Server, and any other relational JDBC data source. The main features of the MongoDB drivers of Unity are (UNITYJDBC, 2017):

- Access to MongoDB collections using SQL including WHERE filters and ORDER BY clause.

- Data manipulation using standard SQL functions that are not natively supported in the MongoDB.
- Use of JOIN clause between MongoDB collections and relational tables of databases that are supported by Unity.
- Full support for nested documents andstrings including functionalities of filters and regular expressions (RegEx).

All that lead to decision that the Unity model should be used in testing hybrid solution. The same example, making the report that shows professors with total number of paper by each professor, was used for presenting hybrid solution based on Unity model. Figure 7shows the example of method that retrieves data from Oralce and MongoDB for the required report.

```
public List<ReportModel> getReport()throws UnsupportedEncodingException {
      List<ReportModel> reportModelList =new ArrayList();
      Connection con =null;
      Statement stmt =null;
      ResultSet rst;
      String url ="jdbc:unity://"+ getWebInfPath()+"/OracleMongoSources.xml";
try{
        Class.forName("unity.jdbc.UnityDriver");
        con = DriverManager.getConnection(url);
        stmt = con.createStatement();
        String sql ="  SELECT PR.ID,\n"
+"       PR.TITLE,\n"
+"       PR.FIRST_NAME,\n"
+"       PR.LAST_NAME,\n"
+"       PR.UNIVERSITY_ID,\n"
+"       PR.FACULTY_ID,\n"
+"       COUNT (1)\n"
+"   FROM Mongo.PROFESSOR_PAPER PP, Oracle.PROFESSOR PR\n"
+"  WHERE PP.doc.professor.id = PR.id\n"
+"GROUP BY PR.ID,\n"
+"       TITLE,\n"
+"       PR.FIRST_NAME,\n"
+"       PR.LAST_NAME,\n”
+"       PR.UNIVERSITY_ID,\n"
+"       PR.FACULTY_ID";
        rst = stmt.executeQuery(sql);
while(rst.next()){
           ReportModel report =new ReportModel();
           Professor professor =new Professor();
           professor.setId(rst.getBigDecimal(1));
           professor.setTitle(rst.getString(2));
           professor.setFirstName(rst.getString(3));
           professor.setLastName(rst.getString(4));
           report.setValue(rst.getLong(5));
           report.setProfessor(professor);
           reportModelList.add(report);}
}catch(Exception ex){
        System.out.println("Exception: "+ ex);
}finally{
if(con !=null){
try{
              con.close();
}catch(SQLException ex){ System.out.println("SQLException: "+ ex);}}}
return reportModelList;}
```

Figure 7. The method that retrieves data from Oracle and MongoDB

The query is executed on two data sources: Mongo.Professor_Paper and Oracle.Professor. These sources are described in the UnityJDBC configuration file OracleMongoSources.xml. The WHERE clause of a SQL query reveals the possibility of linking data from different sources. The query result is a Java object that can be forwarded to the report engine for the formatting and presentation of the retrieved data.

3 Conclusion

From the viewpoint of users, the real value of data, stored either in relational or NoSQL databases, lays in the possibility to use it for better understanding of their businesses, customers and suppliers. In globalized, volatile and dynamic world, data is stored everywhere, in transactional systems, social networks, web sites, and users do not want to be limited in data analysis to the only some data storages. Overall data analysis can result with discovering of knowledge hidden in huge amounts of data and empower the users and their organizations to efficiently respond to present and future business challenges. In that sense, the users see the database technology as a powerful tool that has the task to provide access and use of data wherever is stored. Today, it necessary leads to integration of data stored in different databases, relational and NoSQL.

The paper presents two approaches to integration relational and NoSQL databases: native and hybrid solution. The use of native drivers eliminates the possibility to make queries that canbe performed on both, relational and NoSQL database at the same time, so the programmers are responsible for developing the code that will enable such queries. A hybrid solution means development of additional layer that enables to developers to use familiar SQL on the business layer. In this case, the query is executed on two data sources, relational and NoSQL, but the additional layer is used to enable data integration.

Theseapproachesare also generating additional challenges, including the following:

- Increased responsibility of developers in the optimization of database processes, which means that additional programming and time are necessary for completing the integration of data.
- Difficulties in finding developers with good knowledge of NoSQL databases, while finding developers with knowledge about both worlds, relational and NoSQL, is still equal to a jackpot.
- Finding an appropriate driver or tool for a particular problem is a time-consuming and exhaustive process because the market is full of many different drivers and tools offered by third vendors.

The need for the integration of relational and NoSQL databases can lead to databases evolution in sense that they will provide support for different and often opposite users requirements, by enabling combinations of both approach and tunable and configurable capabilities that will give the users the possibility to use databases on the way that best suits their needs.

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Reverse Engineering of a Generic Relational Database Schema Into a Domain-Specific Data Model

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Abstract. *Information system* (*IS*) *reengineering process comprises reverse engineering process of an existing IS followed by some form of forward engineering or restructuring. An important phase of a data-oriented software system reengineering is a database reengineering process and, in particular, its sub-process – database reverse engineering process. In this paper we present one of the model-to-model transformations from a chain of transformations aimed at transformation of a generic relational database schema into a domain-specific data model based on form types. The transformation is a step of the data structure conceptualization phase of a model-driven database reverse engineering process that is implemented in IIS*Studio development environment.*

Keywords. database reengineering, reverse engineering, relational data model, form type data model, model-driven approach

1 Introduction

The emergence of large and complex information systems (IS) increases the interest in Model-Driven System Engineering (MDSE) and its appliance in information system (re)engineering process. The model-driven approach to information system and software (re)engineering addresses complexity through abstraction. A complex system consists of several interrelated models organized through different levels of abstraction and platform specificity. A model-driven information system engineering process should cover: modeling that produces description models from existing enterprise systems; forward engineering that produces specification, prescription and implementation models; and reverse engineering that produces description models from engineered software systems.

Through a forward engineering process models need to be refined and integrated and used to produce code and therefore they would undergo a series of transformations. Each transformation adds levels of specificity and detail starting from an initial model at the highest level of abstraction (Platform Independent Model, PIM), through the less abstract models, with different levels of platform specificity (Platform Specific Models, PSMs), and resulting in an executable program code that represents a model at the lowest level of abstraction (fully PSM). Conversely, in a reverse engineering process, the abstraction level of models and degree of platform independency are increasing throughout the chain of transformations. PIMs use the domain-specific concepts that are understandable to the users and in that way users get an opportunity to participate directly in the design, implementation, integration and evolution of an information system. Once a domain-specific framework has been established, a new version of the system does not take a long time to generate and deploy using model-driven techniques. All together it enables easier uncovering of the problems and provides the opportunity to correct mistakes early in the IS (re)engineering process.

Through a number of research projects on model-driven intelligent systems for information system development, maintenance and evolution, we have developed the IIS*Studio tool. It is aimed to provide the multi-paradigm approach to IS design (Dimitrieski et al., 2015), generating executable application prototypes (Aleksić et al., 2007; Aleksić et al., 2013; Popović et al., 2015) and IS reverse engineering. Our approach is mainly based on the model-driven information system and software engineering (Bézivin, 2006; Favre, 2005) and domain specific language (DSL) paradigms (Kosar et al., 2010; Dejanović et al., 2010). In IIS*Studio we use form type data model as domain-specific data model (DM). The explanation of basic concepts of this model is presented in Section 2.

Meta-modeling is of great importance in the context of database reverse engineering. In (Ristić et al., 2014) are presented different database meta-

models (MM) in support of IIS*Studio reengineering process. The database reverse engineering (DBRE) is, according to (Hainaut et al., 2009), the process of recovering the conceptual schema of a database and it is divided in two main phases: data structure extraction and data structure conceptualization. In (Ristić et al., 2015) we have proposed a model-driven approach to data structure conceptualization phase of database reverse engineering process. The presented data structure conceptualization is conducted through a chain of model-to-model (M2M) transformations. Each of them is based on two meta-models: source and target meta-model where the source meta-model of a model transformation is at lower abstraction level than the target meta-model of the transformation.

In (Ristić et al., 2016) we have given the blueprint of the final step of the conceptualization phase—the M2M transformation of a generic relational database schema into a form-type model. The transformation is illustrated by an example of simple transformation of a basic relation scheme into a basic form type.

In practice, we face not only with basic relation schemes and form types, but with more complex data structures in both data models (relational DM and form type DM). In this paper we address the problem of transformation of weak and all key relation schemas into complex form types (in the paper they are denoted as $\mathcal{F}_Tree^2$ and $\mathcal{F}_Tree^n$ form types).

Apart from Introduction and Conclusion the paper has six sections. Form type concept of IIS*Studio is elaborated in Section 2. The reverse engineering process in IIS*Studio is described in Section 3. The classification of form types and terms of $\mathcal{F}_Basic$, $\mathcal{F}_Tree^2$ and $\mathcal{F}_Tree^n$ form types are presented in Section 4. Terms of basic, weak and all key relation schemas are introduced and explained in Section 5. The transformation of generic relational database schema into form type data model is presented in Section 6. Related work is given in Section 7.

2 The Form Type Concept

According to (Brinkkemper et al., 2000) three main functions of an IS are: (i) to maintain a consistent representation of the state of a domain (F1); (ii) to provide information about the state of a domain (F2); and (iii) to perform actions that change the state of a domain (F3). A model-driven (MD) approach to IS engineering would support several viewpoints and modeling languages to enable creation of different models that capture the knowledge required to support main functions of an IS. IIS*Studio is based on an MD approach that comply to these requirements.

In order to provide design of various platform independent models by IIS*Studio, a number of modeling, meta-level concepts and formal rules that are used in the design process are created.

A form type is central IIS*Studio PIM concept, used to model the structure and constraints of various business forms. Business forms (documents) are broadly used in organizations to conduct daily operations and to communicate with their affiliated entities (e.g. staff, superior managers, customers, suppliers, etc.). The adjective *business* is used to emphasize that a business form need not to be a part of computer graphical user interface (GUI), but can be a paper form that is filled in manually or a printed report, too. They may provide an important input source for database (db) schema design, since the most widely used data are gathered or reported in them. Forms are objects, easy to read and understand, well-structured and, consequently, easy to formalize. Therefore, business forms are a source for eliciting user information requirements and also for designing and developing user-oriented information systems. Initially, each form type (FT) is an abstraction of a business form. In that way FT concept supports IS function F1. However, it may be enriched by additional specifications that are not included in the entry business form, like specifications of: key and unique constraints; check constraints (both additionally support function F1); allowed database CRUD (Create, Retrieve, Update and Delete) operations applied by means of screen computerized forms to manipulate data of an IS (supporting IS function F3); functionalities concerning relationships between generated screen forms, i.e. transaction programs (supporting IS functions F2 and F3), etc.

In the paper we use the case study of a simplified Airline Ticket Reservation System (ATRS). The business form *Customer Reservations* (*CR-bf*), presented in Figure 1, is used to keep track about the customers and their reservations. A customer reservation is the unit of payment and it can comprise more seats for one or more flights, that are reserved on the same date and that would be paid by single payment.

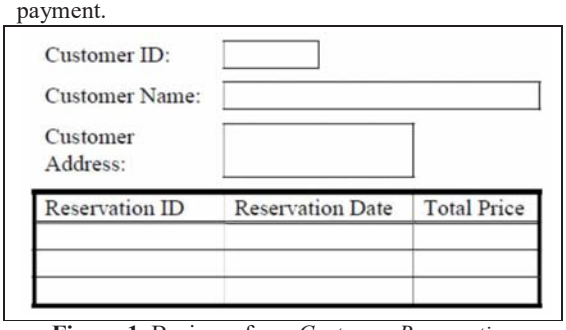


Figure 1. Business form *Customer Reservations*

The business form *Customer Reservations* may be modeled by the form type *Customer Reservations* (*CR-ft*). The simplified representation of the structure of the *CR-ft*, which generalizes the *CR-bf*, is presented in Figure 2. As can be seen, a form type is a hierarchical structure of form type components. The

form type *Customer Reservations* (Figure 2) has two component types: *CUSTOMER* and *RESERVATION*. Underlined attributes represent keys of component types. Letters placed in the rectangle on the right side of the component name stand for the allowed CRUD operations: *r* for retrieve, *i* for insert, *u* for update and *d* for delete.

In the traditional approaches to the IS design, database schema design not rarely precedes the specification of screen or report forms of transaction programs. On the contrary, in IIS*Studio a designer the first specifies screen and report forms, and indirectly, creates an initial set of attributes and constraints. The form type structuring rules provide automatic inference of relational db constraints from form types. A form type in IS design by means of IIS*Studio has a dual role. On the one hand it provides an important input data for database design (to support IS function F1), and on the other hand it is a source for the generation of a sole transaction program (to support IS function F3) and its screen or report form (to support IS function F2).

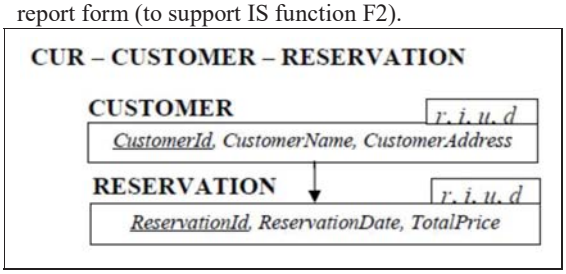


Figure 2. Form type *Customer Reservations*

IIS*Studio introduces domain-specific data model based on form type concept (Luković et al., 2007) and uses it for conceptual database design. In the paper data model based on form type concept is called *form type data model*.

The main advantage of this approach is two folded. Firstly, the FT concept is closer to the end-users' perception of data, than it would be, for example, the concepts of entity and relationship types in the Entity-Relationship (ER) data model. It is a concept that is formal enough to allow a precise expressing all of the rules significant for structuring a database schema. Secondly, a designer by means of FT specifies business, screen and report forms, and indirectly, creates an initial set of attributes and constraints. The FT specifications can be enriched with the specification of future transaction programs and business applications, too.

3 Reverse engineering process in IIS*Studio

IIS*Studio comprises three tools: IIS*Case, IIS*UIModeler and IIS*Ree. These tools communicate by means of shared repository aimed at storing project specifications. The IIS*UIModeler is an integrated part of the IIS*Studio DE, aimed at modeling of GUI static aspects. By means of IIS*UIModeler a designer specifies UI templates.

In a forward engineering process, supported by IIS*Case tool, designers start with a high-level model, abstracting from all kinds of platform issues. Through a chain of M2M transformations, ending up with a model-to-text (M2T) transformation, the initial PIM transforms iteratively to a series of models with less degree of platform independency, introducing more and more platform specific extensions. Conversely, in a reverse engineering process, supported by IIS*Ree tool, the abstraction level of models and degree of platform independency are increasing throughout the chain of transformations.

Relational databases are at the core of most company information systems, hosting critical information for the day to day operation of the company. The knowledge captured in them can serve as an important resource in a legacy information system modernization project and they are a common source of reverse engineering processes. Starting from a physical database schema, that is recorded into the relational database schema data repository, the conceptual database schema or logical database schema may be extracted. The IIS*Ree tool in our IIS*Studio extends IIS*Case tool in order to enable reverse engineering of relational databases to conceptual data models.

Several reasons motivate us to develop IIS*Ree tool. The first one is that an enterprise IS implemented to fulfill organizational information requirements, now more than ever, would adapt to emerging business models and technology changes and innovations. Legacy system replacement or reengineering can be done with significantly reduced amount of effort and cost if the conceptual models are reconstructed from them. IIS*Ree tool conceptualize a relational database into a domain-specific form type data model. That schema may be restructured and improved by means of IIS*Case tool and afterwards transformed into improved relational database schema.

The second reason is to enable database integration of different information systems. Integrated database schema can be used as a platform for ISs integration. The databases of different ISs that would be integrated can be conceptualized into several external database schemas expressed by concepts of form type data model. These external database schemas are the input of IIS*Case tool and its integration process. By means of IIS*Case tool the collisions in expressing real world constraints between different external database schema can be detected and resolved (Luković et al., 2007). In that way, PIM models of legacy ISs are restructured and consolidated. M2M and M2T transformations carried out over consolidated external database schemas are able to

generate transaction programs from form types specifications extracted from legacy databases and restructured and improved by means of IIS*Ree and IIS*Case tools.

Initial database design and further changes are poorly documented mostly thanks to the deadline pressures to which designer are exposed. Database schema design based on the experience mostly incorporates awkward constructs and non-standard design patterns that are hard to understand and communicate. A lot of knowledge about the logical and physical database design is not explicit and is hidden in the repository, program code and in physical data structures. Reverse database engineering enables data structure extraction and data structure conceptualization. In our approach form type database model is reverse engineered from a relational databases. It is very important and useful because IIS*Case tool uses a set of form types to generate, integrate and consolidate relational database schema. IIS*Case tool extracts set of functional and non-functional dependencies from the set of form types and applies modified synthesis algorithm (Beeri & Bernstein, 1979) to generate relational database schema in the 3rd normal form. The detailed description of that extraction process can be found in (Luković et al., 2007). In that way, empirically designed database model without appropriate up-to-date documentation is transformed into a database model that is designed following the disciplined database design approach.

Reverse engineering process in IIS*Ree is implemented by means of a series of *database model transformations* that are M2M transformations between database models. These transformations are based on meta-models that are conformed by the source and target database models of the transformations. In the purpose of specifying and managing meta-models in support of database model transformations implemented in IIS*Ree we use the Eclipse Modeling Framework ("EMF Eclipse Modeling Framework", 2017) Eclipse Juno 4.2.1. and OCL 3.2.1. A blueprint of a model-driven approach to database reengineering process applied in IIS*Studio is presented in (Ristić et al., 2015). Here we present one of the M2M transformations aimed at transformation of a generic relational database schema into a form type data model with focus on weak and all key relation schemes and more complex form types. Firstly, in the next section a formal specification of a form type is presented alongside with a classification of form types.

4 Classification of Form Types

A *form type* $\mathcal{F}$ is a named tree structure, whose nodes are called *component types*. Let $C(\mathcal{F})$ denotes a set of component types making up the form type $\mathcal{F}$. Each component type is identified by its name within the scope of a form type, and has nonempty sets of attributes and keys, and a possibly empty set of unique constraints. Formally, a component type is a named pair $N(Q, O)$, where N denotes name of the component type, Q is the set of component type attributes $Q=\{A_1, .., A_n\}$ and O is a set of component type constraints. O is a union of three sets: a set of key constraints, a set of unique constraints and a singleton containing a tuple constraint. The tuple constraint of a constraint type refers to a set of attribute-based constraints (attribute data type specification and not-null constraint) paired with a tuple-based constraint (constraint on tuple value). Let $C(\mathcal{F}) = \{N_i(Q_i, O_i) \mid i = 1, \ldots m\}$. $W(\mathcal{F})$ denotes a set of the form type attributes that satisfy (1) & (2).

$$\bigcup_{i=1}^{m} Q_i = W(\mathcal{F}) \quad (1)$$

$$(\forall N_i, N_j \in C(\mathcal{F}))(i \neq j \Leftrightarrow Q_i \cap Q_j = \varnothing). \quad (2)$$

A set of allowed database operations must be associated with each component type. The set of allowed operations is a subset of the CRUD operations set. Form types are classified as:

- $\mathcal{F}_Basic$ – an elementary form type containing only one root component type (an example is presented in Figure 3);
- $\mathcal{F}_Tree^2$ – a form type containing a root component type with only one child component type (already presented in Figure 2); and
- $\mathcal{F}_Tree^n$ – a form type that apart from a root component type contains an arbitrary number of child component types (two examples in Figure 4).

Throughout the following text $\mathcal{F}\ T_B$ denotes a set of *F_Basic* form types, $\mathcal{F}\ T_{T2}$ denotes a set of $\mathcal{F}_Tree^2$ form types, and $\mathcal{F}\ T_{Tn}$ denotes a set of $\mathcal{F}_Tree^n$ form types.

5 Classification of Relation Schemes

In the context of M2M transformation aimed at transformation of a generic relational database schema into a form type data model it is necessary to classify relational schemes in the source data model.

During a reverse engineering process of a relational database schema, it is important to be aware of the limited expressiveness of the relational data model compared to other data models, like ER data model or form type data model. In (Hammer et al., 2002) a classification of relation schemes in the context of the transformation of a relational database schema into ER database schema has been proposed. Here we present a classification that is adapted according to the target data model (form type data model) that is

used in the approach presented in this paper. Identifying different categories of relation schemes is performed according to the primary key information and the inclusion dependencies of a relational database schema. We distinguish three kinds of relation schemes:

- Basic Relation Scheme (BR);
- Weak Relation Scheme (WR); and
- All Keys (AK) relation scheme.

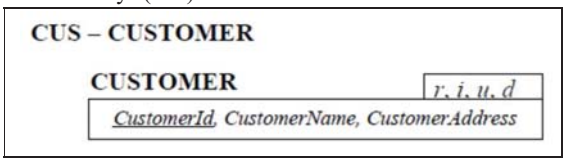


Figure 3. An example of $\mathcal{F}$ _*Basic* form type

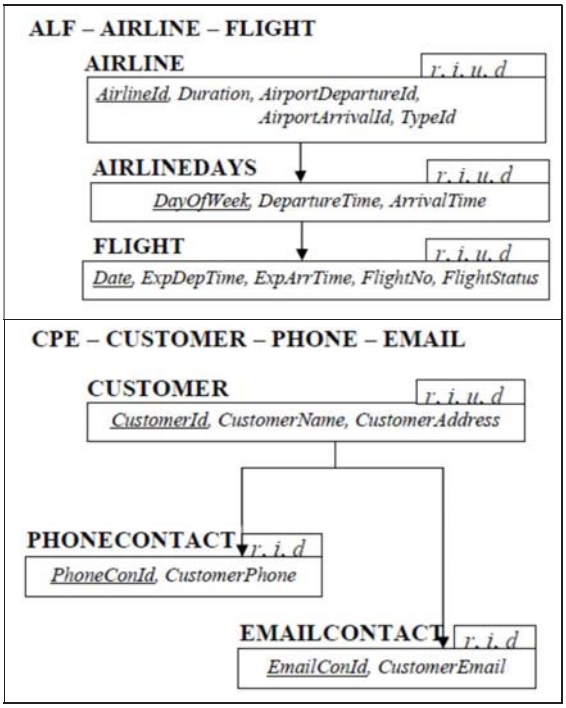


Figure 4. Two examples of $\mathcal{F}$ _*Tree*^{n} form types

A basic relation scheme is a relation scheme whose primary key (PK) does not properly contain a key attribute of any other relation.

A weak relation scheme *N* is a relation scheme that satisfies the following three conditions: i) a proper subset of its PK contains key attributes of other basic or weak relation schemas; ii) the remaining attributes of its PK do not contain key attributes of any other relation scheme; and iii) it has an identifying owner (parent) relation scheme and properly contains the PK of its parent relation scheme.

An AK relation scheme contains only key attributes of other relation schemes, and does not contain any other self-inherent attributes.

A graphic representation of ATRS relational database schema is presented in Figure 5. It contains relation schemes *Company*, *CompanyHasType*, *AirplaneType*, *Airport*, *Airlane*, *AirlineDays*, *Flights*, *Seat*, *Reservation*, *Customer*, *PhoneContact* and *EmailContact*. Underlined attributes belong to a key of a relation scheme. Relation scheme *Airline* has a key that is singleton containing *AirlineId* attribute, and relation scheme *AirlineDay* has a composite key that contains two attributes *AirlineId* and *DayOfWeek*.

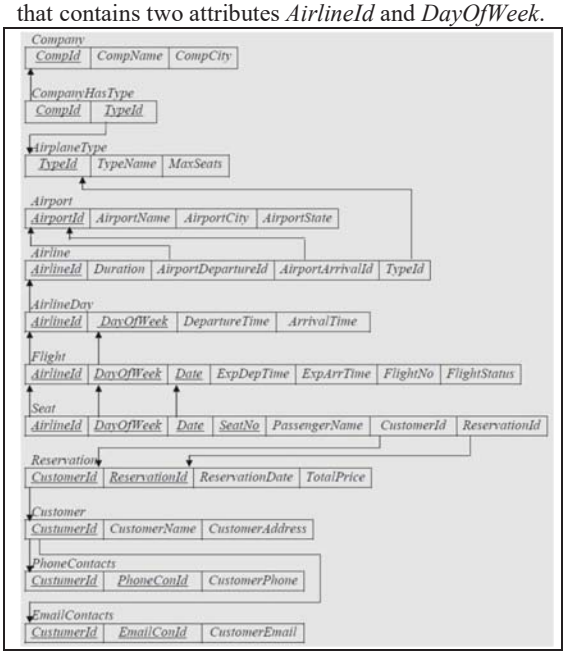


Figure 5. ATRS relational database schema

The relation schemes *Company*, *AirplaneType*, *Airport*, *Airlane*, and *Customer* are basic relation schemas. The relation schemes *AirlineDays*, *Flights*, *Seat*, *Reservation*, *PhoneContact* and *EmailContact* are weak relation schemes. The relation scheme *CompanyHasType* is an example of AK relation scheme.

6 Transformation of a Generic Database Schema into a Form Type Data Model

The input of the data structure conceptualization phase applied in IIS*Studio is XML specification of captured physical database model. This XML specification conforms to XML meta-model. The data conceptualization phase is realized as a chain of three M2M transformations: 1. XML2RDBMS, 2. RDBMS2RM, and 3. RM2IISCase.

The first transformation transforms a model conformant with XML meta-model into a model conformant with an SQL standard meta-model.

The transformation RDBMS2RM transforms a model conformant with an SQL standard meta-model into a model conformant with generic relational db meta-model. It is not possible to transform a model

conformant with an SQL standard directly into a model conformant with FT meta-model. The reason lies in the fact that FT approach to database design is based on the Universal relation schema assumption (URS assumption). Physical database meta-models and database meta-models based on SQL standard do not support URS, while generic relational database meta-models does. Both of aforementioned transformations are PSM2PSM transformations.

The third one, denoted by RM2IISCase, is a PSM2PIM transformation. It transforms a model conformant with generic relational database meta-model into a model conformant with FT meta-model. The transformation RM2IISCase is the main subject of our paper.

We have considered two approaches to implement RM2IISCase transformation. In the first approach the transformation would generate only simple form types (*F_Basic* form types). In this approach a user is free and responsible to add component types and other concepts in initial FT data model obtained by the transformation. In the second approach the transformation is able to generate all relevant combinations of form types. It is a user who chooses form types to be introduced in the form type data model. The remaining form types are deleted. RM2IISCase implementation is based on the second approach. In that way a user will invest less effort to select between already generated form types comparing to the effort that would be invested in the first approach.

The proposed transformation is carried out in three steps. They are aimed at transforming set of relation schemes from a generic relational database schema into three sets of form types, respectively: $\mathcal{F}\ T_B$, $\mathcal{F}\ T_{T2}$, and $\mathcal{F}\ T_{Tn}$. Detail description of the first step of the transformation, with parts of generic relational schema MM and FT data model MM and ATL rules to specify a mapping between the concepts of these MMs is already presented in (Ristić et al., 2016). Therefore, in subsection 6.1 just the input parameters and outputs of that transformation step are given. In subsections 6.2 and 6.3 the other two steps of the transformation are presented in detail.

6.1 Relation scheme – $\mathcal{F}$ _Basic FT transformation

In this step a $\mathcal{F}$ _Basic form type is created for each relation scheme from a relational database schema. The input parameters for this transformation are:

$$S = \{N_i(R_i, O^{RS}{}_i) \mid i = 1,.., n\}, \quad (3)$$

$$O^{RS} = K^{RS} \cup UQ^{RS} \cup CH^{RS}, \quad (4)$$

where S is a set of the relation schemes $N_i(R_i, O^{RS}{}_i)$. N_i is relation scheme name, R_i is nonempty set of its attributes and $O^{RS}{}_i$ is set of its constraints. Each constraint set is a union of three sets containing: key constraints, unique constraints; and tuple constraints, respectively (4).The transformation as output returns a set $\mathcal{F}\ T_B$ containing $\mathcal{F}$ _Basic form types.

6.2 Relation scheme – $\mathcal{F}$ _*Tree*^{2} FT transformation

The next step of the transformation is to create a set of $\mathcal{F}$ _*Tree*^{2} form types. A $\mathcal{F}$ _*Tree*^{2} form type is generated for referential integrity that has WR relation scheme on the left hand side. The set of input parameters in addition to (3) and (4) contains a set of referential integrities of a relational database schema:

$$RIC = \{ric_i: N_l[LHS] \subseteq N_r[RHS] \mid i = 1,.., m\}, \quad (5)$$

where N_l and N_r are relation schemes, *LHS* and *RHS* are subsets of attribute sets R_l and R_r of relation schemes N_l and N_r, respectively. The transformation as output returns a set $\mathcal{F}\ T_{T2}$ of $\mathcal{F}$ _*Tree*^{2} form types.

For each referential integrity $N_l[LHS] \subseteq N_r[RHS]$ from *RIC* (5), with N_l that is WR relation scheme, a $\mathcal{F}$ _*Tree*^{2} form type is created based on the pair of relation schemes (N_l, N_r). In Figure 6 are presented parts of source and target meta-models alongside with ATL rule *ChildCT* to implement transformation of a relational database schema into $\mathcal{F}\ T_{T2}$. In the lowest part of the table several helpers can be found. Four of them (*RS_AllKeys*, *AttributesOfRSs*, *Child-ComponentTypeAttributes*, and *ExistIRIC*) are called directly from *ChildCT* rule and the fifth (*AllRelatedRS*) is called from *AttributesOfRSs* helper. Corresponding calling messages are shaded within the *ChildCT* rule and *AllRelatedRS* helper.

6.3 Relation scheme – $\mathcal{F}$ _*Tree*^{n} FT transformation

The last step of the transformation is aimed at creating the third set of form types—set denoted by $\mathcal{F}\ T_{Tn}$. There are two cases to arise an $\mathcal{F}$ _*Tree*^{n} form type. An $\mathcal{F}$ _*Tree*^{n} form type will be created for each relation scheme that is referenced by at least two WR relation schemes. Besides, an $\mathcal{F}$ _*Tree*^{n} form type will be created for each relation scheme that is referenced by at list one WR relation scheme that is referenced by some WR relation scheme, too.

The input parameters are same as the input parameters of the transformation that creates $\mathcal{F}\ T_{T2}$ set. The transformation as output returns a set $\mathcal{F}\ T_{Tn}$ of $\mathcal{F}$ _*Tree*^{n} form types.

This transformation is based on the same meta-models as the transformation presented in previous section. The transformation use rules and helpers already mentioned in previous transformation steps. Rules *GetFormType* and *ChildComponentType* and helper *Children* that are specific for this step of the transformation are presented in Figure 7. The main

difference lies in the fact that the transformation problem solved by these rules is recursive because a form type tree structure may have several nodes and they can be distributed over several tree levels. The calls of rule *ChildComponentType* and helper *Children* are shaded within the rules *GetFormType* and *ChildComponentType*, respectively.

In that way the transformation process of a generic relational database schema to a form type data model made of a union of $\mathcal{F}\,T_B$, $\mathcal{F}\,T_{T2}$, and $\mathcal{F}\,T_{Tn}$ is finished. End-users are now able to reexamine and to restructure obtained conceptual model and to launch a new forward engineering process to create renewed and improved IS.

7 Related Work

Favre in (Favre, 2005) emphasizes the importance of reverse engineering and its integration with forward engineering in MDSE process to support a smooth evolution of software. Our approach is in compliance with this statement since we integrate forward (IIS*Case) and reverse (IIS*Ree) engineering tools. In (Hainaut et al., 2009) main steps of database reverse engineering are described. The creation of OO conceptual database schema from the relational data dictionary is presented in (Perez et al., 2002) and (Boronat et al., 2004). Beggar et al. (Beggar et al., 2013) propose a reverse engineering process based on MDSE that presents a solution to provide a normalized relational database which includes the integrity constraints extracted from legacy data. Vara et al. have implemented an ATL model transformation that generates an object-relational (OR) database model from a conceptual data model and an MOFScript M2T transformation that generates the SQL code for the modeled database schema (Vara et al., 2009). Our approach uses relational data dictionary, legacy data and ATL model transformations to implement reverse engineering process that conceptualize a relational database into a form type data model.

There are various research works about the use of forms (business or computerized) in different contexts. In (Tsichritzis, 1982) the concepts of form type, form template and form instance are introduced to integrate services in Office Information system, and in (Shu, 1985) they are used to specify system requirements. In the context of database schema design distinguished papers are (Batini, Demo & Di Leva, 1984) and (Choobineh & Venkatraman, 1992) that present usage of business forms as input data for the process of database schema design based on generating ER diagrams and for derivation of functional dependencies from business form, respectively. A form-based approach for reverse engineering of relational databases is proposed in (Malki, Flory & Rahmouni, 2002). A dual role of IIS*Studio form type concept described in Section 2 is what distinguishes our approach compared to other approaches based on forms.

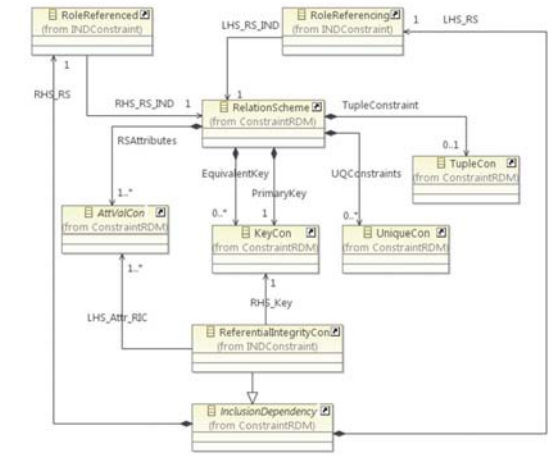
8 Conclusion

One of the main assumptions of the model-driven approach to information system and software development is that systems of large complexity can only be designed and maintained if the level of abstraction is considerably higher than that of programming languages. By means of models, semantics in an application domain can be precisely specified using terms and concepts the end-users are familiar with, such as the form types used in IIS*Studio are. Approaches to database conceptualization are mostly based just on two database meta-models. Vendor-specific physical or standard relational meta-model mainly are found on the source side of M2M transformation. On the other side, EER, class or standard/vendor-specific relational meta-models occur on the target side of M2M transformation. Most of the authors obtain relational database schema as the final result of data structure conceptualization process. According to (Hainaut et al., 2009) relational database schema cannot be seen as a pure conceptual database schema. In our approach FT database schema is obtained as the result of the data structure conceptualization process. FT specification is based on business forms, users are familiar with, and in that manner it models system as-is in a platform independent way. At the same time, the specification is platform independent prescription model of future screen and report forms and input for series of M2M transformations that ends up with model to text transformation generating application prototype.

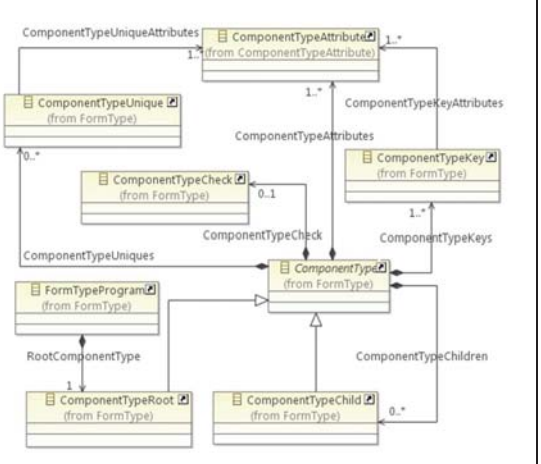
The meta-models and models that we use in our approach are intensional models. Our future research has to consider extensional database meta-models, too. Namely, we have defined the transformations of the models. Problem is what to do with the data that has been accumulated in the database conformant with a source data model. System evolution should be supported by automatic MD data migration and extensional database MM may play important role in its implementation.

Acknowledgments

Research presented in this paper was supported by Ministry of Education, Science and Technological Development of Republic of Serbia, Grant III-44010, Title: Intelligent Systems for Software Product Development and Business Support based on Models.



A part of generic relational dbS MM



A part of IIS*Case PIM (FT) meta-model

```
lazy rule ChildCT{
from
   ric: RM!ReferentialIntegrityCon
to
   ct: IISCase!ComponentTypeChild(
      Name <- 'ComponentType_' + ric.LHS_RS.LHS_RS_IND.Name,
      Title <- 'ComponentType_' + ric.LHS_RS.LHS_RS_IND.Name,
      ComponentTypeAttributes <- if thisModule.RS_AllKeys(ric.LHS_RS.LHS_RS_IND)
      then thisModule.AttributesOfRSs(ric.LHS_RS.LHS_RS_IND,
      ric.RHS_RS.RHS_RS_IND)->collect(e|
      thisModule.RSAttributes2CompTypeAttribute(e))
      else ric.ChildComponentTypeAttribute->collect(e|
         if (e.oclIsTypeOf(RM!NotNullAttr)) then
            thisModule.RSAttributes2NotNullCompTypeAttribute(e) else
            thisModule.RSAttributes2NullCompTypeAttribute(e) endif) endif,
      ComponentTypeKeys <- (ric.LHS_RS.LHS_RS_IND.EquivalentKey->collect(e|
         thisModule.EquivalentKey2CompTypeKey(e))).append(
         thisModule.EquivalentKey2CompTypeKey(ric.LHS_RS.LHS_RS_IND.PrimaryKey)),
      ComponentTypeUniques <- ric.LHS_RS.LHS_RS_IND.UQConstraints->collect(e|
         thisModule.UniqueCon2ComponentTypeUnique(e)),
      ComponentTypeCheck <- thisModule.TupleConstraints2ComponentTypeCheckCon(
         ric.LHS_RS.LHS_RS_IND.TupleConstraint),
      Query <- true,
      Delete <- false,
      Insert <- false,
      Update <- false,
      NoOfOcurrences <- if thisModule.ExistIRIC(ric) then #OneOrMany else
         #NoneOrMany endif
   )
   do{
      thisModule.attributes <- Sequence{};}}
```

Lazy rule **ChildCT**

```
helper def: RS_AllKeys(rs:RM!RelationScheme):Boolean=
   let AllRSAttributes:Sequence(RM!AttValCon)=rs.RSAttributes.asSet() in
      if AllRSAttributes-rs.PrimaryKey.KeyAttr.asSet() = Set{} then true
      else false endif;
helper def: AttributesOfRSs(rs:RM!RelationScheme,parent:RM!RelationScheme):Set(RM!AttValCon)=
let relatedRS:Sequence(RM!RelationScheme)= thisModule.AllRelatedRS(rs,parent) in
   relatedRS->iterate(rsc; rez:Set(RM!AttValCon)= Set{}|
   rez.union(rsc.RSAttributes));
helper def: AllRelatedRS(rs:RM!RelationScheme,parent:RM!RelationScheme):
                                    Sequence(RM!RelationScheme)=
let allRIC:Sequence(RM!ReferentialIntegrityCon)=
                          RM!ReferentialIntegrityCon.allInstances() in
   allRIC->iterate(ric; rez: Sequence(RM!RelationScheme) = Sequence{} |
      if ric.LHS_RS.LHS_RS_IND=rs then
         rez.append(ric.RHS_RS.RHS_RS_IND).excluding(parent) else
         rez.excluding(parent) endif);
helper context RM!ReferentialIntegrityCon
def:ChildComponentTypeAttribute:Sequence(RM!AttValCon) =
self.LHS_RS.LHS_RS_IND.RSAttributes ->
   iterate(attr; rez: Sequence (RM!AttValCon) = Sequence{}|
   if self.RHS_Key.KeyAttr->collect(e | e.AttributeName.refGetValue('Name'))
      ->asSet().includes(attr.AttributeName.Name) then rez else
      rez.append(attr) endif);
helper def:ExistIRIC(ric: RM!ReferentialIntegrityCon):Boolean =
   let allIRIC:Sequence(RM!InverseReferentialIntegrityCon)=
      RM!InverseReferentialIntegrityCon.allInstances() in
      allIRIC->iterate(iric; rez:Boolean = false |
      if iric.RIC = ric then true else false endif);
```

Helpers used (directly or indirectly via some other helper) in the lazy rule **ChildCT**

Figure 6. Relation scheme – to – $\mathcal{F}$ _*Tree*[2] Form Type transformation

```
lazy rule GetFormType{
from
   p: RM!RelationScheme
using {
   children: Sequence(RM!RelationScheme)= thisModule.Children(p);
}
to
   ft: IISCase!FormTypeProgram(
      Name <- 'FormTypeN_' + p.Name,
      Title <-'FormTypeN_' + p.Name,
      ConsideredINDBSchDesign <- true,
      Frequency <- 1,
      ResponseTime <- 1,
      RootComponentType <- ctr
   ),
   ctr: IISCase!ComponentTypeRoot(
      Name <- 'ComponentTypeRootN_' + p.Name,
      Title <- 'ComponentTypeRootN_' + p.Name,
      ComponentTypeAttributes <-p.RSAttributes -> collect(e|
         if (e.oclIsTypeOf(RM!NotNullAttr)) then
            thisModule.RSAttributes2NotNullCompTypeAttribute(e) else
            thisModule.RSAttributes2NullCompTypeAttribute(e) endif),
      ComponentTypeKeys <- (p.EquivalentKey->collect(e|
         thisModule.EquivalentKey2CompTypeKey(e))).append(
         thisModule.EquivalentKey2CompTypeKey(p.PrimaryKey)),
      ComponentTypeUniques <- p.UQConstraints->collect(e|
         thisModule.UniqueCon2ComponentTypeUnique(e)),
      ComponentTypeCheck <- if p.TupleConstraint.oclIsUndefined() then OclUndefined else
         thisModule.TupleConstraints2ComponentTypeCheckCon(p.TupleConstraint) endif,
      Query <- true,
      Delete <- false,
      Insert <- false,
      Update <- false,
      ComponentTypeChildren <- children->collect(c | thisModule.ChildComponentType(c,p))
   )
   do{
      thisModule.attributes <- Sequence{};}}
```

Lazy rule **getFormType**

```
lazy rule ChildComponentType{
from
   rs:RM!RelationScheme,
   p:RM!RelationScheme
using{
   children: Sequence(RM!RelationScheme)= thisModule.Children(rs);
}
To
   ct: IISCase!ComponentTypeChild (
      Name <- 'Child_ComponentTypeN_' + rs.Name,
      Title <- 'Child_ComponentTypeN_' + rs.Name,
      ComponentTypeAttributes <- (rs.RSAttributes.asSet()-
         thisModule.parentKeyAttributes.asSet()) ->collect(e|
         if (e.oclIsTypeOf(RM!NotNullAttr)) then
            thisModule.RSAttributes2NotNullCompTypeAttribute(e) else
            thisModule.RSAttributes2NullCompTypeAttribute(e) endif),
      ComponentTypeAttributes <- if thisModule.RS_AllKeys(rs) then
         thisModule.AttributesOfRSs(rs, p)->collect(e|
         thisModule.RSAttributes2CompTypeAttribute(e)) else rs.RSAttributes ->
         collect(e| if (e.oclIsTypeOf(RM!NotNullAttr)) then
         thisModule.RSAttributes2NotNullCompTypeAttribute(e) else
         thisModule.RSAttributes2NullCompTypeAttribute(e) endif) endif,
      ComponentTypeKeys <- (rs.EquivalentKey->collect(e|
         thisModule.EquivalentKey2CompTypeKey(e))).append(
         thisModule.EquivalentKey2CompTypeKey(rs.PrimaryKey)),
      ComponentTypeUniques <- rs.UQConstraints->collect(e|
         thisModule.UniqueCon2ComponentTypeUnique(e)),
      ComponentTypeCheck <- if rs.TupleConstraint.oclIsUndefined() then
            OclUndefined else
            thisModule.TupleConstraints2ComponentTypeCheckCon(rs.TupleConstraint)
         endif,
      Query <- true,
      Delete <- false,
      Insert <- false,
      Update <- false,
      NoOfOcurrences <- #NoneOrMany,
      ComponentTypeChildren <- children->collect(c |
         thisModule.ChildComponentType(c,rs))
   )
   do{
      thisModule.attributes <- Sequence{};}}
```

Recursive ATL lazy rule **ChildComponentType**

```
helper def: Children(rs:RM!RelationScheme): Sequence(RM!RelationScheme) =
          let allRIC:Sequence(RM!ReferentialIntegrityCon)= RM!ReferentialIntegrityCon.allInstances() in
          allRIC->iterate(ric; rez:Sequence(RM!RelationScheme) = Sequence{}|
          if ric.RHS_RS.RHS_RS_IND=rs and thisModule.isRSforFormType(ric) then rez.append(ric.LHS_RS.LHS_RS_IND) else rez
endif);
```

Helper aimed at finding direct descendents of a relation scheme

Figure 7. Relation scheme – to – $\mathcal{F}_Tree^{n}$ Form Type transformation

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Contextual Spellchecking Based on N-grams

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Abstract. *Croatian Academic Spellchecker is an online web-service used for almost 20 years by thousands of users every day. In recent years, the service enabled rudimentary contextual spellchecking, based on pattern matching. In this paper we describe how it is possible to perform n-gram based contextual spellchecking of texts written in Croatian, regardless of the orthographic complexity of the Croatian language. Simple upgrade of the existing implementation was achieved by separating the system into several components. Using a well-known classifier, tweaking the frequency estimator and separating errors into confusion sets resulted in a contextual spellchecking system with a high score of* $F_1 = 0.95$ *on the examined example.*

Keywords. Contextual spellchecking, statistical approach; n-grams

1 Introduction

With the rise of remote communication, there is an increased need for a system that corrects orthographic and grammatical errors. This paper demonstrates an enhancement to the contextual spellchecking system of Haschek, a Croatian online spellchecker (service available at https://ispravi.me/) designed by Šandor Dembitz and described in Dembitz et al. (2011).
Contextual spelling errors, being the most complicated type of errors, have always been difficult to detect and correct. A spelling error in an intended word may result in the wrong real-word; that change will go undetected in a traditional spellchecker (*sljedeći* vs. *slijedeći*, *zahtijeva* vs. *zahtjeva*, etc.).
For both detection and correction of contextual errors, a statistical language model is needed. For every word that is suspected to be an error, a word with higher probability of occurrence in the given context must be chosen. The substitute word can in be any word in the language, making this computationally theoretically impossible for a smaller system.
The remainder of this paper is organized as follows: Chapter 2 describes the theoretical background behind our research; Chapter 3 explains the data sets used – n-grams collected in the more than 20 years of the usage of Croatian spellchecker and describes the system architecture. Chapter 4 explains the results and Chapter 5 gives detail about future research. Final chapter concludes the paper.

2 Theoretical background

In this section, we describe the theoretical background behind our proposed solution to the problem of contextual spellchecking for Croatian language.

2.1 Confusion sets

To solve the problem of detecting and correcting spelling errors, this paper proposes a solution modeled on Kim et al. (2013). A confusion set is a set of words for which there is a high probability of replacement due to either a typographical error or lack of knowledge about the language. An example of a confusion set is {*zahtjeva*, *zahtijeva*} or {*sljedeći*, *slijedeći*}.
The confusion sets can be generated manually or programmatically by using Levenshtein distance. Levenshtein distance is a measure of similarity of two texts (Martin, Jurafsky, 2000). There are four kinds of operations that can be made on a word – insertion of a letter, deletion of a letter, substitution of a letter or transposition of two letters.
While using an edit distance higher than one is possible, due to the nature of the Croatian language, the most common errors are within edit distance of 1.
Using an edit distance of 2 or more would increase the number of words in confusion sets and thus decrease the results of the classifier. In addition to that, the probability of making two errors in one word is very low.

2.2 Classifier

The classifier used in this paper is based on the well-known Naive Bayes classifier.

$$argmax_{TW} P(TW|CW)$$
$$= argmax_{TW} P(CW|TW)P(TW)$$
$$\approx argmax_{TW} \prod_{cw \in CW} P(cw|TW)P(TW)$$

$$TW = \{tw_1, ..., tw_m\}$$
$$CW = \{cw_1, ..., cw_n\}$$

Figure 1. Naive Bayes classifier

In the formula above (Fig. 2) TW (target words) are words from confusion sets and CW (context words) are words from the context of the target words. The context of the target words consists of words and their size depends on the chosen window size, i.e. if the window size is 5 and the third word is the target word, then the first, second, fourth and fifth word form the context.
Probability *P(CW|TW)* can be calculated from the conditional probability between target and context words, but it can only be approximated because CW in theory represents all words in the input except the target word, while $\{cw_1, ..., cw_n\}$ are words within the chosen window size. *P(TW)* is the probability of occurrence of target words.
Since the Naive Bayes classifier uses the probability of occurrence of the target word, the words that occur more frequently will be considered as correct. Because of that, the Naive Bayes classifier must be modified – instead of the probability of occurrence of the target word, we use credibility reliability (Kim et al., 2013).

$$argmax_{TW} P(TW|CW)$$
$$= argmax_{TW} P(CW|TW)P(TW)$$
$$\approx argmax_{TW} \prod_{cw \in CW} P(cw|TW)CR(TW)$$

$$CR(TW) = \begin{cases} 1-\varepsilon, & TW = \text{target word} \\ \frac{\varepsilon}{m-1}, & TW \neq \text{target word} \end{cases}$$

Figure 2. Modified Naive Bayes classifier.

In the formula above (Fig. 3), CR (credibility reliability) is the reliability of words for which the value of $1 - \varepsilon$ is given to the target word and the other value is given to a word from the confusion set.
ε is the typing error rate for the confusion set ($0 \leq \varepsilon \leq 1$) and *m* is the number of words in the confusion set.

2.3 Simple Good-Turing frequency estimation

The training dataset never contains all the words from the language. In this case, that means that there is a set of n-grams that haven't appeared in the training set, but may appear after the training of the classifier. If no method for frequency estimations is used, the system would assign a probability of 0 to unknown words, which would make the spellchecking of n-grams that contain a previously unseen context word impossible. To avoid that problem, a frequency estimator is used. In this research we use the Simple Good-Turing frequency estimation method (Gale, Sampson, 1995).

3 System architecture and n-grams

Our process of n-gram collection relies on the Croatian Academic online spellchecker Hascheck, and involves collecting n-grams from texts received for spellchecking. Our n-gram filtering is based on dictionary criteria. The texts received for spellchecking are used to create the the n-gram database (n = 1, 2, 3, …, 7). We choose to use 5-grams because they give us enough context while not overloading the system.

3.1 System architecture

The architecture of the contextual spellchecking system (Fig. 1) is relatively simple.



Figure 3. System architecture.

It consists of three separate subsystems. First is the data processing subsystem that takes the submitted text, extracts n-grams and calculates probabilities from the number of occurrences of the n-grams.
The second part is the classifier subsystem which uses the base probabilities to calculate the probabilities of the occurrence of each word in the context of the target words.
The last subsystem's task is frequency estimation and it uses the Simple Good-Turing method to calculate the probability of previously unseen words. The single most important characteristic of this system is that all three subsystems are completely decoupled.
The classifier can be completely changed and only the format of storing the final probabilities must remain the same. That means that the subsystems can be replaced without interfering with the rest of the system.

4 Results

In our research, we used the confusion set {*zahtjeva, zahtijeva}*. The confusion set contains approximately 810.000 5-grams split randomly into two parts – 1000 5-grams used as the testing dataset and the rest used as the training dataset. For consistency of the results, the random split was done only once and the same split was used for every improvement.

Table 1. Examples of extracted 5-grams

n-gram
zahtjeva potrebnih za igranje u
zahtjeva za nadzor i čelnika
oštar pad broja prvih zahtjeva
internetske stranice i zahtjeva korisnika
podnositelja zahtjeva na što je
osobine sustava poput zahtjeva za
zahtijeva pisanje programskog koda prema
zahtjeva u informatičke sustave na
ili prosječnu brzinu dolazaka zahtjeva
u javnosti prolazi set zahtjeva
apartmana ne zahtijeva nužno otvaranje

Table 1. shows a small subset of 5-grams extracted from the Hascheck 5-gram data set.

Table 2. Format of result examples

Original n-gram	Corrected n-gram	Probabilities
5-gram from the data set	5-gram corrected by the classifier	probability of *zahtjeva*, probability of *zahtijeva*

Table 2. contains the explanations of the format of tables shown in the following chapters.

4.1 Using modified Naive Bayes classifier

We start by presenting the results that are achieved by just using the modified Naive Bayes classifier.
Precision is the ability of the classifier not to label a negative sample as positive and the formula is $\frac{tp}{tp+fp}$, where *tp* is the number of true positives and *fp* the number of false positives.
Recall is the ability of the classifier to find all positive examples and the formula is $\frac{tp}{tp+fn}$, where *tp* is the number of true positives and *fn* is the number of false negatives.
The F_1 score is the harmonic mean of precision and recall.

Table 3. Results of modified Naive Bayes

Precision	Recall	F_1
0.92	0.88	0.9

As seen in Table 3., the system achieved a high F_1 score of 0.9. This is significant because, as previously stated, a frequency estimator hasn't been used yet and the classifier is based on the simple Naive Bayes classifier.

Table 4. Sample of results of modified Naive Bayes

Original n-gram	Corrected n-gram	Probabilities
zahtjeva potrebnih za igranje u	zahtijeva potrebnih za igranje u	0.49, 0.51
zahtjeva za nadzor i čelnika	zahtijeva za nadzor i čelnika	0.41, 0.59
oštar pad broja prvih zahtjeva	oštar pad broja prvih zahtijeva	0.0, 1.0
internetske stranice i zahtjeva korisnika	internetske stranice i zahtijeva korisnika	0.33, 0.67
podnositelja zahtjeva na što je	podnositelja zahtijeva na što je	0.33, 0.67
osobine sustava poput zahtjeva za	osobine sustava poput zahtijeva za	0.48, 0.52
zahtijeva pisanje programskog koda prema	zahtjeva pisanje programskog koda prema	0.7, 0.3
zahtjeva u informatičke sustave na	zahtijeva u informatičke sustave na	0.43, 0.57
ili prosječnu brzinu dolazaka zahtjeva	ili prosječnu brzinu dolazaka zahtijeva	0.29, 0.71
u javnosti prolazi set zahtjeva	u javnosti prolazi set zahtijeva	0.38, 0.62
apartmana ne zahtijeva nužno otvaranje	apartmana ne zahtjeva nužno otvaranje	0.82, 0.18

Examples from the Table 4. give us some insight into the current state of the system. We see that there are many examples in which the system is very close to the correct decision and only a few which we probably won't be able to correct by fine-tuning.

4.2 Application of the Simple Good-Turing method

By applying the Simple Good-Turing frequency estimator, the system can assign a default probability to previously unseen words. In addition to that, the probabilities of seen words have also been adjusted.

Table 5. Simple Good-Turing results

Precision	Recall	F_1
0.95	0.94	0.95

The results have increased by a significant margin (Table 5.). The F_1 score has gone up from from 0.9 to 0.95 because of the application of a relatively simple frequency estimator.

Table 6. Sample of Simple Good-Turing results

Original n-gram	Corrected n-gram	Probabilities
internetske stranice i zahtjeva korisnika	internetske stranice i zahtijeva korisnika	0.29, 0.71
osobine sustava poput zahtjeva za	osobine sustava poput zahtijeva za	0.43, 0.57
zahtijeva pisanje programskog koda prema	zahtjeva pisanje programskog koda prema	0.67, 0.33
u javnosti prolazi set zahtjeva	u javnosti prolazi set zahtijeva	0.33, 0.67
apartmana ne zahtijeva nužno otvaranje	apartmana ne zahtijeva nužno otvaranje	0.8, 0.2

Table 6. shows that approximately half of the errors present before the application of the Simple Good-Turing method were corrected.

4.3 Finding the optimal ε value

Results of the modified Naive Bayes classifier depend on the value of ε, as discussed in chapter 2.2. By changing the value of ε from 0 to 1 in 0.05 increments, we calculated the corresponding precision, recall and F_1. The subset of results (0 to 0.4) is shown in Table 7.

Table 7. Simple Good-Turing results

ε	Precission	Recall	F_1
0.0	0.78610288	0.79679378	0.79002095
0.05	0.92286562	0.92286562	0.92286562
0.1	0.95099250	0.94581310	0.94828566
0.15	0.94831142	0.94422327	0.94619281
0.2	0.94668353	0.93717405	0.94154730
0.25	0.95371447	0.94114861	0.94679921
0.3	0.94852399	0.93551566	0.94133470
0.35	0.93908864	0.92749797	0.93272569
0.4	0.78610288	0.79679378	0.79002095

Considering that the test set contained 1000 examples of which 200 were errors, the expected highest value of F_1 was for ε around 0.2. In this case, the highest F_1 value was for ε=0.1.

There are two things we can conclude from the results. First, ε can be set to an approximate value, i.e. the average error rate for Croatian. Second, ε can later be optimized for each confusion set separately, further improving the overall results of the system.

5 Future research

In this section, we describe the next steps that are needed to enhance the system described in this paper, in order to be used in a production environment.

5.1 Word parsing

Like all languages, the Croatian language is based on orthographic and grammatical rules. In the case of the Croatian language, the number of grammatical rules is above average, making it more complicated than i.e. English. In addition to many rules, Croatian has a lot of exceptions from those rules. Considering the size of the Hascheck n-gram data set, there is a good chance of "learning" most of those rules only based on statistics. By separating words into parts of speech and specifying the exact form of the word (i.e. past simple verb) it is possible to further increase the quality of the system. The word parser could be added as a separate subsystem when the word type database will be richer.

5.2 Optimizing data storage

Considering that the size of the 5-gram dataset is currently about 20 GB, optimizing data storage plays an important part in the future development of the system. Considering also that Hascheck is a relatively small project with limited funding, the prospects of providing enough system memory without rigorous data optimization is small. Some of the more basic data storage optimizations have been implemented in this research – extracting words from n-grams and converting words into integers.

5.3 Replacing the subsystems

Even though the Naive Bayes classifier paired together with the Simple Good-Turing frequency estimator had good results, there are other classifiers and frequency estimators that would give even better results (Chen, 1996). This means that regardless of the high F_1 score of 0.95, choosing a better classifier and a frequency estimator optimized for this specific data distribution could make the F_1 score get much closer to 1.

Conclusion

The goal of our research was to create a proof of concept contextual spellchecking system using simple and fast components. It was proven that a contextual spellchecking system with fast training times and high F1 score is possible, even for a language as complex as Croatian, by using confusion sets to reduce the number of possible options. The contextual spellchecking system offers a fast and highly efficient way of correcting most contextual errors, especially in categories that are most frequent, i.e. *ije*/*je*.
The specific execution time is dependent on hardware, but the fact that the spellchecking of the 1000 test n-grams takes less than 0.1s is promising. Considering that there is an ever-growing need for high quality contextual spellchecking, further optimization and implementation of our research will be prioritized in the online spellchecking service.

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Validation of Survey of Preservice Teachers' Knowledge of Teaching and Technology in the Context of Croatian Educational System

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Abstract. *Digital competences should be considered in teacher education but also in the field of teacher professional development. Technological Pedagogical Content Knowledge (TPACK) framework represents teacher knowledge for technology integration and is represented by seven domains. Survey of Preservice Teachers' Knowledge of Teaching and Technology (SPTKTT) is one of the inventories developed to measure TPACK framework. Authors of the inventory have found empirical support for all seven domains of TPACK framework by the use of exploratory factor analysis. Aim of this study is to validate SPTKTT inventory in the context of Croatian educational system by the use of exploratory and confirmatory factor analysis. Results showed that structure of SPTKTT inventory consists of nine factors, while confirmatory factor analysis confirmed that three factors which refers to Content Knowledge domain fall under the one single factor. Internal consistency of the inventory shows high reliability.*

Keywords. TPACK framework, SPTKTT inventory, validation, exploratory factor analysis, confirmatory factor analysis

1 Introduction

Development of education in the 21st century implies the use of the technology in the sense of improving the learning and teaching process. All higher educational systems emphasize the need for development of digital knowledge, skills and accountability of students of educational study programs and in-service teachers. Croatian educational strategies also stress that rapid technological changes place great challenges on the teaching profession that require profound changes in teaching and learning (Vlada Republike Hrvatske, 2014). Competences (as personalized learning outcomes) in the area of education and training include subject-specific (academic) competences and didactic-methodical competencies. Basic teacher's competences imply effective work with information and communication technologies (ICT) e.g. skills and knowledge about them (Agencija za odgoj i obrazovanje, 2014).

Koehler and Mishra (2009) have developed a framework for teacher knowledge for technology integration called Technological Pedagogical Content Knowledge (TPACK). TPACK framework builds on Lee Shulman's construct of Pedagogical Content Knowledge (PCK) to include technology knowledge. In this model (Figure 1.) there are three main components of teachers' knowledge: Content (CK), Pedagogy (PK), and Technology (TK). Equally important to the model are the interactions between and among these bodies of knowledge, represented as: PCK (Pedagogical Content Knowledge), TCK (Technological Content Knowledge), TPK (Technological Pedagogical Knowledge), and TPACK (Technological Pedagogical Content Knowledge). The interaction of these bodies of knowledge, both theoretically and in practice, produces the types of flexible knowledge needed to successfully integrate technology use into teaching (Koehler & Mishra, 2009). It should be pointed out that education for the 21st century, besides acquisition of knowledge, implies the acquisition of skills and competences (European Commission, 2008), (OECD, 2008).

By better describing the types of knowledge teachers need (in the form of content, pedagogy, technology, contexts and their interactions) it allows teachers, researchers, and teacher educators to move beyond oversimplified approaches that treat technology as an "add-on" instead to focus upon the connections among technology, content, and pedagogy as they play out in classroom contexts.

Schmidt et al. (2009) created the inventory for measuring TPACK named Survey of Preservice Teachers' Knowledge of Teaching and Technology (SPTKTT).

This research represents validation of the SPTKTT inventory carried out by the use of exploratory and confirmatory factor analysis in Croatian context.

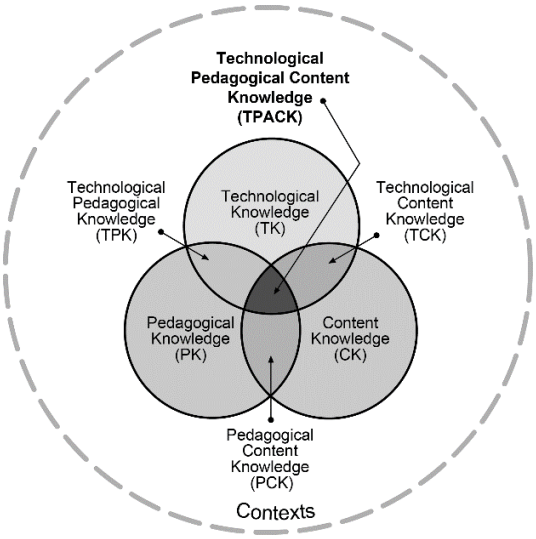


Figure 1. The TPACK framework (reproduced by permission of the publisher, © 2012 by tpack.org)

2 Literature Review

The most significant contribution of the TPACK framework is in the field of teacher education but also in the field of teacher professional development. One of the significant limitations of the TPACK framework is that it is neutral with respect to the broader goals of education. For instance, the TPACK framework does not speak to what kinds of content need to be covered and how it is to be taught (Koehler et al., 2014, p. 109). According to pedagogical approach TPACK framework is considered as pedagogically free and can be used for different pedagogical approaches (Valtonen et al., 2015). Koehler et al. (2014, p. 109) emphasized the need for development in the area of measuring how TPACK works in different disciplinary contexts while Valtonen et al., (2015) distinguished two main challenges related to the available instruments remains—namely, psychometric features and the nature of pedagogical knowledge.

Several TPACK measurement instruments are developed and their factor structure is determined (Table 1).

Rosenberg and Koehler (2015) cite that some researchers have used the measurement of TPACK to confirm the proposed TPACK framework structure composed of seven domains, as represented in Fig. 1, while others have found support for fewer components. Different studies resulted with different number of factors extracted during the exploratory factor analysis: three (Archambault & Barnett, 2010), four (Chai, Koh & Tsai, 2010), five (Koh, Chai & Tsai, 2010), (Lee & Tsai, 2010), (Chai et al., 2011), (Baser et al., 2015), six (Valtonen et al., 2015), seven (Schmidt, et al., 2009), (Pamuk et al., 2013) and eight (Shinas et al., 2013) (

Table ***1***).

Authors of the SPTKTT inventory (Schmidt et al., 2009) conducted exploratory factor analysis over the inventory items and confirmed factor structure with high factor loadings and Cronbach α coefficient values. SPTKTT has been criticised because the process of validation was conducted separately for each of the seven areas of TPACK (Chai et al., 2011).

Based on the reviewed literature, this study aims to address the following research questions:

1. What factors of TPACK are perceived by Croatian students of primary education study programs when a SPTKTT inventory is being used?
2. Do differences in educational systems affect the factor structure of the TPACK framework measured by the SPTKTT inventory?

Table 1. Measurement instruments developed on the base of TPACK framework

Study	Number of items	Participants (context)	Number of determined factors
(Schmidt et al., 2009)	47	Undergraduate students	7
(Archambault & Barnett, 2010)	24	Online teachers	3
(Chai et al., 2010)	18	Singaporean preservice teachers	4
(Lee & Tsai, 2010)	30	Self-efficacy of Taiwanese teachers for web-based learning	5
(Chai et al., 2011)	46	Singaporean preservice teachers (ICT for meaningful learning)	5
(Pamuk et al., 2013)	37	Preservice teachers	7
(Baser et al., 2015)	39	Preservice teachers (English as foreign language)	5
(Valtonen et al., 2015)	36	Preservice teachers (ICT in the context of 21st century skills)	6

3 Methodology

3.1 Sample

The data necessary to validate the inventory were collected during the academic year 2015/16 at five faculties in the Republic of Croatia. The sample consists of 337 students and was collected through different study programmes that educate future pre-school teachers (N=21), 1st through 4th grade primary school teachers (N=301) and 5th through 8th grade primary school teachers (N=15). Sample was collected on the undergraduate and graduate level and includes all study years on both levels.

3.2 Measurement instrument

The Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009) is a 47-item Likert scale survey with items (T1 – 47) that includes 10 subscale measures for each TPACK domain, including 4 subscales for different areas of content knowledge (literacy, social studies, mathematics, and science) (Appendix). Participants rated their agreement with each item on a 5-point Likert type scale (5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree). The measure of TPACK domains used in this study represents participants' self-assessment of their knowledge. Schmidt et al. described the development and validation of this instrument and reported Cronbach's α coefficients for the subscales ranging from .75 to .92. The survey was developed specifically for use with students of the primary and/or early childhood education study, so it included multiple subscales to assess perceived content knowledge in all content areas that the students would potentially be teaching in their future classrooms, including mathematics, science, social studies, and literacy (Abbitt, 2011).

SPTKTT focuses on pedagogical themes on a very general level (Valtonen et al., 2015) and was used in this research because of the generic nature of items, since the sample consists of students of the elementary and/or early childhood education attending different study programmes and courses.

The original SPTKTT inventory was written in English language. For the research presented here it was translated into Croatian language using the double-translation method and was proof-read.

3.3 Data analysis

To determine factor structure of the SPTKTT inventory, exploratory factor analysis was carried out. In order to determine fitting between empirical data and theoretical structure, confirmatory factor analysis was used. Internal consistency of the inventory was represented by the use of Cronbach α coefficient.

4 Inventory validation

4.1 Exploratory factor analysis

Considering the differences in Croatian and USA educational systems exploratory factor analysis (EFA) was conducted to establish eventually differences in factor structure. The exploratory factor analysis was carried out on the basis of all 47 items.

EFA was carried out with the help of Statistica 12.7 software. In the course of factor extraction a principal components analysis was used, as well as varimax normalized rotation for the purpose of an easier dimension interpretation. In order to determine the number of factors a Kaiser criterion of eigenvalues > 1 was used (Kaiser, 1960). The usage of Kaiser criterion resulted in extraction of 9 factors which explain 67.9 % of variance.

For the data interpretation only factor loadings higher than 0.32 were considered (Tabachnick & Fidell, 2013, p. 654). Table 2 shows factor loadings for each item in relation to nine factors after applying varimax normalized rotation.

Items T1-T7 (Technological Knowledge), T20-T26 (Pedagogical Knowledge), T27-T30 (Pedagogical Content Knowledge) and T31-T34 (Technological Content Knowledge) distributed in the same way as in EFA conducted by the authors of the inventory. Items T8-T19 distributed among three factors, despite the EFA conducted by the authors of the inventory where these items loaded into four factors. Items T35-T43 loaded into one factor (Pedagogical Content Knowledge), as well as items T44-T47 (Technological Pedagogical Content Knowledge). Items T40-T43 loaded also into the Technological Pedagogical Content Knowledge factor but with lower factor loadings.

4.2 Confirmatory factor analysis

Confirmatory factor analysis was carried out with the help of structural equation modelling software LISREL 9.2. There are different fit indices for the theory model and empirical data. There are different opinions about the need to list particular fit indices, as well as their cut-off values indicating a good model fit. A review work by McDonald and Ho (2002) states that the most frequently cited fit indices are comparative fit index (CFI), goodness of fit index (GFI), normed fit index (NFI) and nonnormed fit index (NNFI). Although GFI is one of the most frequently cited fit indices, researches have shown its inconsistency.
Combining a large number of degrees of freedom (df) regarding the sample size, the GFI yields lower values (Sharma at al., 2005), whereas its value goes up with big samples (Miles & Shevlin, 1998).
In order to confirm a good fit between the model and the data Hu and Bentler (1999) suggest a combination of two indices, one of which is always standardized root mean square residual (SRMR) (≤ 0,09), and the.

Table 2. Factor loadings for all items of SPTKTT inventory after varimax normalized rotation

Variable	**Factor Loadings** (Varimax normalized) Extraction: Principal components (Marked loadings are >.320000)								
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**	**Factor 7**	**Factor 8**	**Factor 9**
T1	0.173035	0.131705	0.011422	**0.667515**	0.127167	0.196009	0.138205	0.117515	-0.094175
T2	0.059409	0.082655	0.114910	**0.731438**	0.177974	0.025095	0.199975	0.063730	-0.164846
T3	0.061634	-0.005512	0.111991	**0.800331**	0.050166	0.009748	0.062514	0.165128	-0.045069
T4	0.038371	-0.005866	0.118113	**0.776337**	-0.159082	0.106012	0.053215	0.010755	0.209261
T5	0.051833	0.035265	0.077849	**0.779735**	-0.067427	0.216657	0.131650	0.098346	0.134381
T6	0.054271	0.103344	0.027378	**0.698892**	0.173207	0.105881	0.144461	0.014139	0.061781
T7	0.205982	0.042005	0.018260	**0.590959**	0.137798	0.113422	-0.005389	0.076278	0.190329
T8	0.096447	**0.853766**	0.092236	0.083552	0.110161	0.080206	0.058844	-0.002668	-0.021750
T9	0.063385	**0.879355**	0.030641	0.117861	0.086029	0.170269	0.007144	0.052173	-0.022286
T10	0.053230	**0.742583**	-0.004627	0.040052	0.009413	0.238212	0.103616	0.162330	0.187074
T11	0.105297	0.014883	0.131858	0.255574	**0.339561**	**0.576071**	-0.020848	-0.019135	0.096359
T12	**0.372962**	-0.046484	0.076777	0.044865	0.175935	**0.663429**	-0.100741	-0.064809	-0.070354
T13	0.138388	-0.012035	0.066482	0.072899	0.182411	**0.706162**	0.051006	-0.077808	0.260790
T14	0.036491	0.265433	0.074208	0.177561	0.097993	**0.726504**	0.031937	0.140564	-0.045618
T15	-0.019139	0.193453	0.114014	0.178012	0.053727	**0.775783**	0.142523	0.193807	-0.004617
T16	-0.071483	0.258096	0.078839	0.122469	-0.032515	**0.733166**	0.163990	0.244488	0.102308
T17	0.061821	0.117962	0.101489	0.161980	**0.803208**	0.114136	0.117956	0.039958	-0.008222
T18	0.086684	0.104230	0.092600	0.087659	**0.829069**	0.160431	0.156953	0.046995	0.024175
T19	0.081065	-0.004439	0.093177	0.046716	**0.765338**	0.236677	0.108821	0.158668	0.153059
T20	0.100063	0.057367	**0.760569**	0.143349	0.086640	0.040819	-0.081219	0.148333	-0.112826
T21	-0.022029	0.007330	**0.765863**	0.021914	0.099169	0.055152	0.253710	0.139839	0.118827
T22	-0.012368	-0.061393	**0.738486**	0.016992	0.087431	0.066088	0.296029	0.079298	0.107829
T23	0.163274	0.063791	**0.796528**	0.039719	0.068637	0.029388	0.070535	0.098859	0.051802
T24	0.246350	-0.030115	**0.654370**	0.052699	0.048474	0.120489	0.273833	0.076077	0.148870
T25	**0.326815**	0.013285	**0.543568**	0.133066	-0.046868	0.132512	0.068804	-0.180522	0.102796
T26	0.203186	0.188826	**0.603853**	0.101189	0.038259	0.104220	-0.005838	0.147830	**0.335304**
T27	0.181213	0.309014	**0.491314**	0.141015	0.007118	0.080118	0.230117	0.141614	**0.554897**
T28	0.300399	0.013106	**0.438510**	0.149129	0.117692	0.210691	0.129910	0.088509	**0.644434**
T29	0.201669	0.112096	**0.506784**	0.156159	0.024440	0.306422	0.195304	0.206777	**0.516329**
T30	0.253309	-0.002354	**0.448251**	0.067962	0.311154	0.059617	0.182294	0.182008	**0.564667**
T31	0.200324	**0.365351**	0.150268	0.159832	0.027400	-0.005252	0.115207	**0.705263**	0.090211
T32	**0.333070**	0.004356	0.164402	0.188910	0.050088	0.192434	0.170441	**0.648585**	0.134190
T33	0.239908	0.107905	0.183595	0.132482	0.024115	**0.372608**	0.132187	**0.694454**	0.086306
T34	**0.324813**	-0.057856	0.141477	0.125759	0.266378	0.033266	0.242673	**0.658529**	0.094935
T35	**0.396914**	0.018855	0.268498	0.216390	0.203024	0.016379	**0.409795**	**0.384202**	-0.096237
T36	**0.409363**	0.015858	0.280322	0.209754	0.202326	0.007136	**0.446755**	**0.384375**	0.007721
T37	0.051079	0.070074	0.142501	0.055117	0.042688	-0.069456	**0.614434**	0.133409	0.313935
T38	-0.001977	0.071746	0.064334	0.107300	0.106009	0.184005	**0.719462**	-0.031936	0.127952
T39	0.282210	0.049446	0.177673	0.221471	0.083060	0.098454	**0.715104**	0.139560	0.038547
T40	**0.410980**	0.041439	0.142958	0.179492	0.066162	-0.011690	**0.646712**	0.238897	-0.049005
T41	**0.431085**	-0.019787	0.279216	0.077335	0.143574	0.050769	**0.535717**	0.126302	-0.014289
T42	**0.390111**	0.092800	0.258053	0.259113	0.099576	0.145573	**0.436946**	0.112379	-0.071768
T43	**0.462385**	0.078451	0.194947	0.222429	0.163844	-0.033114	**0.484715**	0.224294	-0.027055
T44	**0.699619**	0.289075	0.162192	0.130747	-0.078999	0.030342	0.180235	0.219370	0.077754
T45	**0.789287**	-0.021634	0.161235	0.099308	0.144378	0.075399	0.175974	0.174362	0.175584
T46	**0.762735**	-0.008923	0.159412	0.109399	0.121550	0.160501	0.158011	0.162553	0.259095
T47	**0.733959**	0.150623	0.158615	0.109254	0.008607	0.153186	0.170880	0.248755	0.073425
Expl.Var	4.446140	2.734790	5.076877	4.458359	2.687765	3.753857	3.756096	2.938764	2.076020
Prp.Totl	0.094599	0.058187	0.108019	0.094859	0.057186	0.079869	0.079917	0.062527	0.044171

other one NNFI (≥ 0,96),), root mean square error of approximation (RMSEA) (≤ 0,06) or CFI (≥ 0,96). Kline (2005) states that one should definitely cite Chi-Square test ($\chi 2$), RMSEA, CFI and SRMR when citing fit indices. Hooper and associates (2008) suggest, apart from the previously mentioned, besides Chi-Square test to cite degrees of freedom (df) and the p-value, along RMSEA its confidence interval and also to cite parsimonious normed fit index (PNFI) because stated indices are the least sensitive to the size of the sample, nonspecificity of the model and estimation parameters.

After the confirmatory factor analysis had been carried out, modification indices suggested the addition of error covariance among certain variables in order to improve fit indices (Fig. 2).

Only error covariance among variables belonging to the same factor was taken into account. These changes helped to improve fit indices.

Fit indices of model and empirical data are the following: $\chi 2 = 2117.1$, $p = 0.0000$, $df = 994$, $\chi 2/df = 2.13$, RMSEA = 0.0579 with confidence interval (0.0545; 0.0613), SRMR = 0.0591, CFI = 0.889, PNFI = 0.745.

Regarding RMSEA $\leq$ 0.06 and SRMR $\leq$ 0.09, according to Hu and Bentler (1999), these empirical data fit well into the proposed factor structure, through which this model was confirmed.

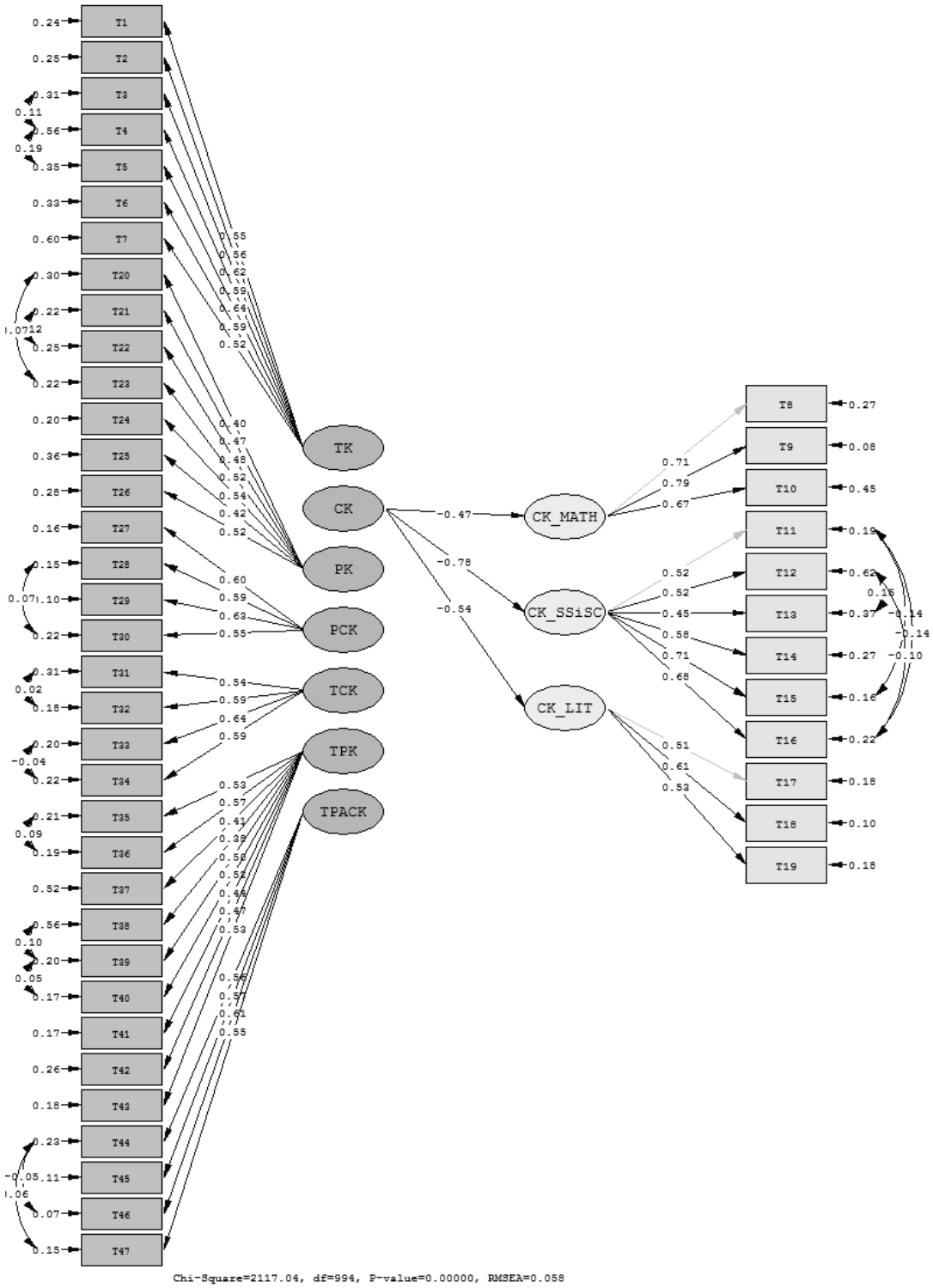


Figure 2. Confirmatory factor analysis of the SPTKTT inventory

4.4. Reliability

Cronbach α coefficients are greater than 0.9 (0.9093 – 0.9328) for every observed item, sub-scale and entire scale which suggests high reliability of the SPTKTT inventory.

5 Conclusion

The main aim of the research presented in this paper is to validate SPTKTT inventory in the context of Croatian educational system by the use of exploratory and confirmatory factor analysis. Results of this research represent empirical support for a TPACK theoretical framework.

In order to answer to the research question 1 exploratory factor analysis was carried out on subscales and items of the SPTKTT inventory, pointing to the structure of the nine factors. The sample used for the factor analysis is suitable for the group of respondents for which the inventory was created. The sample size is also appropriate for the number of items the inventory contains. In order to answer to the research question 2 the differences in the factor structure among this research and research conducted by Schmidt et al. (2009) can be explained with differences in educational systems of the countries in which the research was conducted (USA and Croatia). In the USA school subjects, according to contents, are Mathematics, Science, Social Sciences and Literacy while in Croatia they are Mathematics, Literacy (named Croatian Language) and Social Sciences and Science joined to one subject (named Nature and Society). Confirmatory factor analysis confirmed empirical data and theoretical model.

The reliability of the SPTKTT inventory was shown using Cronbach α coefficient. The results indicate a high level of reliability for all subscales and items of the inventory, what corresponds with already achieved results (Schmidt et al., 2009).

Possible limitations of the research can be observed in the form of inventory that represents self-reported measure and sample that is not representative.

Importance of this research is to analyse Croatian teacher education context regarding knowledge about teaching and technology. As a result it is justified to use the instrument for the further research in Croatia. Since the instrument is content neutral the special challenge can be to align generic items of the instrument to concrete domains and evaluation of knowledge that are not based only on self-reporting.

Acknowledgments

This work has been partly supported by the Croatian Science Foundation under the project Higher Decision IP-2014-09-7854.

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Appendix

Items of the Survey of Preservice Teachers' Knowledge of Teaching and Technology by domains

TK (Technology Knowledge)

T1. I know how to solve my own technical problems.
T2. I can learn technology easily.
T3. I keep up with important new technologies.
T4. I frequently play around the technology.
T5. I know about a lot of different technologies.
T6. I have the technical skills I need to use technology.
T7. I have had sufficient opportunities to work with different technologies

CK (Content Knowledge)

Mathematics

T8. I have sufficient knowledge about mathematics.
T9. I can use a mathematical way of thinking.
T10. I have various ways and strategies of developing my understanding of mathematics.

Social Studies

T11. I have sufficient knowledge about social studies.
T12. I can use a historical way of thinking.
T13. I have various ways and strategies of developing my understanding of social studies.

Science

T14. I have sufficient knowledge about science.
T15. I can use a scientific way of thinking.
T16. I have various ways and strategies of developing my understanding of science.

Literacy

T17. I have sufficient knowledge about literacy.
T18. I can use a literary way of thinking.
T19. I have various ways and strategies of developing my understanding of literacy.

PK (Pedagogical Knowledge)

T20. I know how to assess student performance in a classroom.
T21. I can adapt my teaching based-upon what students currently understand or do not understand.
T22. I can adapt my teaching style to different learners.
T23. I can assess student learning in multiple ways.
T24. I can use a wide range of teaching approaches in a classroom setting.
T25. I am familiar with common student understandings and misconceptions.
T26. I know how to organize and maintain classroom management.

PCK (Pedagogical Content Knowledge)

T27. I can select effective teaching approaches to guide student thinking and learning in mathematics.
T28. I can select effective teaching approaches to guide student thinking and learning in literacy.
T29. I can select effective teaching approaches to guide student thinking and learning in science.
T30. I can select effective teaching approaches to guide student thinking and learning in social studies.

TCK (Technological Content Knowledge)

T31. I know about technologies that I can use for understanding and doing mathematics.
T32. I know about technologies that I can use for understanding and doing literacy.
T33. I know about technologies that I can use for understanding and doing science.
T34. I know about technologies that I can use for understanding and doing social studies.

TPK (Technological Pedagogical Knowledge)

T35. I can choose technologies that enhance the teaching approaches for a lesson.
T36. I can choose technologies that enhance students' learning for a lesson.
T37. My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom.
T38. I am thinking critically about how to use technology in my classroom.
T39. I can adapt the use of the technologies that I am learning about to different teaching activities.
T40. I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.
T41. I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom.
T42. I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district.
T43. I can choose technologies that enhance the content for a lesson.

TPACK (Technology Pedagogy and Content Knowledge)

T44. I can teach lessons that appropriately combine mathematics, technologies and teaching approaches.
T45. I can teach lessons that appropriately combine literacy, technologies and teaching approaches.
T46. I can teach lessons that appropriately combine science, technologies and teaching approaches.
T47. I can teach lessons that appropriately combine social studies, technologies and teaching approaches.

Digital Competence for Science Teaching

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Abstract. *The digital competence of science teachers can be described at the basic (teachers as citizens); general professional; and special professional levels. At the basic level typical competences include use of e-mail, Internet browsers, Word processors, home multimedia; the general-professional level includes ICT usages common to all teachers, such as interactive boards At the special-professional levels subject-specific ICT applications are added, such as the use of data loggers, digital microscopy, subject specific software and virtual laboratory. Three levels of mastery of digital competence are proposed, at the basic (Remembering, Understanding), medium (Applying, Analyzing, Synthesizing) and expert (Evaluating, Creating).*

Keywords. Computers, Digital competence, ICT, Science teachers, Teacher education

1 Introduction

With the exponential growth of knowledge and the emergence of cutting-edge technologies, the basic question becomes how to educate students to perform appropriately in situations that were unknown when they were being educated (Illeris, 2008, p. 2). This refers to all educational levels before the end of formal education. As a consequence of changing demands, the attention of educators has to be reoriented from content towards competences. The European Parliament published a framework of eight key competences for lifelong learning (Recommendation of the European Parliament and of the Council, of 18 December 2006, on key competences for lifelong learning [Official Journal L 394 of 30.12.2006].) as "a combination of knowledge, skills and attitudes appropriate to the context". The proposed list of competences is as follows: Communication in the mother tongue; Communication in the foreign languages; Mathematical competence and basic competences in science and technology; Digital competence; Learning to learn; Interpersonal, intercultural and social competences and civic competence; Entrepreneurship; and Cultural expression. In daily educational practice, this list can be regarded as wishful thinking. The reason is that the competences in the document are not presented in operational form, an omission that places a heavy load on educators who try to implement these guidelines in practice. They need not only to possess these competences but also to be able to prepare instructions and teaching activities in such a way as to enhance their development in students. The problem of operationalizing Digital competence was recently addressed by the Digital Competence Framework for Citizens (DigComp 2.1), with the aim of providing a general frame of reference and self-evaluation tools. Recognition of the need to change teaching strategies toward active, student-centered methods, where students construct knowledge in a safe and socially-rich environment, is insufficient by itself. The question to be answered is, are teachers prepared for this task? The second question is, will they welcome changes to teaching strategies mastered over years of practice? For teachers, there are always two possible ways of including something new into their routines. The first one is to quietly wait for someone else to change their curriculum, a process which, in a semi-rigid system, where decisions are prepared at the state level, can take years. The second one is to take destiny into their own hands and use their right to autonomously choose a teaching method to be used in the classroom. And the third question is, how do we train pre-service teachers for their new role in the classroom?

In recent decades, information and communication technologies (ICT) have become a part of everyday experience for a large number of people, with the potential to change virtually every aspect of human lives. Moreover, "Information and communication technology (ICT) has become, within a very short time, one of the basic building blocks of modern society" (UNESCO, 2002). With innovations emerging on a daily basis, the skills needed to survive in an ICT-rich

world are increasing daily, and the gap between those who possess knowledge and technology and those who do not, is becoming wider and wider (Mariscal, 2005). Terms like (e)competence, digital literacy or digital competence (Mallan and Yarger, 1975; Recommendation of the European Parliament and of the Council, 2006; Bjekić, Krneta and Milosevic, 2010) have been introduced to address the importance of computer-based technologies, both in society in general and in education as one of the most important processes within it. In practice, the use of ICT in education always lags far behind its use in science, industry or communication. For example, the usage of ICT in Slovenian schools outside of specialized subjects like Computer Science or Informatics is encouraged but not obligatory for teachers. As a consequence, in Science education there exists an asymmetry with the expectations of students, who expect the teaching of science to involve a mixture of interesting, multimedia-supported lectures, with frequent laboratory and field work. In reality, they most often get direct instruction intended to cover the textbook content in detail, with success on final examinations as the ultimate goal of education (Krečič, Grmek and Perše, 2008; Šorgo and Špernjak, 2007; Špernjak and Šorgo, 2009). However, in Denmark preservice teachers have to pass a license qualification exam that verifies their digital competency, to ensure quality information and communications technology (ICT) usage (Maderick, Zhang, Hartley, and Marchand, 2016). These expectations have advanced to the point where institutionally this integration has become a requirement for the accreditation of higher education and teacher education programs in the United States (Council for the Accreditation of Educator Preparation, 2014; National Council for Accreditation of Teacher Education, 2011). The key role in ICT education has been assigned to schools, and the heaviest load has been confidently delegated to teachers. The role of ICT usage in schools for learning purposes is twofold. The first one is to serve societal expectations, and the second is to raise the quality of education. In attempts towards better education, it is often forgotten that the presence of ICT cannot raise the quality of education by itself, because ICT is only a prerequisite and a tool for improving the quality of teaching and learning as dominant school activities (Mooji and Smeets, 2001; Tearle, 2003); buying school equipment is the easy part of the job (Hawkins, 2002; Hepp, Hinostroza, Laval and Rehbein 2004; Resnick, 2002).

The implementation of ICT in schools is not – either logistically or materially – a simple task and generally can follow two tracks. One is through specialized subjects like Computer Science or Informatics, while the second is the currently prevailing idea that ICT must be incorporated into the teaching of every subject by all teachers. As a consequence, teachers have to possess, in addition to subject-specific competences, the knowledge, skills, and flexibility to incorporate ICT into their teaching practice, a requirement that can be accompanied by many practical problems in implementation (Selwyn, 2000; Tondeur, van Braak and Valcke, 2007).

If we recognize the demand for flexible and better educated digitally competent citizens as one of the main goals of educational systems, then teachers have to be one step beyond their students. Teachers not only need to possess the appropriate knowledge, skills and attitudes toward the proposed competences, but also need to be additionally competent in the pedagogy of its successful implementation in teaching to enhance learning. As a suitable theoretical framework toward the development of teacher competences, we can use Shulman's (1986) model of Pedagogical Content Knowledge (PCK), extended where technology is used, to Technological Pedagogical Content Knowledge (Mishra and Koehler, 2006; Koehler, Mishra, and Yahya, 2007).

2 Digital competence in science teaching

One of the basic competences is digital competence, which "involves the confident and critical use of information society technology (IST) and thus basic skills in information and communication technology (ICT)". Explanations about digital competence given in the Recommendations can be regarded only as a framework and are not sufficiently operational to be used directly in the case of science teachers, where the introduction of ICT into regular instruction is accompanied by many challenges (Špernjak and Šorgo, 2009; Šorgo et al., 2010). According to Maderick et al. (2016), the term digital competence herein shall be construed and limited to meaning, having the skill, ability, and knowledge to successfully use computers, their related applications and software in the practice of teaching and education.

In the case of teachers, we can recognize the double role of ICT in their lives. The first role is to fulfil their personal needs as digital citizens, possessing the skills with and knowledge of computers in the role of clerical, informational and multimedia tool. On the professional level, their role does not end with the use of ICT to improve their content teaching, maintain school e-administration and function as a desktop library. Teachers must additionally be prepared to cooperate with other educators in the effort to educate digitally competent students. According to Kör, Erbay, Engin and Dünder (2017), individuals with positive attitudes towards technology are more likely to use technological devices.

As science educators, we can easily recognize that general definitions and frameworks concerning digital competence (digital literacy, ICT-competence, etc.) in school work are too narrow because science teaching, especially in practical, laboratory and field work, goes

beyond the common teaching practices used in most other subjects (Moradi, Fallah and Ahmadi, 2009). In practical and laboratory work, ICT is regularly used in the form of data-loggers, digital microscopy, controllers, etc., comprising instructional practices rarely or never used in other subjects. For a complete development of digital competence in science teaching, the teacher must be keen on the basic acquisition, classification, analysis, assessment and presentation of primary data, while also being competent in the sound use of the technology connected with computer interfaces. In such cases we can recognize digital competence as being closely connected to the description of technological competence within the theoretical framework of Technological Pedagogical Content Knowledge (Mishra and Koehler, 2006). In their words (p. 1028), "Teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology …, and knowing how teaching might change as the result of using particular technologies."

There are many possibilities for using ICT in biology (science) instruction. Besides creating documents, collecting information, communication and the use of multimedia, the most important element involves virtual and real computer-supported biological laboratory (CSL) exercises (Rogers and Wild, 1994; Strømme, 1998). CSL offers many advances in biology (science) teaching. Students like to work with ICT to perform experiments (Šorgo and Špernjak, 2007; Špernjak and Šorgo, 2017) in what they consider an interesting way, and this activity results in skills and knowledge of high quality (Pickering, 1980; Beatty and Woolnough, 1982; Kirschner and Meester, 1988; Špernjak, Puhek and Šorgo, 2010), especially when inquiry and problem-based approaches are used (Domin, 1999). By using such techniques, they are developing a wide set of generic and key competences (Michael, 2006). Yet, these promises are fulfilled only for those with access to and competence to use these new technologies (Mariscal, 2005).

On the other hand, demand for using digital technologies in the school laboratory, in field-work, or in the classroom places additional responsibility on science teachers. Students can use computers as sophisticated typewriters, as desktop libraries or communication tools and for multimedia in literally every subject, while the use of ICT units as processors, controllers and data-loggers can be introduced in only a limited set of school subjects or activities (Haydn and Barton, 2007). In this case, if, for example, one teacher at a school does not promote the use of computers in the classroom as a tool for finding information, the loss for students is minor, because with equivalent work in other subjects they can fill the gap. If, on the other hand, science teachers do not use data-loggers in the school laboratory, there is nobody at school to cover the missing knowledge (Špernjak and Šorgo, 2009).

3 Levels of Digital Science Competence

Russell, Bebell, O'Dwyer, and O'Connor (2003) identified six categories of ICT use by teachers: use of ICTs for lesson preparation, material production, student guidance, special education, email, and also for recordings and registers. Braak, Tondeur and Valcke (2004) identified two types of strategies for or patterns of use of ICTs in schools: mere support of the teaching process, and effective use of those resources in teaching development.

As a framework for setting competence levels for digital Science competence, in a range from pre-competence to expert level, we have used and modified levels from a revised Bloom's Taxonomy (Krathwohl, 2002) and combined these with the framework of ICT literacy in the 21st century (Moradi et al. 2009). As a theoretical framework, we produced the 3x3 matrix presented in Tables 1 and 2. First, we can recognize the three levels of digital competence (Table 1). At the first level are competences defined in the Framework as key digital competence that are common to all citizens. At the second level are general professional competences, which are common to all teachers but not to other professions. At the third level are the special-professional digital competences of Science teachers. An example of such a competence is the usage of data-loggers in the school laboratory.

The second divide is at the level of mastery of digital applications, along with the competence to use them correctly in the classroom (Table 2).

Table 1. Levels of digital competence among science teachers

Horizontal circles of digital competence	**Descriptions**	**Examples**
1. Basic	Teachers as citizens	e-mail, Internet browsers, Word processors, home multimedia, etc.
2. General - professional	ICT usages common to all teachers	Interactive boards blackboards, school e-administration, Moodle, etc.
3. Special - professional	Subject-specific usage of ICT	data loggers, digital microscopy, special subject-specific software, virtual laboratory, etc.

We cannot recognize expertise simply by counting the applications that are used by a teacher. A teacher could be at the expert level in using some applications,

while ignoring other applications. On the first, basic level, teachers are able to use ICT in limited ways; on the second level, they can use applications within the common practice proposed by the manufacturer, and on the third 'expert' level, they can make substantial changes to applications or create new content. We believe that reaching the expert level for digital competence in Science teaching is an onerous task because of the need for mastery of a wider list of digital equipment and software than in most other subjects.

Area-Moreira, Hernandez-Rivero and Sosa-Alonso (2016) affirmed a direct relationship between a teacher's competence as a digital citizen and professional behaviour with ICT in the classroom. The higher the level of competence and digital citizen participation exhibited by the teacher, the higher will be the educational use of technology in the classroom.

Table 2. Levels of mastery of digital competence to be used in the classroom

Levels of DC*	Description	Examples
1. Basic	Knowledge / Remembering and Comprehension/ Understanding	Applications are mostly used for teacher preparation or production of materials not used in digital form (tests, work-sheets, etc.). In the classroom they can run applications or show pre-prepared presentations.
2. Medium	Application/ Applying Analysis/ Analysing	Teachers can use ICT within the common practice proposed by the manufacturer, can perform minor adaptations and evaluate ICT and its usage in the classroom
3. Expert	Evaluation/ Evaluating Synthesis/ Creating	Teachers are able to pedagogically optimize use of ICT, are able to change software, create new content, merge applications, combine hardware in novel ways, perform inquiry/ research concerning ICT use, etc.

*DC = digital competence

4 Teacher education for digital competence

Science teachers' education for the integration and full exploitation of available digital technology cannot stop at the level of courses where they are only taught how to use equipment or software, but must include pedagogy and explore the context where and when such technology can be used. According to Guzman and Nussbaum (2009), teacher education should consist of several domains:

1. instrumental/technological: Many wrongly believe that adding a course for pre-service teachers or sending a teacher to an expository course to get basic information about an application or test equipment is sufficient for successful implementation of ICT in teaching practice. An even worse practice is to buy or give them educational ICT without appropriate training. The problem arises whenever they return to school to find such equipment, for which they regularly cannot find support or help when they get into difficulty. In cases where an application can be used exclusively in school, it is less likely to be accepted and used than in cases where an application can be used at home (Šorgo, Verčkovnik, and Kocijančič, 2010; Špernjak and Šorgo, 2009), where teachers can find support from the family.
2. Pedagogical/curricular: Buying equipment or preparing a course is meaningless if the teacher cannot recognize how to include ICT in existing teaching practice in a pedagogically sound manner. Most often teachers can only with difficulty recognize how to combine new technologies with their syllabi and external assessment of knowledge. So, teachers tend to prefer technologies that fit into existing pedagogical-curricular structures.
3. Didactic/methodological: When one medium replaces another without significantly changing the didactic-methodological structures of teaching, it can readily be accepted. We can recognize this pattern in the usage of computers for word processing and as desktop libraries, or in the switch from transparencies and an overhead projector, to multimedia presentations (Šorgo, Verčkovnik, and Kocijančič, 2010).
4. Evaluative/investigative: every technology is successful only within a pedagogical-curricular context; teachers should thus possess the knowledge and skills to evaluate their own work and its impact on students. The assessment should not be on the cognitive level alone but must include assessment of skills and attitudes-values, which implies an additional work-load.
5. Communicational/relational: the potential for ICT to be used as a communication tool is one of its

strongest personal features, besides interactivity. Yet we can recognize from the frequency of usage of different applications among teachers (Špernjak and Šorgo, 2009) that they easily accepted information searches on the internet and e-mail use, but that they did not maintain their own web pages, or use the internet to build online communities. In addition, even tools that allow interactivity, like Moodle, are mostly used as places to deposit papers or presentations.

6. Personal/attitudinal: A system of personal values and attitudes is an important enhancer or blocker of the inclusion of ICT in practical activities. The mere addition of new knowledge will not by itself change attitudes toward technology, so education concerning ICT usage should not be value-free.

One challenge to be overcome at many universities offering teacher education is that existing courses concerning ICT and multimedia are headed by ICT experts, who are rarely experts in, say, Science or Science Didactics. As a result, any connections between domains have to be made by students, which can be a difficult task--at least at the pre-service level. Maderick et al. (2016) believe ″that without accurately knowing preservice teachers' digital competence as Technological Pedagogical Content Knowledge (TPACK), teacher educators may not be able to provide appropriate opportunities for them to learn to integrate technology into teacher learning experiences″ (p. 3). An additional trap is accepting the myth that prospective teachers, as part of the generation of digital natives, are already proficient in the use of digital technology in the classroom (Kirschner & De Bruyckere, 2017).

Our proposal is a concept best described as "learning by doing," where prospective teachers build their digital competence from basic to expert levels. They should be trained in the competent use of technologies in a wide array of teaching contexts, not only in general but in professional contexts, as well.

On the other hand, experienced teachers have already built their personal pedagogical content knowledge, which, if successful, cannot easily be changed. If teachers change such material, there is no assurance that student outcomes will be methodologically or pedagogically better (Špernjak and Šorgo, 2017).

5 Conclusions

We can conclude that digital competence for science teaching goes beyond the general use of ICT in education. Science teachers can at least potentially use applications and equipment not used by teachers of other subjects, which burdens them with greater responsibility to achieve such competence levels. They need to test and practice ICT applications not only as courses or laboratory exercises, but as part of their compulsory and reflective school practice. Simply sending them on a course or including such courses in pre-service training will probably fail if they do not find support when they return to school or begin teaching.

Acknowledgments

The authors acknowledge financial support from the Slovenian Research Agency (research core funding No. J5-8230).

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The Impact of Cultural Dimensions on Student's Use of E-Learning System

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Abstract. *This paper studies relationships in the conceptual model based on cultural dimensions of learning and users' beliefs. For such purpose, a questionnaire consisted of 44 items was developed and administered to 225 students of undergraduate study programmes. Although no respectable cultural differences were found, this paper enhances the understanding of males' and females' perception of using Moodle, social relationships and temporal issues. Also, considerable differences were noted between students of different study programmes in their perception of social relationships.*

Keywords. Cultural dimensions of learning framework, e-learning, learning management system, perceived usefulness, perceived ease of use

1 Introduction

This study aims to better understand the needs of students in terms of e-learning environment which does not always bring the necessary improvement and quality of teaching and learning. There are many studies that report the adoption and use of e-learning system, but do not take into account cultural factors that also influence the use of an e-learning environment (Aparicio, Bacao & Oliveira, 2016).

Hofstede (2011) defined culture as "the collective programming of the mind that distinguishes the members of one group or category of people from others". Over the years, culture was studied from different psychological and sociological aspects trying to explain similarities and differences. A global society has no longer boundaries in knowledge sharing and information transfer because they have evolved under the influences of information and communication technology (ICT) development. Recent researches seek to reveal a degree of society assimilation, to what extent human society accepts the same values and which factors have influence on that process.

In the educational context, the lecturers must be aware of the cultural impact on the experience of students because it has a major influence on their motivation and engagement. Also, during the phase of instructional design (ID), the analyses of cultural characteristics of students is mostly skipped (Parrish & Linder-VanBerschot, 2010). Inevitably, there is a great need for instructional designers to take into consideration cultural biases and try to avoid them during the design.

Nevertheless, cultural differences or similarities between students may exist irrespective of their nationality. Hofstede and Hofstede (2005) have confirmed that there are three sources of influence on human's behaviour and thinking, and they are: human nature, culture and personality. In this study, the culture is treated as the main influencing factor.

The trends of modern teaching are directed at students, thus changing their roles from a passive listener to an active participant. Consequently, a role of the lecturer is replaced by the role of a tutor who is responsible for acquiring the competences of his students and for creating a comfortable working atmosphere for everyone in the group. Also, traditional forms of teaching are replaced by virtual environment for learning in which lecturers are responsible for preparing and publishing materials and various multimedia content. Teaching materials do not necessarily correspond to learners' way of acquiring knowledge, and the aim should be to constantly strive for an individual approach to instructional design. For this reason, as Thomas, Mitchell & Joseph (2002) stated, it is essential that the instructional designer become culturally sensitive, thus they can critically analyse the students' cultural background and adjust the ID setting accordingly.

The main purposes of this paper are: (1) To analyse the relationships between cultural dimensions of learning (Social Relationships, Epistemological Beliefs and Temporal Perceptions) and users' beliefs (Perceived Usefulness and Perceived Ease of Use); and (2) To determine whether there are significant differences between genders or study programmes considering defined constructs.

2 Literature review

Parrish and Linder-VanBerschot (2010) developed Cultural dimension of learning framework (CDLF) which is based on Hofstede's framework (2005), Nisbett's (2003), Levine's (1997), Hall's (1983) and

Lewis's (2006) study. Hofstede and Hofstede (2005) identify four layer of organization culture: values, rituals (practices), heroes and symbols. According to Parrish and Linder-VanBerschot (2010), values are presented by eight cultural dimensions (1 – *equality and authority*, 2 – *individualism and collectivism*, 3 – *nurture and challenge*, 4 – *stability seeking and uncertainty acceptance*, 5 – *logic argumentation and being reasonable*, 6 – *causality and complex system*, 7 – *clock time and event time*, and 8 – *linear time and cyclical time*). Authors claim that the values are the most persistent aspects of a national culture, and that practices or rituals are the reflection of adopted values.

CDLF is a diagnostic tool for recognizing culturally different individual's learning style and afterwards to apply the acquired knowledge to instructional design. The authors of the Framework consider that it is important to recognize differences in beliefs and behaviours, gain empathy towards users and adapt the design accordingly. However, they claim that aim of their framework is not to generalize differences between cultures, but to include their differences into the design if they exist, because as Lemke (1997) cited "humans are highly adaptable, and the situational influences on thought and behaviour are significant".

However, usage of CDLF is only found in a few studies. First example is from Hunt and Tickner (2015) who wanted to reveal the differences between participants of online teacher education courses at New Zealand university. Research has shown that participants mostly have similar preferences in learning and that simple linear scale from 1 to 10 can be probably widely interpreted and in that case inaccurate when it comes to multi-dimensional construct. Woodyard (2016) in her doctoral dissertation investigated autonomy supportive instruction in relation to students' motivational belief of value/usefulness of an ePortfolio. Results have shown that only three (uncertainty acceptance, event time and cyclical time) out of eight dimensions have significant impact on students' perception of ePortfolio usefulness.

On the other hand, there are a lot of technology acceptance theories and models and each has different benefits, but the TAM is a highly-cited model relevant for IS community (Chen et al., 2017). Davis (1989) based his Technology Acceptance Model on the Theory of Reasoned Action that observes individual's attitudes and predicts social behaviour. Perceived usefulness (PU) and perceived ease of use (PEOU) have fundamental importance because of their direct influence on system use. Users will consider a technology usable if it increases the efficiency of their work. Also, perceived ease of use will influence user's perceived usefulness because it depends on how much effort he should invest to work efficiently. TAM is the most frequently used model for studying e-learning systems (Aparicio, Bacao & Oliveira, 2016; Hsu & Chang, 2013) and therefore will be also used in this research. The shortcoming of this model is that it assumes all use decisions are under the influence of usefulness and ease of use which are always measured in the same way (Olushola & Abiola, 2017).

3 Research model, hypotheses and research questions

This paper proposes and examines a conceptual model involving cultural dimensions of learning and users' beliefs. Hypotheses and research questions are created to get an insight into the relationship between constructs of the proposed model.

3.1 Research model

The proposed conceptual model is based on CDLF and two factors from TAM – PEOU and PU described in previous section. Davis (1989) defined perceived usefulness (PU) as "the degree to which a person believes that using a particular system would enhance his or her job performance", and perceived ease of use (PEOU) is considered as "the degree to which a person believes that using a particular system would be free of effort".

Hypotheses about relationships in the model (Figure 1) are presented below in accordance with the previously stated objectives and related literature.

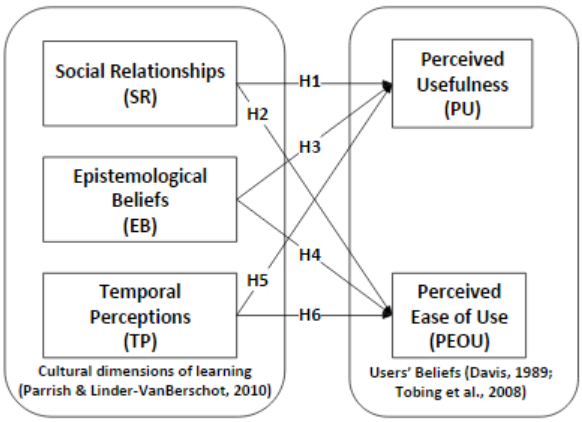


Figure 1. Conceptual model

3.2 Hypotheses and research questions

Cultural dimensions presented in the Figure 1 are cultural values which are considered to have greater impact on users' attitudes and perceptions than on behaviour and job performance (Taras, Kirkman & Steel, 2010).

The starting point was to examine the construct Social relationships (SR) which has three dimensions (Parrish & Linder-VanBerschot, 2010): equality-authority, individualism-collectivism, and nurture-challenge.

Table 1. An example of items and scale extracted from CDLF survey (Parrish & Linder-VanBerschot, 2009b)

INSTRUCTIONS: Circle the number that best indicates the level to which you agree with one or the other statement. Selecting 1 indicates that you strongly agree with the left-hand statement, selecting 10 indicates that you agree strongly with the right-hand statement. Selecting other numbers indicate lesser degrees of agreement with one side or the other.			
0	**Example**: Class discussions are critical for learning.	1 2 **3** 4 5 6 7 8 9 10 Selecting **3** indicates that the left-hand statement describes your opinion best, but only to a moderate degree.	Students should observe in class and not interact unless asked to do so.
1	Students should feel comfortable engaging in dialogue if they disagree with their teacher—it is part of learning.	1 2 3 4 5 6 7 8 9 10	Students should not openly disagree with or challenge their teacher—it disrupts learning.
2*	Class discussions or *LMS forum discussions* are for trying out new ideas, testing one's knowledge, and asking questions.	1 2 3 4 5 6 7 8 9 10	Before class discussions or LMS forum discussions, students should have mastered the course content so that they will have minimal questions.
3	Students should participate in the decision on what is discussed and what activities occur in class.	1 2 3 4 5 6 7 8 9 10	The teacher's assignments and activities defined in the syllabus should be followed without deviation.
Note. Item that is marked with asterisk is modified. New added words are italicized. The survey was conducted online.			

Equality-authority dimension discusses how teachers are treated by students during teaching and learning activities. Individualism-collectivism dimension interprets the interests of the individual and the group. Nurture-challenge dimension covers the topic of cooperation and security, on the one hand, and recognition and advancement, on the other. Tarhini (2013) stated that individualistic cultures unlike collectivistic will find easy to use modern technologies, but they will value the usability more. In relation to such findings, the first set of hypotheses was proposed:

H_1: Social relationships have a significant positive relationship with Perceived Ease of Use.

H_2: Social relationships have a significant positive relationship with Perceived Usefulness.

The construct Epistemological Beliefs (EB) is consisted of three dimensions: stability seeking-uncertainty acceptance, logic argumentation-being reasonable, and causality and complex systems. Research results of Woodyard (2016) have shown that students who are more accepting the uncertainty, will perceive an ePortfolio more useful. Therefore, it can be hypothesized that:

H_3: Epistemological Beliefs have a significant positive relationship with Perceived Ease of Use.

H_4: Epistemological Beliefs have a significant positive relationship with Perceived Usefulness.

The last construct, Temporal perception (TP), is consisted of two dimensions: clock time-event time, and linear time-cyclical time. Woodyard (2016) reported that if students are more event-time (right-sided dimension in the survey) and cyclical time oriented (right-sided dimension) they will consider an ePortfolio more useful. The last set of hypotheses was proposed as follows:

H_5: Temporal Perceptions have a significant positive relationship with Perceived Ease of Use.

H_6: Temporal Perceptions have a significant positive relationship with Perceived usefulness.

Next, research questions were defined to cover some issues that are outside of the conceptual model:

RQ_1: Are there significant differences between males and females' perception of user's beliefs?

RQ_2: Are there significant differences between males and females' perception of cultural dimensions of learning – social relationships, epistemological beliefs and temporal perception?

RQ_3: Are there significant differences in perception of students of different study programmes (IBS and EE) in users' beliefs?

RQ_4: Are there significant differences in perception of students of different study programmes (IBS and EE) in cultural dimensions of learning?

4 Research methodology

The main research involved 225 students within two different study programmes using the created questionnaire as the main tool for obtaining their opinion.

4.1 Sample

Data collection was limited to students of undergraduate study programmes (Information and Business Systems - IBS, and Economics of

Entrepreneurship - EE) at the Faculty of Organization and Informatics, University of Zagreb, in Croatia. The questionnaire was disseminated through two core courses that share the same background (topic), but one of the courses belongs to study programme IBS and another one to study programme EE. All students have voluntarily participated in the study.

4.2 Measurement instrument

A questionnaire was developed to gather information from students about their cultural preferences in learning and their perception of e-learning system (Moodle) they were using. It consisted of two parts:

- Cultural dimensions of learning framework (CDLF) (Parrish & Linder-VanBerschot, 2010): all constructs and associated items have been used, but adapted to existing teaching methods and materials.
- Technology acceptance model (TAM) (Davis, 1989): two core constructs (PU and PEOU) are used due to their nature which corresponds to the purpose of this research.

As already mentioned, in the first part of the questionnaire, CDLF instrument developed by Parrish and Linder-VanBerschot (2009a) was used. It consisted of 36 items arranged in eight cultural dimensions and three main constructs – Social Relationships (SR), Epistemological Beliefs (EB) and Temporal Perceptions (TP). Constructs SR, EB and TP represent independent variables that influence dependent variables (PU and PEOU) of the TAM model

The semantic differential scale (shown in Table 1) from 1 to 10 was used to answer the dichotomous questions (Woodyard, 2016). Score one means "strongly agree with the left-hand statement" and score ten means "strongly agree with the right-hand statement". The selection of other scores means that participant agrees less or more with the statements on the left or right side in the questionnaire. The SR differential scale contains items such as "Student should feel comfortable engaging in dialogue if they disagree with their teacher – it is part of learning" (on the left) and "Students should not openly disagree with or challenge their teacher – it disrupts learning" (on the right). Examples of the EB scale are "Failure is an opportunity to learn" (on the left) and "Failure should always be avoided because it means students are not learning and time is wasted" (on the right). The TP scale contains items such as "Repetition slows down learning" (on the left) and "Repetition is valuable for learning" (on the right).

The second part of the questionnaire is consisted of eight adapted TAM items (Table 2) that were focused on users' beliefs through perceived usefulness and perceived ease of use (Davis, 1989).

Respondents were asked to rate each statement on a five-point Likert scale: 1 (Strongly Disagree), 2 (Disagree), 3 (Neither agree nor disagree), 4 (Agree) and 5 (Strongly agree).

Table 2. Adapted TAM items
(Davis, 1989; Sumak et al., 2011)

Constructs	Items	
Perceived Usefulness	PU1.	I would find Moodle useful for learning.
	PU2.	Using Moodle enables me to accomplish tasks more quickly.
	PU3.	Using Moodle for learning increases my productivity.
	PU4.	If I use Moodle, I will increase my chances of getting knowledge.
Perceived Ease of Use	PEU1.	Moodle is unsuitable for my needs as a student.
	PEU2.	It was easy to learn how to use Moodle.
	PEU3.	Using Moodle requires a great deal of my intellectual effort.
	PEU4.	I consider that I do not need education in how to use Moodle.

5 Research results

In the first subsection, the demographic characteristics are presented using descriptive statistics. Next, the instrument was checked for validity and reliability. Finally, the results of hypotheses testing are shown.

5.1 Descriptive statistics

A total of 225 students participated in the online survey that was conducted via Moodle in April and May 2017. Student age varied from 18 to 29 years, with an average age of 19,6. Of the respondents, 50,2% (N = 113) were male and 49,8% (N = 112) were female. In respect to study programmes, 42,7% (N = 96) of students were from IBS, and 57,3% (N = 129) of students from EE study programme.

Table 3. Descriptive statistics of the constructs

Constructs	Mean *(STD)*	Mean *(STD)* M / F	Mean *(STD)* EE / IBS
Social Relationships (SR)	3.77 *(0.93)*	3.95 *(.94)*	3.64 *(.92)*
		3.58 *(.89)*	3.94 *(.91)*
Epistemological Beliefs (EB)	6.03 *(1.12)*	5.98 *(1.10)*	6.03 *(1.11)*
		6.09 *(1.14)*	6.04 *(1.14)*
	5.24 *(1.09)*	5.37 *(1.12)*	5.14 *(.95)*

Temporal Perceptions (TP)		5.11 *(1.03)*	5.37 *(1.23)*
Perceived Usefulness (PU)	4.04 *(.67)*	3.98 *(.71)*	3.98 *(.70)*
		4.10 *(.64)*	4.13 *(.63)*
Perceived Ease of Use (PEOU)	2.82 *(.52)*	2.83 *(.55)*	2.81 *(.52)*
		2.81 *(.49)*	2.84 *(.52)*
Note. M = Male; F = Female; EE/IBS = Study programmes			

Sample size (N = 225) yielded a respectable subject-to-item ratio (5,11:1) which was adequate for further analysis (Gray et al., 2007, MacCallum et al., 1999). The statistical software IBM SPSS Statistics for Windows, version 23, was used to calculate means and standard deviations for each construct which is shown in table 3.

Parrish and Linder-VanBerschot (2009b) recommended that means of answers should be grouped as following: *left orientation* is 1-3, *no strong preferences* is 4-7, and 8-10 is *right orientation* towards the dimension. The mean score (3.77) for the SR construct shows orientation towards left that includes more equality rather than authority. Other two constructs – EB (6.03) and TP (5.24) show no strong preferences towards any side of the scale. As Hunt and Tickner (2015) stated in their research of CDLF, it could mean that most respondents share the same opinion or the items do not express their beliefs.

Standard deviation represents how distant respondents' answers are from the mean (Field, 2009). The SR, PU and PEOU constructs show relatively small to medium standard deviation compared to their means, but two other constructs, EB and TP show relatively high standard deviation. The exception are students from EE study programme that were more consistent in their perception of temporal dimension (see Table 3).

Skewness and Kurtosis tests were performed to check whether the data is normally distributed. If not, it could impact the validity and reliability of the results (Tarhini, 2013). Table 4 represents calculated Skewness and Kurtosis values for each construct. From the results, it is evident that most values were distant from zero which indicated that the data was not normally distributed. The Wilcoxon rank-sum nonparametric test and boxplots are independent of underlying statistical distribution. Therefore, they were used to graphically describe non-parametric data.

Table 4. Skewness and Kurtosis values for constructs

	SR	EB	TP	PU	PEOU
Skew.	.03	-.15	.24	-.66	-.28
Kurt.	.25	1.66	1.00	1.46	-.70

5.2 Analysis of validity and reliability

The analysis of reliability and validity of the model was conducted in R. Cronbach's alpha was used to test the internal consistency of the items. First round of analysis across determined constructs and in total, 44 items, resulted with low alpha values (below 0.5) for most of the constructs except for PU where alpha was 0.858. To improve the reliability of the scale, it was needed to remove the items that were lowering internal cohesiveness.

First, the Kaiser-Meyer-Olkin (KMO) test for sample adequacy and communalities were used to remove the items that were lowering internal cohesiveness. Following suggestions from Field (2009) and Samuels (2016), a threshold was set as following: KMO > 0.5, and communality > 0.3. A total of 24 items were extracted during the factor analysis which have not satisfied the threshold and therefore, those have been dropped out from further study.

Next, the Principal Component Analysis (PCA) was conducted on the remaining 20 items with orthogonal rotation (varimax) to extract new constructs and to assess their validity (Table 5). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO=.73 ('good' according to Field, 2009). All individual KMO values were > .54, which is above the acceptable cut-off score (Field, 2009). Therefore, four rotated components (RC) were retained in the final analysis.

Table 5. Results of PCA and Cronbach's alpha

Items	RC1	RC2	RC3	RC4
PU1	0.85			
PU2	0.85			
PU3	0.82			
PU4	0.77			
PE4	-0.47			
I10		0.67		
I09		0.65		
I12		0.62		
I08		0.61		
I07		-0.56		
I15			0.68	
I14			0.67	
I16			0.63	
I13			0.57	
I24			0.51	
I30				0.63
I33				0.62
I31				0.58
I35				0.51
I32				0.49
Cronbach's alpha	0.82	0.63	0.62	0.52

Although, the Cronbach's alpha was above 0.5, but did not exceed 0.7 for some constructs (see Table 5), it was decided to proceed with the analysis which is in line with recommendations from Hinton, McMurray & Brownlow (2014). Those authors provide a theoretical background which suggest that alpha values between

0.5 and 0.75 should be generally accepted as moderately reliable scale values.

The four factors (RCs) extracted with PCA were named as follows: "Perceived Usefulness", "Social Relationships", "Epistemological Beliefs" and "Temporal Perceptions".

The first four items from Perceived Usefulness (PU) and the fourth item from Perceived Ease of Use (PEOU) showed respectable internal cohesiveness according to Cronbach's alpha, and were therefore merged into the only one above-mentioned construct Perceived Usefulness. The construct Perceived Ease of Use alongside with the set hypotheses (H_1, H_3 and H_5) have been dropped-out from further analysis.

Three remaining extracted factors matched, in respect to their items, the original constructs from CDLF instrument.

Having a valid and reliable instrument, it was possible to approach hypotheses testing.

5.3 Summary of hypotheses testing

Pearson correlation coefficient was used to measure the relationship between variables and to test hypotheses. Values greater than (±).5 indicate high correlation, (±).3 medium correlation and (±).1 low correlation (Field, 2009). In addition, if p-value is below 0.05 then the correlation between variables is significant.

After the Pearson's correlation analysis was conducted, hypotheses H_2, H_4 and H_6 were rejected, because no positive significant relationship between the constructs was found (Table 6). Only a single significant, but low and negative correlation was indicated:

- H_2: Social relationships and Perceived usefulness ($p = .023 < .05$; Pearson Correlation = -.15); A positive change in the first variable causes negative change in the second variable (Field, 2009).

Other results showed no significance and correlations between variables:

- H_4: Epistemological Beliefs and Perceived usefulness ($p = .24 > .05$; Pearson Correlation = .08);
- H_6: Temporal Perceptions and Perceived usefulness ($p = .53 > .05$; Pearson Correlation = -.04).

Table 6. Results of hypotheses testing

Hypothesis	p-value	Pearson correlation	Result
H_1	/	/	N/A*
H_2	.023	-.15	Rejected
H_3	/	/	N/A*
H_4	.24	.08	Rejected
H_5	/	/	N/A*
H_6	.53	-.04	Rejected

* Hypothesis was excluded from testing due to limitations in the initial instrument (see subsection 5.2).

Next, results were further analysed to answer the research questions set in the beginning of the research.

The distribution of the mean scores of respondents is shown in the boxplots. Comparing the males and females in the boxplot (Figure 2), both have similar low and high scores. Although, the value of median is higher for females which means they have more positive perception of user's beliefs than male students.

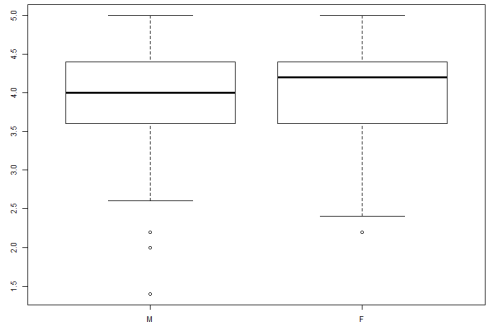


Figure 2. Boxplot of user's beliefs scores by gender

Males students have higher scores, and females have lower scores in social relationships shown in boxplot (Figure 3). The median values are also different for each gender. The results can be interpreted as females have greater tendency towards equality, and males towards authority in social relationships between lecturers and students.

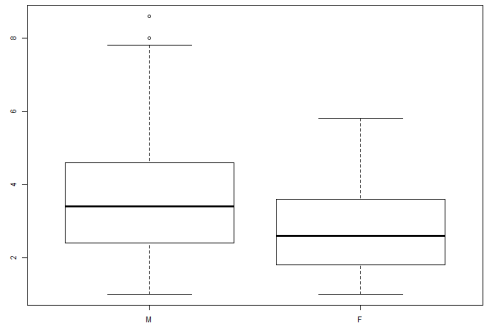


Figure 3. Boxplot of social relationships by gender

Boxplot in Figure 4 represents the females' perception of temporal dimension that resulted with lower scores, and males with higher scores. Female students perceive time as a destination and goals, and males as the cycles where deadlines are important.

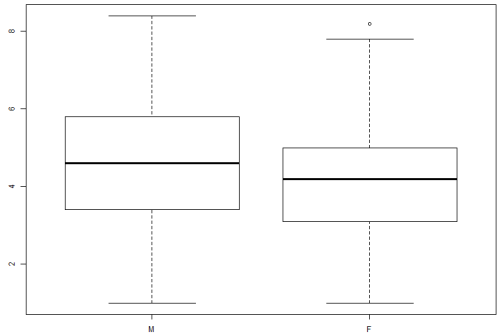


Figure 4. Boxplot of temporal perception by gender

In Figure 5, left box of the boxplot represents the EE, and the right IBS study programme. IBS students have higher scores towards authority dimension, and EE students have lower scores towards equality in the academic society. Their median values differ in a way they are higher for students from IBS study programme.

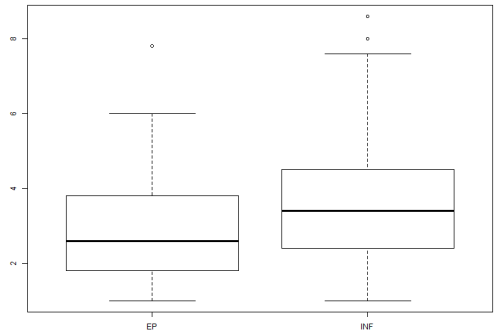


Figure 5. Boxplot of social relationships by study programme

Afterwards, non-parametric Wilcoxon rank-sum tests were computed to make final reflection on the four research questions:

RQ1. The perception of user's beliefs between female and male students is significantly different ($W= 5310.5$, $p = .04$, $p < .05$).

RQ2. The perception of social relationships between female and male students is significantly different ($W = 8106.5$, $p = 0.00027$, $p < .05$). There is also a significant difference between males' and females' perception of temporal dimension ($W = 7646$, $p = 0.007$, $p < .05$). But, no significant differences were found between gender's perception and epistemological beliefs ($W = 6121$, $p = 0.67$, $p > .05$).

Students of different study programmes have a significantly different perception of social relationships in teaching and learning environment ($W = 4610.5$, $p = 0.001$, $p < .05$). However, there was no significant difference found between user's beliefs, epistemological beliefs and temporal perception with different study programmes (UM: $W = 5696.5$, $p =.30$; EB: $W = 6578.5$, $p = 0.42$, TP: $W = 5342$, $p = 0.08$; in both cases $p > .05$).

6 Discussion

The research results are very much in line with the ones from Hunt and Tickner (2015) who also assessed the reliability of the eight sub-scales of CDLF. Their results showed poor correlations between scores on items of the CDLF's eight dimensions and they have also indicated a poor reliability of the instrument. However, they limited their findings due to a small sample size (112 students) and mostly female population. On the other hand, those limitations were minimized in this study, but the similar results were obtained. Besides, students' responses were not consistent within each dimension (data were not normally distributed) which can indicate their different preferences in learning. Also, the questionnaire was conducted only among Croatian students, and it would be interesting to extended it to international contexts where are highlighted cultural biases.

Furthermore, it was needed to carry out major modifications to improve the reliability of the measurement instrument which resulted in omitting one major construct of TAM. Consequently, hypotheses involving Perceived Ease of Use (H_1, H_3 and H_5) could have not been further tested.

Other three hypotheses (H_2, H_4 and H_6) were rejected due to low and negative (H_2) or no significant relationship (H_4 and H_6) between constructs (social relationships, epistemological beliefs, temporal perceptions in relation to perceived usefulness). On the other hand, the perception of user's beliefs, social relationships and temporal dimension is significantly different between male and female students. Also, the perception of social relationships between students of different study programmes is significantly different.

It should be pointed out that female students showed greater tendency towards equality, and male towards authority in social relationships between lecturers and students. Furthermore, it was also shown that females have greater tendency towards equality, and males towards authority in social relationships between lecturers and students.

In the end, summative results of students' responses can be useful for the learning community to adapt virtual learning environment (VLE) and develop new teaching strategies and tactics. Cultural student backgrounds and their learning preferences should be incorporated into the instructional design of VLE, which is often avoided in the name of globalization. On the other hand, students can gain insights into their own preferences and compare them with those of peers.

In future research, it would be worth comparing students from different study programmes at other universities and analyse differences between males' and females' preferences in learning.

7 Conclusion

Digital technologies have removed the boundaries between different societies and their knowledge sharing. Nowadays, educators talk more about individual differences above cultural, which can be also seen from various students' responses in the survey. Some personalities (responsibility, emotional stability, being organized, etc.) are highly appreciated despite of their cultural background.

Future studies should consider this validated instrument for inquiring cultural differences in learning according to three main dimensions – social relationships, epistemological beliefs and temporal perceptions. Sub dimensions should be avoided due to the lack of reliability between items.

It is not a simple matter to adapt the teaching to each student considering his cultural differences. However, it is important for tutors and LMS designers to be aware of different cultural values, especially those which may seem controversial or even offensive. In such sense, this work can help tutors and teachers to approach students' preferences taking into account cultural differences especially in case of large, open universities which enrol students with highly diverse cultural background.

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A Method for Automatic Selection and Interpretation of Student Clustering Models According to Their Activity on E-Learning System

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Abstract. *The paper proposes a method that is part of a new, extended architecture of our web-based intelligent tutoring system (ITS). It was developed to provide hints to students during learning through the application of educational data mining (EDM). The architecture consists of three modules – a) a communication module that enables seamless communication with data mining tools; b) a clustering module that discovers clusters in student data based on their activity and c) a sequential pattern mining (SPM) module that finds efficient frequent learning patterns of students in each cluster. Finally, the obtained results are used by the tutoring module to provide hints to a student on which item to learn next (or previous to the selected one). To improve the hint selection process we developed a method for cluster grading to determine which cluster represents the group that has been using the ITS in the manner closest to an envisioned optimum. We verify the method on data gathered from two groups of students who used the system to master a knowledge domain, and present the obtained results.*

Keywords. Clustering, Educational data mining, Intelligent tutoring system, E-learning

1 Introduction

Intelligent tutoring systems (ITSs) are a valuable teaching tool not only for distance education but also as a complementary teaching/learning tool in traditional (face-to-face) education. Many such systems have been developed for teaching in well-defined domains (e.g., math, physics, etc.) and are mostly standalone desktop applications. On the other hand, the number of web-based ITSs is much smaller (Brusilovsky, 1999), especially for teaching in ill-defined domains (Lynch et al., 2006). Ill-defined domains consist of a number of knowledge units (KUs) that do not have a strictly defined order in which they have to be taught/learned, but instead the system relies on a domain expert to define the structure of the domain. One such system has been developed at our institution to serve as an additional learning platform.

Our web-based intelligent tutoring system (WITS), described first by (Kovačić & Skočir, 2003) and (Kovačić & Jugo, 2009), currently provides teachers with functionalities for creating KUs, teaching materials, various types of questions for assessing acquired knowledge, and an editor to create the KU hierarchy. Each KU is described by a start and a threshold value which students reach by answering the questions correctly. Furthermore, the system features a descriptive statistics module for students and teachers (Kovačić et al., 2012). To further improve the system's overall efficiency we proposed a new architecture which integrates data mining (DM) algorithms (Jugo et al., 2014; Jugo et al., 2015).

A valuable source of data for our system lies in the records of student interactions with the system. We apply educational data mining (EDM) processes (Romero & Ventura, 2007; Romero & Ventura 2010; Fernandez et al., 2014) to these records and use the obtained information to enrich the system's student model and improve the tutoring model. In order for improvements to take place we added several new modules to the tutoring module. The first was an integration layer (Jugo et al., 2013) that creates a continuous communication channel to DM tools Weka (Hall et al., 2009) and SPMF (Fournier-Viger et al., 2014) which are used to execute DM algorithms on data gathered within our ITS. Second was the module for automatic clustering model selection and interpretation (which implements the method described in this paper) to discover different groups of students based on their activity and efficiency levels. Finally, a sequential pattern mining (SPM) (Srikant & Agrawal, 1996) module used to discover frequent patterns (FPs) students take through the knowledge domain. SPM algorithms can produce a large number of FPs. An algorithm that differentiates between productive patterns (those that yield better gains in the

student's knowledge levels) and non-productive patterns (those that represent possible issues with the knowledge domain structure, difficult questions, etc.) was developed. In our system we use both types of patterns: productive patterns are used to enable dynamic creation of learning structures by our tutoring model, while non-productive patterns are presented to teachers so they can make actions to correct their causes.

This paper focuses in particular on the second module – clustering of students based on their activity (ways of using the system) and efficiency (correctness of answers to questions presented by the system) levels. In order to guide the students during their progress through the knowledge domain the system needs to discover clusters of students that use the system in a similar way and consequently determine which cluster represents the highest achieving students, average achieving ones, etc. An important aspect of this system is that it performs automated student model improvements (Koedinger, 2012) by running both clustering and SPM routines at scheduled intervals while the students are progressing through the knowledge domain and increasing the size of the interactions dataset.

With results from both clustering and SPM modules, we can make the tutoring model more adaptive: cluster ordering and discovered productive FPs of each cluster are used to guide students from a lower grade cluster towards the activity levels and learning paths of a higher grade cluster, thus improving the students' learning experience and overall results.

The rest of this paper is structured as follows: Section 2 introduces related work on EDM and focuses on applying clustering in e-learning systems. Section 3 gives an overview of the basic functionality of our WITS which is the environment used for research at hand. The process through which the system obtains clustering models using communication with DM tools is described in Section 4, while Section 5 presents our method for automatic clustering selection and interpretation. In Section 6 we present results of the proposed method and conclude the paper in Section 7.

2 Related work

Combining clustering (Kaufman & Rousseeuw, 1990) and SPM is an approach that has been applied for the purpose of recommending web pages in e-learning systems (Romero et al., 2007) and analysing online collaborative learning data (Perera et al., 2007). An example of integration of data mining tools with an e-learning system can be found in (Zorilla et al., 2010), where authors improved the existing Black Board monitoring tool and in (Romero et al., 2013), where authors presented a Moodle block that enables the users to perform clustering, classification and association rule mining, and export the raw results to a file. This is a useful extension of Moodle functionalities for teachers even though it presents them with "raw" output of DM algorithms which can prove to be difficult to understand. Our system integrates the results of DM algorithms into the process of increasing the system's adaptivity and further presents the results using interactive, in-browser, visualizations that are easy to comprehend and provide immediate insights.

Student clustering is an important research topic in EDM. There are a number of approaches to clustering: connectivity-based, centroid-based, distribution-based, density-based, etc., and an even larger number of algorithms that can be applied on student data. An overview of the clustering analysis critical steps was published by Miligan (1989). In cluster analysis, the fundamental problem is to determine the optimal number of clusters, which has a deterministic effect on the clustering results. It is a well-known optimization problem that has received significant attention. A variety of methods for this problem have been analysed by Gordon (1999), where the author divided them into two categories: global and local methods. The local methods are intended to test the hypothesis that a pair of clusters should be amalgamated. They are suitable for assessing only hierarchically-nested partitions. With global methods, the quality of clustering given a specific number of clusters, g, is measured by a criterion, and the optimal estimate of g, ^G , is obtained by comparing the values of the criterion calculated in a range of values of g. Some of these methods analysed were: Calinski and Harabasz's method, Hartigan's method, Krzanowski and Lai's method, Silhouette statistic and the Gap method. Their performance has been analysed by Tibshirani (2001) and Symons (1981). Our method implements the silhouette statistic approach.

Once a clustering model is selected, it can be evaluated through various statistical methods (Bouchet et al., 2013) or a number of other, more complex methods (Gordon, 1999), while the interpretation depends on the research area and the nature of data. Our method relies on descriptive statistics to sort the clusters based on cluster members' activity levels as well as their learning efficiency.

3 Student data and feature engineering

Each student has his/her own personal approach to using the system. Some students copy the learning materials, study them offline and then come back to answer the questions later, others try to learn from the bottom up or from the top down, yet others try to brute force the system by answering the questions

until they find the right answer. To model the way the students interact with the system, two sets of features were used. The first set of "database" features can be obtained directly from the database using SQL queries. The second set consists of engineered features developed from database features in order to better represent the student's current activity levels and his/her efficiency. The first three features (learning (L), repetition (R) and time spent (T)) are called activity features and represent each student's interactions with the system. While the activity features represent the way a student interacts with the system, the effectiveness feature (E) represent his/her success in answering questions about each knowledge unit being learned within our system. The engineered feature set F_{EF} represents the student's activity in relation to: a) the quantity of content he/she has covered up to this moment and b) the activity of other students in the group. This evens out the activity level of students who use the system in a similar manner in situations where one student has already covered the whole domain and the other has just started using it. Before sending them to Weka, the values of the mentioned features are standardized.

As mentioned in the introductory part of the paper, a new module called "the integration layer" has been developed to enable communication with two DM tools. In this way, re-implementing any specific algorithm into our application has been avoided, which ensures that data can be analysed by a DM expert on another machine running the same DM tools, with absolute confidence that the results will be the same (where it is possible, depending on the algorithm). An important advantage of this architecture is that the administrator can easily change and use any clustering or SPM algorithm provided by either tool. In our system we communicated with Weka to run the kMeans clustering algorithm, and SPMF to run the USPAN algorithm.

Algorithm 1 uses as input the engineered feature set along with some additional information (domain, domain group) and system settings necessary for correct formatting of API calls towards DM tools. With each increment of the number of clusters *k*, a new API call is created and executed. It starts from *k*=2 and increases the value until the DM tool returns a model that satisfies the cut-off condition: "exit the loop if the model contains two or more clusters with just one student in it".

The reasoning behind the condition is that our overall goal is to discover groups of students that use the system in a similar way and then provide hints based on frequent patterns discovered **in their cluster or the cluster graded above** to create a better learning experience for students in each group. Having that in mind, it is not particularly useful to have single member clusters. We did however allow for solutions in which one single-member cluster appears (a possible outlier) because our system is fully automated which complicates outlier detection.

Upon completion, the algorithm returns a set of clustering models for *k*=2, 3, etc.

Algorithm 1: clustering using the integration layer and DM tools

Input:
Domain identifier D_i,
Domain group identifierDG_j,
Engineered features set F_{EF}= [L,R,T,E]
Settings:
tool T ∈ [weka*,spmf],
format FT∈ [arff*,spmf],
alg. A ∈ [kMeans*, EM,…]
Output:
clustering models[centroids, members]

```
prepare dataset D = (Di, DGj, FEF)
generate filename
write dataset to file (fn)
k = sqrt(sizeof(D)/2)   // the "elbow" method
array models[]
for i = 2 to k + 5  // more clusters in small groups
   x = construct_api_call (A,T, i, fn)
   out = execute_api_call(x)
   [centroids, members] = process_output (out)
   models[i] = [centroids, members]
      if (number of clusters in model with no. members == 1) >= 2)
      break
   endif
endfor
return models[]
```

4 Automated clustering model validation and interpretation

The algorithm presented in the previous Section returns a set of clustering models with an increasing number of clusters. The goal of this method is to select the best model and evaluate each of the clusters in that model. The interpretation scores and orders the clusters so that the highest graded cluster represents the group that has used or is using the system in a way that the authors believe to be closest to optimal. The cluster with the lowest grade represents the group that was inactive at the time the clustering routine was executed. As a result, the student's activity model (cluster membership and grade of cluster) is continuously updated in the database with the latest results based on a growing dataset of students' interactions with the system.

4.1. Model validation

As mentioned in Section 2, many methods that determine the quality of distribution (optimal number of clusters in a model) have been developed and tested by Tibshirani (2001) and Symons (1981). Some of these methods require changes to be made in the

source code of the clustering algorithm; other can be applied after the model was acquired. The silhouette statistic belongs to the latter group. The definition of the silhouette statistic is based on the notion of silhouettes introduced by Rousseeuw (1987). According to this approach, silhouettes are constructed to show graphically how well each object is classified in a given clustering output.

The silhouette index, denoted by *s(g)*, is defined as the average of the *s(i)* for all objects (*i*) in the data set. In this way, *s(g)* represents the average silhouette width for the entire data set, reflecting the within-cluster compactness and between-cluster separation of a clustering. The optimum value of *g* is chosen such that *s(g)* is maximized over *g*. Average *s(g)* over accumulated data of a cluster is a measure of how tightly grouped all the data points in the cluster are. Thus the average *s(g)* over accumulated data of the entire dataset is a measure of how appropriately the data has been clustered. The silhouette statistic is implemented so that it receives a variable number of clustering models obtained from Algorithm 1, and returns only one model: the model with the highest silhouette statistic value. This completes the first phase of our method. The second phase grades/orders the clusters in the selected model.

4.2. Model interpretation

The frequency of student results is usually distributed in the shape of the "bell" curve. The area around its highest point represents the majority or the "average" students, while the "wings" represent the highest and lowest achieving students. The basic idea of our algorithm can be summarized as follows: we divide the distribution of results for each activity feature into intervals of equal width, assign a score to each interval and then evaluate the position of each of the cluster centroid values in the distribution. Since the values of our engineered features are standardized, we know that the left-most values represent inactive students and the right-most values represent students struggling to master the learning content. Students that create less than average number of learning material views are regarded as "fast" learners, while those on the other side of the average can be considered "slow", etc. Also, when scoring intervals, we have to give a higher score to the students that are trying ("struggling") than to those that are inactive. This concept is presented in Figure 3.

The score distribution depends of what each feature represents. For instance, the scores scale for the learning feature is completely inverted from the time feature, where we reward the effort in reading the materials thoroughly as opposed to glancing over them. We chose to divide the results into 13 intervals meaning that a cluster centroid value for a feature can receive a maximum of 13 points and a minimum of 1 point. At the end, the cluster with the highest sum of points is the cluster representing the group of students that are/were using the system in a manner we consider optimal.

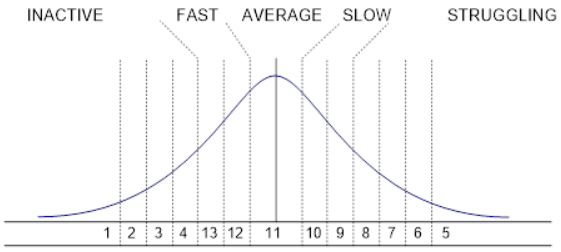


Figure 1. Scoring the intervals of feature values distribution

It is necessary to point out that a smaller or a larger number of intervals could also have been used. A larger number would reduce the chance of getting the same results for multiple clusters, while a smaller one would simplify the calculation process.

As there is no human intervention in our method and we cannot anticipate the distribution of feature values, we have no guarantee that they will follow a normal distribution. In fact, it is very unlikely, especially in the early stages (first day) of granting the students access to the system. Data is sparse during that period as only a few students have made significant progress through the domain. In such cases the curve can be very wide/narrow, skewed to left or right, etc. To account for the high variability, we have developed a flexible algorithm that adapts to the values of the dataset, prepares the grading process and examines each of the centroid values for each cluster.

The basic steps of our cluster grading/ordering method are presented in Figure 4 below.

The first step in the method is to determine the width of the distribution, i.e., the leftmost and rightmost data point in the dataset. Next, this width is divided by 13 to get the interval width, which is the first step in preparing the score-to-interval mapping. Then, the value of the probability density function of the normal distribution for each value in the dataset is calculated. The highest value becomes the centre position of our score-to-interval mapping "bar".

Using this information and the interval width from the previous step, the left and right borders of each interval in our bar are calculated.

If the distribution is skewed to one side, several situations are possible: 1) part of the grading bar goes outside the width of the curve so grades in those intervals become unreachable; 2) the grading bar does not reach the end of the distribution, so any values that appear have to be approximated to the last interval in the bar. Both of these situations are demonstrated in Step 3 of Figure 2. Finally, when the grading bar is set we can read the centroid values of each of the activity features of every cluster in the model, find out which interval they fit in, read the score of the interval, and add that to the subtotal for each cluster.

We now turn to the description of the scoring process for the fourth feature: student efficiency.

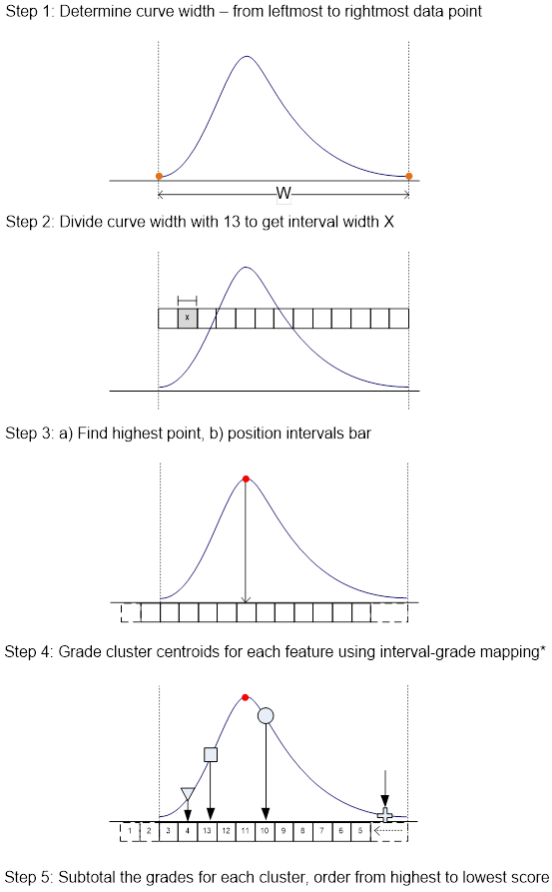


Figure 2. Steps of the selected model scoring algorithm

The students' efficiency feature is an objective measure of his/her ability to answer the questions about the learning materials correctly. The highest value represents the most efficient student. Therefore, the interpretation procedure for this feature is simpler. The first step is to sort the centroid values of each cluster from highest to lowest. Next, the highest value becomes the benchmark and gets assigned 13 points. The points for all other clusters are defined as a rounded percentage of the benchmark value. For example, if the highest value is 3.5 and the second best cluster has a centroid value of 1.8, the points will be calculated by the expression (1.8/3.5)*13 = 6.68 ~ 7 points. The same process is repeated until all cluster centroids for this feature are graded. The score is then added to the subtotal score for each cluster, which completes the scoring/ordering phase. The cluster ordering and the cluster attribute of each student are then updated accordingly in the database.

In this the system is able to continuously update the student's activity and efficiency model until the student masters the domain. This model represents the quality of the student's interaction with the system which reflects to his/her learning experience and the final course grade. Every time the system performs the clustering process the results are stored in the database so both the teacher and the DM expert can analyse the results. The teacher can use the WITS teacher interface to check visualizations of each student's cluster assignment changes in time, while the DM expert can review the results and identify possible improvements to our score-to-interval mappings. In Table 1, we present our current score-to-interval mappings for the three activity features.

Table 1. Score-to-interval mappings for F_{EF}

INT	1	2	3	4	5	6	7	8	9	10	11	12	13
$L\%_{std}$	1	2	3	4	13	12	11	11	9	8	7	6	5
$R\%_{std}$	1	2	3	4	13	12	11	10	9	8	7	6	5
$T\%_{std}$	1	2	3	4	9	10	11	12	13	8	7	6	5
E_{total}	calculated [1…13]												

These are used by Algorithm 2 to evaluate centroid values of clusters for activity features (L, R, T) and the efficiency feature (E). The cluster centroid value interpretation algorithm is presented below.

Algorithm 2: Cluster centroid value interpretation

Input:
  selected clustering model with **k** clusters:
    model=[k, centroids, members, dataset]
  score-to-interval mapping table for f ∈ F_{EF}: M[f][scores]
Output:
  evaluated/graded list of clusters

```
1  array clusterOrder[], array centroidScores[]
2  for each f ∈ F_EF
3     if( f == E )
4        score = calculate_efficiency_score(centroids(f));
5        centroidScores[f][k]=score
6     else
7        ndf = calculate_pdf_ (dataset(f))
8        cw = calculate_dataset_width()
9        iw = calculate_interval_width(cw)
10       peak = max(ndf)
11       M[f][center] = center_grading_bar(peak)
12M[f][borders]= calculate_border_values(peak, iw, cw, dataset(f))
13        for each centroid ∈ centroids[f]
14           i = find_interval(centroid)
15           score = get interval score(i,M(f))
16           centroidScores[f][k]=score
17        endfor
18    endif
19 endfor
20 for each cs ∈ centroidScores
21    clusteringOrder[k] = sum(cs[k])
22 endfor
23 sort(clusteringOrder)
24 return clusteringOrder
```

The highest ranked cluster should always represent the best group of students, while the lowest ranked usually represents the inactive students. Other clusters will be ranked between these two. As we have 13 intervals, the highest possible efficiency score is 13 and the lowest is 1. For the "time" (T) feature, which represents the amount of time the student spent reading learning materials, the grading scale is inverted relative to L and R features. **Therefore, the best student (group/cluster) is the one that needed lower than average number of learning and repetition actions, spent more than average time reading the learning materials and had the highest efficiency** (number of correct answers to questions).

5 Results

The method described in Section 5 was tested on data collected from a knowledge domain "Introduction to web application development" developed for third year undergraduate students at our Department. The domain consisted of forty knowledge units. Participants had access to the domain for 7 days in September, 2015, and were asked to complete it in the allotted period of time. In order to analyse differences in the way students interact with the system, the participants were divided them into two groups that had an equal average result in the pre-test. The basic statistical data is presented in Table 2.

Table 2. Basic statistics of student groups

Groups	G1	G2
Number of students	33	31
Number of active students (had > 0 interactions with the system)	33	30
Percentage of students that completed the domain	97%	98%

In order to test the algorithm for optimal k value selection based on the silhouette statistic we ran the clustering analysis for both groups using the engineered features set FEF after the access period had expired and the majority of students had completed the domain. The obtained results for G1 are presented in Table 3.

Table 3. Silhouette statistics and cluster sizes for G1

k	S(k)	1	2	3	4	5	6	7	8
2	0.34	16	17						
3	0.36	15	4	14					
4	0.33	11	2	8	11				
5	**0.47**	12	2	7	11	1			
6	0.45	9	2	7	9	1	5		
7	0.38	6	2	7	8	1	5	4	
8	0.29	6	2	7	7	1	3	4	3

For both groups the model with k=5 clusters had the highest value of the silhouette statistic. This model has then been employed in the second phase. The second phase began after the best clustering model had been selected. As mentioned earlier, the results presented here were obtained after the students had already finished using the system so the presented dataset is complete. Figures 3 and 4 represent the distribution of values of the two main activity features in F_{EF} for G1 (dots) and G2 (squares). They show that students in both groups had a similar distribution of results. The only exception is one student, who had a specific way of using the system (had almost zero repetitions). These exceptions compelled us to create a flexible solution that is able adapt to the differences between the ways each group interacts with the system.

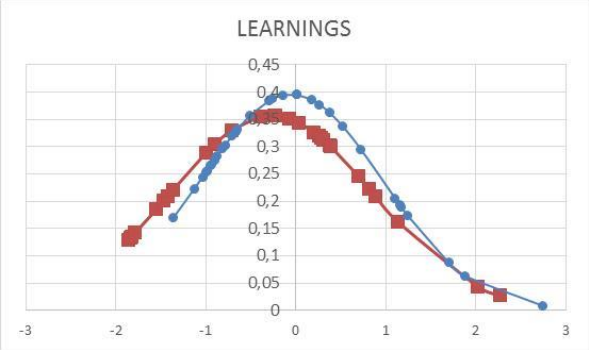


Figure 3. Learning (L%std) feature results distribution for G1 and G2

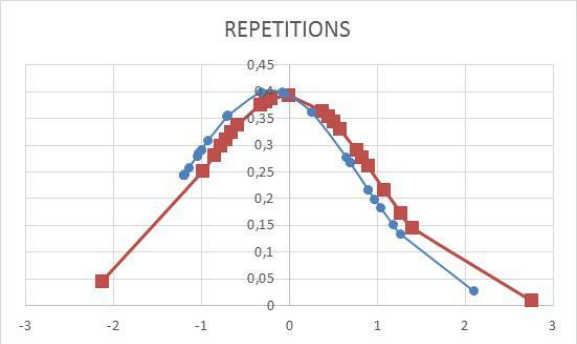


Figure 4. Repetition (R%std) feature results distribution for G1 and G2

Since this process runs in scheduled intervals during the entire time the student have access to the knowledge domain, the distribution of results will vary greatly as the students advance through the domain. The results for G1 are presented in Tables 4 and 5.

The placement row for the activity features gives us a simple visualization that can be useful for quick results interpretation. The best cluster (4) is consistently below average for L and R features, and average for the T feature.

When we add the efficiency feature scoring, it becomes clear that the members of this cluster are the closest to our definition of a high achieving student. It is also clear that cluster 2 represents students that made the least effort and had the lowest efficiency, which leads us to believe they kept guessing the answers to the questions.

Table 4. Interval distribution, scores and cluster placement for activity features for G1

							Center							
L Interv.	-1.86	-1.57	-1.28	-0.99	-0.71	-0.42	-0.13	0.15	0.44	0.73	1.02	1.31	1.59	1.88
L Scores	1	2	3	4	13	12	11		10	9	8	7	6	5
Placement			2		1	4,5							3	
R Interv.	-1.97	-1.72	-1.46	-1.21	-0.95	-0.70	-0.44	-0.19	0.18	0.56	0.93	1.31	1.68	2.06
R Scores	1	2	3	4	13	12	11		10	9	8	7	6	5
Placement				2,3,5		4						1		
T Interv.	-1.89	-1.62	-1.35	-1.08	-0.81	-0.54	-0.27	-0.00	0.26	0.53	0.80	1.07	1.34	1.61
T Scores	1	2	3	4	9	10	11		12	13	8	7	6	5
Placement				2		1	4			3				5

Table 5. Final scores for clusters (G1)

f	*k=5*	Centroid values/scores				
	Clusters	1	2	3	4	5
L	Values	-0.598	-1.150	1.494	-0.220	-0.260
	Score	13	3	6	12	12
R	Values	0.980	-1.025	-1.100	-0.692	-1.200
	Score	7	4	4	12	4
T	Values	-0.488	-0.845	0.329	-0.048	3.660
	Score	10	4	13	11	5
E	Values	0.352	0.155	0.280	0.446	0.060
	Scores	8	4	7	10	2
Subtotal		**38**	**15**	**30**	**45**	**23**
Grading		**B**	**E**	**C**	**A**	**D**

This is supported by the lowest value for feature T (time spent reading/learning the materials).

6 Conclusion

In this paper we presented a method for automatic selection and interpretation of clustering results obtained from a database of students' interactions with our web-based intelligent tutoring system. The proposed method was implemented in a clustering module that is part of a system built to improve the adaptivity of the tutoring module. The clustering module discovers groups of students that interact with the system in a similar manner. This information, combined with the results of the SPM module, is used to provide useful hints to students on which units in the domain to learn next.

The presented method was tested on four different knowledge domains, over the least two years. During this time we identified some aspects of this method that can be improved. First, the method tends to choose a model with two clusters when most of the students have completed the domain, because the strongest difference exists between inactive students and all other students. We will resolve this problem by removing all inactive students from the dataset up front and placing them in a separate, additional cluster graded zero. Second, we will try to implement outlier detection before executing the clustering algorithm. Thirdly, we will develop a visualisation of centroid valued of all obtained cluster models and present them to a teacher to test whether they would select the same model that our method selected based on the silhouette index. Lastly, other clustering algorithms with different distance measures will also be used and their results compared to the ones produced by the algorithm used in this research.

Acknowledgments

This work was supported in part by project "Enhancing the efficiency of an e-learning system based on data mining", code: 13.13.1.2.02., funded by the University of Rijeka, Croatia.

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Students' Perception of Gamification in Higher Education Courses

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Abstract. *This paper presents an analysis of students' perceptions on the concept and elements of gamification, after completing a partly gamified ERPSIM course within the scope of the Enterprise Resource Planning systems course. The results indicate that students' attitudes towards gamification is mostly positive and does not depend on their engagement in playing games in their free time. The most common gamification elements are examined and discussed based on the students' feedback collected via questionnaires. Not all the gamification concepts are regarded/perceived to be equally beneficial. However, students strongly believe that the gamification of courses can contribute to their motivation and learning achievements.*

Keywords. gamification, gamification in higher education, ERPSim, game mechanics, e-learning, teaching methods, gamification elements

1 Introduction

Nowadays more people have or are enrolled in tertiary education than ever before. From 1995 to 2015, the percentage of young (25-34 year old) adults with tertiary education has risen from 23.3% to 42.12% within member countries of the Organisation for Economic Co-operation and Development (OECD, 2015). More people are studying now and the education rate is higher than ever before.

Globalization has changed higher education (HE) forever. The massification of HE among other factors has led to its declining quality. While the top academic institutions have maintained their quality, the system has suffered (Altbach, 2015). This is natural because increasing the quantity several times over, often leads to a drop of quality. It is prime time to react to those changes and address the problem by reinventing the paradigm in higher education once again. But even new paradigms such as e-learning and MOOC (Massive open Online Courses) by themselves do not eliminate/reduce some well-known challenges, namely learners' engagement and motivation, a high dropout rate, etc.

One of the leading forces of change in transforming education is Information Technology (IT). Another industry where IT technologies are omnipresent is entertainment. One trillion dollars are spent yearly on entertainment (Vogel, 2014) out of which more than 100 billion are spent on gaming (Newzoo, 2016).

Games are ubiquitous in the digital world we are living in. In the USA, 42 percent of the population play video games three or more hours per week. Gamers are almost equally represented by both genders: 44 percent of all game players are female; 56 percent are male. The misconception that playing games is only for the young has been proven wrong, with the average game player being 35 years old (ESA, 2015).

Because gaming is widely popular and accepted by population, attempts to use various elements from gaming have been made in work and education. Gamification elements were already used in the early Soviet era as a way to incentivize work. Gamification also re-emerged in the US in the early 1980 (Iosup et al., 2014).

Gamification is the use of game design elements in non-game contexts media (Deterding et al., 2011). Gamification may be a crucial tool that higher education is missing.

Gamification can be successfully integrated with e-learning. E-learning is defined as information and communication technologies being used to support students to improve their learning. It has one major problem; many of its implementations do not achieve the intended objectives due to non-compliance and

lack of knowledge of methods & techniques for the development of online information systems. In those systems, user satisfaction is the most important component and is influenced by six factors: students, teachers, the course, technology, system design and environment. These factors, particularly efficiency, effectiveness, motivation and engagement of students can be improved with the use of gamification (Urh et al., 2015).

Traditional teaching methods in higher education (lecturing, frontal teaching) only convey information from the lecturer to the students, but they do not promote interaction and further thoughts. In recent years, traditional university teaching has changed due to advances in information and communication technology. Learning management systems have emerged, systems that implement administration functionalities, educational interaction and other educating methods can complement traditional teaching methods. Research results have shown that models that integrate game mechanics achieve more motivation and enjoyment, but do not always result in increasing learning efficiency (Siemon & Eckardt, 2017).

Teaching is a multi-step process where each step needs support from the previous steps in the process.

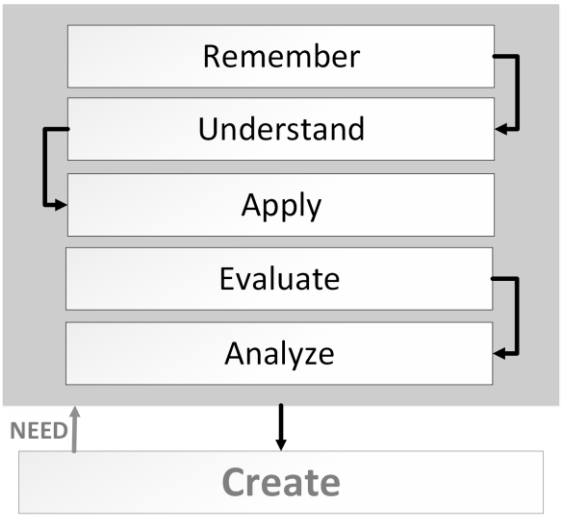


Figure 1. Simplified illustration of teaching according to Bloom's taxonomy (adapted from Jayasinghe & Dharmaratne, 2003)

The five steps in **Figure 1** Simplified illustration of teaching according to Bloom's taxonomy (adapted from Jayasinghe & Dharmaratne, 2003)mean the following tasks need to be completed in order to truly learn something:

1. Before we can understand a concept, we must remember it,
2. Before we can apply the concept, we must understand it,
3. Before we analyze it, we must be able to apply it,
4. Before we can evaluate its impact, we must analyze it,
5. Before we can create, we must remember, understand, apply, analyze and evaluate.

Students can be classified according to their main motivation when engaging in games or gamified activities, by using Bartle's taxonomy (Arnold, 2014):

- Socializers – more interested in having relationships with other players than playing. Spread knowledge and human feeling.
- Achievers – very competitive, enjoy beating difficult challenges.
- Killers – like to provoke other players and impose themselves over other players.
- Explorers – explore the world and finer details of the game mechanics. They thrive on discovering everything.

The use of gamification can guide the students to unknowingly follow the above learning processes, even in difficult academic matters, in an efficient way (Jayasinghe & Dharmaratne, 2003).

Gamification-based teaching can have a positive impact on achievement and students' attitudes toward lessons as well as their attitudes. Students in experimental groups have outperformed those in a control group (Yildirim, 2017).

The gamification of courses can also cause negative side effects, such as an increased workload for both students and teachers (Siemon & Eckardt, 2017).

The purpose of our study was to investigate the viability of using gamification in higher education courses, by analysing the reflection of students after completing a short workshop which used some gamification elements and connecting it with other established studies in this field. We aimed to find the answers to the following questions: *How do students accept the gamification approach? Are students who play games regularly more receptive to gamification? Which practices of gamification are students most receptive to?*

Some positive preliminary results were already collected in (Heričko, Rajšp, Beranič, & Wu, 2017) that investigated use of business simulation game approach for introduction to the postgraduate Enterprise Resource Planning course.

This research paper is structured as follows; first, similar research in using gamification and e-learning for knowledge acquisition is presented, then research on gamification in higher education with the most commonly used gamification elements and ideas is explored; the fourth section gives a short summary of the workshop we executed in the scope of the ERP course; continuing students' feedback on the course gamification approach is presented and in the end the findings are summarized.

2 Related works

Lot of research has already been done on the use of gamification in higher education.

Five gamification platforms (VivoMiles, Youtopia, Uboost, Cdedly, OpenBadges.me, ClassDojo and ClassBadges) were presented, two of them were used (ClassDojo and ClassBadges) to introduce gamification to their study programme. The study found that one of the vital parts of successfully using gamification is participation and willingness to integrate gamification in their courses by the educators. Gamification reinforces not only good behaviour by awarding badges to a student, but also intimidates students to act improperly because of fear of getting punished with badges, which have a negative connotation. Overall, the attitude of students when using gamification elements in their courses improves (da Rocha Seixas et al., 2016).

Review of gamification studies presents the topic in general and presents some of the most common gamification elements (Points, Levels/Stages, Badges, Leaderboards, Prizes and Rewards, Progress bars, Storyline, Feedback) (Fui-Hoon Nah et al., 2014).

The efficiency of e-learning systems can be increased using gamification elements in them. Gamification is a key enabler of e-learning in higher education. In the paper (Urh et al., 2015), a model for the introduction of gamification into the field of e-learning is presented.

(Mora, Planas & Arnedo-Moreno, 2016) investigated if adult learners can be motivated in solving formative activities in a game like a design course. They designed their experimental course on the principles of SPARC: Sense – the activity must make sense to the students; Purpose – the activity must have a clear purpose. The purpose should be aligned with some learning outcome; Autonomy – the activity should be optional, and students should have the ability to make choices; Relatedness – actions should have some positive impact on the rest of participants or the course itself, Competency – the activity must ensure that students will be able to master the rules and the chosen tool. Their course received a very high acceptance of such design and a good degree of engagement.

A gamified software engineering course containing the following gamification elements: narrative (story); progression by use of experience points for completing tasks and levels; badges that were used in displaying player levels; progress bars that show progression to the next level; quests – team based tasks; challenges; achievements, created to study the effects of gamification. (Matsubara & da Silva, 2017) noted that they avoided the use of leaderboards, because players on the bottom may lose motivation upon seeing the divide between them and the top participants. The attendance rate of those participating rose and their average grades on the final exam were higher than those participating in the traditional course.

An empirical literature review concluded that empirical studies investigating gamification have mostly found a positive effect on learning outcomes. Some of the reviewed studies, however, warned of negative effects – increased competition, task evaluation difficulties, and problems in design features. Another limitation regarding gamification studies is their relatively small sample size and the fact they were performed for short periods of time (one workshop or part of a course), so that the long-term benefits could not be fully established (Hamari, Koivisto, & Sarsa, 2014).

Our study was aimed at comparing their results to ours.

3 A case study

3.1 ERPSIM sessions

For the gamification element, ERP distribution simulation game developed by HEC Montreal (Leger et al., 2010) was used. The game was moderated by certified instructor Paul Wu Horng-Jyh. The purpose of the game was to teach the basics of SAP, ERP system, by giving each team a company that distributes water bottles to the retail stores in Germany. The players were split into teams, given instructions and then played the game.

The simulation game contains the following gamification elements:

- Point system and leaderboards: the game measures team performance by their profits and constructs a leaderboard based on that,
- Time restriction: teams have a limited amount of time to make decisions, each day lasts less than a minute,
- Interactive Cooperation: in the simulation game players are forced to split their tasks between team members, because they have limited time to complete their turns,
- Tutorial: players receive video guides and a help sheet on paper,
- Consequences: each action in-game carries some measurable consequences,
- Strategy: the team must find the right balance between pricing products, restocking amount and time and marketing expenses,
- Scarcity: the market was fixed in size and each team had to compete to achieve as much profit as possible,

This allowed students to experience some of the key approaches used in the gamification of education.

The students first met with this game at the start of the ERP course (Heričko, et al., 2017), when we established the usefulness of using an ERP simulation

game as a tool to introduce students to the vast area of ERP systems. In the first iteration, we concluded that using an ERP simulation game was beneficial for introducing students to the ERP course (Heričko et al., 2017). The students felt that they gained a lot of new knowledge, that the workshop was fun and that the approach was suitable to introfducing ERP systems to them. The instructors were interviewed and they all found the ERP simulation game approach adequate.

We observed problems that are typical in gamification: up to 40% of students felt that their main goal was to win, but not to gain new knowledge and almost 40% of students felt that groups were withholding their information to some degree to obtain a competitive advantage (Heričko et al., 2017).

We replicated a gamified ERPSIM session at the end of the course on ERP. The purpose was to show the students an example of gamification in practice. This provided them with deeper insight and understanding of the gamification principles and benefits.

3.2 Research method

We prepared a survey to investigate how suitable and effective gamification in higher education courses is, by analysing the reflections of students after completing a short workshop, which used some gamification elements. The following research questions were formed:

- RQ1 - How do students accept the gamification approach?
- RQ2 - Which practices of gamification are students most receptive to?
- RQ3 - Are students who play games regularly more receptive to gamification?

Data was collected from the workshop participants with an online questionnaire after completing the workshop. The number of obtained observations was 15. The study was performed on 1st year master students at the Informatics and Technologies of Communication programme, which is offered by the Faculty of Electrical Engineering and Computer Science at the University of Maribor.

The participant questionnaire consisted of questions and statements, which respondents were asked to evaluate and assess using a 5-point Likert scale, with the following responses: completely agree; agree; neither agree, nor disagree; disagree; strongly disagree. The statements were grouped into the following categories:

- Statements about the suitability of gamification elements/concepts,
- General statements about gamification,
- Statements about student habits, engagement and participation,

Through the collected results, we were able to examine the suitability and effectiveness of gamification. During the discussion, the results were rounded to the nearest percentage point.

Gamification and each gamification concept was explained to the students in material, which was presented to them in addition to the questionnaire.

3.3 Results discussion

We were interested in the team aspects of the workshop. We asked participants to rate the following statements and received the results seen in Figure 2:

- S1 – The results of engaging in a gamified workshop should be part of the academic grade of a course where possible,
- S2 – Gamification is more suitable when students are divided into groups, because students then feel a sense of belonging,
- S3 – I would rather compete against players than the environment,
- S4 – E-learning environments (such as Moodle) should be upgraded with elements of gamification,
- S5 – Project tasks that are a part of academic courses lack elements of gamification,
- S6 – Participating in educational games in teams leads to specialization of players in individual functions, so we should plan the model in advance to guarantee the rotation of functions within a group,
- S7 – If teaching associates would participate and compete in gamified environments with students, student motivation would be impacted positively,

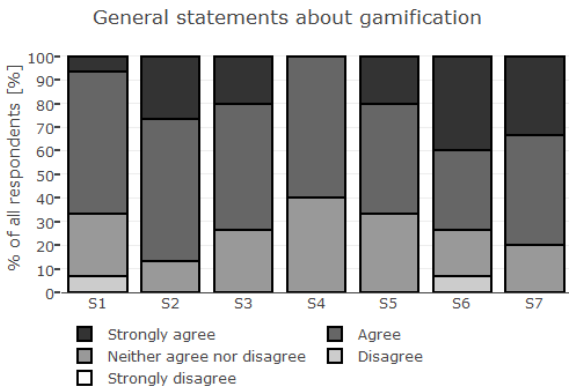


Figure 2. Gamification statements

Students generally agreed with all the statements, but there was less agreement about the possibility of gamified workshops presenting a part of the academic grade of a course where possible (S1) - 67% of all respondents agreed or highly agreed, and that e-learning environments should be upgraded with elements of gamification (S4) - 60% agreed and 40%

neither agreed, nor disagreed. What should be noted is that most students (73%) would rather compete against human competition (players), than some arbitrary environment (S3), which should be noted when preparing a gamified environment. Students liked team-based gamified environments much more than environments, where they are expected to participate alone (S2). It is also interesting that most students would like (if possible) to compete against their teaching associates (S7). Most students would also prefer that project tasks in courses would have gamification elements included in themselves (S5) and agreed that we must be careful, because splitting students into teams with no additional instructions will lead to the specialization of players to specific tasks. The willingness of students to extend gamification found in our study is quite remarkable, since (Domínguez et al., 2013) reports that more than half students felt less motivated when gamification was applied.

Table 1. Answers to "Gamification statements" comparing non-gamers and gamers in %

Stat.	CA[1]		A		NA		D		CD	
1	10	/	50	80	40	/	/	20	/	/
4	/	/	60	60	40	40	/	/	/	/
5	10	40	60	20	30	40	/	/	/	/
	N[2]	**G**	**N**	**G**	**N**	**G**	**N**	**G**	**N**	**G**

We also asked the players if they play games on a weekly basis as seen in **Table 1**. Five of them answered yes and 10 of them no. We then compared the answers to relevant statements (S1, S4, S5) to see, if they approve of gamification. We used the Freeman-Halton extension of Fisher's exact test to test if any correlation exists between individuals that play games weekly and those who do not. We found the following correlations 0.201 (S1), 1.000 (S4) and 0.394 (S5). Because of the small sample size, we could not conclusively determine if significant differences existed between those two groups of students in their perception of gamification.

We were interested in how students rated the suitability for each of the following gamification aspects: *Points, Levels, Trophies/Badges, Virtual Goods, Storyline, Time Restrictions, Aesthetics, Leaderboards, Interactive Cooperation, Experience Points, In-game Rewards, Mission and Objectives, Unlockable Content, Adjustable levels of difficulty, Tutorial, Scarcity, Anonymity, Consequences, Loss Aversion, Strategy, Branching Choices, Customization* (all of elements and concepts adapted from (Jackson, 2016), (Fui-Hoon Nah et al., 2014) and (Marczewski, 2017)).

The gamification elements with the lowest approval rating from students as seen in **Figure 3** were Loss Aversion – only 47% of students agreed or strongly agreed that the concept was suitable; Anonymity had the same suitability rating.

The highest approval was received for both the Tutorial and Mission and objectives– 93% said that the concepts were suitable.

Among other highly rated concepts were Strategy Points, Unlockable Content, Levels, In-game Rewards (in all instances, only 13% felt neutral or less), Consequences (20% did not strongly agree or agree) and Branching Choices (20% did not strongly agree or agree).

Comparing them with other studies, there were some responses that strongly disagreed with Trophies/Badges, which is supported by (Hanus & Fox, 2015) who found that Badges/Trophies can sometimes be harmful to student perception and In-game Rewards, and this is consistent with (Domínguez et al., 2013) who found that some students were not motivated by rewards, and even felt manipulated when they were introduced. Leaderboards received a highly positive rating which is remarkable, considering that (Dias, 2017) found some students feel demotivated by the presence of ranking, because they do not want to be publicly compared to their peers.

[1] CA – completely agree, A – agree, NA – neither agree nor disagree, D – disagree, CD – completely disagree

[2] N – doesn't play games weekly, G – plays games weekly

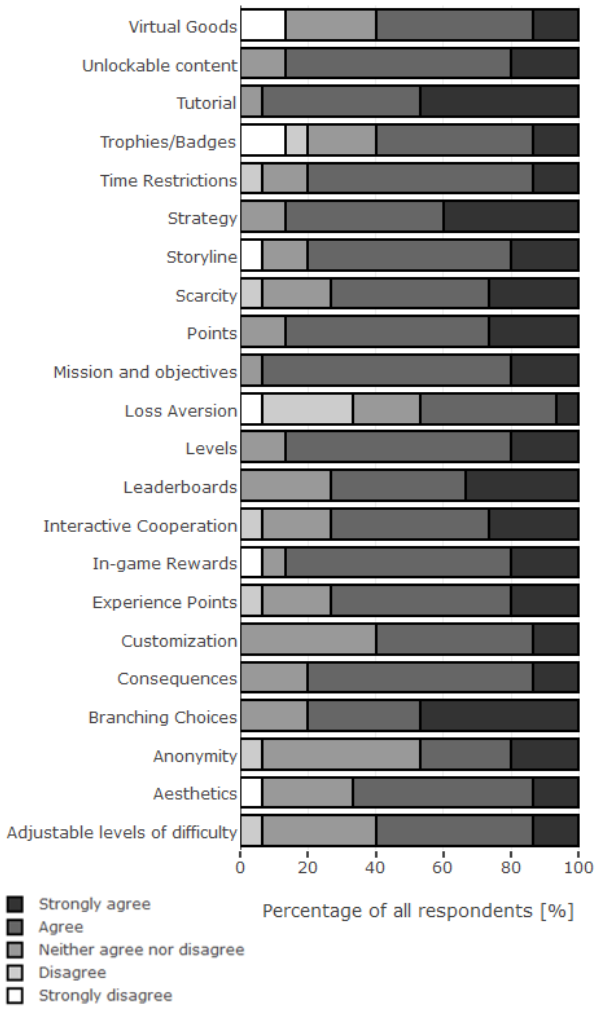


Figure 3. Suitability of gamification concepts/principles as perceived by students

4 Conclusion

Based on positive student feedback, we can conclude that students accept the gamification approach and find it beneficial. Students, to a certain extent, believe that their participation in such workshops could even determine part of their academic grade. They feel that E-learning environments are suitable for gamification.

No correlation was found between playing games and their attitude and opinion about gamification.

Those wishing to implement gamification environments should not just look at the gamification elements themselves, but also acknowledge players' tendency to compete against players, rather than the environment. Another way to increase motivation is to include teachers as participants if gamification offers direct competition among students. But before implementing any competing elements (leaderboards, points, public badges or trophies, etc.) we must carefully design a system in such a way that bottom ranked players do not feel demotivated.

The tutorial as well as the Mission and Objectives were determined to be the most highly regarded gamification concepts for the students. Providing an adequate tutorial for students is a must and students must feel that they have some concrete mission and objectives. Those two elements were closely followed by Strategy, Points, Unlockable Content, Levels and In-game Rewards, which were also widely accepted by the students.

Since a small number of students had a lower approval rating for some gamification elements, further research may include splitting students into a gamified and non-gamified course on a voluntary basis. (Glover, 2013) recommended the gamification be optional and found a negative effect for motivation on perception when gamification was applied to people with already high motivation.

Gamification is just an additional tool to achieve goals in higher education, and not every tool is good for everything. We should not look at gamification as just another buzzword or the next big thing that needs to be omnipresent in our curriculum, but implement it when we have good reasons and arguments to do so.

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Digital Competence Assessment System: Supporting Teachers With the CRISS Platform

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Abstract. *This paper presents the Digital Competence (DC) Assessment System for primary and secondary schools developed in the H2020 CRISS[1] project. A qualitative approach consisting of an integrative literature review, experts' and users' validation, and a proof of principle were used to develop the construct. The system implements a DC operational concept of five areas and 12 sub-competences with associated performance criteria and indicators. The system adopts the integrative pedagogy approach for implementation within the school curriculum. It proposes a process assessment based on a set of scenarios that use multiple methods for evidence collection and that implements rules ensuring validity and reliability.*

Keywords. CRISS, digital competence, assessment, integrative pedagogy.

1 Introduction

Digital Competence (DC) is one of the key competences any individual needs for personal fulfilment, active citizenship, social inclusion and employment in the 21st century (European Commission, 2006; Sargent, 2014). The European Commission has developed a digital competence framework (DigCom) for all citizens composed of 21 sub-competences, where the digital competence is defined as a "set of knowledge, skills, attitudes (thus including abilities, strategies, values and awareness) that are required when using ICT and digital media to perform tasks; solve problems; communicate; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participation, learning, socialising, consuming, and empowerment." (Ferrari, 2012. p.4).

Despite the numerous projects implementing DigCom in different contexts and for different purposes, the initiatives focusing on digital competence evaluation are rare or only tackle the problem partially. Different European programmes, either public or private, have focused on the evaluation and certification of citizens' and, in a few cases, students' digital competences. Most of them are summative-oriented and based on the evaluation of digital skills and knowledge using e-tests with different degrees of difficulty or complexity (e.g. IKANOS[2], PIX Beta[3]).

In recent years, governments have shown increasing interest in digital competence assessment and certification (e.g. ACTIC[4]). Nevertheless, most of these programmes are limited to a set of recommendations and they do not provide enough information on how to apply them in school curricula.

In this paper, we present a Digital Competence Evaluation System developed under the H2020 CRISS project (demonstration of a scalable and cost-effective cloud-based digital learning infrastructure through the certification of digital competences in primary and secondary schools). CRISS is a user-driven, flexible, scalable and cost-effective cloud-based digital learning ecosystem that allows the guided acquisition, evaluation and certification of digital competences in primary and secondary education, and is easily scalable to other educational levels. CRISS aims at developing an innovative adaptive learning solution supported by the most advanced pedagogical methodologies and technologies that will be tested with a pilot involving more than 490 schools including 25,400 students and 2,290 teachers across Europe. CRISS will provide a unique certification system with the aim of

[1] CRISS is a project financed by European Commission, Horizon 2020 (ID:732489, 2017-2019). http://www.crissh2020.eu/

[2] IKANOS is a project on digital competences developed by the Basque Government (Spain). http://www.innova.euskadi.eus/informacion/what-is-ikanos/v62-ikanosi/en/

[3] PIX is a public project for the evaluation and certification of digital competences in France. https://pix.beta.gouv.fr/projet

[4] ACTIC is the accreditation system for digital competences in Catalonia (Spain) http://actic.gencat.cat/ca/

contributing to the standardization of digital competences at the European level.

The CRISS Assessment System was developed in coordination with the deployment of a Digital Competence Operational Concept -DCOC (Guitert, Romeu, Baztán, *2017*) addressed to primary and secondary schools. The DCOC is the result of an analysis and mapping of seven European digital competence frameworks and schemes already in use with the DigCom. The DCOC consists of five areas (digital citizenship, communication and collaboration, searching for and managing information, digital content creation, digital problem solving) that group 12 sub-competences and corresponding performance criteria and indicators. The DCOC provides a comprehensive structure that facilitates DC development through the implementation of learning and assessment activities.

We present below the foundations and methodology leading to the development of a theoretical construct and the basis for a system supporting digital competence assessment and certification.

2 Theoretical Background

Competence assessment goes beyond the traditional evaluation of knowledge, as it also focuses on skills and attitudes. Competence assessment is defined by Pepper (2013) as "*a process of making inferences about individual knowledge, skills, attitudes using information collected through tests, observation, interviews, projects or portfolios usually in regards to predefined criteria*" (p. 1).

The specialized literature identifies three main types of assessment: diagnostic, formative and summative. Competence assessment for **diagnostic** purposes focuses on the evaluation of the background and the student's current level of competence acquisition. It allows learning needs to be identified. **Formative** assessment, according to Taras (2005), focuses on "*feedback which indicates the existence of a 'gap' between the actual level of the work being assessed and the required standard. It also requires an indication on how the work can be improved in order to reach the required standard*" (p. 468). Sargent (2014) points out that feedback is indissociable to competence assessment. The purpose of the feedback is to inform and guide the student in what they must do to improve the competence. Feedback must be timely and include specific suggestions on how to improve future performance. According to the definition provided by the report *Task Group on Assessment and Testing* (1988), formative assessment involves a student's positive achievements that may be recognized and discussed and the appropriate next steps that may be planned. Finally, **summative** assessment is based on recording the student's overall achievement at the end of a learning cycle leading to a score or mark. In some cases, summative assessment is the result of an aggregation of formative assessments. Summative assessment may also lead to certification.

Competence assessment should respect three basic principles: validity, reliability and equity (Pepper, 2013). **Validity** deals with the extent to which an assessment tool measures what it was designed to measure (Pepper, 2013; Wiliam & Black, 1996). **Reliability** is related with the extent to which an assessment tool consistently and accurately measures learning (Harlen, 2005). In this sense, case studies, professional tests and integration situations in general are mostly recommended. **Equity** relates to the social nature of assessment and highlights the need to consider differences which are not the focus of the assessment but which could influence the assessment (Pepper, 2007 & 2013).

Competence assessment is growing in different European educational systems as the new paradigm in contrast with the knowledge assessment approach. Digital competence has attracted special interest for its relevance to all aspects of personal and professional life. Digital competence, in terms of its generic nature, can be understood within the 21st century skills framework (Pepper, 2013; http://www.p21.org). A thorough and systematic review of 21st century skills research provided a set of recommendations for competence assessment (Lai & Viering, 2012):

- Assessment systems should provide multiple measures that support the triangulation of inferences.
- Assessment tasks should be of sufficient complexity and/or offer sufficient challenge.
- Assessments should include open-ended tasks.
- Assessments should use tasks that establish meaningful and/or authentic, real-world problem contexts.
- Assessment tasks should strive to make student reasoning and thinking visible.
- Assessments should explore innovative approaches to address scalability concerns.

According to these recommendations, competence assessment requires advanced assessment solutions based on robust pedagogies and complex situations that provide authentic problem contexts giving sense and meaning to students. Roegiers (2010) introduced "**integration pedagogy**" as a valid approach to developing competence assessment. The pedagogy of integration focuses on learning (mastering) competences, as opposed to the simple juxtaposition of skills (Roegiers, 2000). The goal of integration is to enable students to master situations that they will have to deal with in their lives and the most relevant learning methods associated with this approach are: project-based learning, problem-based learning, work-based learning, inquiry-based learning, case-based learning, game-based learning, etc.

Rather than only testing students' digital knowledge and skills, a model based on integration pedagogy allows teachers to assess students' digital competences as embedded in disciplinary or interdisciplinary problem situations. This approach confronts the student with meaningful situations and demands the mobilization of a set of competences in order to solve the problem or achieve the expected learning outcomes. In this sense, "integration pedagogy" involves developing integration activities that require a higher level of sophistication or complexity than typical standard tests on digital skills or knowledge. At the same time, integration activities are those that allow different competences and subjects to be assessed in the same learning scenario.

With integration pedagogy, CRISS adopts a **learner-centred** approach that puts the learner at the heart of the learning process. Integration pedagogy makes the learning more meaningful, relevant and engaging by contextualizing it within practical situations and daily life (Peyser, François-Marie & Roegiers, 2006). Learner-centred pedagogies are gaining importance whenever the goal of education shifts from memorizing facts to building competences, taking on responsibility, working effectively in teams or promoting creativity (Motschnig, et al., 2016).

3 Methodology

The first phase in the development of the CRISS Assessment System is based on a qualitative approach to define an initial theoretical construct, which is the focus of this paper. The empirical validation of the assessment system (second phase) will be conducted during the pilot tests due to take place in schools in eight European countries.

At this first stage, the development of the assessment system consists of three consecutive methods: an integrative literature review, an expert and teachers' validation, and a proof of principle.

We started with an **integrative literature review** approach as "*a form of research that reviews, critiques, and synthesizes representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated*" (Torraco, 2005: p.356). The aim was to provide an overview and our understanding of digital competence assessment, identify assessment requirements, benchmark existing solutions and elaborate a first construct. This construct should align with the CRISS DC Operational Concept, provide a general assessment approach anchored in school curriculum, and inform the development of the CRISS platform. Firstly, we defined keywords that helped to select relevant literature from the research perspective but also from grey literature and other authoritative sources (e.g. existing related past projects, proposed solutions, tools, etc.). The Mendeley reference management system was used to store and share files and annotations. Salient topics were identified and grouped into categories organized in tables of key concepts and summaries. All the information was mapped in order to support the conceptualization and development of the competence assessment system for the CRISS project.

After creating a first stable assessment theoretical construct, underpinned by theories and other theoretical frameworks and previous empirical research models, we proceeded to an experts' validation by the other academic partners involved in the project annotation and structured feedback. We also conducted a first **teachers' validation** through a discussion with the schools participating in the project. Their comments and suggestions were integrated into an improved construct.

The validation process was completed using a **proof of principle** approach designed to test the construct applicability to actual situations. We used real learning and assessment activities facilitated by schools involved in the project. We employed two project-based learning examples and adapted them to Competence Assessment Scenarios (CAS). This exercise of transposition showed the compatibility of the construct in terms of concept correspondences and structure coherence with the chosen examples. In addition, this proof of principle showed the power of the construct in supporting the refinement of the assessment strategy of the learning examples used.

4 Results: Digital Competence Assessment Framework

The **CRISS Operational Concept** proposes **five areas** that group **12 sub-competences**. Each sub-competence is composed of a set of **performance criteria** (PC) (between two and four) which translate the competences into more concrete elements of what students should be able to demonstrate. Each performance criterion is assessed according to set of **indicators**. These indicators are observable characteristics of the PC and consist of predefined measures or other types of qualitative information which learner evidence will be measured against or evaluated with.

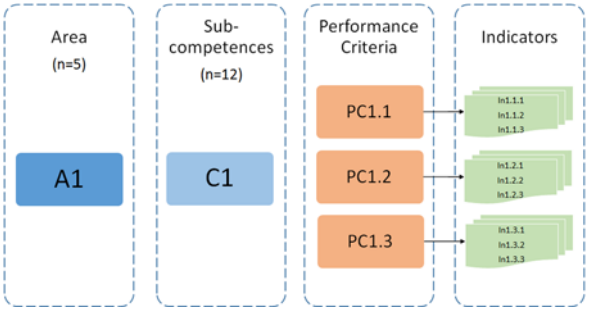


Figure 1. Hierarchical structure of CRISS Digital Competence Assessment System

In order to ensure the validity, reliability and equity of the assessment process, CRISS proposes:

a) Presenting the student with different competence assessment opportunities.

Roegiers (2005) points out the need to ensure fairness and validity in competence assessment. The author proposes using De Ketele's (1996) empirically tested rule that requires providing the learner with multiple opportunities to perform and verify the competences. In CRISS we have established that a DC sub-competence is considered attained when all performance criteria have been successfully fulfilled. The rule of "2/3" applies and gives the student three occasions to verify each performance criteria. Roegiers (2007) also highlights that not all the items assessed may have the same importance for the competence assessment. In order to avoid this possible drawback, the CRISS competence assessment approach gives different weights to PC and indicators according to their relevance.

b) The development of **Competence Assessment Scenarios** (CAS) where digital competences are assessed in context.

CRISS assessment is based on assessing competences through different CAS. These CAS can be implemented at different moments and their duration may vary.

CAS integrate one or more subjects or disciplines in the school curriculum. They are designed on the basis of advanced instructional approaches where the learner or learners are required to solve problems, develop projects or search for solutions in realistic contexts and meaningful situations. Instructional approaches are macro-strategies that "*set a general direction or trajectory for the instruction and are comprised of more precise or detailed components*" (Reigeluth & Keller, 2009, p.31). This pedagogical macro level (e.g. problem-, project-, case-, inquiry-based learning) articulates a set of activities and tasks where competences are performed and assessed.

CAS provide opportunities to develop and assess targeted competences including some or all the corresponding performance criteria. Each performance criterion is assessed using a set of indicators which are assigned different weights according to their relevance. It is crucial to identify/specify the indicators that will provide measurements or the conditions required to interpret the evidence in terms of performance criteria and competence attainment. CAS also adopt/adapt an assessment strategy composed of assessment methods and instruments to ensure the appropriate evidence is gathered in order to assess the competence.

The following figure presents a diagram of a CAS structure and its main components. The CAS proposes a set of activities and tasks that allow one or more performance criteria to be assessed. Each PC is also identified with a numbered event highlighting the specific occasion when it is worked on and assessed.

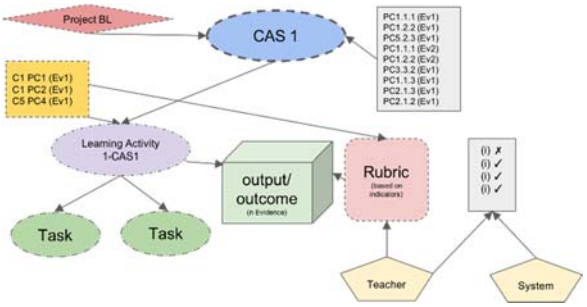


Figure 2. Example of CAS and Learning Activity with tasks and basic assessment with rubric

While the DC Operational Concept and the Assessment System provide a standardized way of understanding the digital competence and defining a generic assessment methodology, the development of CAS remains a highly customizable endeavour. Teachers may design different CAS, precise assessment indicators, and select specific assessment methods and instruments according to their curriculum or other contextual and cultural aspects.

4.1 Assessment methods

A precise assessment of students' competence achievement calls for different assessment methods to be used (Looney, 2011). A wide variety of available assessment methods and instruments (e-portfolios, multiple-choice questions, blogs, free text responses and essays, rubrics, scales, observation grids, etc.) assist in the collection of evidence for assessment. Both the CAS assessment methods and instruments must provide evidence consistent with the predefined indicators.

Redecker and Johannessen (2013) mention that students should be continuously tracked and guided within digital environments, merging formative and summative assessment within the learning process. The CRISS platform is designed to track students while they work on their assigned activities and collect relevant information. At the same time, teachers can/should inform the system by adding relevant information on their students' competence development by using rubrics or other data gathering instruments integrated into the CRISS platform. The CRISS platform will provide an adaptive and intelligent system that helps to link learning evidence to automatic monitoring, advising and assessment. An e-portfolio-like solution forms the basis of this implementation.

4.2 Certification

Each sub-competence has an associated badge reflecting its achievement. The badge is linked to

specific descriptive reports extracted from the e-portfolio. Applying the 2/3 rule, the final assessment for certification takes into account the two best results out of three. Thus, sub-competence assessment is equal to the mean of the best two attempts. The attainment of a sub-competence is established when the mean is equal to or greater than 70%. The **collection of badges** is a requirement for the final certification.

5 Conclusions

The Digital Competence Operational Concept consisting of five areas, 12 sub-competences and associated related performance criteria, together with a set of initial indicators provide a robust standard from which to evaluate the digital competence. The development of the CRISS Digital Competence Assessment System construct builds on the operational concept and stands on best practices and research-informed recommendations for generic competence assessment. The proposed solution is flexible enough to integrate digital competence development and assessment into different disciplines or subject matters, thus adapting to different curricula and organizational structures. It uses Competence Assessment Scenarios that help to contextualize and anchor the assessment in realistic and meaningful situations. The construct provides multiple opportunities to perform and verify the competences, and relies on multiple methods and instruments for gathering evidence to support the assessment and certification process.

Although the assessment system proposed by the CRISS project aims to evaluate and certify digital competence, the approach may be also applied to other type of competences. Its scalability and flexibility is one of the strengths of the system and makes the solution unique and innovative.

Acknowledgments

The research leading to these results has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 732489.

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Analysing Students' Behaviour Patterns in Online Assessment

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Abstract. *The aim of the study was to discover students' behaviour patterns based on the data recorded in a learning management system and the links to their results achieved in a specific e-learning course. In order to identify behavioural patterns during formative online assessment test (multiple access allowed), the collected data are analysed both within and between two generations of students who participated in the e-courses. The students in 2016/17 accessed the e-course more often, achieved better results and accessed the content of the e-course to a greater extent. At the same time, for the same generation, fewer test attempts are noted. Based on the insight into the structure of the content that students have accessed, the best results are particularly positively linked with access to different e-course content.*

Keywords. e-course, online assessment, students' behaviour patterns, educational data mining, learning analytics.

1 Introduction

Latest reports confirm a steady increase in the demand and online course offerings in higher education. As an example, almost 5.3 million students took at least one online course in the year 2013/14 (Murphy & Stewart, 2017). Some of the reasons for this increase in online course offering are related to institutional limitations (e.g. a lack of classroom space, educational costs) but also to a steady student demand for flexible learning options and expectations.

In parallel, and in part as a result of this increase in online course offerings, there is a growing interest of researchers to automatically analyse data generated by students in an online education environment. One of the reasons for this interest is the expanding availability of data (i.e. logs of student activities), which provide ample opportunities to discover behavioural patterns, and any deviations in the student's expected behaviour. Furthermore, it is possible to build prediction models that can calculate probabilities of students' behaviour, all in order to provide timely support to students. The results are typically of more use to teachers since they can use them to tailor/adjust/optimise their teaching and learning strategies and adapt the online education environment.

Without adequate ICT support (usually in the form of data mining tools) the analysis of the generated data from a course with lots of students and countless activities can be a challenging task for the instructor (Burgos et al., 2017). In addition to a great volume of the data, to get the full picture, an additional technical requirement is to combine data from various data sources and from different users (course assessment, lecturer assessment, student assessment, etc.). For some time, new methods for exploring the unique types of data that come from educational settings and their use to better understand learners and the settings is explored as a part of Educational Data Mining (EDM) field (Chalaris et al. 2014). The advancement in terms of data mining methods and tools makes it possible to analyse increased volumes of educational data in order to improve the quality of the educational processes (Asif et al., 2017). One of the most frequent uses of EDM is for examining students' (learning) behaviour in online learning environments (Siti Khadijah & Zaidatun, 2013).

In the paper, the focus in on the analysis of data collected within an e-learning system (Moodle) before and during the online assessment. The students were given the possibility to access the test as many times they wanted. Online testing has become a common way to organize formative assessment in higher education environments. The studies show that when student participation is stimulated by scoring formative tests held in an unproctored, online environment, issues of academic dishonesty occur (Arnold, 2016). Scoring is controversial in formative testing, as chasing the score may distract from deep learning (Wolsey, 2008 in Arnold, 2016). In that line, we hope to provide additional insight into these particular issues.

2 Analyses of student activities' logs in learning management systems

Online courses are delivered through e-learning platforms that allow users to create virtual learning environments. One of the basic functions of the system is to manage e-learning courses. In addition to that, the system enables the creation and presentation of different types of learning media, recording of user data, virtual communication among participants and so on (Ertl et al., 2007). Learning Management Systems (LMSs), often referred to as virtual learning environments, developed a great deal over the last twenty years (cf. McCormack & Jones, 1997). This resulted in the growth of e-learning implementation projects at universities, schools and business organisations (Mazza & Botturi, 2009). These institutions usually rely heavily on the whole range of tools that enable centralization and automation of different aspects of learning through the following functions, among others (Morrison, 2003): user registration, user profile management, e-course catalogue management, storing and delivering e-learning courses, integrating modules and tools required for e-learning, tracking and recording the progress of users, learning assessment, tracking and storing assessment results, and generating various types of reports to manage different processes. The functions are often grouped into ones that support (i) management of learning resources, (ii) communication and collaboration between students and instructors, (iii) assessment of learning, (iv) system support, and (v) access and role management (Coffey, 2007). LMSs either support (i) traditional courses (to a lesser extent, usually for online material delivery), (ii) hybrid approach, and/or (iii) learning that is fully online. The last approach uses the greatest number of features provided by the system.

Analysis of user data generated through interaction with resources in an LMS can be compared with web (data) mining, but with a special emphasis on learning and pedagogic information that is commonly not available in a standard web analytic approach or tools. Although more research has been conducted on this subject lately, there were a number challenged related to systematic approach to analysing a large number of logs generated by student activities and a common architecture (Scheuer et al., 2009). Increasing volumes of data about learning and teaching processes generated in different educational contexts (whether formal or informal, higher education or lifelong learning) led to advent of concepts such as learning analytics (LA) and EDM. Learning analytics is often defined as the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs (Siemens, 2011). The definition is adopted and promoted by Society for Learning Analytics Research (SoLAR).

LA and EDM develop rapidly due to advances in data management (Elias, 2011). In addition to modern day tools for data management, a large number of tools for (big) data analysis are available on the market.

In higher education, one of the key questions is how to increase student engagement and, in the process, achieve transformative learning outcomes. LA and EDM are crucial tools for answering such a complex question (Siemens & Baker, 2012). Approaches behind LA and EDM are very similar. The key difference is that LA relies on human interpretation of the data, data visualization and social network analysis, whereas EDM is based on automated machine learning i.e. data mining methods.

Drawing on number of success stories and research reports, we recently explored and assessed appropriateness of LA and EDM concepts and tools in one higher education institution (HEI) in Croatia and advocated an analysis that goes beyond basic reports provided within centrally managed academic information systems. As a proof of concept, a data mart that combines data from couple of data sources (Moodle LMS and custom academic information system) was presented as a basis for systemic, real-time analysis of educational data in HEIs (Maršić et al., 2016).

Here, we focus on the potential of log files that result from the automatic tracking of all interactions within a LMS. As stated earlier, this data can be used to analyse and evaluate learning activities with the purpose to improve the activities or the learning environment (Avouris et al., 2009). By using logs, it is possible to explore how the student's behaviour in the e-learning system affects their success, as studies show that more successful students spend more time and are more engaged in e-learning courses compared to less successful students (Campbell et al., 2006). Knowledge discovered from log data can be used by students, teachers, and system administrators (Romero & Ventura, 2007). For students, it is possible to recommend activities, teaching materials and assignments in a way that facilitates and improves the learning process. Recommendations can be made on the basis of the student's behaviour as recorded in the system and the behaviour of other similar students. Teachers can get a more objective feedback, evaluate the structure of teaching content/course and determine the effectiveness of the program. Furthermore, teachers are offered the ability to classify students into groups based on their needs for additional help and guidance, to explore behavioural patterns in the system, to look for the most common errors. At the same time, the administrators can monitor the parameters important to improve system performance (optimal server size, network traffic distribution, and so on).

The link between using the course material and the success achieved in the final test has been studied for a while now (e.g. Rafaeli & Ravid, 1997). The

limitation of such studies is that they do not analyze the activities that students spend offline, due to the fact that a large number of online materials will be printed and used in a paper version whenever possible. It has been confirmed that time spent on assignments and frequency of participation is important for successful online learning (Morris et al., 2005); the good predictors of the final grade are the number of discussion posts posted, the number of visited pages with content, and the time spent in viewing the discussion pages. Differently, Ramos and Yudko (2008) confirm that that opening and reading of online course pages is a good predictor of success, but posting in discussions and its reading are not. To explore the case in detail, we have conducted a study presented hereinafter.

3 Research questions

In order to discover student behaviour patterns (based on the data recorded by the LMS) which could be related to their score required to pass the specific e-course, the research questions have been posed:

- Is there a correlation between accessing the content of the e-course and the results obtained in the final test of the e-course?
- Is there a correlation between the number of accesses to the final test and the results achieved in the final test of the e-course?
- Which of the two links is stronger when observing the result achieved during the first access to the test?
- Which of the previous two links is stronger when observing the best achieved result on the test?

These questions are set in the context of the online test where the possibility of multiple access is enabled. The answers to these questions will be based on the data analysis within and between the two generations of students who have accessed the e-course.

4 Methodology

4.1 Research setting

The LMS Moodle that has been used at the Faculty of Economics, University in Split since 2008 was the platform that delivered the course. Students enrolled in the first-year course "Information Technology" were able to access the e-course "Information Security" for 4 weeks. The objective of this e-course is to educate students about the concepts of information security and the measures of protection of information resources. The students were able to access the resources and the activities (reading text, watching video material, complete the surveys, etc.) in the sequence and dynamics that suited them. To successfully complete the e-course, the students were required to achieve 70% score on the final test but there was no limit on the maximum number of accesses to the test or the time between taking the test.

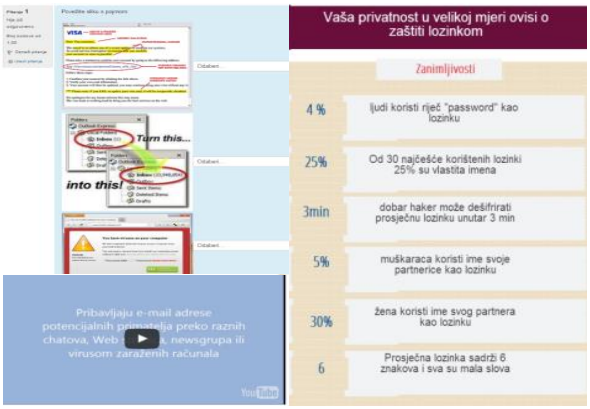


Figure 1. Test, video and infographic within e-course

The Information technology course is structured around various activities where continuous monitoring of student progress is employed through a model of accumulation of points. Students who successfully passed the e-course were awarded bonus points. The Quiz module which was used to develop the test is one of the most complex and most flexible parts of the Moodle system. For the test, we opted for randomly generated questions from the databank. The feedback is immediate. For the questions with more than one correct answer, the correct answers were scored as positive, and the incorrect as negative, so the sum of positive and negative points gives the final result on that question. The result could not be less than zero.

4.2 Participants

The participants of the study were the first-year students of the Faculty of Economics. In the academic year 2015/16, 271 students participated in the hybrid course Information technology. The age of the students was between 18 and 22 years, 72% were female and 29% male. In the academic year 2016/17, 269 students participated in the same hybrid course. The age of these students was between 18 and 22, 69% were female and 32% male. The respondents come from a relatively homogeneous group (first-year students) and share a similar background in terms of education, economic situation etc. The age and gender structure between the two generations of students is very similar.

4.3 Collecting and analysing data

The data about student behaviour in the e-learning course was collected from the Moodle system where detailed logs on students' activities are tracked. Data was collected from two groups of students who had access to the e-course "Information Security". For the purposes of reporting on the results and student behaviour, there are two different modules in Moodle that allow easy downloading of textual or tabular files – the Grader report for the results of activities that are scored, and the Log that captures activity data for available resources within the system.

Selected data from the system were exported to the .xls file whereby pivoting the data, it was reduced to a format suitable for further analysis. From the first generation (15/16) over 168,000 records were collected. In 16/17, a new version of the Moodle was used so the number of collected records was over 299,000. The data collected from the Grader and the Log was merged into a flat file with the ID of the student and all the activities the student had done in the course. Using the IBM SPSS tool, descriptive and correlative analysis was performed for each generation and the differences between the generations were tested using t-test.

5 Results and discussion

The results are first presented for the 15/16 generation, and then for 16/17, followed by the comparison of the results for the two groups. Table 1 presents the descriptive statistics for the first result/attempt that students achieved when they submitted the online test (in 15/16). The average value is 74.94, above the 70-point threshold.

Table 1. Descriptive statistics for the first result/attempt on the test (generation 2015/16)

	N	Min.	Max.	Mean	St. Dev.
First result	263	6.67	100.00	74.94	15.10

Figures 2 and 3 shows data sorted by the number of points achieved on the test in their first attempt. Figure 2 shows a significant increase in the number of accesses to the test (log test) after the number of points falls below 70 (which is the threshold to pass the e-course), while Figure 3 does not indicate a significant increase in the activity of accessing the content of the e-course when the result falls below 70. This suggests that in the conditions of multiple-access to online tests, the students are more likely to opt for trial & error system than for reading the content.

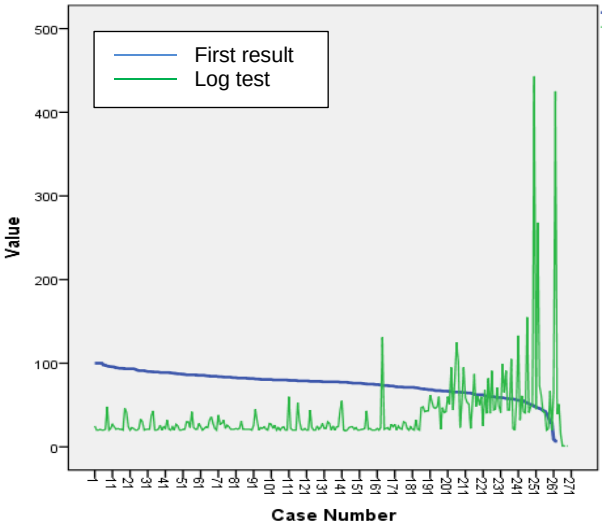


Figure 2. Points achieved on the first attempt and number of times accessing the test (gen. 2015/16)

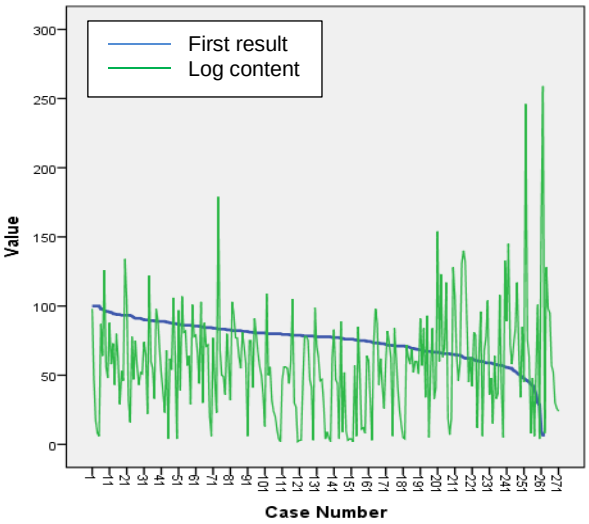


Figure 3. Points achieved on the first attempt and number of times accessing the content (gen. 2015/16)

Table 2 presents the correlation of the points achieved on the test (the first attempt) and the numbers of times accessing the test and the content. There is a negative and statistically significant correlation between the activity of accessing the test and the content and the results achieved on the first attempt.

Table 2. Correlation of the first test result and accessing the test and the content (gen. 2015/16)

		First result	Log test	Log content
First result	Pearson Corr.	1	-.485**	-.178**
	Sig. (2-tailed)		.000	.004
	N	263	263	263
Log test	Pearson Corr.	-.485**	1	.440**
	Sig. (2-tailed)	.000		.000
	N	263	268	268
Log content	Pearson Corr.	-.178**	.440**	1
	Sig. (2-tailed)	.004	.000	
	N	263	268	271

As can be seen in Fig 1 and 2, the observed negative link is stronger between multiple access to tests (log test) and the first result (-0.485**) than to accessing the content (log content) (-0.178**), meaning that students with a lower number of points (especially points below the 70-point threshold) after taking the test for the first time, re-take the test and access the content of the e-course more than students with better scores.

Table 3 presents the descriptive statistics for the best result/attempt that students achieved when they submitted the online test (in 15/16). The average value is 81.94, with standard deviation of 9.85.

Table 3. Descriptive statistics for the best result on the test (generation 2015/16)

	N	Min.	Max.	Mean	St. Dev.
Best result	264	28.89	100.00	81.95	9.85

Table 4 presents the correlation between the best test result and the total number of accesses to the test and content. The above-mentioned repeated access to the test and content is positively related to the best score that a student has achieved. A somewhat stronger link is between the best result and accessing the content (0.262**) compared to accessing the test (0.198**), both statistically significant.

Table 4. Correlation of the best test result and accessing the test and the content (gen. 2015/16)

		Best result	Log test	Log content
Best result	Pearson Corr.	1	.198**	.262**
	Sig. (2-tailed)		.001	.000
	N	264	264	264
Log test	Pearson Corr.	.198**	1	.440**
	Sig. (2-tailed)	.001		.000
	N	264	268	268
Log content	Pearson Corr.	.262**	.440**	1
	Sig. (2-tailed)	.000	.000	
	N	264	268	271

If the best results from the first attempt (presented in Table 5) are taken into account, the correlation with accessing the content is positive (0.253**), and similar to the correlation coefficient for multiple access (0.262**). A conclusion can be drawn - students who achieve a higher result in the first test attempt, access the contents of the e-course more frequently. Those students who achieve lower result than the threshold are more focused on subsequent test attempts than accessing content.

Table 5. Correlation of the best test result and accessing content (generation 2015/16) [If access to test =1]

		Best result	Log content
Best result	Pearson Corr.	1	.253**
	Sig. (2-tailed)		.001
	N	181	181

With regards to generation 2016/17, Table 6 presents the descriptive statistics for the first result/ attempt that students achieved when they submitted the online test. The average result is 77.98, which is above the 70-point threshold. Compared to generation 2015/16, the average result is 3.04 higher. Smaller range of points is noted (min 32.22 - max 97.78) as well as standard deviation (12.68). The statistical significance of the differences in the points achieved as well as the potential causes will be analysed further in the paper when the results of the two generations are compared.

Table 6. Descriptive statistics for the first result/attempt on the test (generation 2016/17)

	N	Min.	Max.	Mean	Std. Dev.
First result	269	32.22	97.78	77.98	12.67

Figures 4 and 5 show data sorted by the number of points achieved on the test in their first attempt. Even more significant increase in the number of test attempts (log test) after the number of points falls below 70 (the threshold) is observed in Figure 4. Similar to a year before, there is no significant increase in the activity of accessing the content of the e-course when the first result falls below 70.

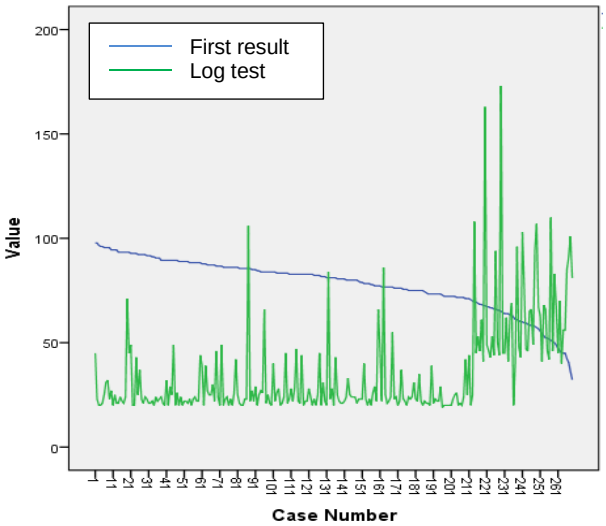


Figure 4. Points achieved on the first attempt and number of times accessing the test (gen. 2016/17)

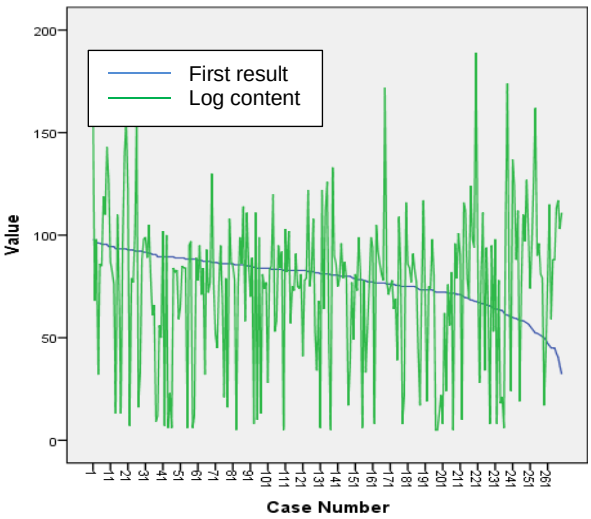


Figure 5. Points achieved on the first attempt and number of times accessing the content (gen. 2016/17)

Table 7 presents the correlations between the points achieved on the test (the first attempt) and the numbers of times accessing the test and the content (in 2016/17). As illustrated, there is a stronger statistically significant negative correlation between numbers of times accessing the test and the first result (-0.560**). Students with a lower number of points (especially points below the 70-point threshold) after the first attempt, re-take the test rather than access the content. This pattern of behaviour is even more obvious than in the previous generation.

Table 7. Correlation of the first test result and accessing the test and the content (gen. 2016/17)

		First result	Log test	Log content
First result	Pearson Corr.	1	-.560**	-.079
	Sig. (2-tailed)		.000	.197
	N	269	269	269
Log test	Pearson Corr.	-.560**	1	.360**
	Sig. (2-tailed)	.000		.000
	N	269	269	269
Log content	Pearson Corr.	-.079	.360**	1
	Sig. (2-tailed)	.197	.000	
	N	269	269	269

Table 8 presents the descriptive statistics for the best result/attempt that students achieved when they submitted the online test (in 16/17). The average value is 83.08, with standard deviation of 7.37. The average is slightly higher (1.13 percentage points) with lower standard deviation compared to year before.

Table 8. Descriptive statistics for the best result on the test (generation 2016/17)

	N	Min.	Max.	Mean	St. Dev.
Best result	269	56.11	97.78	83.08	7.37

Table 9 presents the correlation between the best test result and the total number of accessing the test and the content. Accessing the content is positively correlated to the best score that a student has achieved (0.241**). The link between accessing the test and the best test result is not statistically significant.

Table 9. Correlation of the best test result and accessing the test and the content (gen. 2016/17)

		Best result	Log test	Log content
Best result	Pearson Corr.	1	.010	.241**
	Sig. (2-tailed)		.866	.000
	N	269	269	269
Log test	Pearson Corr.	.010	1	.360**
	Sig. (2-tailed)	.866		.000
	N	269	269	269
Log content	Pearson Corr.	.241**	.360**	1
	Sig. (2-tailed)	.000	.000	
	N	269	269	269

If the best results from the first attempt (presented in Table 10) are taken into account, the correlation with accessing the content is positive (0.223**), and similar to the correlation coefficient for multiple access (0.241**).

Table 10. Correlation of the best test result and accessing content (generation 2016/17) [If access to test =1]

		Best result	Log content
Best result	Pearson Corr.	1	.223**
	Sig. (2-tailed)		.001
	N	201	201

Table 11 presents the correlations between the test results (the first and the best) and the access to different types of content. Based on this insight into the structure of the content that students have accessed, it can be stated that the best results are particularly positively linked with access to different e-course content. In contrast, the link with the first test result is not confirmed. What is more, the students with a lower number of points focus their activities on multiple test attempts.

Table 11. Correlation of the first and the best test result and accessing different types of content (generation 2016/17)

		Best result	First result
File	Pearson Corr.	.188**	-.144*
	Sig. (2-tailed)	.006	.034
	N	216	216
Choice	Pearson Corr.	.252**	.117
	Sig. (2-tailed)	.000	.085
	N	219	219
Glossary	Pearson Corr.	.009	.042
	Sig. (2-tailed)	.906	.576
	N	176	176
Page	Pearson Corr.	.281**	-.100
	Sig. (2-tailed)	.000	.120
	N	241	241
System	Pearson Corr.	.207**	-.098
	Sig. (2-tailed)	.001	.107
	N	269	269

Table 12 presents the differences between the presented results for the two generations. Overall, the students in 2016/17 accessed the e-course more often, achieved better results (both for the best and the first attempt) and accessed the content of the e-course to a greater extent. At the same time, for the same generation, fewer test attempts are noted.

Table 12. Comparison of the results for students from 2015/16 and 2016/17 generation

	Gen.	N	Mean	Std. Dev.
Total e-course access	2015/16	271	95.29	69.44
	2016/17	269	109.54	50.34
Best result	2015/16	264	81.95	9.85
	2016/17	269	83.08	7.37
First result	2015/16	263	74.95	15.10
	2016/17	269	77.98	12.68
Log test	2015/16	268	37.53	43.2
	2016/17	269	35.04	23.01
Log content	2015/16	271	58.18	38.58
	2016/17	269	74.51	37.26
Number of test attempts	2015/16	263	1.62	1.96
	2016/17	269	1.44	0.95

The differences in total e-course access, the first and the best test result and access to e-course content between the two generations are statistically significant, as presented in Table 13.

Table 13. T-test for equality of means

		t	df	Sig. (2-tailed)	Mean Difference
Total e-course access	Equal variances assumed	-2.73	538	0.007	-14.26
	Equal variances not assumed	-2.73	492.48	0.007	-14.26
Best result	Equal variances assumed	-1.51	531	0.132	-1.13
	Equal variances not assumed	-1.50	487.12	0.133	-1.13
First result	Equal variances assumed	-2.51	530	0.012	-3.03
	Equal variances not assumed	-2.50	510.47	0.013	-3.03
Log test	Equal variances assumed	.835	535	0.404	2.49
	Equal variances not assumed	.834	406.92	0.405	2.49
Log content	Equal variances assumed	-5.00	538	0.000	-16.33
	Equal variances not assumed	-5.00	537.59	0.000	-16.33
Number of test attempts	Equal variances assumed	1.39	530	0.165	0.18
	Equal variances not assumed	1.38	376.33	0.168	.1849

6 Conclusion

The changes in higher education are characterized by the increased expectations of the various implementations of ICT in educational processes. LMSs facilitate the development and management of e-learning courses as well as monitoring of student behaviour. The importance and the implications of studies focusing on student behaviour in VLE are presented in the first part of the paper (section 2). This study focused on the analysis of student activities' logs generated within one specific (integral) part of the hybrid course Information technology delivered fully online.

By using log data from the institutional LMS for two generations of students who have accessed the e-course Information security, answers to the research questions (listed in section 3) have been presented (in sections 4 and 5). The results point to correlation between certain student activities in the e-course and their test results. The results of both studies indicate that students who visited content pages more frequently achieved better results on the test. Also, it turned out that those students who achieve scores lower than the threshold, largely direct their activity to re-attempting the test instead of reading i.e. learning the content of the e-course. These results correspond with the research of Morris et al. (2005) who found that more successful students associate their online activities to what they believe is essential to achieve the passing grade. Though, in their study, the activities of successful students were, in addition to frequent visits to content pages, the participation in and following of the online discussions. Likewise, the research conducted by Macfadyen and Dawson (2010) implies that student's online activities such as using forums, sending emails, and online (self-)assessment are significant predictors of the final grade in the e-learning course.

A positive link between accessing the content and the achieved results is confirmed by testing the significance of the differences between the two generations - the students from the 2016/17 generation who accessed the e-course and the e-learning content more frequently achieved a better result while simultaneously taking the test fewer times.

When we analysed the student behaviour in the LMS focusing on the online assessment, it became apparent that students in the conditions of multiple-attempts allowed, decide to access the test more times based on the trial & error system instead of learning the content itself. Other authors have raised caution about the problem of cheating while testing students in the online environment since the focus apparently shifts from deep learning to passing the score threshold (Arnold, 2016; Wolsey, 2008). This research, looking at the results within and between generations, shows that the best results achieved in the test are still linked to learning the content rather than guessing the answers. However, students who do not achieve the threshold in the first attempt resort to guessing the questions in subsequent attempts. This issue can be resolved in the e-learning system by introducing a time delay between the two tests (this is planned in 2017/18). Notable positive outcomes of self-assessment tests with one-hour time delay within the same hybrid course (Information technology) within and between generations are presented in our earlier paper (Ćukušić et al., 2014).

Acknowledgments

This work has been partly supported by Croatian Science Foundation under the project HigherDecision IP-2014-09-7854.

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Preliminary Evaluation of a 3D Serious Game in the Context of Entrepreneurship Education

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Abstract. *Under umbrella of the Student Business e-Academy project, a digital start-up game was developed as a complementary material to the entrepreneurship curriculum. The paper brings the preliminary results of the evaluation of two different aspects of this game: usability of the interface and the sense of presence in a 3D virtual environment. The results indicate that, as far as these criteria are concerned, the improvements should be considered and implemented in both aspects. Several specific guidelines for further development of the game are outlined in the paper as well.*

Keywords. Serious games, 3D virtual worlds, Entrepreneurship, Evaluation, Usability, Presence

1 Introduction

New approaches to Technology Enhanced Learning (TEL) often explore the use of virtual, serious games within different areas of learning and with different types of users. There is great evidence (some of it is presented in the following section) that gamification, role playing, simulations, and virtual games have positive effects on a range of perceptual, cognitive, behavioural, affective and motivational impacts and learning outcomes. Still, more research has to be done in order to better understand the tasks, activities, skills and functions that different kinds of games can offer and to explore how these might match desired learning outcomes is apparent (Connolly et al., 2012; Hamari et al., 2016).

The paper presents a study focusing on a couple of less explored aspects, usability and presence, of a serious game used for educating learners on different entrepreneurship topics. After short theoretical context (section 2), the development of a digital game is described (section 3) followed by the evaluation procedure (section 4) and presentation of results (section 5). Discussion of obtained results and outlines for further work are presented in the last part of the paper (section 6).

2 Virtual worlds and 3D games for TEL

Based on 129 papers, a systematic literature review of empirical evidence on computer games and serious games (Connolly et al., 2012) showed that these games have a potential of creating learning environments to better reach the educational and training goals. The use of games (and competition) has a positive influence on motivation and learning process itself (Ercil, Ozcelik & Sahin, 2015). Even in the case of using existing 3D virtual environments such as Second Life, there is evidence that 3D virtual environments could indeed facilitate students in achieving better learning outcomes through constructivist learning (Chau et al., 2013).

Serious games allow learners to develop a range of different skills (analytical and spatial skills, strategic thinking, psychomotor skills etc.). Some of the advantages of using serious games in higher education are: student autonomy, problem recognition, problem solving, decision-making, better short-term and long-term memory etc. (Dragičević, 2016).

Even through there are many benefits to using games and simulations in the classroom, they are underused in practice (Bichsel, 2013); the percentage of games and simulations used in lessons is less than 25%. In addition to lower levels of use (many believe due to their complexity and strict higher education curricula), there are critics emphasising the issues and distrust behind game-based education such as faculty perspective, slowness of innovation adoption, time, costs etc. (Arai, 2005; Shea, Grenier & Boots, 2015). These issues are often times explored and evaluated with users - teachers and learners (see examples further on in the paper).

Games for learning are being used across a wide range of subject disciplines with health the most popular one followed by games about social issues, science and business (Connolly et al., 2012). With regards to entrepreneurship related curricula, majority of the programmes still focus on multimedia content encompassing case studies, self-evaluation exercises

and, recently, traineeships and competitions for both young and adult learners. As in entrepreneurship related curricula, the knowledge and experience of the real-world regulations and business context is very valuable, the educators started exploring with the use of role playing, business simulations and serious games only as of lately (mostly developing the scenarios and games within EU funded projects).

An example of massively multiplayer online role-playing game (MMORPG) is illustrated in Figure 1. Simulations of (macro-/micro-)environments and systems allow participants to experience situations that are impossible in the real world for security reasons, costs, time, etc. The online world provides a virtual learning environment that could faithfully illustrate reality.



Figure 1. Symphony – Macroeconomic MMORPG (http://projectsymphony.eu)

3 Development of digital start-up game

The development of the 3D game and related preliminary study presented in the paper was conducted within the framework of the project Student Business e-Academy (project reference: 2015-1-HR01-KA203-013080) funded through Erasmus+ programme (key action: *Cooperation for innovation and the exchange of good practices*; action type: *Strategic Partnerships for higher education*)[1].

The main goal of the SBeA project (10/2015-10/2017) is to produce a high-quality, personalized e-learning program for young people interested in entrepreneurship in order to provide them with necessary resources to bring their business ideas to life as well as to prepare them for entering the market (SBeA project website, 2015). The blended program, available from a customized virtual platform consists of 6 modules (3 per semester) and 2 training seminars/conferences. SBeA program is developed by three partner institutions: University of Split (Croatia), University of Malaga (Spain) and Middlesex University (United Kingdom).

Digital start-up game was developed as a complementary material to SBeA curriculum (SBeA project proposal, 2015). Since the emphasis was put on developing and piloting the international, innovative entrepreneurship program, not much restriction was put on the type and the functionality of the game. Therefore the partners were free to deliberate on the choices of the technical solution and the underpinning philosophy during the first part of 2016 to ensure:

- the relevance of the game scenario for the project and the wider/international context,
- the links to developed curricula to ensure scaffolding and simulation of real-life business environment adapted to specific needs of the user group,
- the interest and the programme longevity beyond project consortium and the project timeframe.

The scenario was developed by University of Split (Ćukušić, Ugrčić, Paušić, 2016). In September 2016, following the presentation of the solution prototype, due to the complexity of the technical solution and the scenario scope, the partners revised the proposed scenario and decided to develop only one scenario fully (as opposed to developing three scenarios but to a certain extent/phases). The scenario titled Starting a business in Tourism sector (opening and operating a tourist agency) is planned through three main phases (market research, budget estimation and raising funds) as illustrated in Figure 2.

The player is located in Split, CRO. Start of the game is at the city centre. The player takes on a role of entrepreneur. At his/her disposal is a budget of 10.000 euro and then he/she: either raises the rest of the money from the bank or other investors or starts the business using initial budget. The goal is to establish and run a business with a relatively limited budget and simulate one year of operation. Start is in the Mentor's office. The mentor is there to introduce the game (interaction is initiated on approaching the mentor's desk and pressing the E key). After that, the player can move around different stops. He/she is supposed to e.g. define the targeted customer segments, choose a loan package, define the products, sales prices, product costs, employ people etc. The game is successfully completed if at the end of the simulation (12 months) the player has profit.

As of early 2017, the game is fully functional and available for download and installation from the project's website http://e-learning.efst.unist.hr/ upon registration. In addition to an offline version, web access would be offered to all registered users as well. The game is available in three languages (Croatian, English and Spanish).

[1] Details about the project and the funding are also available from the Erasmus+ Project Results database (access to descriptions, results and contact information of all projects funded under the Erasmus+ programme is available from the platform): http://ec.europa.eu/programmes/erasmus-plus/projects/.

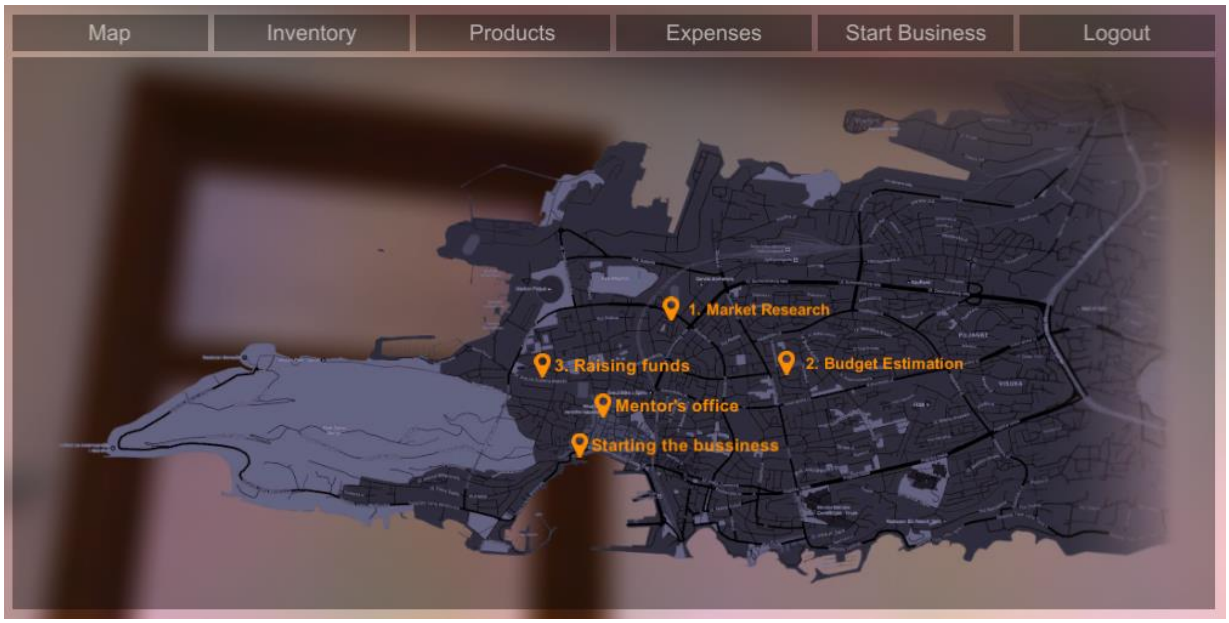


Figure 2. SBeA game dashboard (screenshot)

Technologies used for game development are: Grails framework, Java, C# and Unity game development platform. The choice of the game development platform was based on the experiences from earlier project – V-ALERT (V-ALERT, 2016) and the report on 3D virtual worlds platforms and technologies (Maratou & Xenos, 2014) and the popularity of the Unity platform. Unity plays an important part in a booming global games market. More games are made with Unity than with any other game technology. The proportion of developers relying on Unity as their primary development tool and using Unity is growing all the time[2].

The great advantage of developed solution is that it does not require any additional software to be installed on the client computer for playing the game. Hardware requirements of the game are also commonly met on personal computers with average performances. These features ensure the availability of the game to a wide range of potential users and the longevity of the game as a significant project outcome.

4 Preliminary evaluation of digital start-up game

Evaluation of the game covers two aspects: usability of the interface and the sense of presence in 3D virtual environment. Currently, the preliminary evaluation is completed in order to briefly assess the levels of usability and presence and to develop guidelines for further improvements of the game.

[2] The statistics are available from the official website (https://unity3d.com/). For illustration, 5 billion downloads of 'Made with Unity' games are made in Q3 2016; 34% of top 1000 free mobile games are 'Made with Unity'.

In preliminary evaluation, several empirical methods were employed: two attitude questionnaires and semi-structured interviews along with evaluator's observations for acquisition of additional feedback. Thus quantitative and qualitative measures were acquired.

The pilot study was conducted at University of Split, Faculty of Economy, in May 2017. Eight students from graduate study of Information technology management applied to participate in the study. Two of them were female and six male students, aged between 22 and 24.

The students were given an entry questionnaire (in Croatian) through which they have provided certain personal information, level of study, experience in using computers and Internet, gaming in general and playing 3D games, as well as information about their prior knowledge on entrepreneurship. According to the obtained data, all participants have basic knowledge on setting up a company and one student declared that he already started his own business. All students use computer and Internet on daily basis. Six students play computer games, with frequency ranged from few times a month to few times a week, while two students do not play computer games at all. With regards to prior experience in playing 3D games, answers are almost equally distributed from "not experienced at all" to "somewhat experienced". It is evident that none of the students have significant prior experience in using 3D games.

After completing the entry questionnaire, the students were directed to download the game form the project website and to run the game on a personal computer. All students completed the registration process successfully and started to follow in-world scenario tasks without requiring any kind of assistance from the supervisor of the evaluation study.

Some students played the game in English while others choosed to play in Croatian.

The students were asked to take a screenshot of the final screen that contains the information about their income at the end of the game. An example of a student's final screen is given in Figure 3. Playing the game, including the registration process, took approximately 30 minutes.

Upon finishing the game, the students were asked to complete the exit questionnaire. This four-part survey obtained users' subjective perception about (i) personal success in the game and relation between prior knowledge on entrepreneurship and the score in the game, (ii) usability of the interface, (iii) presence in the virtual environment and (iv) general likes, dislikes and possible comments. The first three parts of the survey are designed as quantitative instruments while the fourth set of questions allowed acquiring the answers in open form.

Following the perception of the participants on their success in the game, the second part of the exit survey is the SUS questionnaire (Brooke, 2013), a well-established instrument for quick usability assessment of an interactive system from end-user perspective. Usability is the general concept that describes how user interfaces are easy and pleasant to use. According to ISO standard (ISO 9241-11, 1998), usability of an application is strongly related to the specified users, their goals and context of use. SUS questionnaire is integrated into our exit survey in its original form which uses 5-point Likert scale to annotate users' answers. To keep participants' engagement in the context of the study, the word "system" is replaced by "game" in all questions. The whole list of questions in the SUS questionnaire will be presented further on in the paper (Table 1).

The third part of the exit survey is the extract from Presence Questionnaire, PQ (Witmer, Jerome & Singer, 2005). Presence is the user's subjective experience that includes two dimensions: first, the involvement in virtual environment, i.e. the ability to focus his/her attention and energy on stimuli in virtual environment and second, the sense of immersion, i.e. perceiving him/her as a part of the virtual environment sensory inputs, events and activities (Witmer & Singer, 1998).

Considering the nature of the user experience in digital start-up game, we have extracted an applicable set of questions from the PQ, version 3.0 (Witmer, Jerome & Singer, 2005). For example, our game does not include any sound options so all the questions related to sound or a combination of sound and other stimuli in virtual world are excluded from the study instrument. Consequently, the selected set of 23 applicable questions for this study out of 32 questions in the PQ version 3.0 covers the factors of Involvement, Adaptation/Immersion, Interface Quality and Distraction. None of the questions addressing the factor of Sensory Fidelity were applied in the study. The selected set of questions is presented in Table 3 along with the results obtained by the 7-point Likert scale.

The SUS and PQ questionnaires are given to Croatian students in English since the English versions of these questionnaires are validated measuring instruments. In addition, SBeA curriculum and training modules are also in English, as described in Section 3, so the use of English versions of evaluation instruments was appropriate. All students reported that they are fluent in English and none of them asked for translation in any of the proposed questions.

After completing the exit survey the students were free to comment their experience in the form of a semi-structured interview with the supervisor of the study.

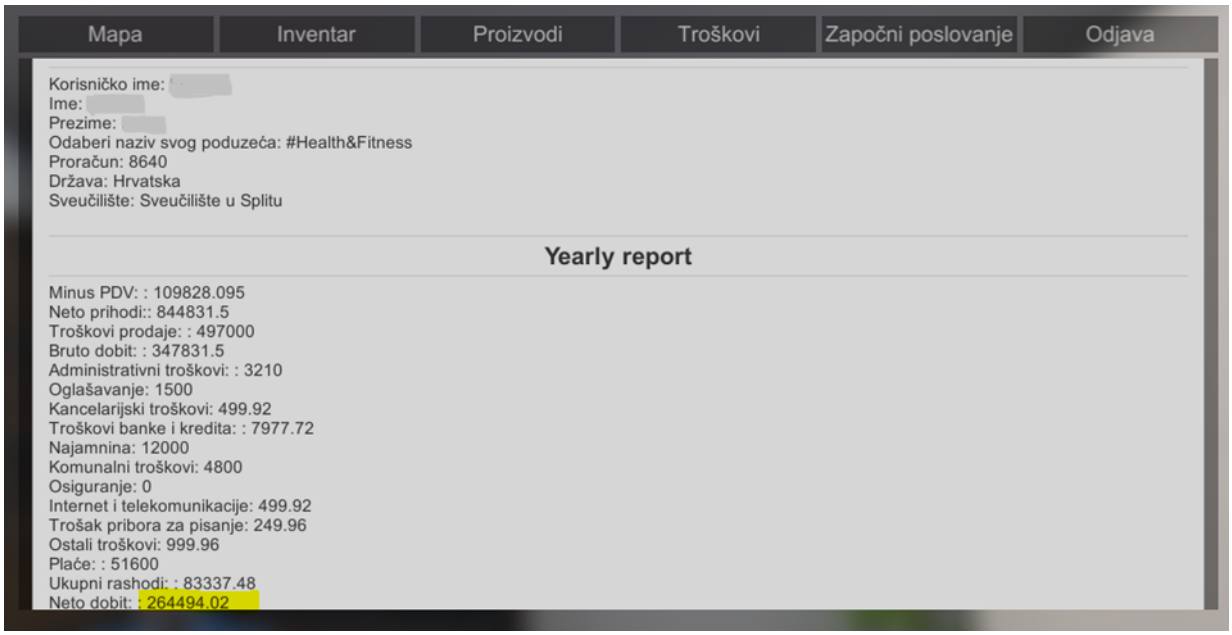


Figure 3. SBeA game final screen with highlighted income at the end of the game (screenshot)

5 Results of the study

In the first part of the exit survey the participants reported their subjective satisfaction about their personal achievement in the game. Two students did not finish the game, three of them reported unsatisfying income, one student was satisfied and three students were extremely satisfied with their incomes.

The answers in the SUS questionnaire are analysed as follows. For odd numbered questions the score is calculated as the scale position of the answer minus 1. Even numbered questions have reversed polarity and their score is calculated as 5 minus scale position of the answer. All questions along with calculated scores (means scores ranged 0 to 4) and standard deviations per question are presented in Table 1. For even numbered questions the higher score means the less agreement of the participants with the statement. Thus for all questions the higher score represents the higher level of participants' satisfaction with the game. The total SUS score of each participant is the sum of his/her scores in all questions. Multiplying the total score by 2.5 we get the scores ranged from 0 to 100. An average of obtained scores by all participants is considered as a SUS result of the study.

Table 1. Results of SUS questionnaire per question

SUS questions	Mean	SD
1. I think that I would like to use this game frequently	0.88	0.83
2. I found the game unnecessarily complex	2.38	1.30
3. I thought the game was easy to use	2.38	1.30
4. I think that I would need the support of a technical person to be able to play this game	3.38	1.06
5. I found the various functions in this game were well integrated	2.00	1.07
6. I thought there was too much inconsistency in this game	1.38	0.92
7. I would imagine that most people would learn to use this game very quickly	2.38	1.30
8. I found the game very cumbersome to use	1.75	1.16
9. I felt very confident using the game	2.25	1.04
10. I needed to learn a lot of things before I could get going with this game	3.38	0.74

Table 2 presents the overall value of the pilot study along with related descriptive statistics.

Table 2. Summary of SUS questionnaire

N	Mean	SD	Min	Max
8	55.31	11.37	42.50	72.50

Analysis of the PQ questionnaire follows the previously explained method for calculating the score of SUS questionnaire. Questions 11, 14, 15, 18 and 19 have reversed polarity and their score is calculated as 7 minus scale position of the answer. For all other questions, the scores are calculated as scale position of the answer minus 1. Thus the total scores of all participants range from 0 to 138.

However, our current analysis showed that one participant regularly chose the first answer (21 answers are "1" and two answers are "2"). We can assume that this participant did not make an effort to complete the PQ seriously/carefully therefore this extreme score is eliminated from the study. Presence measurement with the rest of the sample (N=7) reaches the scores from 46 to 94 with the mean of 69 and standard deviation of 16.02. These values are considered reliable and further analysis of PQ is based on the related sample. It is important to note here that the repeated analysis of the SUS on this 7-participant sample did not reveal considerably different results in descriptive statistics. The SUS score of the 8th participant is 42.5 which is the minimum in the sample (as shown in Table 2). However, another participant achieved the same score, thus the minimum value remains unchanged. Compared to Table 2, the mean SUS score of the new sample is slightly higher (57.14) and the standard deviation is slightly lower (10.94). With this rationale, and bearing in mind that the main purpose of this preliminary study is to get users' feedback to be employed for improvement of the game, we decided to accept the SUS score of the 8th participant as valid. Since qualitative feedback is more important than quantitative scores in this phase of our research, it is possible that contribution of the 8th participant is valuable to us in all other segments except the presence evaluation.

Table 3 presents selected questions of PQ for the study (as explained in previous section) along with mean scores (ranged 0 to 6) and standard deviation values per question, considering the 7-participant sample as discussed above.

Similar to SUS scores, the total PQ score of each participant is the sum of his/her scores in all questions. These sums are pondered to get the scores in percentage and the average of obtained scores is considered as the overall result of PQ for this study i.e. the level of presence in the game. This result is presented in Table 4.

Table 3. Results of PQ questionnaire per question

PQ questions	Mean	SD
1. How much were you able to control events?	3.57	1.99
2. How responsive was the environment to actions that you initiated (or performed)?	2.86	1.95
3. How natural did your interactions with the environment seem?	2.00	0.82
4. How much did the visual aspects of the environment involve you?	2.29	1.25
5. How natural was the mechanism which controlled movement through the environment?	2.43	0.79
6. How much did your experiences in the virtual environment seem consistent with your real world experiences?	2.57	0.79
7. Were you able to anticipate what would happen next in response to the actions that you performed?	3.57	1.51
8. How completely were you able to actively survey or search the environment using vision?	3.14	1.77
9. How compelling was your sense of moving around inside the virtual environment?	2.86	1.95
10. How involved were you in the virtual environment experience?	2.86	1.57
11. How much delay did you experience between your actions and expected outcomes?	2.14	1.46
12. How quickly did you adjust to the virtual environment experience?	3.57	1.62
13. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	3.00	2.16
14. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?	3.86	1.07
15. How much did the control devices interfere with the performance of assigned tasks or with other activities?	3.29	0.95
16. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?	2.86	1.07
17. How completely were your senses engaged in this experience?	2.43	1.90
18. To what extent did events occurring outside the virtual environment distract from your experience in the virtual environment?	3.57	1.27
19. Overall, how much did you focus on using the display and control devices instead of the virtual experience and experimental tasks?	3.29	1.38
20. Were you involved in the experimental task to the extent that you lost track of time?	2.43	1.62
21. How easy was it to identify objects through physical interaction, like touching an object, walking over a surface, or bumping into a wall or object?	3.71	1.70
22. Were there moments during the virtual environment experience when you felt completely focused on the task or environment?	3.00	1.29
23. How easily did you adjust to the control devices used to interact with the virtual environment?	3.71	1.60

Table 4. Summary of PQ questionnaire

N	Mean	SD	Min	Max
7	50,00	15,19	30,43	71,01

The fourth part of exit survey allowed students to note in open form what aspects of the game they liked the most, what they did not like and what changes they propose for the next version of the game. The most liked feature of the game was the fact that the virtual environment included the map of the virtual world, as reported by 5 students. They also added that they had the high level of understanding the real situations in virtual environment. Three students appreciated the simulation of the investments, the possibility to control their budget and the very clear relationship between causes and consequences, i.e. *"I liked the virtual perception of possible state and future occurrences."* On the contrary, two students reported that they did not like the game. In the second

question, related to dislikes, 6 students reported several bugs in the game and 2 students stated the game was confusing in some steps of the process. In the third open form, asked for improvements suggestion, 2 students proposed more frequent guidelines for running a business instead of general directions at the beginning of the game (i.e. proposed smaller chunks and context, phase related guides). In addition, one student suggested that meeting more people in the hallways and offices would be much more realistic.

In the semi-structured interview at the very end of the evaluation session, the students explained that the most of the bugs are related to opening the door of the offices which is possible only from a small range of distances and directions in front of the door. All other aspects of navigation and orientation in the space were well accepted. We have noticed during the session that 6 students used the default English interface although the game is also available with Croatian interface. Discussing this issue, we have concluded that he drop-down list for the language selection should be more visible and accessible to students (only one student has deliberately chosen to play in English).

6 Discussion and conclusion

When discussing results of the exit survey we have to place each student' answers in the context of his/her experience reported in the exit questionnaire as well as in relation with his/her objective result obtained in the game. For example, it happens that a student who rated his/her success in the game as intermediate achieved twice as higher income than the student who rated his success as excellent.

Reviewing the overall SUS result (55.31) we can conclude that it is below average and that there are several usability issues that need to be resolved. Most of the SUS questions need to be considered for improvement of the game interface, particularly the questions numbered 6 and 8. In addition to students' answers in open forms of the exit survey along with the feedback obtained in the interview, the technical issues of moving through the virtual environment are the priorities to improve.

The best rated SUS questions are statements numbered 4 and 10 (it is worth noting that the smallest standard deviation is observed for statement numbered 10). This means that students mainly do not need technical assistance to play the game and also that their progress through the scenario does not depend on their prior knowledge. Since the game is intended to be used by students who are finishing the Student Business e-Academy taking place fully online, it means the game will be used also completely online as the entire program, without a mentor or supervisor. Therefore, this aspect is very important. The game has to be fully playable without any technical assistance from another person. This means that in-world situations and events need to provide implicit guidance for the user to successfully complete the scenario. In case of the need for explicit directions, respective instructions have to be provided at the right time and place, i.e. they should be offered as small chunks of information integrated into respective steps of the scenario. This allows the player to act immediately and decreases the need for memorizing the directions which is important aspect of usability of any interactive system.

The results of the PQ are in-line with the SUS results and the qualitative feedback from the users. According to presence evaluation, it seems that interaction with the environment should be more natural (question number 3) and that players have experienced unexpected delays between their action and outcomes (question number 11). Both issues are strongly related to the graphics processor power thus we have to consider suggesting the use of more powerful computer or graphics card to play the game. On the other hand, the question number 14 which is related to visual display quality scored the maximum value in PQ, which means that the level of interactivity in the game was not decreased by the quality of the interface. In addition, high scores were achieved for identification of objects through physical interaction (question number 21), which is also confirmed in the interview with the participants, and for using control devices (question number 23). The last outcome is expected because the interaction is achieved simply by the common peripherals (mouse and keyboard). We can conclude that simplicity of the interaction is very important factor for the sense of "being there" and it should be kept in the next version of the game. The shortcomings of the interaction, which are detected by the PQ as well as by other instruments used in the study, are results of already reported bugs and will be treated in the same way.

Although the study has provided a number of quantitative data, due to the small number of participants we cannot rely on the obtained results as objective measures thus. On the contrary, the intention of this preliminary evaluation is not to generalize obtained results but to observe developed game from different perspectives and to identify aspects that should be improved for reaching better user experience.

As the next step of the research, the full evaluation of the game will be conducted. Along with empirical methods (user testing as conducted in pilot study but with significantly larger sample of users), we plan to apply analytical methods, such as heuristic evaluation with a number of usability experts. Since analytical methods regularly provide complementary set of usability issues of evaluated application, we expect that using both empirical and analytical methods will provide full perspective of developed serious game as well as valuable conclusions and implications for practitioners.

Acknowledgments

The project Student Business e-Academy has been funded with the support from the European Commission through Erasmus+ programme.

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Digital Maturity Framework for Higher Education Institutions

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Abstract*. Digital technologies in educational institutions have the potential to be one of the main catalysts of quality education.*
The purpose of this paper is to analyse digital maturity frameworks, to describe their development methodologies and to propose a Digital Maturity Framework for Higher Education Institutions (DMFHEI). The methodology for framework development consists of five main steps: literature search and data extraction; two focus group analyses; applying the Q-sorting method; reviews by two experts; and a summary of results. Results presented in this paper show that the DMFHEI has recognised seven areas that can be divided into 43 describable elements.

Keywords. digital maturity, framework, higher education, higher education institutions

1 Introduction

Since the end of the 20th century, developed countries have realised the importance of establishing a strategy for developing and integrating new technologies in all areas of civil and economic life. In this context, e-readiness can be defined as the degree to which a community is prepared to participate in the networked world (CID, 2000) and the degree to which an economy or community is prepared to participate in the digital economy (APEC, 2000).

According to the European Commission's report (2013) 'Opening up education through new technologies', rapid digital change in our society and economy mean greater demand for digital skills and competences. Education and training must address this need, which requires investment in infrastructure (e.g., broadband, digital devices), teachers' training, organisational change and the development of high quality educational resources, including apps and software. Technology, when used correctly, can also help us to learn better, more efficiently and creatively and make it possible to access wider and more up-to-date sources of knowledge.

Digital technologies enable change in learning and teaching, but these changes do not guarantee sustainability. Changes require a multiple-system approach, including investing in infrastructure, investing in the professional development of professors, changing curricula, reviewing how students are assessed and professors are evaluated, promoting and encouraging collaboration and open content, integrating everything into a well-run environment and quality control.

Digital technologies in educational institutions have the potential to be one of the main means of delivering quality education in line with their mission and vision. For this reason, the adoption of digital technologies and their integration into educational systems is considered a form of educational innovation and implies changes in three basic dimensions: pedagogical, technological and organisational.

Using a digital maturity framework and instrument for higher education institutions (HEI) makes it possible to estimate the maturity level at which an HEI is currently estimated, to identify all needed improvement areas, to identify which recommendations need to be made and to specify in which areas and elements the level of digital maturity should be raised. An e-readiness assessment allows for the positioning, or determining of the starting point, of an institution's readiness for participation in the information society.

E-readiness is the degree to which an HEI is prepared and ready to participate in the adoption of ICT. The readiness of an HEI to adopt digital technologies is an important prerequisite to becoming a digitally mature institution.

With the above in mind, digital maturity frameworks and instruments for HEIs contain identified digital maturity areas and elements that allow for an initial point assessment of an HEI, which is included in the e-readiness concept, and includes the ability to provide recommendations for improvements, such as an upgrading in relation to the concept of e-readiness.

This paper is divided into the following sections: an introduction, presented in Section 1; a systematic literature analysis of the digital maturity frameworks used in this study, and an explanation of the research methodology in Section 2; a focus on summarising research results and presenting the DMFHEI, in Section 3; and a conclusion, presented in Section 4.

2 Research Methodology

The development of a digital maturity framework aims to identify areas and elements of HEIs' digital maturity and to identify key areas and elements needed to raise their levels of digital maturity. Developing the framework requires the application of a complex methodology, which includes a set of methods, techniques and instruments, such as qualitative analysis and the comparison of similar frameworks that describe digitally mature organisations from the perspective of the concept and strategic documents at the national and international level, analyses of existing projects' documentation, the Q-sorting method and focus groups.

The developed framework has areas and elements that are not mutually exclusive or disjointed. Moreover, they are complementary and interconnected, thus forming a unified whole. The framework development methodology, as well as the areas and elements of the framework that are important for determining an HEI's level of digital maturity, are described in detail in Section 3.

A qualitative analysis of the literature identified 15 digital maturity frameworks, which are further analysed and presented in this section. They are as follows: 1) Assessing the e-Maturity of your School (Ae-MoYS); 2) DigCompOrg (DigCompOrg); 3) eLearning Roadmap (eLearning Roadmap); 4) eLemer (eLemer); 5) The ePortfolios & Open Badges Maturity Matrix (ePOBMM); 6) Future Classroom Maturity Model (FCMM); 7) HEInnovative (HEInnovative); 8) Jisc Strategic ICT Toolkit (JISC); 9) Ledning, Infrastruktur, Kompetens, Användning (LIKA); 10) Microsoft Innovation Framework & Self-reflection Tool (Microsoft IF & SRT); 11) NACCE SRF (NACCE SRF); 12) OPEKA (OPEKA); 13) Up-scaling Creative Classrooms in Europe (SCALE CCR); 14) School Mentor (School Mentor); and 15) Venstress (Venstress).

Within the present analysis, special attention was paid to the following elements: the existence of an accompanying instrument; the framework's areas, elements and descriptors; implemented development approaches; application areas and examples of their best practices. Below is a brief description of each analysed framework.

1. Ae-MoYS is a framework and online self-evaluation questionnaire described by 5 areas and 30 descriptors. It employs both qualitative and quantitative development approaches with application areas at the elementary and high school levels. Its best practice examples are in the EU.
2. DigCompOrg is a framework described by 5 areas, 15 elements and 74 descriptors. It uses a qualitative development approach with application areas at the elementary school, high school and HEI levels and best practice examples throughout the world.
3. eLearning Roadmap is a framework and matrix described by 5 areas and 108 descriptors. It uses a qualitative development approach with application areas in elementary and high schools and best practice examples in Ireland.
4. eLEMER is a framework and online self-evaluation questionnaire described by 4 areas, 40 elements and 10 descriptors. It makes use of both qualitative and quantitative development approaches with application areas in elementary and high schools and best practice examples in Hungary.
5. ePOBMM is a framework and matrix described by 7 areas and 300 descriptors. It employs a qualitative development approach with application areas mostly in HEIs and best practice examples in the EU.
6. FCMM is a framework and online self-evaluation questionnaire described by 5 areas and 25 descriptors. It uses a qualitative development approach with application areas in elementary and high schools and best practice examples in the EU.
7. HEInnovative is a framework and online self-evaluation questionnaire described by 7 areas and 44 descriptors. It takes a qualitative development approach with application areas in HEIs and best practice examples throughout the world.
8. JISC is a framework and online self-evaluation questionnaire described by 6 areas and 69 descriptors. It uses both qualitative and quantitative development approaches with application areas in HEIs and best practice examples in the EU.
9. LIKA is a framework and online self-evaluation questionnaire described by 4 areas and 78 descriptors. It adopts a qualitative development approach with application areas in elementary and high schools and best practice examples in Sweden.
10. Microsoft IF & SRT is a framework and online self-evaluation questionnaire described by 4 areas, 16 elements and 96 descriptors. It uses both qualitative and quantitative development approaches with application areas in elementary and high schools and best practice examples from around the world.
11. NACCE SRF is a framework and online self-evaluation questionnaire described by 6 areas, 11 elements and 220 descriptors. It makes use of both qualitative and quantitative development approaches with application areas at the nursery, elementary and high school levels and best practice examples in the United Kingdom.
12. OPEKA is a framework and online self-evaluation questionnaire described by 3 areas, 17 elements and 145 descriptors. It uses both qualitative and quantitative development approaches with application areas in elementary and high schools and best practice examples in Finland.
13. Scale CCR is a framework described by 8 areas and 28 elements. It employs a qualitative development approach with application areas in elementary and

high schools and best practice examples from throughout Europe.

14. School Mentor is a framework and online self-evaluation questionnaire described by 6 areas and 150 descriptors. It makes use of both qualitative and quantitative development approaches with application areas in elementary and high schools and best practice examples in Norway.
15. Venstress is an online self-evaluation questionnaire described by 20 indicators. It takes a qualitative development approach with application areas in elementary and high schools and best practice examples in the Netherlands.

Our analysis revealed that DigCompOrg, on account of its favourable characteristics, is best suited to serve as the basis for creating the Digital Maturity Framework for Higher Education Institutions. It is worth mentioning that further modifications and adjustment are needed because the mentioned framework needs to be adjusted for HEIs. DigCompOrg provides a comprehensive and generic conceptual framework that reflects on all aspects of the process of systematic integration of digital learning into an educational institution. The framework is primarily designed to focus on learning and teaching and the activities undertaken by the educational institution to support learning. DigCompOrg includes domains, subdomains and descriptors that can be considered organisational (e.g., ICT infrastructure) or individual responsibility (e.g., learning and teaching).

DigCompOrg is a framework for digitally competent educational institutions and includes all the main areas of digitally competent educational institutions but its main purpose is to serve as a generic framework. It represents a very complex and comprehensive framework that can be the basis for development of specific framework and assessment tool of specific educational systems. So we have used DigCompOrg as a base in developing our Framework.

A digitally competent educational institution needs a balanced mix of strong leadership and management, staff and stakeholders who are willing to take personal responsibility for independently running actions and initiatives leading to the prosperity of the educational institution.

The initial set of the DMFHEI are defined (see Table 1) based on the results of the qualitative analysis of the e-readiness assessment tools and qualitative analysis of the digital maturity frameworks.

The results presented in Table 1 were generated using the methodology we have described (areas and elements defined based on qualitative analyses).

The results of applying the entire method are shown in Section 3.

Table 1. Area, elements and references of the DMFHEI

Area	Elements / References
Leadership, planning and management	The relationship between the HEI and the state, from the aspect of ICT integration (DigCompOrg; European University Association)
	Strategic planning of ICT integration in HEIs (Ae-MOYS; DigCompOrg; The e-Learning Roadmap; eLEMER)
	Managing the integration of ICT in learning and teaching at an HEI (Ae-MOYS; DigCompOrg; The e-Learning Roadmap; eLEMER)
	Financial investment in the use of ICT in learning and teaching; research and development; the business of the institution (DigCompOrg)
	Regulated access to ICT resources (Ae-MOYS; DigCompOrg)
	Personalisation and support for under-represented groups by using ICT in learning and teaching (DigCompOrg; The e-Learning Roadmap; eLEMER)
Quality assurance	ICT quality assurance policy (ENQA; European University Association)
	Procedures for determining the needs, development or acquisition of ICT resources and their application (ENQA; European University Association)
	Approved procedures and follow-up of student enrolment, their progress through study and the completion of studies supported by ICT (ENQA; European University Association)
	Monitoring and periodic review of study programmes from the aspect of ICT application (ENQA; European University Association)
	Evaluation of the work of teaching, research, administrative and technical staff (ENQA; European University Association)
	Continuous monitoring of the results of scientific-teaching work and progress (ENQA; European University Association)
	Administrative support for ICT (ENQA; European University Association)
Scientific-research work	Managing the integration of ICT in scientific research at HEIs (ENQA; European University Association)
	Use of ICT in the preparation and publication of scientific papers (National Research Council)
	ICT support in the preparation and management of scientific research work and projects (National Research Council)

	A system of support for researchers at the beginning of their careers for applying ICT in scientific research (Pažur Aničić & Divjak, 2016) (Mangematin & Robin, 2003)
	Information system for supporting business processes of HEIs (National Research Council)
	Access to ICT research infrastructures (National Research Council)
Technology transfer and service to society	Networking and collaboration of researchers with ICT support (Finne, 2011) (DigCompOrg; The e-Learning Roadmap; European University Association; ePOBMM; Higher Education Funding Council for England)
	Collaboration with stakeholders (employers, local community, pre-tertiary education) supported by ICT (Finne, 2011) (Higher Education Funding Council for England)
	ICT research (collaborative ICT research on HEI) / (Finne, 2011) (European University Association; Higher Education Funding Council for England)
	Applied research and professional projects supported by ICT and/or ICT (Finne, 2011) (Higher Education Funding Council for England)
	Intellectual property licensing of HEIs (Finne, 2011) (DigCompOrg; Higher Education Funding Council for England)
	A wider digital environment (monitoring global trends in HEIs) (DigCompOrg; ePOBMM, European University Association)
	Continuous training of researchers in ICT application in scientific research (Finne, 2011) (Ae-MOYS; DigCompOrg; The e-Learning Roadmap; ePOBMM; OPEKA; European University Association)
Learning and teaching	Enlightenment and participation of employees in training programmes for the development of digital competences (Ae-MOYS; DigCompOrg; The e-Learning Roadmap; eLEMER)
	Planning and implementation of training of HEI employees in the field of digital competencies and ICT application (DigCompOrg; The e-Learning Roadmap)
	Employee education on ICT application (DigCompOrg; The e-Learning Roadmap; eLEMER; OPEKA)
	Self-confidence and motivation of employees on the importance of ICT application (DigCompOrg; The e-Learning Roadmap; OPEKA)
	Informal employee learning (DigCompOrg, The e-Learning Roadmap, ePOBMM)
	Development of teachers' digital competence (DigCompOrg; The e-Learning Roadmap; ePOBMM; OPEKA)
	Preparation, storage and use of digital content in learning and teaching (DigCompOrg; eLEMER; ePOBMM; OPEKA)
	Development of digital literacy and the promotion of innovativeness in ICT application with HEI employees (DigCompOrg; ePOBMM)
	Innovative learning and teaching methods with ICT (FCMM)
	Development of students' digital competence (DigCompOrg; eLEMER; ePOBMM)
	Ubiquitous learning and open curricula (Chen & Kidd, 2011)
	Use learning analytics to improve learning and teaching (HEInnovative)
	Students' experiences with the application of ICT (DigCompOrg; The e-learning Roadmap; eLEMER; ePOBMM)
ICT culture	The network presence of HEI (DigCompOrg; The e-Learning Roadmap; eLEMER; ePOBMM; OPEKA)
	Using ICT in HEI promotion (DigCompOrg; The e-Learning Roadmap; eLEMER; ePOBMM)
	HEI policy in ICT integration and monitoring global trends (DigCompOrg; ePOBMM)
ICT resources and infrastructure	Planning and procurement of ICT infrastructures (Ae-MOYS; DigCompOrg; The e-Learning Roadmap; eLEMER; ePOBMM)
	Network infrastructures at HEIs (DigCompOrg; The e-Learning Roadmap; eLEMER; ePOBMM; OPEKA)
	Technical support and maintenance of ICT resources at HEIs (DigCompOrg; ePOBMM)
	Availability of ICT resources (hardware and software) for learning and teaching (DigCompOrg)
	Availability of ICT resources for scientific research (DigCompOrg; The e-Learning Roadmap; OPEKA)
	Access to ICT resources for students (both in and out of the classroom)

	(DigCompOrg; The e-Learning Roadmap; eLEMER; OPEKA)
	Providing access to and support in the application of ICT infrastructure (DigCompOrg; The e-Learning Roadmap; eLEMER; ePOBMM;)
	Digital environment and information systems for employees and students (DigCompOrg; The e-Learning Roadmap; eLEMER; ePOBMM)
	Information security systems (DigCompOrg; eLEMER; OPEKA)
	Application of ethical standards, copyrights and intellectual property in the ICT field (DigCompOrg; The e-Learning Roadmap; ePOBMM)

The Digital Maturity Framework for Higher Education Institutions (DMFHEI) has been in development since July 2015. The methodological approach we used for the process was mostly qualitative. In the first phase, we completed a qualitative analysis of 15 frameworks for digital maturity, with a particular focus on information and communication technologies (ICT), as explained in Section 2.

After conducting qualitative analyses of the e-readiness assessment tools and of the digital maturity assessment frameworks, in the second phase of the framework development process, two focus group studies were held to obtain input from experts on defining new framework areas and their elements. The focus group method is a qualitative form of research involving a group discussion about a given topic. The primary focus of such a group is to initiate a deep discussion and to explore the values or attitudes of respondents to a problem or topic.

The first focus group was heterogeneous (comprised of university professors, PhD students, a representative of the University Computing Centre - SRCE and a representative of the IGH institute) with 15 participants (N=15), of whom four were PhD students (N=4). The second focus group was also heterogeneous (university professors and PhD students) and had ten participants (N=10) three of which were PhD students (N=3). The results of the qualitative analyses of 15 frameworks for digital maturity, and the results of the two focus groups, led to the proposal of seven areas (leadership, planning and management; quality assurance; scientific-research work; technology transfer and service to society; learning and teaching; ICT culture; and ICT resources and infrastructure) and 53 elements for the DMFHEI.

In the second phase of the framework development process, the sorting cards (Q-sorting) method was applied. The Q-sorting method is a theoretically based quantitative tool for examining opinions and attitudes. The method enables researchers to examine human subjectivity systematically and quantitatively. Participants are experts who are theoretically relevant to the research problem. During the Q-sorting process, experts were asked to sort 53 element cards into seven proposed areas. After this was complete, we calculated a content validity ratio (CVR).

The CVR calculation formula was proposed by Lawshe (1975); according to it, only items that more than 50% of respondents considered to be valid / understandable were retained in further research steps.

The CVR formula is:

$$CVR = (n - N/2)/(N/2) \quad \ldots\ldots\ldots(1)$$

In Lawshe's formula, *n* denotes the number of participants that a particular variable (in this case, an element) considers desirable. *N* represents the total number of participants in the Q-sorting method. When analysing data, each of the elements is described on a three-step scale: 1 - valid/understandable, 2 - desirable, 3 - non-relevant.

Table 2. Results of Q-sorting and CVR calculation

Areas	Initial number of elements	Number of elements after performing Q-sorting and CVR
Leadership, planning and management	6	8
Quality assurance	7	6
Scientific-research work	6	6
Technology transfer and service to society	7	3
Learning and teaching	13	7
ICT culture	3	6
ICT resources and infrastructure	11	7
Total	**53**	**43**

The CVR was calculated for each of the 53 proposed elements.

After the Q-sorting and calculation of CVR were complete, the number of elements decreased by ten, from 53 to 43 (Table 2). The ten elements not recognised as important during Q-sorting were: administrative support for ICT; employee education on ICT application; employees' informal learning; students' experience with ICT applications; HEIs' intellectual property licensing; enlightenment and participation of employees in training programmes for the development of digital competences; planning and procurement of ICT infrastructure; access to ICT research infrastructures; regulated access to ICT

[1] CVR calculation formula proposed by Lawshe

resources; and wider digital environment (monitoring global trends in HEIs). The other 43 elements are presented in Section 3.

In the third development phase, the results obtained by qualitative analysis, the research from the two focus groups, the Q-sorting process and the calculation of CVR ratio were analysed by two external experts to yield a proposal for the DMFHEI.

3 Digital Maturity Framework for HEI

The proposed Digital Maturity Framework for Higher Education Institutions (DMFHEI) consists of seven areas, which are presented in Figure 1.

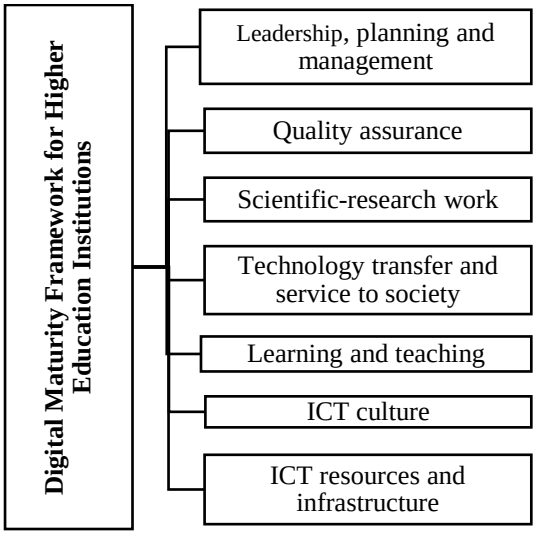


Figure 1. Areas of DMFHEI

Each area consists of a larger number of elements. Due to length limitations, the other six areas (quality assurance; scientific-research work; technology transfer and service to society; learning and teaching; ICT culture and ICT resources and infrastructure) are not shown in figure form.

The quality assurance area consists of six elements: ICT quality assurance policies; monitoring and periodic review of study programmes, from the aspect of ICT application; evaluation of the work of teaching, research, administrative and technical staff; continuous monitoring of the results of scientific-teaching work and progress; procedures for determining the needs, development or acquisition of ICT resources and their application; approved procedures and follow-up on student enrolment, their progress through study and the completion of studies supported by ICT.

The scientific-research work area consists of six elements: the use of ICT in the preparation and publication of scientific papers; ICT support in the preparation and management of scientific research work and projects; ICT research (collaborative ICT research on HEIs); a system of support for researchers at the beginning of their careers in applying ICT in scientific research; continuous training of researchers in ICT application in scientific research; and networking and collaboration of researchers with ICT support.

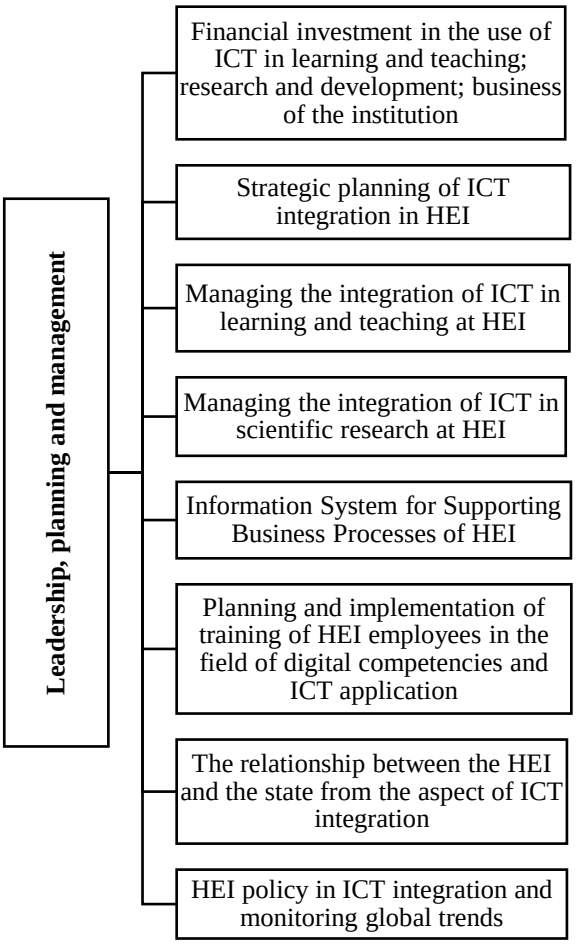


Figure 2. Elements of Leadership, planning and management area

The technology transfer and service to society area consists of three elements: collaboration with stakeholders (employers, local community, pre-tertiary education) supported by ICT; applied research and professional projects supported by ICT and/or ICT; and networking of researchers and users of research (stakeholders) supported by ICT.

The learning and teaching area consists of seven elements: preparation, storage and use of digital content in learning and teaching; innovative learning and teaching methods with ICT; the development of teachers' digital competence; the development of students' digital competence; the use of learning analytics to improve learning and teaching; ubiquitous learning and open curricula; and personalisation and support for under-represented groups by using ICT in learning and teaching.

The ICT culture area consists of six elements: the network presence of HEIs; using ICT in HEI

promotion; the development of digital literacy and the promotion of innovativeness in ICT application with HEI employees; self-confidence and motivation of employees on the importance of ICT application; providing access to and support in the application of ICT infrastructure; and the application of ethical standards, copyrights and intellectual property in the ICT field.

The ICT resources and infrastructure area consists of seven elements: the availability of ICT resources (hardware and software) for learning and teaching; the availability of ICT resources for scientific research; network infrastructures at HEIs; access to ICT resources for students (both in and out of the classroom); digital environment and information systems for employees and students; technical support and maintenance of ICT resources at HEIs; and information security system.

Table 3. Elements and descriptors of technology transfer and service to society

Area	Elements	Descriptors
Technology transfer and service to society	Collaboration with stakeholders (employers, local community, pre-tertiary education) supported by ICT	The HEI encourages and directs employees and students in cooperation with employers, businessmen, the local community (face to face, online or a combination) for counselling or future co-operation.
	Applied research and professional projects supported by ICT and/or ICT	Applied research is a theoretical or experimental work undertaken to achieve new knowledge and primarily aimed at achieving a practical goal, such as developing a new technology or product. The HEI encourages and directs employees and students to applied research and professional projects supported by ICT and/or ICTs for promoting development and innovation, collaboration between the economy and the scientific research sector and technology development and transfer activities.
	Networking of researchers and users of research (stakeholders) supported by ICT	HEIs are committed to the cooperation and exchange of knowledge with the support of ICT through partnerships with other educational institutions, the private and public sector and across the community as users of research.

After determining the DMFHEI area and elements, the next step was to determine the descriptions of each element. Due to space limitations, we are not able to show descriptors for all 43 elements.

4 Conclusion

The purpose of this paper is to analyse digital maturity frameworks, describe development methodology and propose the Digital Maturity Framework for Higher Education Institutions (DMFHEI). The DMFHEI identifies seven areas (leadership, planning and management; quality assurance; scientific-research work; technology transfer and service to society; learning and teaching; ICT culture; and ICT resources and infrastructure) with 43 elements.

One limitation of research is the number of domain elements based on which a measuring instrument for digital maturity of higher education will be developed. The instrument will require a high level of concentration and time resources of stakeholders involved in the research.

The next step in this research is creation of the instrument by organising areas as a rubric with elements. Each element should be described on five levels of maturity. Testing and feedback of a rubric will be conducted through a series of expert consultation, workshops, focus groups and semi-structured interviews.

After completion, developed instrument (rubric based on the DMFHEI) can be used as a tool in the form of a self-evaluation questionnaire to evaluate an HEI's digital maturity level and to identify the areas that need to be improved for the better prosperity of the institution relative to ICT development.

Pilot testing of developed instrument will be conducted at several higher education institutions.

Acknowledgments

The Croatian Science Foundation supported this work under project IP-2014-09-7854.

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Emerging trends in ICT

Luka Hrgarek, TatjanaWelzer, Marko Hölbl
Web Browser Data Collection and User Awareness Regarding Web Browser Data Exposure

Katarina Pažur Aničić, Maja Bedeniković, Nikolina Smetiško
Which Are the Most Desired E-Competences of Future ICT Professionals?

Petar Djerasimović, Gordan Gledec
An Overview of Identity Management Systems Usage

Web Browser Data Collection and User Awareness Regarding Web Browser Data Exposure

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Abstract. *The World Wide Web has been transformed from a collection of hyperlink-connected documents to a global application platform. During this transformation process the role of users has changed from passive readers to contributors, collaborators and interactive users who have made their (personal) data a valuable resource for web applications. We present the possibilities and methods of browsers and user devices data collection via a dedicated web application and the analysis of user awareness regarding the possibility of collecting such data. The results show that web applications can retrieve a large amount of data about browsers and devices without the user's permission. Furthermore, our research showed that users are well aware of data collection possibilities.*

Keywords. privacy, web browser, fingerprinting

1 Introduction

In the early age of the Web, users enjoyed a large level of anonymity (Puglisi, Rebollo-Monedero, & Forné, 2015). In 1990, the Web was just a collection of static hypertextual documents connected by hyperlinks (Berners-Lee & Cailliau, 1990) – no user input or personalization was available. Nowadays, when taking into account all the changes which the web has undergone, many users are confronted daily with the problem of privacy while using the web. Websites and applications record users' data, which is for most users out of their scope of awareness. Such monitoring of user browsing habits raises privacy concerns since the collected data can be used to build a user profile, which is especially worrying if such a profile can be linked with the user's identity (Wills & Zeljkovic, 2011).

The degree of privacy, which websites offer to their users can be closely related to the amount of user trust. McKnight and Chervany (1996) defined *trust* as "*the extent to which one party is willing to depend on somebody or something in a given situation with a feeling of relative security, even though negative consequences are possible*". If a website does not offer adequate privacy to users, this greatly impacts their trust towards a website.

In this paper we study the extent to which data can be obtained from user devices using web browsers, together with techniques and methods of how to implement this collection.

2 Data collection methods

When users browse the Web, a complex network of personalization services monitor their preferences via the tracking of their browsing habits. This data is used to provide tailored suggestions, in terms of products users could buy, interesting resources, social connections, etc. Personalization services rely on combining different services and techniques to track users across different websites and applications (Puglisi et al., 2015).

We will describe different techniques, which make obtaining data about user browsers and devices possible.

A **web cookie** is a small string (usually just an ID-number) that a server sends to the user's web browser. The cookie is saved on the user's hard drive and later sent back to the server. Browsers started using cookies in 1995 to help facilitate authorized user access and personalization settings. Web cookies have two major drawbacks: the cookie can identify only one browser application and it can be deleted, which means that the identifier can be lost (Boda, Földes, Gulyás, & Imre, 2011). However, the method is still widely used (Gomez, Pinnick, & Soltani, 2009).

Capturing browsing history is a technique, which exploits the JavaScript method `getComputedStyle()` that can check the color of a hyperlink. In a hypothetical scenario, a website can automatically generate an array of hyperlinks as DOM objects and execute `getComputedStyle()` on each hyperlink. In this way, a website can determine which sites you have already visited and make a profile of your interests. As of 2010, CSS 2.1 specifications (World Wide Web Consortium et al., 2011) include a note in which W3C warns about the aforementioned shortcomings. Also, Weinberg, Chen, Jayaraman, and Jackson (2011) con-

clude that capturing and analyzing browsing history causes privacy and security risks which outweigh potential benefits. Today it is no longer possible to capture browser history with the `getComputedStyle()` method.

Geolocation API, defined by W3C, is a high-level interface to location information of a device, such as latitude and longitude. The API is designed to allow *one-shot* and continuous access to location data. However, specifications do not guarantee that the interface will provide the exact location. Since W3C considers that location data can potentially compromise the user's privacy, the browser vendor's implementation of the specification must *provide a mechanism that protects the user's privacy* and *should ensure that no location information is made available through this API without the user's express permission* (Popescu, 2013).

Battery Status API is a browser mechanism that enables access to power-related data. It can provide data about the battery level, the charging time, the discharging time and the charging status (Lamouri & Kostiainen, 2016). In JavaScript, it is accessible via the `navigator.getBattery()` method. The API does not require explicit user permission to access this data, which means that any website or related third party script can use it. Likewise, the specifications do not require web browsers manufacturers to implement a mechanism that would inform the user about the website accessing their battery data (Diaz, Olejnik, Acar, & Casteluccia, 2015). In the "*Security and privacy considerations*" section of the W3C specification that describes the Battery Status API, the following is stated: "*The information disclosed has minimal impact on privacy or fingerprinting, and therefore is exposed without permission grants*" (Lamouri & Kostiainen, 2016). Nevertheless, Diaz et al. (2015) showed that the Battery API, as implemented by GNU/Linux and Firefox browser, enables device fingerprinting and tracking due to high precision measurements.

Device Orientation API allows for the obtaining of information about the physical orientation and movement of the hosting device. Mobile devices, such as mobile phones, tablets and smart watches use this data to automatically rotate the display to remain in an upright position. The interface for the orientation of the device in a W3C-specification was introduced in March 2010. The first browser which partially implemented this feature was Google Chrome version 7 in October 2010 (Can I use, n.d.). The W3C considers that this information is not sensitive enough for a need to request the user's authorisation to operate. However, recent academic efforts showed how device orientation sensors can be used for device and browser fingerprint. Despite W3C's assertions that access to device orientation sensors is not safety-critical, Mehrnezhad et al. (2016) in his study showed the potential risks. By analyzing and processing the input data using neural networks, it was possible to guess a four-digit PIN code with a success rate of 74%. In the second and third attempt, the success rate of identifying increased to 86% and 94%, which represents a serious threat. The mentioned findings facilitated the idea of possible user permission requirements or a visual indicator which would inform the user about the sensor's usage.

Ambient Light Sensor provides information on the amount of light in the room where the device is located. The main measurement used built-in light detector device and the results is the unit *lux* (Kostiainen & Langel, 2016). In the "*Security and privacy considerations*" section of the W3C specification that describes the Ambient Light Sensor indicate that there are no specific security and privacy considerations regarding the use of an ambient light sensor. However, Azizyan, Constandache, and Roy Choudhury (2009) have shown that the ambient light sensor in combination with other mobile sensors, such as sound and geolocation, provides a platform of interoperable and mergeable data that can be used to derive a logical location.

User-Agent is a field contained in the HTTP request header. It can be accessed via the JavaScript method `navigator.userAgent` which returns a string like `Mozilla/5.0 (X11; Linux x86 64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/57.0.2987.133 Safari/537.36`. The user-agent can be accessed without permission and contains data about the operating system, the browser vendor and version, the rendering engine, browser details etc.

3 Web application and survey

In scope of the possibilities of browser fingerprinting of user data, we conducted research into the possibilities of data collection using web browsers. Additionally, we conducted a survey to investigate the scope of user awareness regarding the possibilities and threats of web browser data collection.

3.1 Web application

We developed a web application with the help of which we analyzed the possibilities of access to browser and device data by a website. The obtained data were divided into two parts. In the first part we asked the users for their permission to access their camera and geolocation API. The second part (Figure 1) of the application captured a range of data which is accessible without any user interaction, i.e. without their permission or awareness. The application backend was developed using the Node.js framework, a single-page frontend with AngularJS and the CouchDB database for data storage.

Each entry in database contained:

- A timestamp,
- UUID identificator,

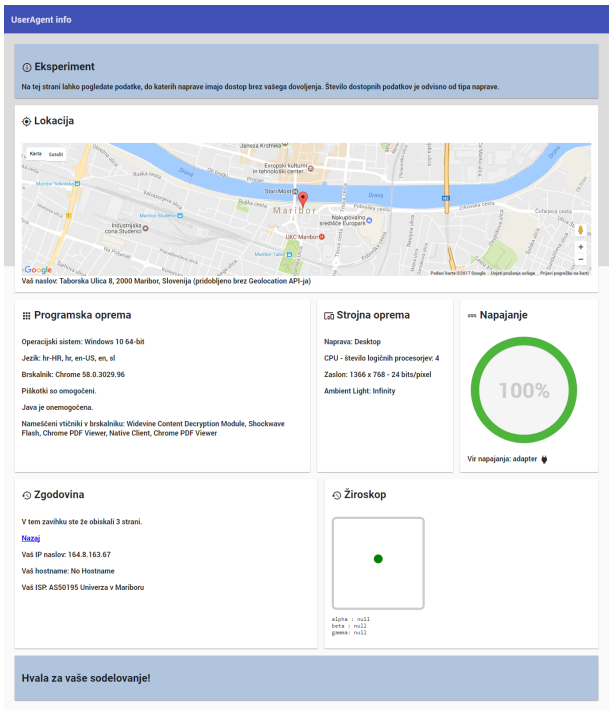


Figure 1. The developed web application for browser data collection

- camera permissions (`true/false`),
- possible camera error description,
- location permission (`true/false`),
- possible location error description,
- operating system,
- primary and supported languages,
- browser name and version,
- cookies enabled (`true/false`),
- Java enabled (`true/false`),
- number of logical processors,
- screen resolution,
- number of pages visited in current tab,
- IP address.

The database stored all the data with the aforementioned structure in the JSON format.

Some methods of data collection in browsers today are no longer available, because the W3C pointed to potentially dangerous in their requirements and recommendations functionality. An example is the exploitation of the functionality of the pseudo-class `a:visited`, to determine which sites a user has visited without his consent.

All data cannot be retrieved on all devices, since there are a variety of hardware and software limitations. The web application has been tested on devices running Microsoft Windows 10, Ubuntu Linux 16.04, Android 7.1.2, iOS 10.3 and Windows Phone 8.1. Difficulties occurred when displaying web pages in Microsoft Edge on the Microsoft Windows Phone 8.1, in which the web page was not displayed correctly. Mozilla Firefox supports most of the functionality of the web application with the exception of access to the Battery Status API and Device Orientation API. In Safari on iOS it is not possible to access the camera and battery status. Although the feature is implemented in Safari's engine, Apple has not enabled it (Olejnik, 2016). Opera supports all the functionality of the web application, since it uses the same rendering engine as Google Chrome.

3.2 Survey

To assess the privacy and data exposure awareness of web users, a survey was conducted in May 2017. The survey was distributed among the students and staff of the Faculty of Electrical Engineering and Computer Science at the University of Maribor and one high school.

The survey consisted of 32 questions that were divided into 3 parts. After the first part with demographic questions, the respondents were provided with 6 claims relating to the user's online experience, awareness of privacy threats and social networks. Next to each claim a 5-point Likert scale was offered. We also wanted to know if the user was willing to allow a website to access their location and camera. The third part of the survey started with the following claim: *I believe that it is possible that a website can access the following data about my device without my permission.* Hereinafter were listed 17 different possibilities and respondents were asked to answer on a 5-point Likert scale with an additional possibility of *I do not know this concept*.

At the end of the survey, for the purpose of tracking a particular respondent between the survey and web application, we generated a UUID number for each respondent which was linked with the survey and concatenated with the web application URL as a GET parameter.

3.3 Results and findings

The data from the survey and the web application was collected for 14 days. In that time 108 respondents participated, of which only 76 completed the survey and used the web application.

Among the respondents there were 27 women (36%) and 49 men (64%). Most of the respondents were in the age group 18-24 years (68%), and the age group 34-44 years (16%). Other age groups were represented with 9% or less.

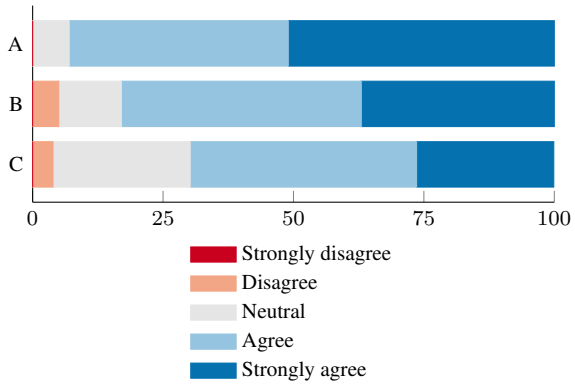


Figure 2. The ratio between the answers to the questions *How much do you agree with the following statement? – I have a lot of experience using the Web* (A), *I believe that I am aware of online threats* (B) and *Anonymity on the Web is important to me* (C)

Most respondents thought that they were very experienced web users, since 51% of them fully agreed (choice 5) and 42% agreed (choice 4) with the statement (Figure 2, A). They also thought that they were well aware of the dangers and threats on the web (Figure 2, B).

Users were most aware of the possibility that a website could access data about the type of their device (mobile/desktop), their operating system and their language without their permission. Only 28% of the respondents allowed access to their location and only 14% of respondents allowed access to their camera. Despite the fact that the majority of respondents believe that they are experienced and informed, it turns out that this does not affect their awareness of how much it is possible to obtain information about their browser.

4 Conclusion

The use of different Web applications, which often acquire the personal data of users is increasing (Krishnamurthy & Wills, 2006). However, each individual can decide whether they will provide data to an application, web site, provider or not. On the other hand, web applications are able to access certain data using browsers without user permission and awareness. Due to today's relationship between users and their devices (computers, smartphones,...) and installed browsers, the question of data access using web browsers is today more relevant than ever before. It is possible to locate, identify and follow every device that has Internet access (Michael & Clarke, 2013). Therefore, they can be used for monitoring and tracking, in a manner that adversely affects the interests of the user.

An example of the (mis)use of this data is the case of the American company Uber. It was uncovered that Uber charged people with low or almost empty batteries more, since they were more likely to pay for surge (Keith Chen, 2016). This further raised concerns that other companies could also abuse such data (e.g. analyze the battery's status in order to increase the prices for users) (Biz Carson, 2016; Jordan Golson, 2016).

We do not claim that all collectable data is a threat to privacy. However, it is important that users are aware of *what* is collected, *how* and whether this is *really necessary*.

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Which Are the Most Desired E-Competences of Future ICT Professionals?

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Abstract. *Nowadays, almost every business system faces challenges caused by the increase development and use of information and communication technologies (ICT). In this respect, there is an evident need for the ICT-skilled professionals who will be in charge of the development and implementation of new ICT solutions in different domains. This paper elaborates the acquisition of relevant e-competences directly and indirectly within higher education institutions, analyses the most desired competences of ICT professionals as perceived by employers on the current labour market and provides recommendations for the development of most desired e-competences within higher education needed for the development and implementation of new ICT solutions, based on the European e-Competence Framework.*

Keywords. ICT professionals, higher education, e-Competence Framework, job advertisement analysis

1 Introduction

Nowadays, information and communication technologies (ICT) are a key asset of any organization that wants to be competitive and succeed in today's dynamic and constantly changing environment. ICT affects changes on the global level, but as well on the institutional and individual level. Different profit organizations use the potential of ICT to optimize their processes, reduce costs, obtain competitive advantage etc.

The need for the ICT skilled workers and the lack of them on the labour market is recognized as an important issue at the European level. Latest statistics show that ICT skilled professionals are in demand, not only in the ICT sector, but across many other sectors (European Commission, 2016b; Eurostat, 2016). Even more, statistics show that 55% of ICT practitioners work in other industries than ICT (European Commission, 2012). Many latest European strategic documents indicate a need for more skilled ICT workers. One of the latest European initiatives, Digital Skills and Jobs Coalition, put emphasize on four main target groups, one of which are digital skills in education (European Commission, 2016a). Although there is a strong emphasis on the lack of skilled ICT professionals both within the relevant strategic documents and within the scientific literature, it should be stressed that digital skills are required in all types of jobs, which indicates the importance of the development of such skills not only from ICT students, but from the students in different domains and within a variety of job profiles (European Commission, 2014). Moreover, the effective use of ICT and other relevant digital competences are considered nowadays as one of the key generic and lifelong learning competences (European Commission, 2007; Tuning Educational structures in Europe, 2008). Consequently, in the context of higher education, there is a pressure on higher education institutions (HEIs), as the main generator of highly educated and skilled workers, to provide high quality processes of teaching and learning that enable student development of relevant digital competences.

This paper first elaborates different types of digital competences and then describes the need for student acquisition of digital competences within higher education from two different aspects – the digital competences developed indirectly through the use of different ICT solutions that support higher education processes (learning, teaching, administrative and managerial processes etc.) within different study domains and the digital competences developed directly through the curriculum for students in the ICT study domain. Further focus of this paper is put on competences of students in the ICT domain that should be developed directly through the curriculum, based on the empirical research. The empirical research presents the analysis of job advertisements for the ICT sector in order to detect the most desired e-competences of ICT professionals on the current labour market, as it is evident that ICT specialists are employed across the all industry sectors. Therefore, the main research question is: *Which e-competences are most desired from employers on the current labour market and should be developed to a large extent within higher education of future ICT professionals?*

Further work proposes the research about the digital competences in study domains other than ICT from two aspects – the development of certain digital competences within study period and the need for such competences at graduates' job positions.

2 Requirements for e-competences

The intention of this chapter is to explain the main terms related to digital competences and the ways of achieving them within higher education.

At the European level there are several relevant documents/initiatives elaborating digital competences. First, as a results of the European E-skills Forum, three main categories of e-skills were recognized: *ICT practitioner skills*, *ICT users skills and e-Business skills* (European Commission, 2004).

In the context of *ICT practitioner skills*, the European e-Competence Framework (e-CF) is developed as a common framework for ICT professionals in all industry sectors (European Committee for Standardization (CEN), 2014). This framework comprises 40 e-competences organized around five e-competence areas (plan-build-run-enable-manage), with indicated proficiency levels and a sample of knowledge and skills for each e-competence. As this framework covers all industry sectors, it may also be used to recognize the most important competences of future ICT professionals for the development and application of new ICT solutions. Except the *ICT practitioner skills*, it may be also said that the e-CF covers the aspect of *e-Business skills* which consider the exploitation of opportunities of new ICT solutions. This is evident from the areas *Enable* and *Manage*, which consider the strategic planning and exploring capabilities of new ICT solutions within organizations. However, most of the competences contained within the e-CF are related to the development of new ICT solutions, supported with their implementation and maintenance (areas *Plan*, *Build* and *Run*).

The *ICT user skills* are covered within the Digital Competence Framework (DigComp) which identifies key digital competences for all citizens in general in five areas: 1) Information and data literacy, 2) Communication and collaboration, 3) Digital content creation, 4) Safety and 5) Problem solving (Vuorikari, Punie, Carretero, & Van den Brande, 2016). The set of competences presented within DigComp indicates competences needed in the digital era by all ICT users and not only the ICT professionals, as it is the case with the e-CF.

Except the distinction of three main types of digital competences, the usage of ICT may also be considered as one of the main generic competence as well as one of the key lifelong learning competence which are expected from all citizens and not only from graduates in the ICT domain. As this paper focuses on ICT professional skills based on the e-CF, the importance of digital skills expected from other graduates is not researched in detail, but is elaborated within the conclusion and further work.

It should be also stressed that previous relevant scientific literature recognizes different competences required from ICT professionals, including both technical (hard) and generic (soft) skills (Nelson, 1991; Lee, Trauth, Farwell, 1995; Todd, 1995; Gallivan, Truex & Kvasny, 2004).

As already mentioned in the introduction, from the aspect of achieving different types of digital competences within higher education, two main directions may be recognized – indirectly through the use of ICT solutions that support different processes within higher education (learning, teaching, administrative, managerial etc.) and directly through the curriculum for students in the ICT study domain. The next subchapter summarizes different types of information systems used in higher education and therefore indicate a need for students' ICT user skills in different study domains that are, to some extent, acquired by the usage of different ICT solutions during their higher education experience. Further empirical research is focused on e-competences that should be developed within the curriculum for study programmes in ICT domain.

3 ICT solutions in higher education supporting the development of *ICT user skills*

The usage of ICT in higher education is evident in all phases of student engagement with an HEI, from pre-entry, through several years of studying to their alumni period. Therefore, this considers the application of digital skills at certain proficiency level during their study experience. The level of proficiency to which students will acquire certain digital competences is certainly affected by number and complexity of different ICT solutions used within HEIs. Therefore, this chapter describes in short different types of ICT solutions that are used in HEIs, regardless the study domain.

First, in the pre-entry phase, information system assists high school graduates in the process of application for the certain HEI and when entering the HEI. This information systems do not only support students in the admission phase, but also provide HEIs information about the structure of the cohort entering the HEI, helping them to collect and organize information about freshmen in one place etc.

During their study period, students face with the ICT in the processes of learning and teaching. One of the most important role of ICT within education is enhancing the quality of student learning experience, while the appropriate use of different ICT resources support student centred learning and creates more creative learning environment (Fu, 2013). As an addition to the traditional face-to-face learning, numerous examples of different use of ICT in education can be recognized, organized around different types of e-learning: ICT supported face-to-face learning, blended learning and fully online learning (Begičević, Divjak, & Hunjak, 2007). In recent years, the trend of e-learning in education is

evident in the development and use of Massive Open Online Courses (MOOCs) (Baggaley, 2013), with the evident use of MOOCs in traditional classrooms as well (Bralić & Divjak, 2016). Along with the development of e-learning and MOOCs, learning management system (LMS) appears no longer to be enough, and the importance of the development of learning analytics systems (LAS) in education became a very popular issue (Greller & Drachsler, 2012). The use of mentioned ICT solutions to support learning and teaching processes within higher education indicates a need for all the competences contained within the DigComp framework, both from students and teaching staff.

Although the usage of ICT for supporting processes of teaching and learning is widely represented in literature, evidence on the use of ICT for supporting managerial and administrative processes also exist (Ghavifekr, Afshari, & Seger, 2013). Among the most important benefits of ICT in education is a huge number of variety of data collected through different information systems. Those data are very valuable managerial asset as they provide basis for the effective decision-making, benchmarking with other HEIs etc. Even more, the application of a comprehensive information systems, so called Enterprise Resource Planning (ERP) that support the provision of a whole range of educational services from the perspective of internal resources planning is evident in educational organizations (Abugabah & Sanzogni, 2010). The value of data collected through different information systems within higher education indicate the importance of student active usage of those systems during their higher education experience.

Once graduates leave HEIs, HEIs can still use a certain information system to collect information about their alumni career progress and stay connected with them (Mijić & Janković, 2014). This is particularly important because graduate studies are recognized as a very valuable asset for improving the quality of education and aligning the educational processes with labour market needs. As such, graduate studies supported with an online system may provide increasingly important inputs for HEI management regarding different processes, including strategy development, improvement in curriculum design and delivery, organization of student support services and extra-curricular activities etc.

The presented short literature review indicated various types of information systems used to support a whole range of internal and external processes within HEIs. The usage of ICT in higher education requires certain ICT skills from teachers and there are numerous papers on this topic available in the scientific literature. Moreover, there are also requirements for ICT user skills needed from students in different study fields. Finally, there is also a need for skilled ICT professionals who would develop and implement such information systems. Therefore, this paper further puts focus on professional digital skills (e-competences) which are required for the development and implementation of new ICT solutions, and should be developed directly through curriculum for future ICT professionals.

4 Labour market requirements for the *ICT practitioner skills*

4.1 Methodology

Empirical part of this research includes the analysis of e-competences needed for development and implementation of new ICT solutions, which are required from ICT professionals on the current labour market. This research is based on qualitative analysis of job advertisements announced at the online portal MojPosao (http://www.moj-posao.net/). For purpose of detecting the most desired competences of future ICT professionals (current ICT students) and providing recommendations about competences that should be developed within ICT curricula, job advertisements in category "ICT & telecommunications" were analysed in period between 1st and 31st of April 2017. The analysis included 119 job advertisements that were active in that period. The analysis of job ads on this portal was chosen as appropriate method for several reasons: 1) actual job ads are a very good indicator of desired competences of ICT professionals on the current labour market from the employers' point of view, 2) job ads on this portal are structured in a way they contain job description with main tasks and responsibilities and the qualifications and skills for a certain job position so they are suitable for the analysis according to the e-competence framework with pre-defined competences categories.

E-competences were analysed according to the e-CF that comprises 40 e-competences organized around five e-competence areas (plan-build-run-enable-manage) which cover the entire ICT solution lifecycle. The *Plan* area is related to designing new ICT solutions, including innovation processes, *Build* area consider development of new ICT solutions (programming), the *Run* area supports implementation of developed ICT solutions in practice, the *Enable* area contains all supporting processes that enable implementation of new ICT solutions while the *Manage* area is related to managerial and quality assurance activities within process of new ICT solutions development and implementation.

The analysis within this research was conducted in a way that appearance of each e-competence in a certain job ad was marked in an Excel spreadsheet, rather than frequency of appearance of certain competence. This type of analysis is known as content analysis. It should be stressed that in some cases e-competences were not mentioned explicitly in the job ads but they were recognized from the context of a job description in relation to the description of knowledge

and skills available for each of e-competences within e-CF. For example, a description "documenting standard demo flows" within one job ad was recognized as a competence *B5 Documentation Production* from e-CF. This analysis follows the methodology presented in previous work of Pažur Aničić & Arbanas (2015), who used the same approach to initial analysis of the most desired e-competences and generic competences within job ads related to future ICT professionals.

4.2 Results

Fig. 1 shows presence of e-competences from e-CF in the set of analysed job ads according to these five e-competence areas. As can be perceived, the most desired competences are within the category *Build* which contains 6 competences, followed by the category *Plan* with 9 competences. Categories *Run* (4 competences) and *Enable* (12 competences) are almost equally represented within the analysed job ads, while the competencies from the category *Manage* (9) were recognized in the smallest number of job ads. Additionally, from the 40 e-competences contained within the e-CF, none of them is recognized in more than a half of analysed job ads. Around one half of competences are recognized in 10 or more job ads, which makes only around 10% of analysed job ads. Only four competences appeared in around 1/3 of ads or more. To provide more detail insight into the recognized competencies, graphical representation for each of five areas separately is presented below.

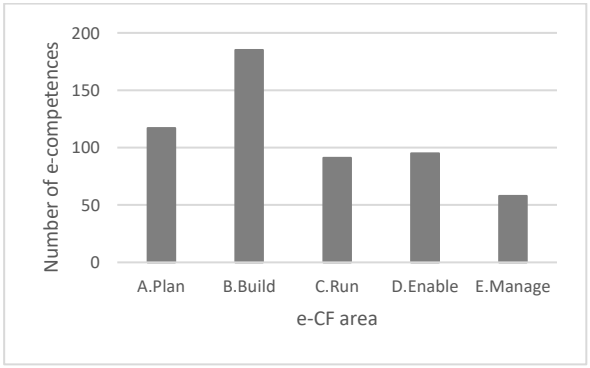


Figure 1. E-competences in job ads according to the e-CF competence areas

First category, *Plan*, represents a strategic area as it involves competencies necessary to detect organizational processes for which ICT may be used for improving efficiency and effectiveness. However, this area is not focused only on existing processes, but also requires strategic thinking about future organizational directions and how ICT may support future developments and contribute to the achievement of set goals. It is interesting to notice the most present e-competence from this category is *A.9. Innovating*, followed by the *A.6. Application Design* (Fig. 2). This innovating considers creative thinking about ICT solutions and it is closely connected with the *A.7. Technology Trend Monitoring* aimed at exploiting the latest technological developments and identifying their potential within organizations. Monitoring of new trends in ICT industry and innovative thinking are a prerequisite for designing of new ICT solutions (*A.6. Application Design* and *A.5. Architecture Design*) in accordance with customer needs. It might be noticed that competences related to the business planning and strategic development are recognized in considerably smaller number of job ads. The reason for this probably lies in a fact that analysed job ads are mostly for ICT practitioners and not managers in charge of strategic planning processes within an institution.

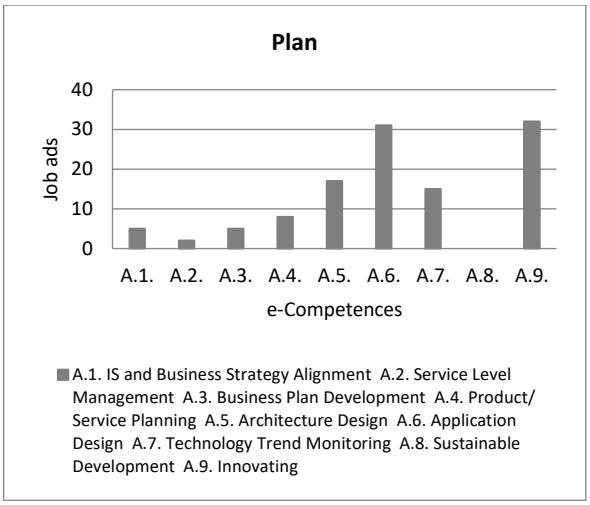


Figure 2. E-competences in the area *Plan*

The second area, *Build*, is associated with development and implementation of new ICT solutions. As its description says, and as it is evident from general results shown in Fig. 1 and more detailed results for this area shown in Fig. 3, competences within this area are the most important for the incorporation of new IT solutions in any organization. However, it should be stressed that successful development of innovative ICT solutions requires support in planning processes that precede development itself, but also the further provision and maintenance contained within processes in the *Run* area. Fig. 3 shows that the most desired competencies from the *Build* area are *B.1. Application development, B.5. Document Production and B.3. Testing*, followed by the *B.2. Component Integration* and *B.4. Solution Deployment*.

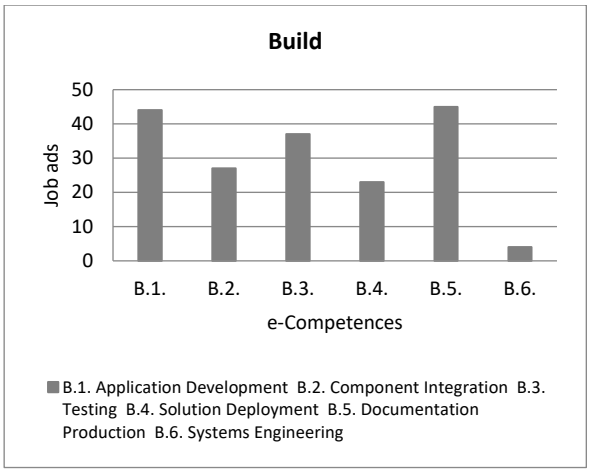


Figure 3. E-competences in the area *Build*

The *Run* area is the most important for successful provision of new ICT solutions developed within the area *Build*. Fig. 4 shows that the most desired competence is *C.2. Change Support*, which is focused on guiding the evolution of an ICT solution. Changes in ICT solutions may be caused by certain problems or incidents that occur so this competence is closely related to the *C.4. Problem Management.* Except dealing with needed changes and recognized issues related to the ICT solutions within an organization, this area contains also the competence *C.1. User Support* that consider clearly communication with users and providing them with instructions on how to implement and use new ICT solutions in their everyday tasks.

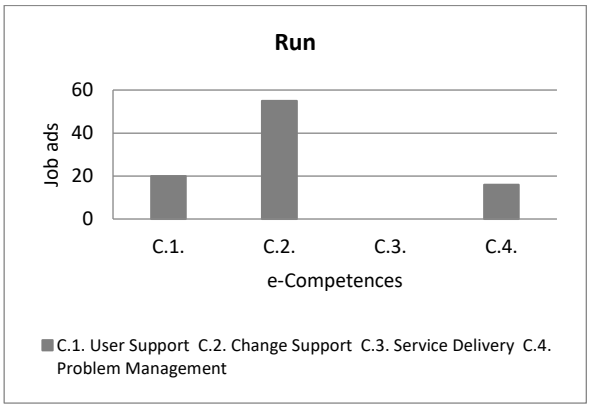


Figure 4. E-competences in the area *Run*

Enable area contains the highest number of e-competences – 12 of them. This comprehensive area may be described as a managerial horizontal area that contains competences need in all the phases of an ICT solution life-cycle. The most important competence in this area is *D.10. Information and Knowledge Management*, which consider identifying, gathering, storing, analysing and interpreting knowledge and information related to all segments of a new ICT solution development and implementation. Three additional competences from this area were found to be moderately represented in ICT job ads – *D.7. Sales Management*, *D.11. Needs Identification* and *D.12. Digital Marketing*. All the other competences from this area appeared in a few job ads (Fig. 5).

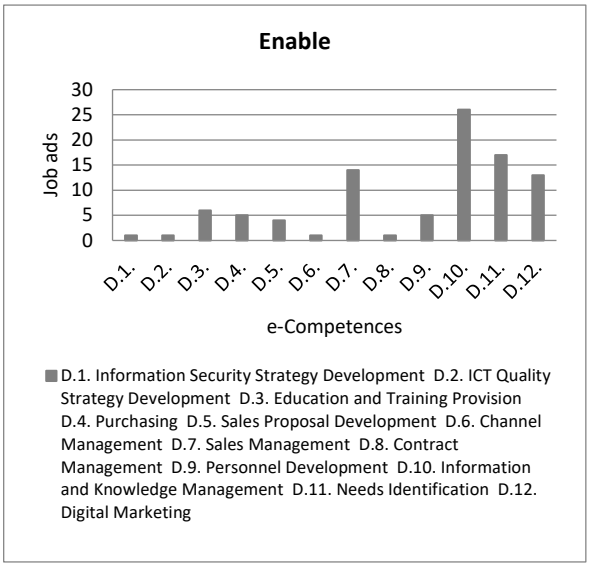


Figure 5. E-competences in the area *Enable*

Finally, the area *Manage* consist of competences needed for everyday administrative and operational tasks related to different ICT solutions in organizations (Fig. 6). *E.4. Relationship Management* is recognized as the most desired competence in that context, as it considers establishing and maintaining positive relationships with all stakeholders affected by the use of new ICT solutions within an organization. *E.2. Project and Portfolio Management* and *E.5 Process Improvement* are also recognized as important.

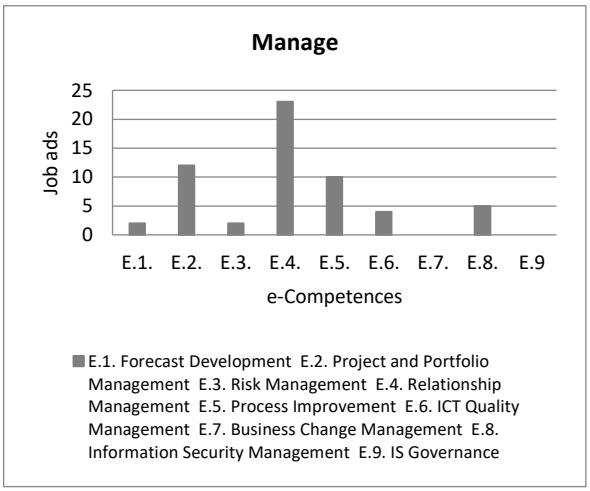


Figure 6. E-competences in the area *Manage*

This chapter provided overview of the most common e-competences which can be found in the active job ads for the ICT professionals. Except the comparison with the e-CF, the analysis also included the appearance of generic competences in job ads. As the generic competences are not in the main focus of this research paper, only those recognized in the highest number of job ads will be stressed here, which are: knowledge and

understanding of the subject area; understanding of the profession and the ability to apply knowledge in new situations; ability to communicate both in foreign language and mother tongue; teamwork and interpersonal skills. However, it should be stressed that the usage of ICT, which also appears on the list of generic and lifelong learning competences, was not observed as generic competence in the context of this research as it analyses e-competences as professional competences within ICT domain.

5 Recommendations about future e-competences in the education of ICT professionals

Based on the presented research results, this chapter provides recommendations for the development of e-competences in the education of future ICT professionals within HEIs, taking into account the most desired skills as resulted from the analysis. The e-CF showed five main areas of competences – plan, build, run, enable and manage. This framework indicates that, for successful implementation of new ICT solutions within an organization, it is crucial to cover competences from all areas. Moreover, the e-CF proposes needed e-competences at certain proficiency level for 23 ICT profiles, organized around six main families: *business management, technical management, design, development, service & operation* and *support*. (European Committee for Standardization (CEN), 2012). The recommendations within this paper are organized around these main ICT profiles' families, based on the results of actual job ads which indicate the most desired competences from employers at the current labour market. However, it is important to emphasize that diversity of required competencies within job ads on the labour market makes it hard to divide them strictly into one of proposed ICT profiles. In some cases, a combination of more ICT profiles may be recognized within one job ad. Therefore, these recommendations does not strictly follow the ICT profiles, but are rather organized by the authors of this paper around skills needed for the education of *business managers* as the main initiators of the implementation of new ICT solution and *lower level managers* responsible for the implementation of those solutions in practice. Further, there is a need for *ICT specialists* proficient in design, development and implementation of new ICT solutions and the *ICT support personnel* responsible to support all the stakeholders in the use of new ICT solutions.

The recommendations begin with a set of e-competences that may be considered important from future business managers in different organizations, which can be, in the context of e-CF related ICT profiles, recognized as *Business Information Manager*, *Chief Information Officer (CIO)* and *ICT Operations Manager*. Persons at those managerial positions should, first of all, have the vision and long term institutional strategic plans and recognize the potential for supporting the achievement of those plans with new ICT solutions (*A.1. IS and Business Strategy Alignment*). A very appreciate characteristic of managers is that they are familiar with the latest technology development in a certain field so they can recognize the potential of these new ICT solutions for achieving certain goals and optimizing processes within different organizations (*A.7. Technology Trend Monitoring*). When thinking about new ICT solutions, managers should be able to recognize the needs of all relevant stakeholders, both internal and external (*D.11 Needs Analysis*) and try to propose creative and innovative solutions that add a certain value to the stakeholders' experience with the institution (*A.9. Innovating*). Of course, it is well-known that managerial positions require certain work experience, but some general skills and knowledge for these positions should also be developed already during the study period. This particularly refers to the competences such as innovating and technology trend monitoring which are today considered, not only as e-competences, but also a kind of generic competences. Moreover, students' experience with the usage of different ICT solutions (LMS, MOOCs, ERP etc.) within higher education is also important as it provides them an overview of the complexity of such solutions and processes they support within a concrete organization.

While business managers are responsible for recognizing the potential benefits of new ICT solutions on the organizational level, their role is usually not to plan those solutions in detail. The operationalization of implementing new ICT solutions should be a task of technical level ICT managers, such as *Quality Assurance Manager, ICT Security Manager, Project Manager* and *Service Manager*. As a bridge between the management decisions about new ICT solutions on one hand and ICT professionals who should implement those solutions on the other hand, a persons in charge of that role should have high level of technical skills, but also understanding of the domain in which the technology will be implemented. In that sense, the e-competences recognized as the most desired from higher level managers (*A.7. Technology Trend Monitoring, A.9. Innovating* and *D.11 Needs Analysis)* are also desired from technical managers. However, technical managers are additionally expected to be proficient in more operational tasks, including the design of new ICT solutions both on the level of hardware and software (*A.5. Architecture Design* and *A.6. Application Design*). Although it is not expected that technical managers themselves develop new ICT solutions, they should be very well versed in programming skills in order to monitor and direct the work of ICT professionals in the process of new ICT solutions development. To summarize, the technical manager takes responsibility to manage the entire project of new ICT solution development and

implementation. This requires knowledge and skills associated to the e-competences *E.2. Project and Portfolio Management*, *E.5. Process Improvement* and *E.8. Information Security Management.* The implications for HEIs in this context are the involvement of project-based lessons and embedded work-related activities based on the complex real-world problems and teamwork, so the students can acquire the needed competences. In that context, collaboration with employers within formal curriculum should be a high priority, as well as student internships as an integral part of curriculum.

The demanding job of development of new ICT solutions proposed by higher level ICT managers and further designed by technical managers is on ICT professionals. Their main tasks are organized around the *Build* and *Run* area from e-competence framework, which are in the context of ICT profiles divided into *Design* and *Development*. Therefore, they are expected to be proficient in a whole set of skills related to the development of new ICT solutions (*B.1. Application Development*, *B.2. Component Integration*, *B.3. Testing*, *B.4. Solution Deployment*, *B.5. Documentation Production* and, to smaller extend, *B.6. Systems Engineering*) and skills that enable the implementation of those solutions in practice. This considers the successful service delivery and supporting the evolution of an ICT solution (*C.2. Change Support* and *C.4. Problem Management*), but as well the support for end users (*C.1. User Support*). This latest set of skills may be found within the ICT profiles categories of *Service & Operations* and *Support*. In the context of HEIs, the development of this set of competences requires a lot of laboratory work, which enable students' practical work on the development of new ICT solutions in different programming languages. Job ads also indicate that many companies give advantage to candidates with knowledge of specific programming language. Therefore, HEIs should rethink about the flexible curriculum that enable students' acquisition of a wide range of programming skills, according to their own preferences or the preferences of their desired future employers.

Finally, end users of new ICT solutions are expected to have skills necessary for using those solutions in an effective way to support their daily activities. However, the end-users' e-competences are not in the scope of this research, but it should be stressed that end-users should be provided adequate support for using the new ICT solutions. Except the already mentioned e-competence *C.1 User Support*, this also requires ICT students to have knowledge and skills related to the e-competence *D.3. Education and Training Provision*.

6 Conclusion and further work

This paper is based on the analysis of job advertisements in the ICT domain, which indicated the most desired competences from ICT professionals on the current labour market, based on the e-Competence Framework. The results of this analysis provided insight into the competences that should be included to a larger extend into the curriculum for the ICT professionals, in order to educate students that will have potential to find meaningful employment on the labour market. Recommendations on the development of future e-competences are organized according to the several main types of ICT-related jobs, including business managers, technical managers, developers and user support personnel. It is interesting to notice that some of the most desired e-competences are today also considered as generic and transversal competences, such as *innovating*. In order to enable the development of a wide range of recognized e-competences within HEIs, a new student centred learning and teaching approaches should be used within higher education, such as problem-based learning, project-based learning, work-based learning etc. The value of different student centred approaches lies in a fact that they enable the development of a wide range of e-competences, but as well support the development of generic competences. Moreover, these approaches often consider the collaboration with employers and students' work on real-work projects. Employer active involvement in curriculum is among the most desired university-business cooperation strategies as it has direct impact on the development of students' competences that increase their employability potential.

One of the main limitations of this research is a focus to only the job ads in the Republic of Croatia. Further work should include more job ads from different countries. Moreover, more ads included in the analysis could lead to more detailed recommendations related to certain ICT families or even on the level of ICT profiles. However, from 40 e-competences contained within e-CF, the analysis extracted smaller number of them which appears to be the most important from the employers' point of view.

Except the e-competences needed from the ICT professionals, the introductory chapters of this paper indicated the need for the acquisition of digital competences from the professionals in other domains. Therefore, plans for further work include the analysis of the requirements for e-competences in domains other than ICT, but also the analysis of the level to which digital competences are developed within different study programs and the level to which such competences are required at different types of workplaces. This kind of analysis will provide an overview of the need for digital competences as one of the main generic skills across a spectrum of domains.

Acknowledgments

This work has been supported by the Croatian Science Foundation under the project Higher Decision IP-2014-09-7854.

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An Overview of Identity Management Systems Usage

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Abstract. *Identity management systems have been a staple of enterprise and academic digital landscapes for decades, practically since the first computer networks were organized. Today, the rising importance of online services in our daily lives, as well as growth of complexity and scale of online services and associated systems, mandates continuous development of identity management systems and their use in completely new scenarios. This paper provides an overview of the current state of identity management systems usage, challenges posed to successful development and deployment of these systems and related technologies; provides a brief overview of the most popular technologies used and estimates of their real-world use.*

Keywords. Identity management, identity, security, privacy, IMS

1 Introduction

Originally, the need for organized identity management arose in the enterprise. Solutions built upon protocols like LDAP and Kerberos met the needs of employees and administrators by providing centralized management of personal information and services like SSO within the enterprise, or more specifically, within a single domain. As time passed by, growth, splitting and merging of the enterprises increased complexity of the management of personal data and accompanied services. Also, new applications of identity management emerged, and at significantly greater scales. These came from public services where application domains like public healthcare and education posed new challenges to the management of personal data. Thus, the need was created for organized effort in providing best solutions to satisfy these new challenges, including enhanced privacy concerns, security at greater scale, easier and friendlier access for end users, mobility across domains in some cases and more complete isolation of domains in others. As the online activities of general population increase and online services enter our lives in more and more ways, the need to address these challenges to the management of our private data continues to increase. For the time being and in the near future, we can expect that in the changing landscape of our online lives we'll need to continually address these issues.

With that in mind, this paper provides a look at the current state of the field of identity management. The rest of this paper is organized as follows: in section 2 we list some of the traditional challenges met by identity management systems, as already established through previous research by various authors. To demonstrate how those challenges are currently handled, in section 3 we describe a selection of the most prevalent current technologies in use, especially with regard to the mentioned requirements. Section 4 discusses featured technologies and how they solve some of the previously introduced problems, as well as existing research into real-world data and estimates on current number of installations of discussed technologies. Finally, we conclude with a section that discusses expected future challenges.

2 Problem definition

In this section, we briefly describe a selection of the most commonly encountered challenges as described in the existing literature, e.g. in (Bertino et al., 2009), (Torres et al., 2013).

2.1 Modelling identity

To manage identities, firstly they must be expressed in a workable way and therefore precisely and unambiguously defined. However, basic phenomenon of identity is itself not as straightforward to define as it may appear. Usual approaches start by axiomatically asserting the existence of well-defined entities as a basic commonly understood term (alternatively one can also find some definitions of an entity, e.g. in (Cameron, 2005, pg. 7) "a thing with distinct and independent existence"). Within the target context entities are personae, computers, organizations, etc., and entities exhibit characteristics that differentiate

them from each other. Therefore, a common approach like in (Alpár et al, 2011) is to define the identity of an entity as a set of all characteristics attributed to this entity. An important realization is that identity is not absolute, but relative to a scope. For example, within a relatively small organizational unit, two people may be identified by their names alone – most often there are no namesakes within a small enough group. However, within a larger scope like a register of citizens, additional characteristics must be introduced to differentiate various entities (people), like dates and places of birth or ID card numbers. When dealing with computerized systems, these characteristics are more formally encoded as entity attributes – values from well-defined, representable and computable domains (i.e. sets of symbols).

Even if this definition may seem intuitive, some authors argue that there is no merit in observing entities and their characteristics. Cameron (Cameron, 2005) for example argues for a digital subject instead of entity as an identity-carrier, where a digital subject is "a person or thing represented or existing in the digital realm which is being described or dealt with". He makes a point that entities are of interest only if interacted with, and whether entities that aren't in any interaction exist or not is "a moot point". Common traits with the previous approach is that identities of subjects are both context-dependent and defined through their attributes. Additionally, Cameron argues that identities don't have to be unique even within a single context but that in certain scenarios it is even desirable for a single identity to represent more than one subject. The given example concerns groups of subjects being granted the same right to some resource in a foreign domain where from the viewpoint of that domain it's not of importance which subject of the group accesses the resource, therefore all the subjects are representable by the same identity.

2.2 Establishing trust

A simplified definition of trust is willingness of a party to assume a vulnerable position towards another party, expecting the other party to refrain from taking advantage it perceives (more formal definitions are available in (Alpár et al, 2011), (Meyer et al, 1995) and (Jensen et al, 2012)). IdM systems are built with trust assumptions on various levels. The most obvious trust assumption is that the relying party (the party that identity information is delivered to) trusts the identity providing party's (IdP) claims about a particular entity. Aside from this, the user is also assumed to "trust the IdP to make a particular claim about herself to a particular relying party" (Alpár et al, 2011). And then there is additionally the establishing of trust in more complex systems involving more actors and security domains, such as federated identity systems where more than one IdP or relying party interacts in a flow of data. Even harder to achieve is the dynamic establishing of trust, which is necessary in many scenarios where parties from different domains with no prior experience wish to interact. Unfortunately, this need for dynamic establishing of trust contradicts both the common wisdom that trust is earned with experience (which of course always applies) and also contradicts the desire for untraceabillity and unlinkability (described later in this paper) both of significant importance in many scenarios.

2.3 Privacy

In some contexts, privacy is not desirable, but on the contrary all actions performed are supposed to be visible within the context. Examples may include access to shared resources within an enterprise or to vital resources in a military environment. However, in other contexts where entities (usually users) have the right to privacy of their actions, the adoption of IdM solutions may significantly depend upon its ability to ensure user privacy. This is especially true in widely accessible solutions on the Internet whose adoption depends mostly on their reputation with the end-users. There are varying levels of privacy that must be ensured for user data, depending on the nature of the data and the context of use. Examples of the former may include health or financial data and the latter is illustrated by the difference of accessing a trusted personal resource (e.g. an online data storage facility) vs. accessing a site the user perceives as less reputable or trustworthy.

2.4 Linkability and traceability across domains

Two of the special privacy concerns are user data linkability across domains and traceability of user transactions across domains. In many scenarios users of an identity management scheme would prefer their actions not to be linkable or traceable. The most pervasive example is using the IdM system on the Internet for SSO purposes. Users performing purchases on a site that allows session establishment through any of the popular SSO systems (e.g. based on OAuth or SAML) would prefer the site not to be able to link the data it has with data from other similar sites. Additionally, users would prefer the IdP system used for establishing sessions to various such sites not to be able to link their data. The latter is expectedly especially hard to achieve since the IdP necessarily interacts in transactions to various relying parties.

2.5 Security

Security is of paramount importance in an IdM system. This stems from the fact that data kept is personal and misuse of it can lead to serious negative consequences. IdM systems are by design part of more complex environments where they interact with other systems on behalf of users whose identities are managed. That

means that breaches to security of IdM systems may result in identity theft or malicious data manipulation to some party's disadvantage.
By principle of proportionality, an IdM system will be more useful the more data it stores about its managed entities (usually personae) – various scenarios require various data about users, so the more different facts about users are available, the more scenarios the system can service. On the other hand, with more data the system stores about managed entities, it becomes more interesting to malicious parties wishing to subvert it and the consequences of its security breach become potentially worse. The risks rise and in ultimate case the IdM system may become a single point of failure. Unfortunately, to the best of our knowledge, there is no resolving of these contradicting requirements beyond a compromise between usability and risk.

3 State of the art solutions

As mentioned in the introduction, this section gives a brief overview of the most prevalent technologies in current use with regard to requirements explained in the previous section. Selected technologies are those currently in wide real-world use as described in the existing literature, e.g. (Vapen et all, 2016).

3.1 SAML 2.0

SAML is a well-established standard developed by the OASIS consortium for authentication and authorization. Developed during early 2000s, now in the version 2.0, it is an XML-based standard heavily influenced by the enterprise technologies popular at the time, especially the WS-* stack (which is a set of protocols standardized by the W3C that define how XML- and more precisely SOAP-based[1] web services should be implemented and includes publications defining SOAP, WS-Addressing, WS-Policy, WSDL etc.). Similar to some other XML-based standards, it defines a hierarchy of basic concepts – assertions, protocols, bindings and profiles. It was developed mostly for enterprise and business needs and is widely adopted in these domains as well as in public services mainly through Shibboleth, an open-source identity provider that builds upon SAML 2.0. Shibboleth is being developed and maintained by Shibboleth Consortium, whose members include educational, research, healthcare and other public organizations from more than 20 countries (including UK, Swiss, Ireland, Brazil, Czechia, Italy, Austria, etc.)
The most common SAML profile (simplified, profiles are essentially use-cases) is multi-domain web single-sign-on and includes interaction between three parties – a user, an Identity provider, and a Service Provider as illustrated in Fig. 1., taken from (Hughes, Maler, 2005.).

In this scenario, the user already has an established session with one web site, during which the user is redirected to a new web site. The original website acts as an IdP and relays information to the redirected website that acts as a Service provider.

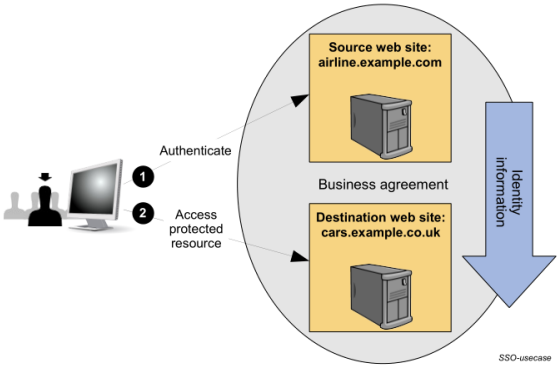


Figure 1. Basic OpenID flow.

The relayed information effectively authenticates the user through a SAML message allowing for a session between the user and the redirected website to be established. In SAML terms, the first website is generally referred to as the asserting party and the second as the relying party.
This use-case depends on various other interactions, including an agreement between parties what information to forward, what transport layer to use, whether to link user representation with both parties or to decouple them, whether to store user data or to rely on transient identifiers that get destroyed after the session is done, etc. SAML 2.0 provides mechanisms to address most of these questions on-the-fly. Additionally, there are many variations of this example flow (e.g. user-initiated instead of AP-initiated as in the example) as well as different flows supported by SAML 2.0, making it a very versatile and robust standard.
However, this also adds complexity which is often viewed as a drawback of the standard prohibiting it from use in some other scenarios, particularly those where some of the security concerns may be somewhat relaxed. Added to that the XML legacy of the protocol is also often viewed as cumbersome and out-of-date in scenarios demanding more lightweight solutions due to processing power and other technical limitations, e.g. smartphone and similar applications.

3.2 OAuth 2.0

OAuth 2.0 standard is published and maintained by IETF through a set of RFC documents, the core consisiting of RFC 6749 (Hardt, 2012 (1)), RFC 6750 (Hardt, 2012 (2)) and RFC 6819 (McGloin, 2013). OAuth 2.0 is foremost an authorization protocol. The user provides permission to a third party (a client in OAuth terms) to access some of user's data at the identity provider as shown in Fig 2., taken from (Hardt,

1

2012 (1)). For example, the user allows a site like fit4life.com read-only access the user's fitness data stored at google.com (an authorization server and resource server in OAuth terms), without necessarily divulging any of the user's other confidential data.

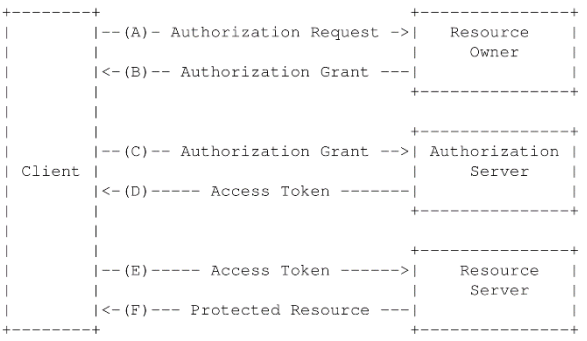


Figure 2. OAuth 2.0 Abstract protocol flow.

However, most of the real-world websites and services use this information to authenticate the user in a good-enough manner. For example, a blogging service or a news portal may use a user's email address or login name at a popular identity provider as a good-enough authenticator for the users posting comments on a blog or a news article, so obviously there's a small step to make between authorization of a client (the blogging service) to a good-enough authorization of a resource owner (the user).

Being a more modern protocol that targets not only web applications and services but also handheld devices, OAuth makes a clear distinction between public and confidential clients based on their ability to authenticate securely with the authorization server. This has important consequences on types of scenarios that are allowed (called grant types) for clients to obtain access tokens. OAuth specification defines four grant types as well as an extension mechanism for additional grant types. These grant types allow OAuth to be versatile in deployment to a heterogenous set of environments and use-cases including traditional web-based service access, as well as use by mobile apps and trusted third parties.

3.3 OpenID Connect

OpenID Connect is an authentication protocol specified and maintained by the OpenID Foundation. The foundation's members are mostly international corporations including well-known names like Google, Microsoft, Oracle, PayPal, Verizon, RSA, VMWare, Deutsche Telekom. The protocol is defined through a set of OpenID specifications including the core specification (Sakimura, 2014) and accompanying specifications detailing additional services (like dynamic provider discovery, dynamic registration with providers, response types, etc.) Unlike the previous versions of OpenID, the current one (final specification launched in 2014) is based on the previously described OAuth 2.0 protocol. The specification extends and additionally specifies parts of the OAuth specification that have been left open by OAuth, so OAuth-based mechanisms could be used in authentication scenarios. For example, one of the most important additions by OpenID is the definition of the ID token – defined are both the contents and the representation of a data structure containing claims made by the authentication server about an end-user's authentication. Some of the other extensions introduced are a list of standard claims about a user, subject identifier types (enabling an IdP to issue different subject value to each client for the same end-user with the purpose of disabling correlation of end-user information by different clients), list of allowed encryptions, etc.

4 Discussion and real-world data

The protocols mentioned in this paper are the most prevalent ones, judging both from the number of resources and size of literature (both academic and non-academic), as well as from usage claims by the groups promoting each of them. This is underlined by the fact that commonly known names in the online world like Facebook, Google and Twitter provide services based on these protocols.

There has been a number of efforts in recent years trying to ascertain the size of various protocols' install base. These efforts are unfortunately not as frequent as the changes observed in the field (primarily on the Internet) so there is to the best of our knowledge no single complete work estimating all the current technologies. A considerable obstacle here is the sensitive nature of the subject and most commercial entities using forms of identity management refrain for security reasons from divulging details of the backbone technologies they use. We speculate this to be the reason a lot of SAML installations aren't visible in existing research datasets.

The most directly observable part of identity management landscape is the Internet-wide public SSO landscape comprised of publicly available services primarily based on OAuth and OpenID/OpenID Connect. For concrete numbers, we'll turn to results of a recent study from 2016. (Vapen et all, 2016) that among several experiments did a web-crawling of a sample set of over 35.000 sites (a pick from top 1M sites by Alexa rank). In this set the study found 1865 relying parties and 50 identity providers. Of the top 10 global identity providers by number of attached relying parties, all were implementing OAuth or OpenID (in favour of OAuth) where the first five providers were facebook.com, twitter.com, qq.com, google.com and yahoo.com. As per the study, facebook.com dominates this list with 1293 found relying parties.

Even though SAML doesn't appear in datasets obtained through collection of publicly visible IdP services and connected relying parties, it's inclusion in this paper is justified by the number of known subjects using solutions based on the protocol. The most notable

implementation of SAML is the Shibboleth software provided by the Shibboleth Consortium (https://shibboleth.net/consortium/).
This implementation is known to be popular in academy and public services – many resources detailing the use of Shibboleth providers are available on the Internet, and the Consortium's website alone lists over 80 known installations mostly in academia and the public sector (and we know first-hand that the list isn't exhaustive since the existing installation at our own university isn't listed).
The brief description of these three standards hints at variations in how challenges introduced earlier in the paper are solved. As stated, the OAuth is primarily an authorization protocol, however, for a lot of websites in the wild the OAuth model suffices for basic authentication purposes – this is because for such websites a single user attribute (most commonly the user's email address or Facebook username) suffices to identify the user, making it a simple model of user identity. OpenID builds upon the OAuth capability by specifying (through the mentioned ID token structure) a set of attributes it considers useful and sufficiently defining of a user's identity. In SAML, the subject data is transferred encoded in XML elements like statements and assertions that are defined in respect to various scenarios (more specifically "profiles" in SAML) and in a loose manner (many elements are optional and of varying content). This allows certain freedoms to specific implementations, effectively letting the parties involved (identity providers and relying parties) to define the necessary attributes for user authentication. This allows for versatility of the protocol, but also introduces the possibility of implementation divergence – something OAuth protocol has been criticized for in the past. OAuth has also been criticized for leaving too many details outside its core specification scope. The most widely known of these critiques comes from one of the contributors to the original specification (Hammer, 2012). The problem of varying implementations and their interoperability observed in the current identity management landscape, was omitted in this paper in favor of more fundamental problems listed earlier, but was documented in earlier works (Jensen, 2012, Cameron, 2005).
Trust is mostly implied – the publicly available services mentioned earlier in the section, especially those from the mentioned top 10 list are trusted by their relying parties and end-users to the extent desired by their typical uses. We can reasonably argue that users will trust a Facebook or Google implementation in typical online scenarios like signing into a social application or picture sharing service, but would probably weigh again the risks involved in letting these public services access their health or financial records. The use of a solution based on such a service in an environment requiring highest trust (e.g. e-voting) is and probably will stay in foreseeable future only a hypothetical possibility.
Similarly, the privacy these services provide is at least questionable. Privacy was a goal in development of these standards - SAML's provision for pseudonym usage was mentioned, as well as OAuth's (and by implication OpenID's) end-user's conformance to sharing data to third parties. However, users often have no way of assuring the services based on them hold up to high privacy standards. Users are informed in variously specific detail about data they are sharing (e.g. "OAuth 2.0 Scopes for Google APIs" or "Permissions Reference – Facebook Login") and often have no real control in behind-the-scenes sharing of information. Experience shows that most users will implicitly accept some privacy disruption. E.g. the willingness to be traceable on the web is evidenced by wide success of online tracking technologies used in advertisement purpose, so even if aware of their traceability by IdPs and the linkability of their transactions across the Internet, the users still put enough trust in available IdPs to continue using them.
Similarly to trust, the security of the solutions is implicitly accepted by end-users. Here the earlier mentioned rule about trust and experience applies especially, as does the tradeoff (from user's perspective) between the security-related expectations and willingness to use the services to their full potential. A typical user will usually refrain from providing overly sensitive data to an online service even if it means abstaining from some online services requiring such data – it is acceptable to leave one's email address with an online IdP provider, but not necessarily a real-world address, no matter how many form autofills it could potentially provide with online shops.

5 Future research

Currently research regarding identity management is conducted in various directions. Projects like LIGHTTest, Aries, CREDENTIAL and many others are examining the suitability of blockchain technology to manage identities, the possibility of using the existing DNS infrastructure to support identity management as well as the possibility of implementing cloud-based yet privacy friendly identity providing services. These projects are still in early development so there is no definite literature available on the topic, but they have already garnered enough attention to receive institutional support (e.g. through EU's Horizon 2020 Programme).
In light of this interest in the topic of identity management and the open problems described in previous sections, we propose another, to our knowledge not yet examined method. The traditional model of attribute-based identity as described in section 2.1 deals with entity's characteristics (attributes) and considers them constant for each entity they are attributed to. We believe that by extending these constant attributes and viewing them as time- and

geolocation-dependent values (functions of time and location) we can create a model of identity that allows for a finer-grained control of information. Potentially this would allow for an easier and more natural "sharding" of identity information where different security domains would be able to keep and be responsible for information naturally belonging to those domains. A simple example would be a person's address after moving from a country to another one – each county assumedly possesses a system to store such data about their residents, so each of those systems is responsible for a person's address at various time intervals (pre- and post-move). This approach introduces various complexities regarding the data consistency, more complex security concerns, data federation concerns etc., but we believe those to be worth researching for the expected gains in overall accuracy of the stored data as well as the flexibility of systems based on such model.

6 Conclusion

As discussed in the previous sections, the technologies in current usage address the challenges identified and presented in previous academic body of work. Those challenges are, however, met in a limited manner. No current system can guarantee complete fulfillment of all requirements posed by end-users or other parties involved in all scenarios involving IdM systems. In our view, the reasons for this are twofold.

On the one hand, various stakeholders in the field have various expectations from identity management schemes. This is primarily observable with the privacy concerns. For example, we believe that to be the reason why the discussed technologies don't provide facilities to anonymize user transactions from the IdP system itself i.e. don't completely satisfy the user wish for untraceability, even though there exist known solutions that provide higher levels of privacy in this regard, e.g. (Camenisch, 2002).

On the other hand, even from the view of a single party, e.g. the end-user, some challenges seem to be in contradiction, as mentioned in sections on trust and security. These contradictions have, however, to our knowledge not been proven, and viewed from the current stand there may exist a solution that satisfies all the apparently contradicting demands.

Therefore, we conclude that further research will be required as long as the apparently contradicting expectations and requirements aren't either satisfied through a more complete solution or such a solution is definitely proven to be unattainable.

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ICT Entrepreneurship and Innovation

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Abstract. *The use of cloud technology in business firms contributes to business process optimization and to building infrastructure, platforms and software solutions for the whole supply chain via Internet. The biggest advantage of cloud based technology systems is their simplicity. Cloud eliminates the compatibility problem by using the platform approach and enables connection in every part of the supply chain. Supply chain in cloud computing should be identified and controlled having in mind both business and technical perspective. Supply chain in cloud computing is network of interconnected business firms in the field of cloud technology that are included in provision of final products and aggregated service packages for final users. Business firms that are using supply chain management applications, like e-procurement, warehouse management, transport management, supply chain planning, business intelligence and analysis are already using SaaS solutions or setting clear strategy in order to organize its business activities in the cloud surrounding. The application of cloud technology can be divided into several supply chain activities. Activities like planning and forecasting, making catalogues, procurement, logistics and inventory management are activities within supply chain where cloud technology can be implemented most efficiently. Cloud technology has a great potential for value creation in any business firm. In this paper the usage of the cloud technology in supply chains will be described and the aim of the paper is to define theoretical framework of the cloud technology, analyze the existing literature on the usage of the cloud technology in supply chains and give a review on the future of the cloud technology usage in supply chains.*

Keywords. Cloud technology, supply chain, information technology

1 Introduction

The quality of information in supply chain is of extreme importance and is seen in three conditions which include acquiring the right information, maintaining the information correct and efficiently transferring the information. Information technology is of significant importance in every phase of supply chain management because it enables organizations to acquire and analyze information within and out of organization. Cloud technology contributes organizations in optimization of business processes, building infrastructure, building platforms and online software solutions for whole supply chain. Cloud technology has potential to create value for supply chain in any organization and therefore organizations are using cloud solutions for certain activities like net cooperation, administrative support, transport and logistical management. Activities within supply chain in which cloud technology can be efficiently implemented are planning and forecasting, making catalogues, procurement, logistics and inventory management. It is of extreme importance for contemporary companies to assess their cloud applications, make continuous plans for their improvement assessment and to react at the right time on clients' needs in cloud computing in global supply chain. The application of cloud computing in global supply chain shall significantly improve organizational features of companies and enable them to achieve business goals in the digital era.

The subject of this research is application of cloud technology in supply chains, while main goal of the paper is definition of theoretical framework of cloud technology, analysis of cloud technology application in supply chains and consideration of potential for cloud technology application in supply chains.

2 Theoretical framework of the cloud technology

Cloud is related to a special surrounding of information technology designed with the purpose of distance reservation of scalable and measurable resources of information technology. Cloud represents a certain metaphor for the Internet, i.e. a net of more interconnected nets that enable working on distance with aggregate of decentralized IT resources. Cloud is not the same as the Internet, since cloud is a unique surrounding for distance IT resources allocation and has its finite borders and also there can be more unitary cloud surroundings on the Internet (Erl, Mahmood & Puttini, 2013). Cloud computing is an aggregate of services on the Internet, usually in form of Infrastructure as a Service – IaaS, Platform as a service – PaaS and Software as a service – SaaS, and it is possible to lease any of the named services in business or private purpose which is a cheaper model than buying these services (Lamza-Maronić, Glavaš & Filko, 2012). Other authors, such as Fingar (2009) and Rittinghouse and Ransome (2010) are adding Monitoring as a service – MaaS and Communication as a Service – CaaS. Different business models that are achievable through cloud computing are presented in the work of Chang et al. (2013) as all-encompassing review of the future business framework, especially for small and medium enterprises.

There are computer services that are extremely important for work in modern organizations, no matter the size and profile of the organization, such as antivirus protection, safe copies and net disc space for saving documents. Cloud technology enables making of the services that satisfy quality and safety working standards. Space on net providers in the cloud that may be hired on the Internet is simple and favorable solution for the problem of local net disc space and at the same time it is a solution for the problem of safety copies, antivirus protection and risk of losses associated with abruption of IT equipment (Lamza-Maronić, Glavaš & Filko, 2012). Cao, Schniederjans and Schniederjans (2017) argue that at the moment safety and data breaches are one of the primary constraints for cloud technology application. Therefore, inter-organizational trust is of extreme importance between partners in the supply chain as a mean for announcing information in the cloud computing.

Basic value of cloud technology lies in the fact that it can be used as supporting and leadership technology in constantly changing and dynamic environment of supply chains net. According to Apostu et al. (2013) some of the main advantages of cloud technology usage are: cost efficiency, almost infinite saving space, safe copies and data return, automatic software integration, simple approach to information and quick transfer on new business modality. Markim (2015) argues that cloud technology enables supply chain management providers the ability to use new processes related to ethereal space. Further on, according to Gray (2015) inventory information is accurate at any time according to the cloud technology and users do not have to wait for central providers to fill in the information via the supply net. According to Maziliauskaite (2015) companies may use cloud computing in order to exchange data reviews on inventory and sales in the real time, which results in quicker integration of channels, more efficient supply chain and user analytics.

On the other hand, there are also some disadvantages of cloud technology usage. Desmond (2016) argues that, in spite of many advantages of the cloud technology, research also indicates a few of its disadvantages. First is related to the novelty of this technology that results in the lack of managerial insight in the application of the cloud computing. According to Connors (2016) the use of the cloud technology in the supply chain has caused managerial and compliance problems related to data on residency, sovereignty and security. For example, with SaaS, data saving and data maintenance are often conducted by third party companies. Organizations, especially smaller ones, have to be aware of certain risks when starting business activities that encompass cloud technology. Risks that most commonly occur when working with a cloud are related to technical difficulties and safety problems. Although data contained in the cloud may be approached from any location, there are moments when system has certain breakdowns. Organizations therefore have to be aware that this type of technology is inclined to technical abruption. Safety has to be pointed out as main disadvantage since organizations are sharing their data with service providers which may lead to certain risks. Organizations therefore have to choose reliable service providers that will keep their information in total safety. According to Apostu et al. (2013) there are following disadvantages of cloud usage in business activities: possibility of attacks, dependence on the Internet connectivity, non-compliance of application with business activities and lack of support from the service provider. It is necessary to identify and assess risks by using probabilistic risk analysis, such as the Fault Tree Analysis, Event Tree Analysis, Monte Carlo Analysis, Scenario Planning, Sensitivity Analysis, or Failure Mode and Effects Analysis. These risk assessment methods are useful only in case sufficient data is available. In case there is not enough accurate information available for risk assessment, Fuzzy techniques are more appropriate. Identified risk factors, the probability and severity of risk information, as also continuity plans for the case of crisis emergence, are necessary for the development of the risk optimization model (Vemula & Zsifkovits, 2016).

There are four different models of cloud technology implementation that are independent of service

providing models (SaaS, PaaS, IaaS) and each of four models is conducted on four different modes, in dependence of specific organizational needs. According to National CERT (2010) four modes of cloud technology in computing are: public cloud, private cloud, community cloud and hybrid cloud. Public Cloud is a platform that is available and open for the public and is in ownership of the company that sells cloud computing services. Public clouds offer changeable infrastructure which decreases safety risks and costs. One of their advantages lies in the fact that they are much bigger than private clouds and offer the possibility of increasing or decreasing of leased part of the cloud. Also the responsibility, in case of unplanned risks occurrence, lies on the service provider and not on the organization itself. The services of the public cloud are sold on demand, usually per minute or per hour. The buyers are only paying for saving or broadband width. Infrastructure of the private cloud is anticipated for usage of one organization strictly and it contains more business units. Banerjee, Paul and Biswas (2016) argue that private cloud services are delivered from the business data center to private users. This model offers practicality and versatility, but also management, control and safety. This model is used in organizations when they are trying to achieve higher degree of data control than can be achieved when using public cloud. In this case organizations have highest safety and control over data on their own infrastructure and may manage structure of the cloud on their own (Mell & Grance, 2011). In the community cloud infrastructure is anticipated strictly for usage of certain organizational community that shares certain missions, safety claims and policies. Finally, hybrid cloud is made of two or more different cloud types (public, private or community) that remain unique entities but are interconnected by standardized or appropriate technologies that enable efficient data or application transfer. Hybrid clouds are connecting public and private cloud models. The feature of private cloud expanding with public cloud resources may be used in order to maintain service levels in order to support high burden. The aim of the hybrid cloud is to make a unique scalable surrounding that helps in using all the public cloud infrastructure and that can help in control maintenance over the key data.

3 The application of the cloud technology in supply chains

Organizations are conducting research over efficiency of the cloud technology usage in supply chains. Organizations are exploring different methods aimed at cost optimization and increase of operational efficiency in every phase of the supply chain, such as planning, forecasting supply, logistics and related services. Supply chain management consists of design, planning, execution and control of all activities within supply chain, with the aim of increasing net value, building competitive infrastructure, using logistics around the world and synchronizing stocks and demand. Recent technology development enables organizations the exchange of information within these activities, but also coordination of activities related to chain management (Animesh & Megha, 2013). According to the research conducted by IDG Enterprise (2015), key factors (the speed of implementation, lower costs of ownership, enabling business continuity, exchange of technology, the need for data at the certain moment, quicker return on investment and improvement of the service) are encouraging investment in the cloud innovation in large enterprises. The research also indicates that there is significant difference in cloud spending between large enterprises on one hand and small and medium on the other. The research conducted in small and medium enterprises related to cloud adoption indicates that many of the enterprises do not believe that cloud is safe and are therefore following traditional information exchange methods with related parties (Gupta, Seetharaman & Raj, 2013). On the other hand, Vemula and Zsifkovits (2016) argue that usage simplicity and practicality are main factors for the cloud adoption in small and medium enterprises. Advances in safety and privacy are another important factor in the cloud technology adoption and following is cost reduction.

Cloud computing is designed as key technology in economies of scale in implementation and IT solutions and is a useful technology that contributes to business process optimization by providing infrastructure, platform and software as service and solution for whole supply chain via Internet. The usage of cloud computing based services contributes to financial and operational advantage. Some of advantages include: lower costs in comparison to local cost related to infrastructure, the stability of platform and flexibility of cooperation between cooperatives through supply chain.

The number of organizations using cloud technology as their primary manner of using applications is exponentially growing but organizations should keep on mind that cloud technology is a relatively new mode of business activity in organizations, i.e. in supply chains. Due to many advantages of cloud technology, organizations are interested in their application but may not fully be aware of risks and difficulties related to their implementation, some of which include high and unexpected costs related to professional education of employees related to cloud technology usage, new regulation and transition process. Although cloud solutions help in minimization of costs in the beginning, they usually increase repetitive costs (Troung & Riddle, 2014).

The service model of cloud computing combines general organizational approach for IT delivery, infrastructural components, architectural approach and economic model. The possibility of gaining resources and using and managing cloud computing infrastructure enables organizations to approach and use software like SaaS, PaaS or IaaS, which decreases total cost of ownership (TCO) in comparison with traditional data modeling centers. The infrastructure that supports cloud computing increases the possibility of adjustment, flexibility and scalability of gaining resources and using and managing bigger number of users and applications from one data center (Lindner et al., 2010). According to Gray (2015) there are three ways how cloud computing and SaaS may help enterprises to grow and develop and not just to solve current problems. These are: visibility, reaction to change and scalability. As for visibility is concerned, supply chains based on the cloud computing may enable all decision makers' full information on the supply necessity and inventory, where materials for fulfillment are available in the logistic system with newest and full data on costs and reliability. Related to reaction to change, even large enterprises that already know how to manage supply chains, are sometimes facing difficulty when going on new or bigger market. Members of the enterprise that are in primary interaction to clients and who see what is available on the shelves may enable decision makers or logistics of the third party to know whether there is sudden unexpected new demand or important feedback on certain item. Finally, related to scalability, software solutions based on the cloud are enabling resources during multiyear period or period of growth and then decrease in slow down period. If handled internally, sudden increase in new staff, followed by decrease in staff and decrease in IT budget, may cause moral problems and productivity problems.

Lindner et al. (2010) argue that the usage of supply chain concept in cloud computing is innovative and that it opens space for many possibilities. Supply chain consists of two or more associates connected with goods, information and cash fund flows. If cloud computing is added to these flows a unique definition of supply chain in cloud computing can be derived: supply chain in cloud computing consists of two or more associates supplied by cloud service and connected with information and funds. There are two general functions in supply chain and these are (Lindner et al., 2010):

1. Physical function that consists of manufacture from raw stocks or finished components and transport of all components on the right spot;
2. Intermediary function on the market that is used with the aim of ensuring that the product will be delivered to customer as the customer wants it.

Physical function dominates for functional products while intermediary function is more important for innovative products. Mixed features of supply chain in cloud computing are of great importance, such as insurance of software services that are main product of cloud services, but the most important is the intermediary function that is derived from modular design of these services. Supply chain in computing has to be identified and managed from business and technical point of view. Supply chain in computing is a net of interconnected organizations in the cloud computing area that are engaged in providing final products and aggregated service packages. Therefore, execution in supply chain is managed and coordinated by two-way service, information and funds movement through the whole supply chain in cloud computing. These movements include insurance of infrastructural services and services control, such as insurance of virtual engines and informational processes for accounting or payment process support. Kaufmann and Saw (2014) state that supply chain management is an integrative discipline, very closely related to key management functions, such as strategic management, marketing and finance. Stable processes in supply chain in dynamic surrounding are supporting enterprises' competitiveness (Ivanov & Sokolov, 2012).

Fig. 1 (Lindner et al., 2010) *The Cloud Supply Chain*) represents the components of supply chain in cloud computing. Service deliverers in cloud computing in supply chain may have several roles: providers of infrastructure, platform or software may be in direct contact with end users, i.e. organizations. They also may be intermediaries or business partners for certain service that, combined with services of other providers, offers new functionalities and this is how composite service is created. Example of this type of service is certain software that presents certain service on the top of one platform. This means that software as a service is the end product for organization. When this type of supply net is created it is very important to maintain visibility and transparency of all processes and data for control, accounting and payment. This type of service may be composite and is offered from service providers through cloud supply chain.

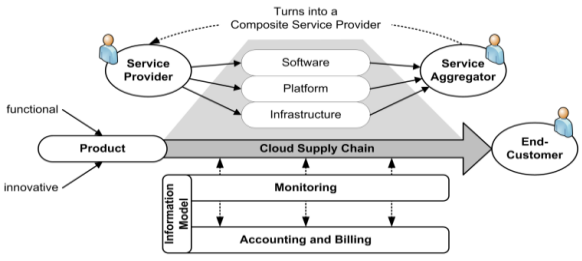


Figure 1. Components of supply chain in cloud computing

Lindner et al. (2010) classify products within supply chain based on demand patterns as functional and innovative products. There are three criteria a product must satisfy in order to be eligible for consideration as functional product:

- satisfaction of basic needs that are not significantly changed when analyzed in dependence with time;
- predictable and stable demand with low level of uncertainty and
- longer life cycles, usually longer than two years.

Functional products are good for competitiveness due to their stability which leads to lower product margin and consequences of their features are decrease in inventory costs, low diversity of products and slower obsolescence of products. On the other side innovative products are characterized by:

- feature that gives buyer incentive other than basic need to buy the product,
- unpredictable and changeable demand and difficulty in forecasting and
- short life cycle of the product, usually three to twelve months.

Innovative products require continuous innovation due to growing competitiveness but are inclined to achievement of higher selling margins for organizations. In general, products coming from new information technologies are classified as innovative products but they also have some characteristics of functional products. Cloud services have to satisfy basis user needs and increase competitiveness due to their renewability. Innovative characteristics in cloud services are represented in the fact that demand is unpredictable and there are many adjustments due to competition and changeable market needs in very short time period. Therefore, cloud services are to be classified as innovative with features of functional products. Cooperatives in supply chains are connected by data flows containing information and funds. Funds are related to payments between service provider and cloud infrastructure provider. There are several information types that are exchanged between service provider and cloud infrastructure provider, together with many sub processes in supply chain services.

According to Saideep & Aditya (2014) there are four ways how organizations may benefit from cloud technology usage related to key market trends that are redefining traditional supply chain:

1. non stabile conditions in supply chain - cloud technology contributes to quicker reaction on changes in supply chain,
2. non adequate information flow within and out of organization – organizations are required to have information flow through whole organization and by using cloud technology supply chain becomes one intelligent information net,
3. control of funds flow by digital tools – working in the cloud enables organizations higher flexibility, i.e. adjustment of their products and services,
4. end-to-end business – connected cloud enables cooperation in real time.

Cloud computing consists of several elements and these include clients, database centers and distributive servers. They also include break down tolerance, bigger availability, scalability, decreased burden for users, decreased organizational costs and on-demand services. Introduction of cloud technology helps in reducing compatibility problems when using the same platform for approach and simple access is provided, i.e. connectivity in all parts of the supply chain. Exchange of information of all participants in supply chain is ensured and cooperatives may easily be added within supply chain by using their identification marks and passwords. After that all participants are enabled to work with processes and applications on the same platform which decreases response time between participants of supply chain.

According to Animesh & Megha (2013) connectivity, technology, scalability and speed are four most important advantages of cloud technology application in digital supply chain. Picture 2 represents participants of digital supply chain and their connection that enables visibility and influence on supply chain in real time. Organizations can connect easily with their suppliers, buyers and sellers and these connected supply chain are becoming more dynamic and visible, approachable in real time, interactive and their abilities are compiled out of physical borders. Once digital supply net is connected analytics and usage of smart applications that are providing information for decision making are increased. These technologies enable supply chain managers proactive decision-making related to basic tasks. When supply net becomes connected with different new technologies it also becomes scalable which means that human resources, processes and technology are integrated and finally maximum efficiency is achieved by enabling organization to use individualized products and services. Once supply chain is built based on three previously named advantages, organizations have on their disposal higher speed of supply net and are able to successfully manage their operational tasks. More speed in planning and executing results in quicker market response and higher resources transfer within and out of organization.

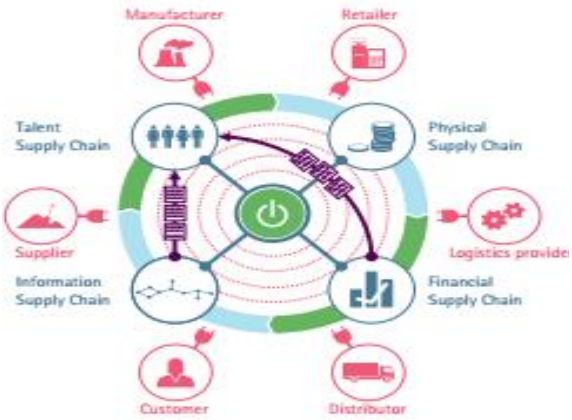


Figure 2. Advantages of digital supply chain

According to Fig. 2 (Saideep, R., & Aditya, S. 2014) one of the greatest advantages of cloud technology lies in the fact that it makes digital supply net extremely connected and therefore whole supply chain becomes very visible for all participants. Visibility is key factor in whole supply chain management and it makes whole buyer net more transparent. Systems based on cloud technology contribute to visibility of delivery in real time and improve logistic management.

Cloud technology is an important factor in changes of business process and it contributes to more efficient approach to innovative solutions for supply chain delivered through SaaS model. Organizations using applications of supply chain management, business intelligence and analysis, e-procurement, stocks management or transport management are already using SaaS solutions or setting clear strategy in order to organize their business activities in cloud surrounding. Applications of cloud technology may be divided into several activities within supply chain. The most common activities within supply chain in which cloud technology may efficiently be implemented are planning and forecasting, making catalogues, procurement and inventory management and logistics. In the context of planning and forecasting cloud platforms are designed in a manner to help organizations improve service level by coordinating participants (buyers, suppliers and distributers) that have key role in forecasting demand in the supply chain net. These platforms may collect data online, conduct basic analysis and more accurately conduct statistical forecast of demand for all participants in the supply chain. Processes in this supply chain activity lead do decrease of information asymmetry between different phases of supply chain which enables managers to be more aware of real market demand. When a buyer has certain demand, distributers are sending data into a public cloud which enables all information related to demand to visible in whole supply chain. In the context of making catalogues and procurement, cloud platforms are based on databases containing data from different suppliers and are therefore efficient for organizations that are analyzing this data. Based on this data organization can also choose those suppliers that are eligible for delivery of specified material in requested time period. In the context of logistics cloud technology is useful in inventory management, storage and transport due to the fact that it enables logistic operations tracking for more members of the supply chain. In this case integrated cloud platform offers advantages of more modern transport leading to savings in yearly cargo transport. In the context of inventory management cloud technology enables organizations to integrate logistic and adverse logistic in one closed loop in supply chain model. Radiofrequency identification technology (RFID) enables tracking of inventory location and sending this information into the cloud application. The end result of this activity is detailed insight into inventory movement visible to all supply chain participants, from manufacturer to the end user and vice versa. At the same time one cloud platform enables guarantee tracking, processing of inventory return, list of spare parts and status of reparation technicians.

Peerless Research Group (PSG) conducted a research in 2014 in companies included in logistic activities with the aim of researching changes in their habits and intentions in previous two years related to cloud software usage in supply chain. Approximately 70 % of companies included in the research responded that their software usage in supply chain has not been changed in this period, while approximately 26 % of companies named that software usage in their supply chain is in increase. These companies have also expanded their software packages in the researched period and have noticed improvement in inventory control and better transport visibility and control. The results of this research suggest that main reasons why companies are not using software solutions in higher extent are system differences and complexity of certain software integration into companies. 26 % of companies included in the research had planned to buy a new supply chain software in the year following the research and the solutions that they planned to buy or expand were Warehouse management systems – WMS, Transportation management systems – TMS and Inventory optimization applications. Approximately 17 % of companies believed that cloud technology is not the right solution for them due to security and data privacy risks, system reliability and data integrity (Jung & Kim, 2014). The combination of safety reasons, increased sensitivity to data privacy and a few private data issues have made companies very careful before starting to use cloud technology in business activities. The companies that are using and expanding cloud infrastructure are recognizing quality and related benefits of this business logistics, although they are trying to minimize the costs related to these activities, while companies that are indecisive related to cloud

technology usage in their activities have perception that information exposure and price are main disadvantages. Besides structural improvements, organizations are also reorganizing human resources that require additional learning and specialization.

Werber et al. (2015) have conducted a research in 2014 on Slovenian and Croatian micro enterprises' awareness on the cloud computing. The results were similar in both countries and suggest that the most important features of the cloud computing are reliability, safety and performance. According to this, cloud computing may present a good business opportunity for micro enterprises. The results of the research are also consistent with Rittinghouses and Ransomes (2010) research results that cloud services are useful solution for micro enterprises at the beginning when they are not able to invest in hardware and software. Most of the Slovenian micro enterprises (44 %) are interested in IaaS and then in SaaS (38,4 %) and 28 % in the full package (IaaS and SaaS). Other results are obtained on the sample of Croatian companies where most of the micro enterprises are interested in full package usage (43,1 %), while only 19 % in software solutions. No statistical differences were found.

According to Croatian National Bureau of Statistics (2015) the usage of cloud technology in Croatia is only at its beginning point and only 22 % of companies are using it in their business activity. The structure of cloud technology usage according to company size is even, i.e. there are no significant differences in its usage by small, medium or large enterprises. As for type of service, cloud technology is mostly used in business activities (37 %), service activities (27 %) and publishing and communications (19 %). According to service type in year 2015, 81 % of companies have used cloud technology for e-mail processing, 47 % for data storage and 43 % for accounting services and as office software. The company *Perpetuum Mobile* conducted a research at the end of year 2014 on 342 respondents on usage and attitudes of cloud technology users in Croatia. 55 % of respondents have pointed out that company they work in is using cloud technology. From the remaining 45 % being employed in the company that is currently not using cloud technology, 11 % have pointed out that their company has plans to introduce cloud technology into their business activity in the future. Respondents have pointed out safety (15 %), privacy (9 %), finance (7 %), lack of understanding (13 %) and lack of adequate IT skills (6 %) as main impediments to cloud technology usage in their company. Companies using cloud technology are mostly using public cloud (21 %), private cloud (19 %) and the least hybrid cloud (14 %). According to the respondents coming from the organizations using cloud technology main reasons for cloud technology usage in their business activity are: increase of business agility (36 %), safety copies (30 %) and savings (29 %). Most of companies from the sample (55 %) are conducting software integration independently in their company while 18 % are relying on their software suppliers; 14 % of companies are using service providers as third party for software integration. Decisions on procurement of new software are brought by teams within company consisting mainly of employees belonging corporate management, storage, distribution, logistics and procurement. The most important factors that influence new software procurement in logistics business sector are: compatibility with existing systems, adaptability, service and support, adequate options for certain functions, suppliers' financial stability and installation simplicity (Perpetuum Mobile, 2014).

4 Future of the cloud technology in supply chains

The most common problems occurring related to cloud technology usage in organizations are data safety and privacy problems. Often there are also problems related to age of business systems, system availability and lack of adjustment. Access to data in the cloud should be available only to members with permission, i.e. only members in the supply chain that enjoy highest trust. Unfortunately cloud systems as software product cannot always insure reliability and as therefore the risk of hacking is often present. The data hacked by other companies may impose a direct threat to the whole supply chain (Toka et al., 2013). Companies using cloud technology are often concerned on potential consequences when sudden system crash occurs because processes in the supply chain have direct impact on financial stability of the company and delays due to cloud system crash may cause significant consequences. At the same time users may have problems accessing the cloud due to bad Internet connectivity in different geographical areas.

Cloud technology has potential to create value in organizational supply chain. At the same time, it is of great importance to recognize how centrifugal forces are pushing the information technology through business activity in the whole. Organizations are increasingly starting to use cloud solutions for certain activities like net cooperation, administrative support, transport and logistics management. In the future more key technologies that shall enable more innovation in supply chain management, big and fast databases and analytics and Product Lifecycle Management (PLM) solutions are expected. Kasemsap (2015) argues that for contemporary organizations that are conducting their business activity on very potential markets, the quest for new sources of competitive advantage is necessary in order to keep it in the time of the social media age. It is

expected that applications developed in the cloud computing shall change the PLM market in the short term especially as bigger business support and in improving collection and data analysis on buyers. New generation of applications and real time data platform are penetrating the market. Data analysis that previously required hours of work will now on be available in a few seconds due to new in-memory databases. It is expected that basic analytics in supply chain will be moved into tactical analytics departments and that deeper insight into supply chain management will be enabled.

5 Conclusion

Nowadays adequate decision making is the basis for quality business activities in organizations. This process, as also the organization of people and their working activities, is simplified in case the organization is using certain type of business logistic and quality information system. One of latest and mostly developed system is cloud technology, a concept enabling networking of individuals into the system and availability of information, records, documentation and programs into the cloud. Vemula and Zsifkovits (2016) state that cloud computing is one of the most significant trends in IT industry, while according to Bhoir and Principal (2014) the value of the cloud computing lies in the fact that it is the right technology for support and management in constantly changing and dynamic net and also for supply chain management. Cloud is accessible at any time and from any location connected to the Internet and this way decision making and business activity in general are improved. Efficient supply chains are of extreme importance for many enterprises. Supply chain management has effect on operational processes, divergent and consolidated information flow and interaction processes with different business partners.

The evolution of cloud technology influences organizations and their supply chains on several ways, one of which is competitive advantage enabling start-up organizations insurance of their positioning on the market in very short term and without significant investment in infrastructure. Increase in products and services that are achieving high profits is leading to big pressure in supply chains because organizations have to launch their products and services quickly onto the market and cloud technology is of great usage in this field. Increased flow of new products and services is forcing organizations to renew their infrastructure and traditional supply chains what makes them more dynamic, scalable and supportive towards financial goals of organization. Implementation of the cloud technology in enterprises is not an easy task and therefore different tools are prerequisites for its adequate implementation with the minimum risks for the enterprise. Enterprises must use efficient decision models, risk assessment models and risk optimization models that will enable decision makers in determination of optimum investment in safety with the aim of reducing mistake costs.

As for usage of cloud technology in supply chains in Croatia, there are only a few companies using cloud technology in their business activities and most often in the field of communication and manufacture. Most common reasons for mistrust in the cloud technology include safety and data privacy which is understandable when having in mind number of participants in the supply chain that are all connected in one digital net in which important and confidential data are shared. This data availability contributes to competitive advantage by enabling quick access to information and decision making. On the other hand, certain level of safety and confidentiality may be achieved by allowing only employees with permission to access data in the cloud. Companies using cloud technology in their business activities are perceiving also financial benefits due to improved competitiveness achieved by quick reaction on consumer needs and transparent and efficient business processes. Finally, decision makers in the supply chain may use risk assessment models in order to identify risks and companies have to use risk optimization models in order to determine optimum investment and decrease mistake costs.

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Institutional Field in the Republic of Croatia: Perspective of Entrepreneurs Pertaining to Computer Programming Activities

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Abstract. *The aim of this paper is presentation of results of qualitative research oriented on attitudes of entrepreneurs on the structure of institutional field of Republic of Croatia based on the application of the Bourdieu's concept of the „field" (Bourdieu & Wacquant, 1992). Empirical data has been collected by conduction of in-depth interviews with 28 Croatian entrepreneurs registered in the activities of computer programming. The results of the research suggest that most of respondents comprehend institutional field as restraining factor in relation to fair fight within the entrepreneurial field. Most common features allocated to institutions by entrepreneurs encompass non-flexibility, slackness, passiveness, over standardization, not understanding the logic of the entrepreneurial field. All of these features together contribute to entrepreneurial emotions related to mistrust, antagonism, fear, uncertainty and disappointment with Croatian institutions.*

Keywords. Institutional field, Bourdieu's theory of practice, computer programming

1 Introduction

The activity of computer programming, consultancy and related activities (J62.0: NKD 2007.) may be considered as the „mover" of Croatian industry based on criteria of export orientation, employment capacity and income before taxes, interest and amortization (Republic Croatia, 2014a). Besides being one of rare sectors in Croatia that has had growth of gross added value and employment in period of highest economic recession, its significance is further on corroborated by projections of distinctly propulsive future due to the fact that activity of computer programming is currently in the growth phase within the life cycle of Croatian sector of professional and business services[1]. Its contribution to Croatian employment is showing a continuous upward trend, while profitability measured by gross profit margin is above average and indicates convergence to European Union average and growth rates above total Croatian economy growth in upcoming period (Republic Croatia, 2014a; Republic Croatia, 2014b). Although expectations related to future trends are highly optimistic, the intensity of their realization is hard to estimate due to the fact that it is dependent not only of market conditions and individual company factors, but also of factors related to national and local entrepreneurial surrounding. Generally speaking, entrepreneurial surrounding (no matter whether it is restrictive or seminal) presents an important aspect of realization success in all phases of entrepreneurial activity, from opportunity perception, entrepreneurial intent birth and undertaking the entrepreneurial project to management of survival process and company growth. Institutional context decomposed of macroeconomic policies, programs oriented towards entrepreneurship stimulation, physical entrepreneurial infrastructure and entrepreneurial supporting institutions is determining the level of availability and quality of entrepreneurial surrounding (Singer et al., 2016). According to recent findings of Global Entrepreneurship Monitor (GEM) Croatia cannot be satisfied with its institutional context. According to GEM data for 2016 the quality of total entrepreneurial surrounding is still significantly deteriorating when compared to the average of 21 European Union members included in the GEM project. One of Croatian especially unsatisfying results lies in the field of institutional segments of entrepreneurial surrounding, especially the ones related to government policies oriented on entrepreneurship support, regulatory framework functioning and government programs for entrepreneurs. Croatian grades in the mentioned segments of institutional context are far below

[1] According to the Croatian Financial Agency data, Croatian enterprises in the activity of computer programming, consultancy and related activities have increased number of employees by 9,9%, profit by 3,7% and export by19,9% in 2014 when compared to 2013 (Financial Agency, 2016).

satisfying what makes Croatia one of the lowest positioned European Union members. Critical areas, besides government policies and programs, also include the quality of commercial and business infrastructure and the level of administrative barriers as an indicator of market openness. Also the multiyear continuity in adversity of indicators related to efficiency of entrepreneurial ecosystem (especially segment related to government policies and programs) implies the question of responsibility for "not-doing" and indicates longevity of lost entrepreneurial chances (Singer et al., 2017).

The aim of this paper is presentation of features of the institutional segment of entrepreneurial surrounding from the perspective of entrepreneurs that operate in the activity of computer programming by holding the premise that in-depth qualitative research of entrepreneurial surrounding from different point of views of included actors may offer a rich situational diagnosis and contribute to preciseness in identification of important action areas. To be more precise, presented are the results of qualitative research that questioned entrepreneurial attitudes about the structure of Croatian institutional field by using Bourdieu's concept of the "field" (Bourdieu & Wacquant, 1992).

2 Conceptualizing the institutional field

From perspective of Bourdieu's sociology ***field*** is "a relatively autonomous sociological micro space, that is a space of objective relationships as a place of special and irreducible logic and necessity in comparison to other fields" (Bourdieu & Wacquant, 1992, p. 97). It is an dynamic play arena of its kind, the front of demolishing actors that are fighting for power featured by valuable resources (Forson et al., 2014; Fanuko, 2008). Actors are entering the field and actively playing by producing, exchanging and spending different types of resources due to belief that there is profitability of roles. The play in the field is led by desire to acquire monopoly over resources that are especially valuable in a particular field, but also by the attempt to impose its own definition of "valuable". Hence actors in the field are actually fighting for valuable resources, but also for its legitimacy. Play in the field exists as long as there is ***illusio*** – the belief of actors that the field is legitimate and that the play is worth playing (Fanuko, 2008; Swartz, 1997). Illusio of the field is actually tacit entrance compensation that field imposes to its actors and it can be considered as a set of standards and rules of world view that is common for all actors within the field (Tatli et al., 2014).

Besides competing over valuable resources, the field also connotes the logic of hierarchy. Different power distributions are producing objective membership of already established and newcomers, regnants and subregnant actors, by supposing that each of them is accepting the existing, formally treated or tacit standards and rules (Kalanj, 2002; Fanuko, 2008; Forson et al., 2014; Tatli et al., 2014). Standards and rules, although robust, are not unchangeable in their nature. Constant measurement of strengths may result with change in positions between different actors across power matrices with time. This implies that the play is then led by new regnants who are imposing their own standards and rules by demolishing current and building new logic of the field. This way field is modified (Bourdieu & Wacquant, 1992; Özbilgin & Tatli, 2011).

There are as many fields as there are interests. Some of the fields include cultural, academic, scientific or business field according to Fanuko (2008). Certain fields are better marked when compared to others and all are in hierarchical relationship. Bourdieu (1985) is comparing strengths of the art field and the business field by accenting that the latter has the tendency to be more powerful.

Being a symbol of structured space of positions, field is a concept that implies the analysis of scientific phenomena on the level of structure within relational continuum actor-structure. Therefore, the applicability of the concept is recognized in entrepreneurship research, especially in contextual analysis of entrepreneurial activity. In this sense field is suitable for operationalization in research of (regulatory, public and sectoral) framework in which entrepreneurial activity is taking place, structural positioning of key players that are influencing the shape of entrepreneurial context and research of entrepreneurial surrounding on reproduction and modification of entrepreneurial field (Tatli et al., 2014). Spigel (2013) is using the concept of the field in context of researching influence of regional culture on entrepreneurial practice and concludes that they are not solely the consequence of play in the entrepreneurial field but the result of mixing logic of multiple fields in which entrepreneurs are included. In this paper conceptual basis is in Bourdieu's theory and the aim is to understand the logic of the ***institutional field***[2] of Croatian entrepreneurs in the activity computer programming and according to this aim following research questions are formulated:

1. *What features are entrepreneurs from the activity computer programming attaching to logic of institutional field in the Republic of Croatia?*
2. *How is perception of institutional field logic influencing entrepreneurial attitudes about opportunities and limitations that institutional field is imposing to their entrepreneurial activity?*

[2] In the context of this research institutional field encompasses social space decomposed of relations between different actors responsible for shaping and operationally achieving regulatory framework within entrepreneurial activity in Republic of Croatia is being taken off.

3 Methodology

In order to research the proposed questions a methodological framework based on qualitative research approach is used. Generative data is collected by conducting in-depth interviews with 28 entrepreneurs chosen from previously defined research population[3]. The selection of participants in the sample was conducted on the mixed purposeful sampling principle (Patton, 2002) and interviews with entrepreneurs were conducted by person, mostly at the business location of the company. Final sample of participants encompasses entrepreneurs from six municipalities in different regional parts of Republic of Croatia. Before starting the interview, interviewees were given ethics declarations about using the data collected in the field research and every interview has been recorded by audio recorder. After making the transcripts, manual analysis of data has been conducted and it included editing the empirical database, determining the coding unit, conducting the open coding process, defining relevant terms and identifying categories and formulating relationship model between categories (Kletečki Radović & Kregar Orešković, 2005, according to Mesec, 1998). Open coding is analytic process of data categorization in which data is fragmented in smaller units in order to determine similarities and differences in the dataset (Halmi, 2005). This is the most often used qualitative analytics method in which codes represent "heuristic tools" that are enabling reconsideration about data by using new and different approaches (Graneheim & Lundman, 2004). After having modelled the open codes, second step in qualitative analysis has been conducted: embedding related terms in categories and organizing terms according to the abstractness level. Table 1 illustrates a coding excerpt. For the need of this analysis categorization of data has been conducted on four levels of abstractness.

4 Results

According to Fig. 1 the analysis of qualitative data has resulted in identification of 15 subcategories grouped into 3 middle categories: "*illusio* of institutional field", "reflection on entrepreneurs' emotions" and "influence of political forces".

The category ***illusio* of institutional field** represents perceptions of our interviewees related to the structure of institutional framework within entrepreneurial activity in Croatia is being set. According to related subcategories, the logic of institutional field that is featured by **non-flexibility, slackness and passiveness** and **over standardization**, is not comprehensible to market oriented agile entrepreneurial habitus. For instance, all the interviewed entrepreneurs are facing administrative barriers in relation to the institutional field actors, where they are especially revolted towards bureaucracy and slackness of local and national institutions. At the same time, entrepreneurs that have experience on the global market have the tendency to compare domicile institutional field with the ones in the other countries and they are noticing significant Croatian retrogression as for processes regarding easing institutional flexibility. Passiveness and slackness are especially seen through slowness of institutions when it comes to following contemporary trends of integrated public sector informatisation which, in pair with the need for physical attendance to certain institutions, increases the feeling of constant struggle with administrative barriers. Although this problem is mentioned by most of the interviewees, an illustrative example is statement of the interviewee I8: *…today we are „like" connected in the net. There's e-citizenship, e-services, but these services are, like, not connected one to another. If I went to Croatian Employment Bureau that is connected to the Pension system, then they should be able to see that I have, for instance, submitted request to register an employee, and not that I have to go to the Pension, go and print the request and bring it back to the Employment Bureau. We're back to nowhere…* (I8).

The source of slackness and passiveness of institutional field is seen also through **non-competence** of public institutions' employees by a significant number of interviewees and also by absence of their motivation towards adoption of contemporary IT skills according to interviewee I28 (*…and the take out from the Commercial Court, not older than six months. Do you know how this is done in Croatia? You have to write a request and send it to a certain fax machine number. I ask: Do you have an e-mail? No. Send it on the fax machine. Where do I find a fax? Who is still using this?...* (I28)).

[3] Research population is composed of directors or management board presidents of active companies registered in the Republic of Croatia whose main activity is computer programming, consultancy and related activities (NKD 2007: J62.0).

Table 1. Excerpt from open coding and grouping codes into categories

Interview excerpt	Open codes	Subcategories	Categories
[Institutions]*…are hardening. This means they are creating uncertainty. Creating the feeling of entrepreneurship criminalization because you must be aware... There are so many rules and common things that every entrepreneur that wishes the best, is every day in breach because, you know, we are coming to that. Should the building have a lightning rod or not? Should it have… You know, how many fire machines on how many meters? So every entrepreneur is always in this kind of psychosis that if some inspector comes he can always find that some paper is missing and it should have been there. Erm, and this is simply impossible to follow. Literally, it is physically impossible to follow that you are doing everything by the law, even if you have absolutely every intention of doing it.* (Interviewee I4)	- Institutional field as a hinder of entrepreneurial activity - Feeling of uncertainty due to constant regulatory changes - Fear from inspection - The inability to track regulatory changes	- The feeling of oppression - Fear and uncertainty	- **Reflection on entrepreneurs emotions**

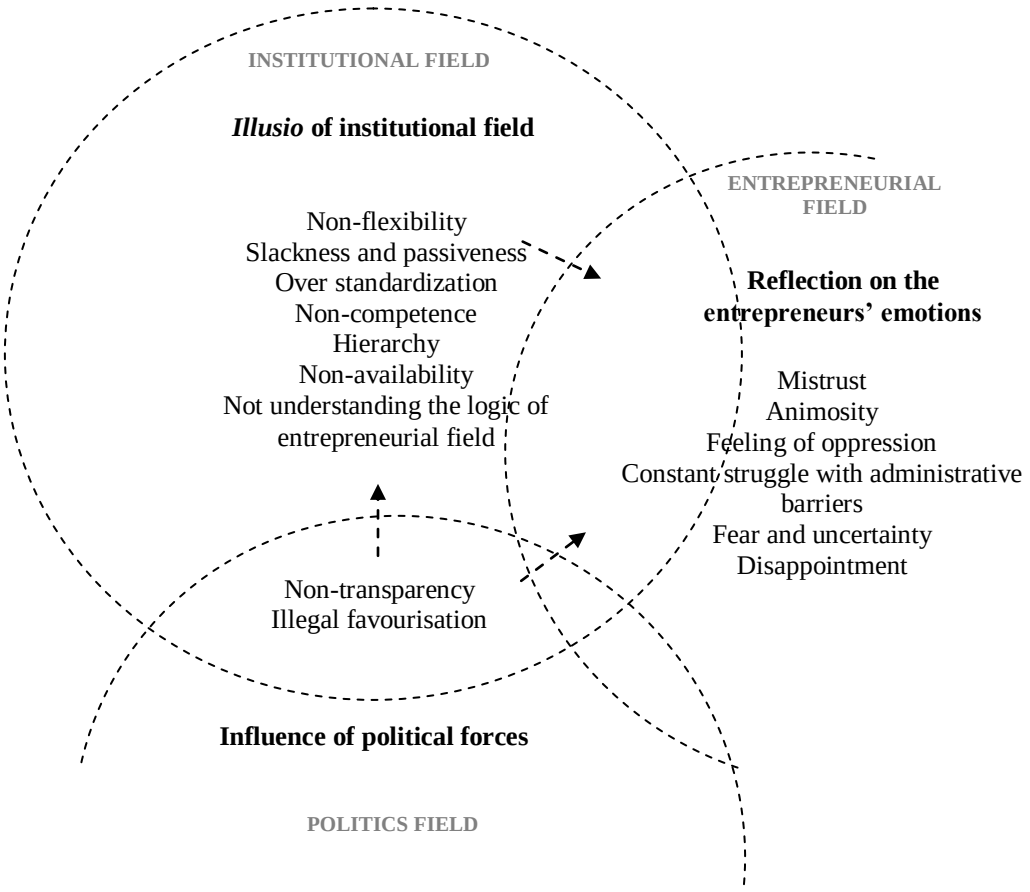


Figure 1. Relationship model between identified categories and related subcategories

Besides already mentioned, one of the features that is often associated with the institutional field by our interviewees is rigid **hierarchy**. Usually when contacting employees within institutional field entrepreneurs are reaching to instances set on lower levels of hierarchical structure. They have no authorization to decide on matters that are overcoming the operational level and are therefore not able to help entrepreneurs solve significant problem. According to interviewee I17, this sort of hierarchy hardens the communication and makes a feeling of **unavailability** of institutions to the ones they are made for (*...regulator has its own IT service that is very distant and we simply have no contact with them because we cannot reach them ...*(I17)). Interviewees have also stated that there is a slow reaction (operational and other types) on queries in communication with the actors from institutional field, multiple responsibility avoidance and ambiguous feedback.

The described structure of the institutional field is creating a distance from entrepreneurs and it is therefore not surprising that significant number of interviewees state that institutional field actors do **not understand the logic of entrepreneurship**, especially in the context of regulations that are not in compliance with realistic business environment and conditions and that they are ignoring specific needs of micro and small business entities. The latter is recognized by entrepreneurs in too strong orientation of programs and entrepreneurship activity incentives towards large business entities, where the example of Croatian Chamber of Economy and amenable Ministry is often alleged related to non-return incentives for entrepreneurs.

Further on, the category **influence of political forces** represents perceived features of institutional field that interviewees are relating to influence of the politics field on the logic of institutional field and includes two subcategories: **non-transparency** and **illegal favourisation**. These features are especially recognized in the processes of application for non-return incentives where, according to statements of some entrepreneurs, criteria related to political fitness and relationships overbears the formal criteria of project evaluation. According to interviewee I9, relationships on higher level of political hierarchy are stronger guarantee that individual goals will be achieved (*...politically, yes… purely politically. ... either local or directly related to some centerline. It usually comes from Zagreb. Here it is when we're being direct…*(I9)). Non-transparency and illegal favourisation are also recognized in public procurement processes by interviewees which, from their point of view, results in artificial distortion of fair fight within the entrepreneurial field.

The logic of the institutional field presented by the first two categories is being reflected on attitudes and feelings of interviewees towards national, regional and local institutions synthetized in the category **reflection on the entrepreneurs' emotions**. According to identified subcategories related to individual actors, i.e. institutions from institutional field, interviewees are showing **mistrust, animosity** and **a feeling of oppression**. Most interviewees do not believe that their contact or cooperation with institutions will have a positive result and they feel that institutional actors do not understand (nor want to understand) their problems and therefore perceive them as enemies that primarily have repressive instead of advisory function. These feelings are especially strong in cases when interviewees were penalized by the institutions, such as interviewee I5 who states: *…We didn't have assessment of... what's it called…of danger on the workplace, like we as an IT firm should have this. Firstly, I didn't know I should have it, I was uninformed; secondly, when I collected all that was necessary and came to the inspector and said… here, it's okay now, she rudely said to me that we'll never be okay and that she'll always find something ….* (I5)).

Further on, the result of the perception of over-standardization, slackness and non-flexibility of the institutional field is the feeling of **constant struggle with administrative barriers**, what is seen in the statement of entrepreneur who has a subsidiary in the United States of America: *…So, the difference in this bureaucracy and papers for both firms is enormous. It's huge difference. In the USA, we have a firm where we have to present one paper yearly for taxmen and that's it… And here we have each month…20 pages of papyrology and you have to bring it by person…* (I26).

Further on, constant regulatory changes and its complexity are generating a feeling of **fear and uncertainty** and it is even more accentuated by previously mentioned perceived communication problems with the actors in the institutional field. The feeling of fear generated from awe of non-conscious violation of regulation is illustrated by statement of interviewee I16: *…here you constantly have a feeling that someone will knock on your door and give you a penalty. I often said that if someone comes and charges me 500 kuna penalty, I will shut down the firm. I really don't have the need to work and try if I see that people are punished for everything instead of warning them if something isn't done properly. And I'm sure that in this moment I'm not doing correctly at least 10% ...*(I16).

The constant feeling of repression and fear and passiveness of institutions related to adjustment of entrepreneurship incentives to realistic business conditions have resulted in the feeling of **disappointment** in interviewees related to institutional contribution to the entrepreneurial field development. This feeling is so strong that some interviewees are motivated to move their business activities outside of Croatia. Disappointment is generating hopelessness and apathy related to institutional contribution to the entrepreneurial field.

As illustrated by the statement of interviewee I22: *...Croatia doesn't have a development strategy for anything so why should it have for this. You know, we depend on ourselves and the state doesn't care, we don't care* ...(I22)), these attitudes and entrepreneurs' perceptions are generating a nature of relations on the intersection of the institutional field and entrepreneurial field that is often described by entrepreneurs by syntagme "we do not need anything, just let us work".

5 Conclusion and implications

Based on the results of the analysis it is evident that the entrepreneurial and institutional field in the Republic of Croatia are closely related and that the latter has the tendency to be more powerful. From the interviewees' perspective the formal punishment penalty instrumentary gives institutional field actors symbolic advantage that is not channelized as support and help but through repressive function. Therefore, most of the interviewees consider institutional field as mechanism of distortion of fair fight within the entrepreneurial field. Non-flexibility, slackness and passiveness, over standardization and non-understanding the entrepreneurial field are the most common features attached to institutions and their employees by entrepreneurs. When the influence of political field into institutional and entrepreneurial field is considered, common features include non-transparency and illegal favourisation. All of the stated contributes to emotions like distrust, animosity, fear and uncertainty and disappointment with institutions. Still, some of the interviewees (mostly younger generation) show some optimism by stating that younger generations of public institutions employees are not satisfied by this kind of field structure and are declining to reproduce it. According to these interviewees, the young generation is a carrier of positive processes and transformation of institutional field that, although slowly, still has impact on institutions' efficiency increase.

As for implications for entrepreneurship incentive policies and self-employment policies, the improvement area is recognized in advisory measures system that interviewees believe to be an efficient method for entrepreneurship incentive when compared to direct financial support for entrepreneurs. Also, interviewees are indicating the need for urgent integrated informatization of public sector that would enable exchange of all documents electronically (including exchange and database sharing between different institutions within the system). This kind of system would significantly contribute to decrease in the level of administrative barriers and increase the perceived efficiency of the field. Finally, according to interviewees' attitudes, Croatia should take example of good practice (especially the ones from Germany and Austria) and enhance the system by simplifying regulatory framework, more efficient communication with entrepreneurs and easing the repressive actions. For instance, instead of giving financial penalties immediately, entrepreneurs are suggesting measures of previous warning and counseling when non-compliance with accounting, tax or other regulation is present. This would contribute to decrease of entrepreneurs' feeling of mistrust towards institutions and would decrease constant fear of being non-complied with regulations.

Finally, it should be mentioned that attitudes presented in this paper are not subjective perceptions of the researcher, but are based on the statements of most of the interviewees. The stated attitudes and perceptions are shaped solely by taking into account entrepreneurial perspective therefore further research should take into consideration perceptions of other key actors, like employees in public institutions and actors in the field of politics.

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Selected Structural and Business Indicators in Manufacturing, Trade and Information and Communication Activities in the Republic of Croatia

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Abstract. *The aim of this paper is to determine structural and business differences and specificities of manufacturing industry, trade and information and communication activities in the Republic of Croatia. Therefore, descriptive analysis of selected structural and business indicators has been conducted (minimum efficient size, market concentration and capital intensity) for manufacturing industry, trade and information and communication activities according to the company size and for time period 2008-2015. Databases of Financial agency have been used as a data source. The results of conducted analysis indicate that in the context of total income, minimum efficient size is, as expected, most significant in manufacturing industry, following is trade and then information and communication technology. The information and communication technology activities are characterized by highest concentration and capital intensity and following is manufacturing industry and then trade. The trends of selected indicators movement are indicating decrease in minimum efficient size, concentration coefficients (except in trade) and capital intensity of analyzed activities in selected time period.*

Keywords. Structural and business indicators, manufacturing industry, trade, information and communication

1 Introduction

This paper is oriented on analysis of state and movement of selected structural and business indicators in manufacturing industry, trade and information and communication technology in the Republic of Croatia. The motivation for selection and analysis of business subjects in manufacturing industry, trade and information and communication technology is determined primarily by their significance for the Croatian economy. According to financial data analysis of Croatian companies that are obliged by the profit tax regulation (banks and insurance companies are excluded), three of the most significant activities in Croatian economy are manufacturing industry, trade and information and communication technology (Financijska agencija, 2009). The named activities are participating by more than 50% share in total business results (number of companies, employee number, income, expenses, earnings after taxation, loss after taxation, net profit, investment) which is constant when analyzing year 2012 and 15 years backwards. As shown on **Pogreška! Izvor reference nije pronađen.**, in 2008 the named activities have participated by 46,17% in total number of companies, by 53,71% in total number of employees, by 65,37% in total income, by 65,56% in total expenses, by 56,71% in earnings after taxation, by 52,65% in loss after taxation and by 60,85% in total net profit (Financijska agencija, 2009). When analyzing investment in new long-term assets the selected activities took part by 39,52% (Financijska agencija, 2015). In 2014 selected activities encompassed 41,51% of total number of companies, 52,53% of all employees, 63,82% of all income and 63,66% of all expenses, 48,15% of earnings after taxation and 34,23% of loss after taxation and 84,07% of total net profit (Financijska agencija, 2015). Additionally, 43,88% of new long term assets of the economy has been invested (Financijska agencija, 2015).

In continuation, according to the latest available data of Croatian Bureau of Statistics, manufacturing industry and trade are two activities with highest gross added value in 2015 (Croatian Bureau of Statistics, 2017). To be more precise, gross added value in manufacturing industry for 2015 amounts 42.372 million kuna (12,63%), and trade 33.180 million kuna (9,89%) (Croatian Bureau of Statistics). Gross added value of information and communication activities amounts 12.335 million kuna (3,68%) (Croatian Bureau of Statistics, 2017).

Further on in this paper, methodological framework of the paper and analysis of selected structural and business indicators (minimum efficient size, market concentration, capital intensity) for manufacturing industry, trade and information and communication activities will be presented. This

analysis will lead to conclusion related to character, similarities and specificities determination for the analyzed activities.

2 Methodological framework of the research

The research sample consists of companies registered in the Republic of Croatia in one of the following activities according to National Classification of Activities 2007: C (Manufacturing), G (Wholesale and retail trade; maintenance and repair of motor vehicles) and J (Information and communication) and the companies that are present in the Financial agency database in time period 2008 - 2015. Planned time horizon for the research encompasses eight years (2008-2015). The selection of this time period is primarily the result of the fact that it is the longest and nearest time period with available and comparable data on manufacturing, trade and information and communication activities according to National Classification of Activities 2007 on companies registered in Croatia. The boundedness on time period after 2007 is the result of discontinuance in data time series caused by methodology audit regarding statistical application of national classification of activities dating in year 2007 and that is applicable from January 1, 2008.

Used dataset originates from Financial agency database and it encompasses time period 2008-2015 and data on number of employees, total income and long-term assets. These data were then used in order to calculate the selected structural and business indicators: minimum efficiency size, concentration coefficients (C4, C8, C50 and HHI) and capital intensity coefficients for certain activity, company size category and in a certain year. The analysis of selected structural and business indicators of the selected activities by year and company size has been conducted by using descriptive statistics.

3 Minimum efficient size

The minimum efficient size is characteristic of activities that is used as a measure of sunk cost or as a measure of economies of scale and therefore makes entry barrier and company's survival determinant (Kovačević, & Vuković, 2007)**.** The larger economy of scale, i.e. minimum efficient size, the smaller the probability of new company survival due to the cost deficiencies for entrants that are operating on suboptimal level (Audretsch, 1995). But on the markets on which companies lesser than minimum efficiency size make larger share in activities population, newer companies may have larger chance for survival, although there is a lack of empirical evidence (Mata, & Portugal, 1994).

Distribution of total income for companies belonging to selected activities is asymmetric (positively asymmetric) minimum efficiency size is calculated as a median of total income for companies in specific activity in certain year. Calculated minimum efficiency size according to the activity, company size and year is shown in **Pogreška! Izvor reference nije pronađen.**. The results of the calculation are indicating that minimum efficiency size is, as expected, highest in manufacturing, following is trade and then information and communication technology. The average of minimum efficiency size (median of total income) for eight years in the sample (2008-2015) in manufacturing industry amounts 687.767 kuna of yearly total income of the company. In trade this indicator amounts 485.569, and in information and communication activities 281.542 kuna of yearly total income of the company. It is understandable that in all three activities minimum efficiency size is the highest in larger companies, following are medium sized and finally small companies. Average eight-year minimum efficiency size in large companies is the highest in trade (512.250.674 kuna), following is manufacturing (370.926.267 kuna) and finally information and communication activities (342.544.191 kuna). In category of medium-sized companies the indicator is also highest in trade (102.850.462 kuna), following is information and communication activities (98.795.616 kuna) and finally manufacturing (63.174.464 kuna). The highest average eight-year minimum efficiency size in category of small companies is characteristic of manufacturing (600.595 kuna), and following are trade (462.721 kuna) and information and communication activities (273.578 kuna).

The analyzed results are leading to suggestion that aggregately in three selected activities, minimum efficiency size is the smallest barrier to entrance of new companies, i.e. it represents the highest survival chance in information and communication activities. It is somewhat harder to enter and survive in trade and most difficult in manufacturing. In continuation, when having on mind the company size, the hardest entrance and survival chance in category of large and medium companies is in trade, while entrance and survival in category of small companies are the hardest in manufacturing. In category of large companies according to entrance barrier and survival chance, following are manufacturing and information and communication activities; in category of medium-sized companies' information and communication and manufacturing, whilst in small companies' trade and information and communication activities.

When comparing minimum efficiency size in the beginning and final point of the analyzed time horizon (2008-2015), it can be concluded that aggregately this indicator is in decrease in all three activities (C: -25,00%; G: -30,77%; J: -28,15%). The latter is indicator of a general trend of easier entrance and survival chance for companies in selected activities. The highest relative decrease of minimum efficiency size is observed in trade (-30,77%), and it is

determined by decrease of minimum efficiency size in category of small (-30,39%) and large (-10,00%) companies and by increase in minimum efficiency size in middle-sized companies (1,14%). In continuation, in information and communication activities aggregate minimum efficiency size in 2015 is by 28,15% lesser than in 2008. Decrease of minimum efficiency size can be observed in all categories of companies by size (small: -28,08%; middle-sized: -9,40%; large: -17,78%). Significant decrease of minimum efficiency size is observable also in manufacturing (-25,00%) where the cause for this decrease lies in decrease of minimum efficiency size in category of small companies (-23,12%), and growth in category of middle-sized (3,34%) and large companies (19,45%). Finally, it is observable that only in category of small companies' minimum efficiency size is in decrease in all three analyzed activities.

4 Concentration and activity structure

The level of activity concentration usually represents determination of number and relative size of companies within the activity and as such it is an important structural variable of certain activity (Tipurić, et al., 2002). This indicator enables differentiation of activities' structures, i.e. definition of basic shape of activities' structure. If structure of buyers is included, it enables also the differentiation of basic shape of the market structure (Tipurić, et al., 2002). Besides already mentioned, the concentration level is, according to several authors, an important factor used for explanation of higher or lesser efficiency in different activities (Tipurić, et al., 2002).

Therefore, competitive structure of certain activity, when measured by concentration level, may range from strongly fragmented to highly consolidated (Tipurić, et al., 2002). Consolidated activities, i.e. activities with larger concentration level have smaller number, i.e. one or a few companies that are controlling higher share of total sales in certain activity (Tipurić, et al., 2002). Main feature of this type of activity structure is accentuated interconnectedness between companies that is seen in the fact that actions of one company are influencing profitability and market shares of other companies (Tipurić, et al., 2002). According to certain hypotheses, the more concentrated the activity, the higher is the chance that companies pertaining to it will recognize its mutual dependence and will not encourage strong competition that may lead to decrease of profitability for all (Tipurić, et al., 2002). Fragmented, atomistic, i.e. non-concentrated activities are characterized by larger number of relatively small companies with approximately same smaller sales share (Tipurić, et al., 2002). Therefore, no company holds significant market share and is therefore not dominant nor has the power to influence the movements in certain activity (Tipurić, et al., 2002). Moreover, the larger the number of companies, the lesser is their market share and weaker influence on total movements in the activity (Tipurić, et al., 2002). The companies in this type of activity are usually accepting the price dictated by the market and this is the price that is minimizing or removing the economic profit (Tipurić, et al., 2002). Features that are influencing the fragmentation of the activity include: low overall entrance barrier, the lack of economies of scale and learning curve effect usage, high transportation or stock costs, sudden sales fluctuations, weak position towards buyers or suppliers, diversity in the market need, high product differentiation especially based on image, small exit barriers, youth of the activity and others (Tipurić, et al., 2002). The strategy of cost minimization is often the most suitable strategy in fragmented activities and its purpose is to increase profit scissors that are captured by low prices (Tipurić, et al., 2002).

Concentration of the activity, i.e. market power, may be measured differently. In this paper two indicators are used for quantification: concentration coefficients, i.e. concentration shares for 4, 8 and 50 biggest companies in the activity (C4, C8 and C50) and Herfindahl-Hirschman index (HHI). It is generally considered that non-concentrated (fragmented) activities have HHI lesser than 1.000, and highly concentrated activities HHI 1.800 and higher (Tipurić, et al., 2002). On the other hand, it should be noted that real concentration is lower than the measured one since the data includes only domestic production whereas export is excluded (Samuelson, & Nordhaus, 2011).

Pogreška! Izvor reference nije pronađen. shows concentration coefficients C4, C8 and C50 and Herfindahl-Hirschman index of selected activities for each year in the analyzed period. All analyzed concentration indicators are suggesting that it is the least in trade and highest in information and communication activities. The market concentration in manufacturing is in between. When observing C4 the eight-year average in trade amounts on average 11,58%, in manufacturing 20,72%, and in information and communication 46,40%. The concentration of first eight companies in the activity (C8) is also indicating the least concentration level in trade, 16,38% on average, and following are manufacturing with 25,86% and information and communication with 53,08%. The market shares of 50 largest companies in trade amounts 37,61%, in manufacturing 47,94%, and in information and communication 73,95%. Finally, average HHI amounts: G: 69,54; C: 268,00; J: 834,94.

These results are suggesting that all three activities may be considered non-concentrated, i.e. fragmented, where trade and manufacturing are marginally strongly fragmented, while information and

communication activities are not. Since four largest companies in information and communication activity are covering more than 40% of the market (in period 2010-2015) this activity may be considered oligopolistic (Hrvatski telekom d.d.; Vipnet d.o.o.; Hrvatska radiotelevizija i Tele2 d.o.o.)[1]. Higher concentration ratios in latter may lead to measures of retaliation towards new companies and decreased survival chance, while on the other hand high concentration level allows companies to collect higher price-cost relations which should lead to survival probability (Kovačević, & Vuković, 2007). One of the evidence for this lies in increased number of small and medium-sized companies that are neutralizing dominance of large companies in information and communication activity.

In continuation, although movements of concentration coefficients are not consistent in analyzed period for selected activities, when comparing years 2008 and 2015 it can be concluded that trade developed into more concentrated and manufacturing and information and communication less concentrated. Trade, as the least concentrated between analyzed activities, is characterized by increase in all coefficients when comparing 2015 to 2008: (C4: 44,71%; C8; 44,19% C50: 22,94%; HHI: 80,25%). As opposed to this, in information and communication activity, as the most concentrated, the concentration in 2015 is significantly lower than in 2008 (C4: -27,35%; C8; -17,80% C50: -9,15%; HHI: -25,49%). Finally, manufacturing is in 2015 also more fragmented than in 2008 (C4: -10,35%; C8; -6,91% C50: -5,03%; HHI: -28,70%).

5 Capital intensity

Capital intensity, i.e. ratio of capital and labor, is characteristic of activities that may be treated as measure of sunk cost and entrance and exit barrier and consequently survival and profitability determinant of the company (Kovačević, & Vuković, 2007). In activities in which begin of the business activity requires high begin capital the probability of barrier is higher (Kovačević, & Vuković, 2007). Capital intensity is also a significant determinant of survival and profitability of the company. The results of the research conducted by Tveterås and Eide (2000) and Doms et al. (1995) are indicating negative connection between capital intensity and failure risk. Consistent with latter, Audretsch (1995) and Agarwal, & Gort (2002) are arguing that the level of capital intensity on the level of activity is negatively related to the failure rate. One of the possible solutions lies in the fact that companies that have higher capital-labor ratio usually have lower ratio of variable and fixed costs, i.e. higher level of sunk costs which makes it more probable for the company to survive (Kovačević, & Vuković, 2007).

Pogreška! Izvor reference nije pronađen. shows capital intensity coefficients according to activity, company size and year. The capital intensity coefficient indicates the share of constant funds of certain activity in constant funds of the economy according to employee share in certain activity in total national employment (Kovačević, & Vuković, 2007). Coefficient higher than 1 indicates that company is capital equipped above economy's average and lesser than one indicates it is capital equipped below economy's average. Based on insights arising from **Pogreška! Izvor reference nije pronađen.** it is evident that, except for large companies in information and communication activity, no other category has capital intensity coefficient higher than one which suggests that manufacturing, trade and information and communication activities are below average when capital equipped is concerned. This feature is significant entrance determinant, but not also the survival determinant. Aggregately highest capital intensity coefficients are present in information and communication activity, following is manufacturing and then trade. Average values of capital intensity coefficients are as follows: J: 0,74; C: 0,58 and G: 0,50. The latter are indicating that information and communication is covering 74% of share in economy's employment by its share in total value of constant funds, manufacturing 58% and trade 50%. Highest coefficients of capital intensity in information and communication and in manufacturing have been present in 2008 (J: 0,95; C: 0,62) and in trade in 2009 and 2010 (0,55). The lowest capital intensity coefficients are observed at the end of the analyzed period which indicates a general decrease trend (J 2014: 0,67; C 2015.: 0,54; G 2015.: 0,46). The latter is noticeable also in categories of companies by size.

It is understandable that small companies in all three activities have lowest capital intensity coefficients, following are middle-sized companies and then the large ones. What is interesting is the fact that the order according to the coefficient size of small companies is adverse to order for all companies. In small companies' category highest capital intensity coefficients are noticeable in trade (ranging from highest 0,49 in 2009 to lowest 0,35 in 2015), then in manufacturing (ranging from highest 0,34 in 2011 to lowest 0,30 in 2014) and finally in information and communication (highest 0,30 in 2008 to lowest 0,18 u 2015). Further on, more significant variations of capital intensity coefficient for middle-sized companies are making it impossible to be consistent in ranking. Middle-sized companies in trade have at the same time highest and lowest coefficient (2010.: 1,04 and 2012.: 0,43). As for middle-sized companies in the information and communication activity its movement is in range from highest 0,84 in 2011 to

[1]According to McConell, & Brue (1996) activity is oligopolistic when 4 competitors on the market are controlling more than 40% of the market.

lowest 0,53 in 2014, while companies in manufacturing have the highest in year 2009 (0,63) and the lowest in 2015 (0,45). Finally, the ranking of large companies in analyzed activities by the capital intensity coefficient follows the ranking of all companies. This means that in category of large companies, highest coefficients are observed in the category of information and communication (average value: 1,45), following is manufacturing (average value: 0,92) and finally trade (average value: 0,66). The highest capital intensity coefficients in large companies have been detected in 2008 (J: 1,95; C: 0,98; G: 0,73) and lowest are as follows: J 2010: 1,28; C 2015: 0,87; G 2009, 2010, 2011, 2013 and 2015: 0,64.

As previously mentioned it can be observed that there is a general trend of decrease in capital intensity coefficients in all of the analyzed activities, both aggregately and individually. Relatively, highest decrease is noticed in year 2015 when compared to the year 2008 in information and communication activity (-28,14%), following is manufacturing (-11,69%) and then trade (-8,80%). Decrease in capital intensity in information and communication activity is determined by decrease of constant funds in total economy funds share (-8,72%) and growth of employment share in total economy's employment (27,03%), while in trade the result is determined by relatively higher decrease of constant funds in total economy funds share (C: -15,65%; G: -16,16%) when compared to decrease of employment share in total economy's employment (C: -4,49%; G: -8,08%).

In information and communication relatively highest decrease of capital intensity is observed in small (-39,13%) and then large (-23,80%) and middle-sized companies (-12,36%). The decrease in capital intensity of small and large companies has been caused by decrease in their share of constant funds in total constant funds of the economy (small: -19,29%; large: -8,26%) and increase of employment share in total economy employment (small: 32,59%; large: 20,39%). When middle-sized companies are concerned, the latter is the result of higher increase of their share in employment (23,69%) when compared to growth of share in constant funds (8,41%). Adversely when compared to information and communication, the decrease of capital intensity coefficient in manufacturing is the result of relatively highest decrease of the coefficient in large companies (-12,12%), after which following are middle-sized companies (-6,71%) and finally the small ones (-1,52%). The decrease of capital intensity coefficient in large and middle-sized companies is the result of relatively higher decrease of constant funds share in total constant funds of the economy (large: -22,79%; middle-sized: -12,03%) when compared to decrease of employment share in total economy employment (large: -12,14%; middle-sized: -5,70%), while in the small companies this is the result of smaller increase of constant funds share in total economy funds (2,46%) when compared to increase of employment share in total economy employment (4,04%). Finally, relative decrease in capital intensity in trade in 2015 in comparison to 2008 is most significant in the category of middle-sized companies (-16,29%), following are large companies (-13,00%) and finally the small ones (-9,56%). The decrease of capital intensity coefficient in small and middle-sized companies is determined by relatively higher amount of decrease of constant funds share in total economy constant funds (small: -24,25%; middle-sized: -29,75%) in comparison to the amount of employment share decrease in total economy employment (small: -16,24%; middle-sized: -16,07%). For large companies the latter coefficient is the result of decrease of constant funds share in total constant funds of the economy (-2,07%) and growth of employment share in total economy employment (12,55%).

6 Conclusion

When starting the analysis from the point of total income value, the minimum efficiency size is, as expected, the highest in manufacturing, following is trade and afterwards information and communication. When comparing the minimum efficiency size in years 2015 and 2008, it is observable that aggregately its value is in decrease in all of the three analyzed activities which is an indicator of a general trend of easier entrance to the market and higher survival probability for companies in analyzed activities.

In continuation, market concentration is the highest in information and communication, following is manufacturing and finally trade. At the same time, manufacturing and trade can be considered marginally very fragmented, while this is not the case for companies pertaining to the information and communication activity. The trend in concentration coefficients movement leads to the suggestion that trade is the most concentrated and manufacturing and information and communication are more fragmented when comparing year 2015 to the year 2008.

Finally, all of the analyzed activities are, except large companies pertaining to the information and communication activity, when comparing to the economy average, under average when capital equipment is concerned. This is one of significant determinants for the market entry, but not for survival. Aggregately, activities ranking according to the level of capital intensity is equivalent to ranking based on the level of market concentration. Capital intensity is dominant in information and communication activity, following is manufacturing and finally trade. According to the decrease of minimum efficiency size and concentration level (except in trade) in analyzed time period, generally it may be observed that decrease in capital intensity coefficient is present in all three analyzed activities, both aggregately and by company size.

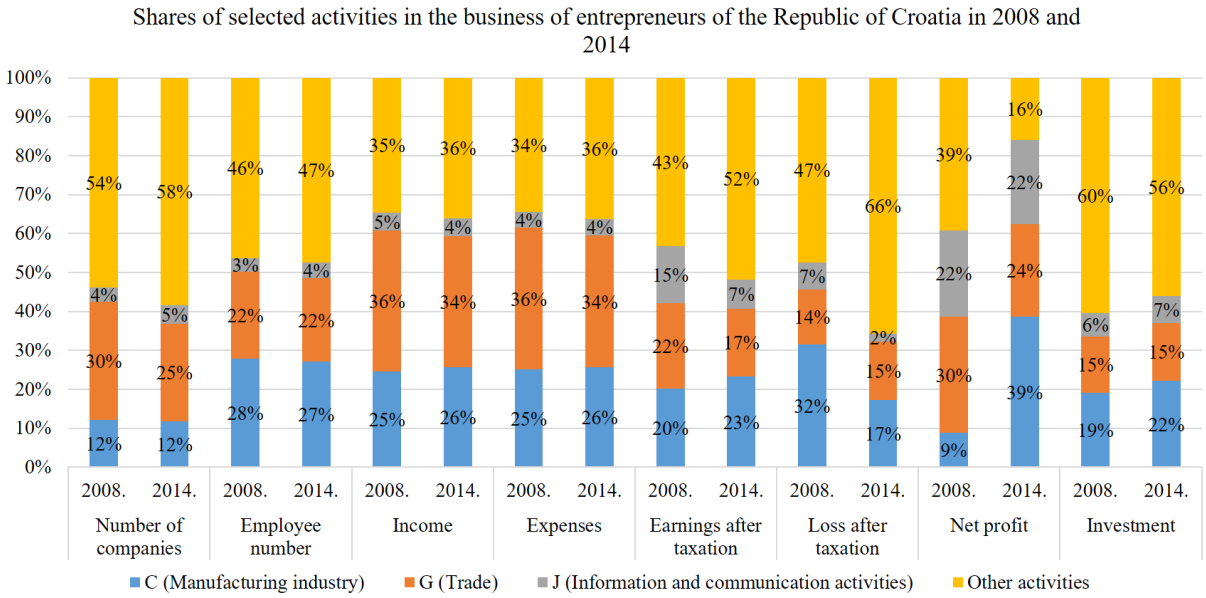


Figure 1. Share of selected activities in the business of entrepreneurs of the Republic of Croatia in 2008 and 2014 (Work of authors according to Financijska agencija (2009) i Financijska agencija (2015))

Table 1. Minimum efficient size according to the activity, company size and year (Authors calculation according to data purchased from the Financial Agency) in 000 kuna

Activity	Company size	2008	2009	2010	2011	2012	2013	2014	2015	Average values for period
C (Manufacturing industry)	small	770.675	672.973	572.915	572.685	562.546	529.386	531.080	592.501	600.595
	middle-sized	69.523.368	54.462.761	54.962.302	62.509.572	61.535.611	62.266.777	68.291.948	71.843.370	63.174.464
	large	362.877.765	337.328.225	343.835.192	387.085.105	359.295.736	361.242.761	382.305.652	433.439.698	370.926.267
C total		898.618	783.148	647.994	642.856	650.586	599.465	605.465	674.003	687.767
G (Trade)	small	638.644	513.706	447.188	424.812	421.066	408.052	403.756	444.542	462.721
	middle-sized	111.994.826	84.077.617	92.849.210	103.548.675	102.510.076	108.290.162	106.256.972	113.276.158	102.850.462
	large	590.828.879	447.769.141	509.477.801	513.285.053	477.959.951	509.641.406	517.305.760	531.737.400	512.250.674
G total		671.688	544.443	469.423	443.183	442.654	425.909	422.262	464.993	485.569
J (Information and communication activities)	small	372.035	320.737	264.615	250.512	245.143	235.956	232.055	267.572	273.578
	middle-sized	103.801.449	96.114.016	100.471.784	113.673.727	90.097.573	103.160.126	88.999.930	94.046.324	98.795.616
	large	402.817.104	360.935.541	295.228.824	338.416.583	328.107.054	355.725.379	327.923.871	331.199.172	342.544.191
J total		381.475	330.062	272.725	257.905	252.516	244.111	239.465	274.077	281.542

Table 2. Concentration coefficients and Herfindahl-Hirschman index according to the activity and year (Authors calculation according to data purchased from the Financial Agency)

Acitivity	Concentration indicator	2008	2009	2010	2011	2012	2013	2014	2015	Average values for period
C (Manufacturing industry)	C4 (%)	20,06	18,15	21,55	22,40	22,20	21,98	21,48	17,98	20,72
	C8 (%)	25,01	23,16	26,47	27,97	27,58	26,85	26,53	23,28	25,86
	C50 (%)	46,90	45,51	49,73	50,76	51,48	48,04	46,58	44,54	47,94
	HHI	259,97	197,91	282,15	319,52	307,34	307,89	283,83	185,35	268,00
G (Trade)	C4 (%)	8,69	9,39	11,65	12,57	13,05	12,74	11,95	12,58	11,58
	C8 (%)	12,48	13,33	16,29	17,32	18,09	18,29	17,21	18,00	16,38
	C50 (%)	32,31	34,02	37,31	38,80	39,75	40,05	38,95	39,72	37,61
	HHI	45,94	55,20	67,19	73,06	78,97	77,98	75,22	82,80	69,54
J (Information and communication activities)	C4 (%)	52,27	49,19	50,41	47,61	46,67	44,57	42,49	37,98	46,40
	C8 (%)	58,89	56,68	55,89	53,08	52,77	50,53	48,40	48,41	53,08
	C50 (%)	77,38	75,85	75,42	74,58	74,67	72,70	70,70	70,30	73,95
	HHI	906,87	726,73	1.077,45	953,72	882,69	773,16	683,19	675,70	834,94

Table 3. Capital intensity coefficients according to activity, company size and year (Authors calculation according to data purchased from the Financial Agency)

Activity	Company size	2008	2009	2010	2011	2012	2013	2014	2015	Average values for period
C (Manufacturing industry)	small	0,33	0,31	0,32	0,34	0,32	0,32	0,30	0,32	**0,32**
	middle-sized	0,48	0,63	0,61	0,50	0,47	0,47	0,48	0,45	**0,51**
	large	0,98	0,91	0,90	0,94	0,93	0,93	0,89	0,87	**0,92**
C total		0,62	0,61	0,60	0,59	0,57	0,56	0,55	0,54	**0,58**
G (Trade)	small	0,38	0,49	0,37	0,39	0,39	0,39	0,38	0,35	**0,39**
	middle-sized	0,56	0,61	1,04	0,52	0,43	0,45	0,44	0,47	**0,56**
	large	0,73	0,64	0,64	0,64	0,68	0,64	0,67	0,64	**0,66**
G total		0,51	0,55	0,55	0,48	0,49	0,48	0,48	0,46	**0,50**
J (Informacije i komunikacije)	small	0,30	0,23	0,23	0,22	0,22	0,23	0,21	0,18	**0,23**
	middle-sized	0,63	0,59	0,60	0,84	0,69	0,54	0,53	0,55	**0,62**
	large	1,95	1,49	1,28	1,31	1,32	1,41	1,37	1,48	**1,45**
J total		0,95	0,81	0,71	0,70	0,71	0,72	0,67	0,68	**0,74**
Total small companies		0,35	0,39	0,34	0,35	0,35	0,35	0,33	0,32	**0,35**
Total middle-sized companies		0,51	0,62	0,75	0,52	0,47	0,47	0,47	0,46	**0,53**
Total large companies		0,95	0,86	0,83	0,86	0,86	0,85	0,84	0,82	**0,86**
Total		0,59	0,60	0,59	0,55	0,54	0,54	0,53	0,52	**0,56**

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Cluster Analysis of Research and Development Expenditure in EU

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Abstract. *Most authors agree that innovations increase country's competitive advantage. One of the aims of investing in research and development (R&D) is stimulation of increased innovative efficiency of the economy. European Union is encouraging its member states to invest 3% of their GDP into R&D. In this paper cluster analysis has been conducted and the results indicate that, when analysing expenditure for R&D and national competitiveness measures, Croatia is in the same cluster as Bulgaria, Greece, Hungary, Poland and Romania. Further analysis indicates that these countries are investing in research and development less than the European Union average.*

Keywords. Innovation, cluster, cluster analysis, research and development

1 Introduction

Innovation is one of the sources of country's competitive advantage and therefore investment in research and development is one of the basic means to achieve growth and development of a country. National innovation effects are becoming a subject of scientific discussions and measurements and consequently different indices are developed in order to enable comparison between different countries.

The aims of this paper are to present a short overview of innovation and its significance in achievement of national competitiveness. This will be done by using cluster analysis in order to find a latent relationships between European Union member states considering certain variables. Groups of European Union member states will be identified based on expenditure in R&D and based on competitiveness measures related to innovation.

2 Theoretical framework of innovativeness

Depending on the perspective we take, innovation can be defined in different ways. Generally, innovation is a process in which creative ideas are implemented into organization (Amabile et al, 1996.). Atkinson and Ezell (2014) argue that innovation must encompass novelty and a sustainable business concept. The same authors are accenting that innovations are the key to economic growth, employment, income, better life quality and country's competitiveness.

According to Baković and Ledić-Purić (2011) innovation is the source of competitiveness of national economies, but also of organizations. The interconnectedness of innovation, economic growth and employment is also recognized by the European Union and therefore innovation is put in the centre of its strategy for growth and jobs creation. The European Union member states should invest 3% of their gross domestic product into research and development by year 2020 which would enable approximately 3.7 million jobs (European Union, 2017). Currently member states invest from 0.49 (in Romania) to 3.26 (in Sweden) according to the provisional Eurostat data for 2015 (Eurostat, n.d.).

Innovation is leading to economic growth and therefore presents the basis for global competitiveness between countries. Besides the creation of new jobs, the aim of the European Union is to become competitive towards innovative giants such as USA and Japan. The European Union sees innovation as the core of economic growth and competitive strategy.

Small and medium-sized enterprises (SMEs) are the fundament for European Union development. According to Kutnjak (2010) small and medium-sized entrepreneurship is the generator of innovation and country's economy dynamics. The same is also stated by Božić and Radas (2005) who claim that SMEs who conduct innovative activities are becoming the base for national growth. Kuratko, Morris and Covin (2011) state that the basic dimensions of entrepreneurship are seen in innovativeness, proactivity and risk taking.

Since SMEs are making 99% of all enterprises in the European Union (European Parliament, 2016), innovative SMEs are one of the main competitiveness generators in the European Union.

Rammer, Czarnitzki and Spielkamp (2009) state that investment in research and development is one of the possibilities for the creation of innovation in small and medium enterprises. According to Bečić and Dabić (2008) sectoral investment into research and development are not only economic, but also a political priority of the European Union. Having in mind all the stated about innovativeness of SMEs as the generator of competitiveness, one of the variables for measurement of investment into development of innovation is business enterprise expenditure on R&D (BERD). According to Bečić and Dabić (2008) business enterprise expenditure on R&D must result in bringing about the innovations to the market and must be oriented towards their commercialisation in order to contribute to economic growth and national competitiveness.

According to Lane (2012) higher education is also one of the economic generators and universities are critical spots of regional development strategies and innovation systems. Therefore, higher education expenditure on R&D (HERD) is another prerequisite of national competitiveness. Government intramural expenditures on R&D (GovERD) have direct impact on science and knowledge dissemination. The effect is seen in improvement of quality of life, but it is not necessarily reflected in increased productivity. Therefore, measurement of results of GovERD is often neglected (Guellec & Van Pottelsberghe de la Potterie, 2004). Conlé i Shim (2009) state that cooperation between educational and research institutions and companies should result in synergy effects and lead to quicker knowledge dissemination and commercialization of new technologies. The same is also confirmed by Kearney (2009) who sees the exponential growth of collaboration between state, business sector and universities which leads to connecting new knowledge with the development goals of the country.

Human resources in science and technology (HRST) also present one of the significant variables for measuring innovativeness. Karaman, Aksentijević, Ježić and Đurić (2008) consider that knowledge based economy efficiently uses human resources in order to encourage economic growth and development. In this case, innovations resulting from human creative intellectual input are becoming the driving force for development and a source of competitiveness. Knowledge based economies are encouraging development of environment conducive to innovation, inter alia by higher number of researchers (Karaman Aksentijević, Ježić i Đurić, 2008). Conlé i Shim (2009) compared indicators of R&D and found evidence that the developed countries not only are investing more in R&D, but they also engage higher number of scientists that work in the R&D sectors or departments.

Research and development expenditure should contribute to innovation increase and consecutively to increased national competitiveness. Measure that is most often used to compare national economies competitiveness is Global Competitiveness Index (GCI) published by World economic forum (WEF, 2017). One of its components is also innovation as a factor that significantly contributes to international competitiveness.

In recent years Global Innovation Index (GII) emerges as a leading innovation measure and a tool that governments use for evidence based decision-making. One of its aims is also to support countries in improvement of their innovation systems. Therefore, GII may be considered a control measure of country's innovation effects and a tool for its improvement. (GII, 2017)

3 Summary Innovation Index

In order to analyse innovation efficiency of the European Union member states, the European Commission is conducting research of the strengths and of the weaknesses of national innovation systems on yearly basis, which should lead to improvement of innovation activities. The result of the analysis is the so called Summary Innovation Index (SII). The framework for its measurement is based on four basic pillars that include ten dimensions and a total of 27 different indicators for measurement of innovativeness. Basic pillars and dimensions according to European Commission (2017) include:

- Framework conditions (Human resources, Attractive research systems, Innovation-friendly environment
- Investments (Finance and support, Firm investments)
- Innovation activities (Innovators, Linkages, Intellectual assets)
- Impacts (Employment impacts, Sales impacts)

This year's SII is calculated on rather changed methodology compared to previous versions (2010-2016) therefore there is no straightforward data comparability in time series.

Figure 1 (European Commission, 2017) shows the results of cluster analysis of the European Union member states according to their average innovation efficiency. The countries are classified into 4 different clusters.

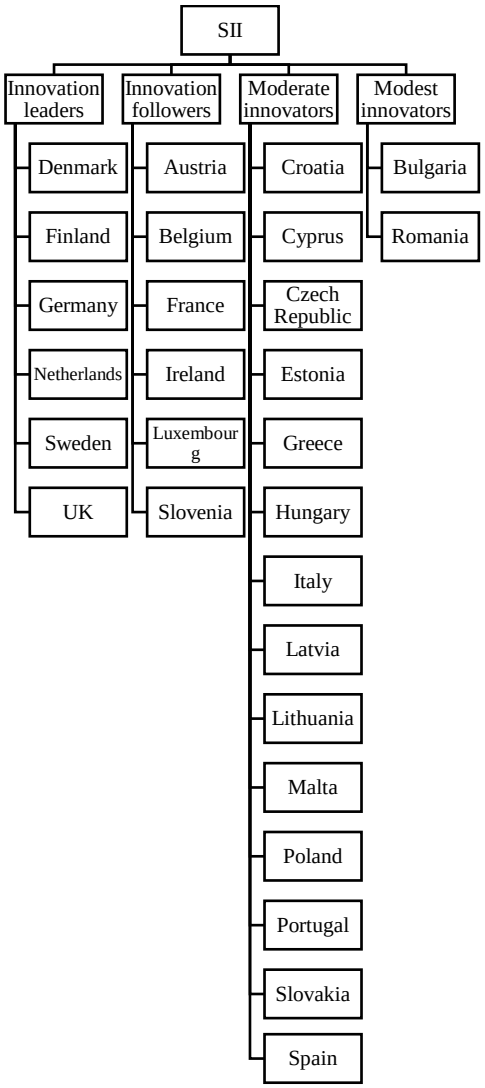


Figure 1. Classification of the EU member states according to SII

The data for calculation of SII indicators is out of date. The indicator has been used for clustering in 2016 and the time horizon of data set included in calculation ranges from 2005 to 2014. Innovation should contribute to national competitiveness improvement and it is therefore necessary to use competitiveness dimension of a certain country as a control measure and in this particular case of SII this component is missing.

4 The cluster analysis methodology

The taxonomy analysis enables clustering certain system based on multidimensionality, i.e. by using more variables for clustering. The use of taxonomy analysis is appropriate for modelling entities based on their common features (Halmi, 2016). It is used in the case when sample needs to be modelled in groups with homogenous features (Halmi, 2016).

The aim of the conducted cluster analysis is to determine groups of the European Union member states based on the homogeneity of investment in research and development, innovation and competitiveness. Other specific aims of the paper include:

a) finding a latent relationship between the European Union member states having in mind the mentioned variables,

b) determining cluster in which Croatia is included and

c) conduct a comparative analysis of countries belonging to the same cluster as Croatia.

The sample consists of 27 European Union member states. Due to the lack of data Ireland was not included in the sample. Clustering has been conducted based on the data for 2015 according to variables whose significance for this topic has been discussed in previous section of the paper:

- Business enterprise expenditure on R&D as a percentage of GDP (BERD),
- Higher education expenditure on R&D as a percentage of GDP (HERD),
- Government intramural expenditure on R&D as a percentage of GDP (GOVERD),
- Human resources in science and technology (HRST) as a percentage of active population,
- Global Innovation Index and
- Global Competitiveness Index.

Since all variables are numerical, Euclidian distance has been used as appropriate measure for similarity, i.e. for measuring distance between analysed entities. This implicates that variables are more similar when distance between them is smaller. Having in mind that similarity measures are sensitive to different measurement units, the analysis has been conducted based on standardised data. The method used is hierarchical method. In order to measure distance between certain clusters the method of maximum (method of complete linkage) has been used with the aim of ensuring highest distance between all couples in particular clusters. The results of the conducted analysis are presented in following section.

5 The cluster analysis results

Hierarchical analysis does not define exact clusters but they are assessed by the researcher. Figure 2 shows the results of the hierarchical analysis.

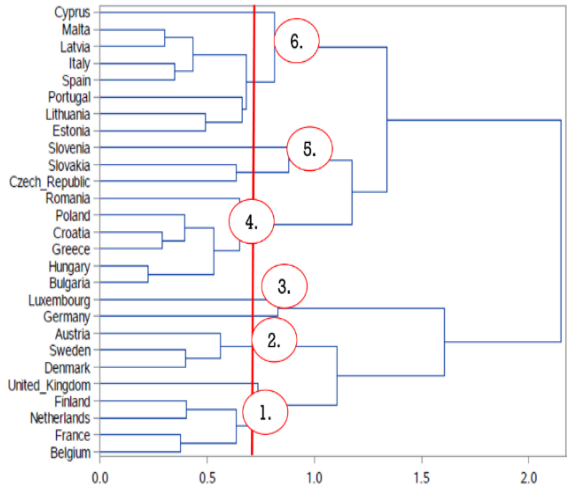


Figure 2. Hierarchical cluster analysis

The results indicate existence of 6 clusters:

- Cluster: Belgium, France, Netherlands, Finland and United Kingdom;
- Cluster: Denmark, Sweden and Austria;
- Cluster: Germany and Luxembourg;
- Cluster: Bulgaria, Hungary, Greece, Croatia, Poland and Romania;
- Cluster: Czech Republic, Slovakia and Slovenia;
- Cluster: Estonia, Latvia, Portugal, Spain, Italy, Lithuania, Malta and Cyprus.

Table 1 (Eurostat, 2017) presents an overview of data on research and development expenditure as a percentage of GDP for business and government sector and higher education sector for countries classified into the Cluster 4.

Business enterprise expenditure on R&D (% of GDP) for analysed countries is smaller than the EU average. The average of the cluster in BERD amounts to 0.53%, which is 0.77% less than the European Union average. Expenditures for analysed sector in Croatia are even smaller than the cluster average and amount to 0.44% of GDP. Lower business enterprise expenditure on R&D is present only in Greece and Romania.

Average of Cluster 4 in Government intramural expenditure on R&D (% of GDP) is also lower than the European Union average, but only by 0.02%. Greece invests 0.02%, and Poland 0.01% more than the European Union average (0.24%).

The average of analysed countries for Higher education expenditure on R&D is 0.47% of GDP. Average of cluster 4 is 0.20% which makes it less than the EU average by 0.27%. Croatia is investing even less, i.e. only 0.21% of its GDP. When compared to other countries belonging to the same cluster, Croatia is investing more than Bulgaria, Hungary and Romania.

Table 1. Expenditure on R&D % GDP

	2015.		
Country	(BERD % GDP)	GOVERD % GDP	HERD % GDP
Bulgaria	0.7	0.2	0.05
Greece	0.32	0.26	0.37
Croatia	0.44	0.21	0.21
Hungary	1.01	0.18	0.17
Poland	0.47	0.25	0.29
Romania	0.21	0.19	0.09
EU -28	1.3	0.24	0.47
Cluster average	0.53	0.22	0.20

Figure 3 shows BERD, GOVERD and HERD variables of the cluster 4 countries in relation to the European Union average and it is evident that the countries belonging to cluster 4 are investing less than the European Union average. This also results in weaker competitiveness of their economies.

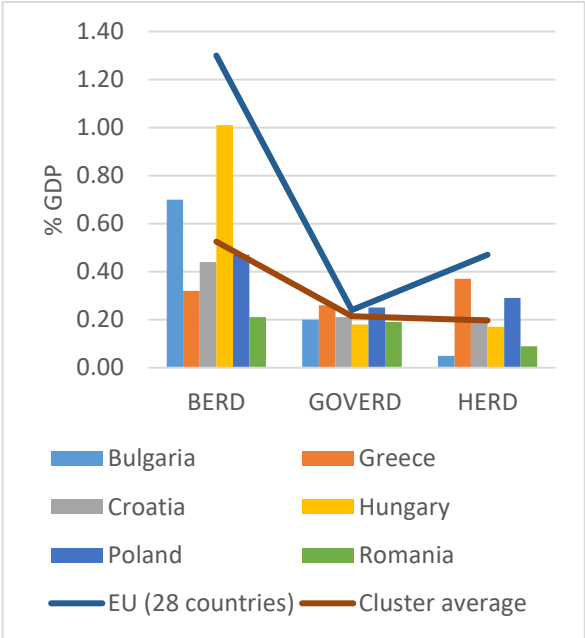


Figure 3. BERD, GOVERD and HERD for Cluster 4

7 Conclusion

Most authors agree that investment in research and development has positive impact on innovation efficiency and national competitive advantage where more emphasis is put on the investment of the business sector. The same is recognized by the European Union, who wants to improve its innovation efficiency to become more competitive compared to USA and Japan by increasing investment in research and development.

The results of the hierarchical cluster analysis on the level of the European Union indicates existence of 6 clusters based on investment in research and

development and measures of national competitiveness. The results indicate that Croatia is the most similar to Bulgaria, Greece, Hungary, Poland and Romania. The average of this cluster indicates that the named countries are investing in R&D far less than the European Union average. If these countries want to catch up more developed countries in the EU and improve their competitiveness, they should improve their innovation systems and form the environment more conducive to innovation by raising the gross expenditure on R&D. Learning by example from their more advanced co-members shouldn't be as hard considering the free movement of people, knowledge and capital within the EU.

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Intelligent Information Systems

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Agent-Based Simulation Model for Real-Time Traffic Analyses

Proposal for Developing an Autonomous Intelligent and Adaptive E-Learning System (AIAES) for Education

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Abstract. *Intelligent tutoring systems are among the most recent advances in educational technology, being recognized as powerful adaptive educational systems providing services and modules for personalized learning to students with varying backgrounds, abilities, behaviours and knowledge. Proposals are presented for construction of an Autonomous Intelligent and Adaptive E-learning System (AIAES) for education based on assignments, tasks and exercises for the improvement of information literacy.*

Keywords. e-learning systems, intelligent systems, adaptive learning systems

1 Introduction

Intelligent tutoring systems (ITS) are among the most recent advances in educational technology (Sani & Aris, 2014). ITSs are powerful adaptive educational systems, providing services and modules for personalized learning to students with varying backgrounds, abilities, behaviours and knowledge (Crockett, Latham, & Whitton, 2017).

ITSs are software systems designed to use artificial intelligence technologies to provide individualized/personalized instruction to students based on their profiles (Aparicio, De Buenaga, Rubio, & Hernando, 2012; Crockett et al., 2017; Lo, Chan, & Yeh, 2012). The goal of any ITS system is to provide an immediate and efficient solution to a student's learning problems and to help the student achieve maximum learning gain. To achieve this, ITS builds a model of the goals, preferences and knowledge of each student, and uses this model to provide a degree of intelligent assistance (Crockett et al., 2017). Each individual student is provided with the learning content and instructional methodology that best suits his or her personal needs.

The architecture of an ITS is always designed with the following principles: whom to teach (student module), what to teach (domain module), how to teach (pedagogical/instructor module) and the user-system interaction environment (interface module) (Sani & Aris, 2014). The student module is the basis for making the ITS adaptive and is responsible for managing the cognitive state by creating a student's profile that includes information such as the student personal data, preferences, current level of knowledge, etc. The instructor module is responsible for making instructional decisions related to the pedagogical aspects of learning, such as (1) correct choice of teaching methods and learning materials that best suit an individual student's profile; (2) deciding on the appropriate time to present the content; (3) assessing the cognitive state of the individual learner, and (4) deciding whether the student is able to proceed to the next learning stage.

There is a range of techniques that can be used for modelling students and instructors. In the existing literature, ITS solutions were designed and proposed based on techniques such as ontology (Grubišić, Stankov, & Peraić, 2013; Kumar, Gress, Hadwin, & Winne, 2010), neural networks (Cabada, Barrón Estrada, & Reyes García, 2011), data mining (Lin, Yeh, Hung, & Chang, 2013; Roll, Aleven, McLaren, & Koedinger, 2011), collaborative filtering (Roll et al., 2011), fuzzy logic (Dias & Diniz, 2013; Voskoglou, 2013), intelligent agents (Mikic Fonte, Burguillo, & Nistal, 2012; Yaghmaie & Bahreininejad, 2011), and Bayesian Network (Conati, 2010; Grubišić et al., 2013). Among these, Bayesian techniques and fuzzy logic have been found to be the most promising in handling uncertainty issues in modeling students and instructors (Sani & Aris, 2014).

An Autonomous Intelligent and Adaptive E-learning System (AIAES) supporting the cognitive learning approach (Dolenc & Aberšek, 2015) is planned to be developed. The work on design, testing and validation of AIAES with assignments, tasks and exercises for the improvement of information literacy (Šorgo, Bartol, Dolničar, & Boh Podgornik, 2017) among adolescents and their educators is in progress.

The project has received a three-year grant and is assigned to Universities of Maribor and Ljubljana, along with the private college of DOBA, in Maribor. The work in progress started in May 2017 and is planned to be finished in April 2021.

2 Perspectives on the application of Autonomous Intelligent and Adaptive E-learning Systems in education

Much has been said about the potential of new technologies to transform education and training, but only a handful of these statements have been supported by research or even tested by thorough scientific research. Following the initial testing of programmed instruction, Skinner believed that Learning Machines could be an excellent means to save teachers' time and facilitate their work. If a teacher relegates to the machine those learning tasks that can be mechanized, then he is free to perform the irreplaceable human tasks in the learning process (Skinner, as cited in Dolenc & Aberšek, 2015).

Learning with technology refers mostly to situations when technology is used with the purpose of encouraging learning. Today's term "learning with technology" mostly reflects what Lowyck (Lowyck, as cited in Dolenc & Aberšek, 2015) calls "a common impulse to (try to) use available technology for schooling purposes". The explosion of personal computers with the potential for internet connection in the second half of the 20th century revolutionized the way we communicate and has therefore profoundly influenced learning and teaching. At this stage we need to distinguish between two different directions: technology-oriented and learning-oriented approaches to teaching (Dumont, Istance, & Benavides, 2010). In the technology-oriented approach, the use of technology is at the center of education, enabling access to the latest technology.

What is therefore wrong with the technology-oriented approach? The major problem with this approach is that in the 20th century it underwent numerous important cycles of inflated promises, and some introductions into schools, followed by failures. We need to be aware that each system is characterized by structure and function. One without the other is incomplete and cannot be conceived. Thus, it seems that the primary problem of the technology-oriented approach is that it remains inconceivable, that technology remains self-serving, mostly because it considers neither the teacher nor the student; it is not concerned with its actual purpose or the goals of education, and it "demands" that students and teachers adjust to this technology instead of the technology adjusting to their needs.

On the other side, in the learning-oriented approach, we focus first on how people learn, and we perceive technology merely as an aid to and as a tool for learning. Therefore, it seems that technology must be adapted to the needs of both students and teachers in order to create suitable methods for working with it and a suitable pedagogical approach (innovative one-to-one pedagogy) (Aberšek, Borštner, & Bregant, 2014). In short, the majority of yesterday's optimistic forecasts about the influence of educational technology on education have not come true. Taking into account these previous disappointments, in teaching with technology we must strive for an approach aimed towards the students; moreover, the student and his experience need to be placed at the center of the educational process (Dumont et al., 2010). In short, we can agree that in traditional methods of e-learning (in the technology-oriented approach), the individuality of the student is omitted (Dolenc & Aberšek, 2015). The majority of traditional e-material does not consider the varied parameters that influence the learning and learning habits of the individual; because of this, students cannot influence the course of their own learning (Picciano, Saba, as cited in Dolenc & Aberšek, 2015). Autonomous Intelligent and Adaptive E-learning Systems (AIAES) are a generation of new learning systems that include the individuality and personality of the student in the learning process, similar to what happens in a traditional individualized lesson with one teacher and one student. This traditional human tutoring process has proven successful and has represented the most efficient method of learning and teaching since the beginning of teaching.

Fletcher's study has provided some reference points for all future research that deals with evaluating the effectiveness of e-learning systems (Fletcher, 2003). On the basis of meta-analysis of research from this field, he classified and calculated effect size for different e-learning systems. For calculating an e-learning system's effectiveness, he used the distribution theory of the Glass estimator of effect size. The results of Fletcher's research show that modern Autonomous Intelligent and Adaptive E-learning Systems are around 1.05 sigma better than conventional classroom teaching, which however, is still less than 2 sigma, the difference that Bloom measured between tutorial instruction (one-to-one tutoring) and conventional classroom teaching. This difference of 2 sigma (2 standard deviations) was the foundation for all subsequent research in the field of e-learning. An important study in this field was done by VanLehn (VanLehn, 2011), who compared a human tutor, his intelligent learning system and conventional classroom teaching. For calculating effect sizes, he used Cohen's estimator of effect size. VanLehn's study did not confirm such a difference between human tutoring and conventional classroom teaching as did the Bloom study. The effect size of human tutoring compared to conventional classroom teaching was only $d = 0.79$, and his intelligent learning system achieved

an effect size of d = 0.76, which is almost as effective as human teaching.

Developing AIAES is connected to varied fields, because a correct and therefore successful implementation of a human teacher, needs to link different fields, from cognitive sciences, artificial intelligence and functional literacy, to many fields connected to education. Computer systems such as ITS should provide the same instructional advantages as a human tutor (teacher), which certainly implies the interdisciplinarity of these fields. Within AIAES, the content is in accordance with the cognitive learning approach, and the system provides services for intelligent analysis (collection of various variables and metadata), which enables machine learning and adaptability to a learning course, based on the learner's individual characteristics and ability during the learning process. The results of the latest meta analysis of effectiveness in such intelligent learning systems (Ma, Adeosope, Nesbit, & Liu, 2014) support the claim that AIAES can be an effective tool for learning in all levels of school.

3 Design of an Autonomous, Intelligent and Adaptive E-learning System with assignments, tasks and exercises

The main objective of the AIAES is to establish an intelligent e-learning environment providing advanced services for the educational process, which will be able to adapt based on a student's learning experience, learning style, cognitive level and personal preferences. The AIAES will be focused on understanding learners' learning styles and cognitive capabilities, putting students and their learning experience at the centre of the educational process (Dumont, Istance, & Benavides, 2010). Based on data gathered, the AIAES will be able to adapt the study course based on a learner's individual characteristics and abilities in the learning process, simulating the traditional individualized lesson with one teacher and one student, which is one of the most efficient methods of learning and teaching (Dolenc & Aberšek, 2015).

The AIAES system should provide e-learning services (see **Pogreška! Izvor reference nije pronađen.**) for both educators and students. Educators can use the system for creating and managing online courses, learning materials (content and tasks), and metadata, together with the rules needed for adjusting the difficulty of the learning content for students based on their achievements while performing learning tasks. The AIAES system should assist educators in planning and creating learning materials, in providing information about reading strategies and functional literacy, and should serve as a validation service for checking e-materials created by educators. The validation services should evaluate attributes such as text length, organization and structure preparation and validation of learning materials, data aggregation and visualization, intelligent instructor services, and metadata (Figure 1).

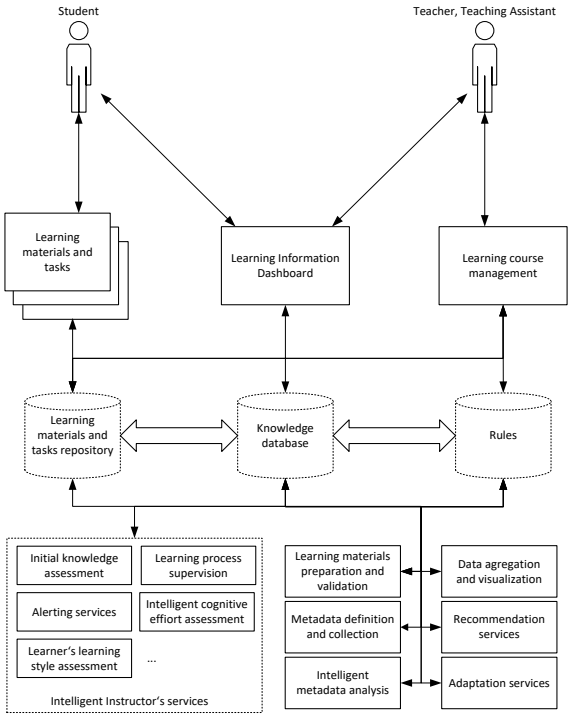


Figure 1. Design of an Autonomous, Intelligent and Adaptive E-learning System with assignments, tasks and exercises

Technically, the first part of the system should be designed as a rule-based adaptive expert system, using production rules for storing expertise and automatically making inferences about the type and level of content and tasks to be communicated to the learners. The second part of the system should collect learners' metadata (results from the learners while using the content and solving the tasks), and perform collective data analysis using machine learning algorithms in order to automatically assess a learner's progress and predict the type of content and tasks to be given to the learner in order to achieve the best possible progress.

In order to support the cognitive learning approach, the AIAES system should provide several features and characteristics, which can be divided into the following services:

1. Intelligent instructor services
2. Services for students
3. Services for educators
4. Domain-based (educational) services
5. Interface services

3.1 Intelligent instructor services

The AIAES will provide advanced services, which will help the learner to consume learning materials and

learn based on the results of intelligent assessment. Based on intelligent analysis of the data gathered during the learning process, the AIAES must be able to perform actions and make decisions related to various pedagogical aspects of learning:

1. choosing teaching methods that best suit the individual student's profile,
2. choosing learning content most appropriate for the individual student's profile,
3. choosing and recommending the time when learning content should be studied,
4. assessment of the cognitive state of the student,
5. deciding whether an individual student is able to proceed to the next learning level,
6. indicative, formative and summative testing and evaluation of outcomes.

The AIAES has to provide the same instructional advantages as a human instructor. The traditional human tutoring process has proven successful and has represented one of the most efficient methods of learning and teaching since the beginning of teaching. In order to include and enable the individualization and personalization of the student in the learning process, similar to what happens in a traditional individualized lesson with one teacher and one student, an intelligent instructor will be developed. The design and implementation of an intelligent instructor implies interdisciplinary work between many fields, such as cognitive science, artificial intelligence and functional literacy connected to education. To enable an intelligent instructor within the AIAES, various services will be modelled and implemented, as follows:

1. - Services for initial analysis and assessment of the learner's cognitive abilities and knowledge. Based on initial assessment and classification, the system will be able to provide appropriate study materials. The assessment of the learner's cognitive abilities and knowledge should be repeated within different phases of the learning process in order to evaluate the learner's progress and to be able to make decisions about future actions related to education.
2. - Services for supervision during the learner's studying process - assessment of how much time the learner needs to read the study materials, the amount of content that the learner reads, checking whether the learner has read the full content, checking if questions have been read fully and understood by the learner, checking if the learner is taking enough time to answer individual questions, etc.
3. - Services for collecting metadata gathered during the supervision
4. - Services for alerting the learner
5. - Services for advising the learner
6. - Services for intelligent assessment of the learner's cognitive effort during the learning process
7. - Services for assessment of the learner's learning style – the AIAES system should collect and analyze metadata about learner perceptions, processing and understanding during the learning process.

3.2 Services for students

The idea of adaptive learning is that there exists no one learning style that fits the needs of all types of learners (Yaghmaie & Bahreininejad, 2011). In the existing literature, several learning adaptation approaches have been introduced, such as (1) adaptability based on knowledge about the learner, controlled by the system and (2) student-controlled adaptability based on user preferences. The learning process should be fully adaptable in accordance with the learner's cognitive level, learning style and various preferences (e.g. of device, which can be a desktop computer, laptop, tablet PC, smart phone, etc.). In order to be able to make the AIAES adaptive, the AIAES must provide services for managing the cognitive state of a student. The student's cognitive state must be linked to the student's profile with information such as the student's personal data, learning style and preferences and current level of knowledge. The student's learning style is one of the most important factors in adaptation, since it reflects the learner's characteristics, preferences and needs (Yaghmaie & Bahreininejad, 2011). Based on the student profile, the AIAES should provide services to help the learner process learning materials based on the intelligent assessment of various metadata collected using quantitative and qualitative methods during the learning process.

The system should provide several services for intelligent analysis of data gathered during the different learning phases. These services should provide assessment of the learner's learning capacity, cognitive level, current knowledge and learning style. Based on these assessments, the system should recommend the most appropriate learning content. Additionally, the system should be able to assess the learner's emotional state (e.g. based on keystroke dynamics and mouse movements (Kolakowska, 2013), facial expression analysis, eye-tracking, etc.), which can lead to further adaptation of the learning process, motivating the learner to stay focused on the content.

3.3 Services for educators

The AIAES should be used in two ways. The primary idea is for it to be used as an individual learning tool. However, one potential idea, not yet tested, is for it to be used as a background for learning scaffolded by teachers. Because the system is planned to be launched under a CC licence, it must allow design of content by enthusiastic teachers. Therefore, content prepared by the educators should enable guidance of the learner according to current knowledge and learning capacity. The AIAES system should provide services for preparing the learning materials in an appropriate structure, which can be used for aggregation and presentation to the learners in the learning process according to their given level of learning capacity. Based on the prepared learning content and metadata collected about the learners' status, an information dashboard should be designed to provide important data aggregations in the form of visual analytics (Podgorelec & Kuhar, 2011). The aim of such an information dashboard is the perpetual monitoring of progress in both single learners and learner groups, in order to enable educators to make intelligent predictions and take timely actions, as well as allowing the intelligent instructor to adapt its course of action.

3.4 Domain-based (educational) services

The AIAES should also enable adaptability of the learning content. In the existing literature, there are two general approaches for adapting learning content (Yaghmaie & Bahreininejad, 2011): (1) adaptation of learning content according to individual needs, which is referred to as adaptation in content level, and (2) adaptation of learning content based on learner needs, which is called link-level adaptation. The AIAES must be able to organize learning content based on accepted standards, which were designed and developed to enable sharing and reusing learning content between different learning platforms by providing reusability, durability, accessibility, interoperability, etc. One of these standards is the Sharable Content Object Reference Model (SCORM); however, the SCORM enables only instructor-based adaptation of learning content.

Knowledge about the domain (expertise) is a key area in intelligent behaviour of the AIAES in order to enable intelligent adaption of the content and manner of presentation of certain topics based on learner abilities. Ontology is one technique that will be considered in designing and formalizing knowledge in the AIAES. Ontological description of the domain knowledge provides formalization of declarative knowledge, which can be achieved using various tools that support working with concepts and relations (Grubišić, Stankov, & Peraić, 2013).

3.5 Interface services and other technologies

The AIAES interfaces should be fully adaptable in accordance with learner preferences (e.g. a device, which can be a desktop computer, laptop, tablet PC, smart phone, etc.). The system should be based on modern web technology providing users access to the learning environment on any device (e.g. desktop/laptop computer, tablet PC, smart phone, etc.). Numerous, pre-existing open source online classroom platforms can serve as a basis for development in this project. In particular, Moodle is one of the most widely used such platforms and provides for extensive plugin capabilities. In this case, the PHP programming language should be used. There are no modules so far allowing Moodle or any other online classroom platform to utilize artificial intelligence for student and teacher activities, so this is the part that would have to be developed from scratch. Wenger (Wenger, 2014) suggests multiple approaches to integrating artificial intelligence into a tutoring system. Butler et. al. (Butler, Marsh, Slavinsky, & Baraniuk, 2014) also researched the integration of machine learning methods in STEM classrooms. Kloft et. al. (Kloft, Stiehler, Zheng, & Pinkwart, 2014) used machine learning in MOOC to predict student dropout rates. All these and numerous other studies in combining machine learning with the learning environment will be used to determine the usefulness of integration of these two paradigms and to choose the right method for implementation in the online classroom platform of eventual choosing. The most obvious usage is in predicting the dropout rate with various classification methods, such as statistical methods (naïve Bayes (John, Langley, 1995), logistical regression (Velez, et. al. 2007)), k nearest neighbours (Aha, Kibler, & Albert, 1991), SVM algorithms (Vapnik, 2011), decision trees (Quinlan, 2014) and neural networks (Haykin, 2001). In addition, the same classification algorithms could be used to determine whether a student is ready to proceed through the course and to customize the pace of the learning experience to each student individually.

4 Conclusions

At this point development of AIAES is still in its exploratory phase, and can be regarded as work in progress. Because of vivid progress, both in hardware and software design, applied solutions should be robust and adaptable to new, at this point, unknown technologies. According to planned continuous testing, in both system performance and feedback concerning the suitability of tasks and tests, some of the proposed solutions can be changed, adapted or even abandoned in some situations and added in others. Thus, we plan to design and implement the AIAES in such a manner that will allow agile customization and efficient technological upgrades, without losing the main focus

– a seamless adaptive system for supporting a personalized learning and the improvement of information literacy.

Acknowledgements

The authors acknowledge the financial support from the Slovenian Research Agency (research core funding No. (J5-8230).

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Survey of the Determinations of Business Intelligence Systems Adoption in SMEs

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Abstract. *Business Intelligence Systems (BISs) are a technological innovation, therefore it is essential to understand the determinants of information technology (IT) adoption. This paper is focused on the technology, organization, and environment (TOE) framework and BISs. The aim of the research is to compare a number of scientific papers within two fields (BISs and IT adoption).Based on the results of a comprehensive literature review, several determinants were selected as comparison variables. The expected contribution is in increasing scientific public awareness on the topic and on the potential of research in the field of the determinants of BISs adoption in SMEs.*

Keywords. Business intelligence systems, adoption, technological innovations, technology-environment-organization framework determinants, small and medium enterprises.

1 Introduction

These days, it is accepted that IT and related technological innovations are an essential tool for achieving competitive advantage and improving decision-making in a company. The benefits that a company can achieve from the use of technological innovations are diverse and important for achieving business success. These benefits cannot be fully achieved if the innovations are not properly and widely adopted (Zhu, Kraemer and Xu, 2006). Therefore, it is crucial to understand the determinants of technological innovation adoption (Karahanna et al., 1999).

The aim of the paper is three-fold: (1) to conduct a comprehensive literature review in order to identify the factors relevant for the success of BIS adoption; (2) to establish a list of TOE determinants for BIS-specific adoption factors in SMEs and (3) to compare the most emphasized determinants within two research fields (BISs and IT/IS innovation adoption) that were found in the literature.

After a short introduction, business intelligence (BI) and BISs are defined and their definitions analysed. (Section 2).Furthermore, the importance of using BISs in SMEs is presented. In Section 3 the most important determinants of TOE framework are identified and described. The comparison between the number of papers in the field of BIS adoption and other IT/IS adoption through the TOE dimensions is presented and elaborated in Section 4. Finally, the conclusions and proposals for future research are given.

2 BIS and SMEs

Precise, timely and quality information represents a key factor for companies wanting to attain and retain their competitive advantage and to achieve their goals. The immense measure of data generated on a daily basis is a direct consequence of an expanding number of business transactions. Therefore, it is of utmost importance for an organization to transform the acquired transaction data into invaluable information with the help of information technology (IT).

2.1. BI: an Overview

The apparent need for data transformation into valuable information resulted in an increased interest for the study of BI and its capabilities. A large number of publications published over the last ten years indicates that a large number of researchers and practitioners are interested in BI. (Chuah and Wong, 2011, Zulkifli Abai, Yahaya and Deraman, 2016, Neely, 2007).

Regardless of the emphasis on the importance of BI in the academic literature, a universally accepted definition of this concept cannot be found there. Taking into consideration various approaches, BI can be described as a group of different abilities that enable the company to cope with new market conditions (Patil, 2016; Pavkov, Poščić and Jakšić, 2016; Koupaei, Mohammadi and Naderi, 2016; Muan Sang, Xu and de Vrieze 2017). In order to improve business decisions, BI exposes previously concealed knowledge or information altered by information

technology (IT) in the collected internal or external business data (Panian, 2007). BISs aim to provide a comprehensive insight into business data, company performance and user needs, with the goal of boosting the quality of decision making in the company (Muan Sang, Xu and de Vrieze, 2016). BISs diagnose the state of the current business environment and the reasons why something happened, what should be done, and what is the next appropriate step in a business strategy. These are the essential functions of BI (Panian, Klepac, 2003). BIS can be described as set of tools, technologies and solutions that support gathering, organizing and analysing data from different sources, such as data warehousing, data mining, online analytical mining (OLAM) and on-line analytical processing (OLAP) (Elbashir, Collier and Davern, 2008).

Since a large number of successful companies implemented the concept of BI, the adoption and use of the BIS became the focus of many authors (Muan Sang, Xu and de Vrieze, 2017, Koupaei, Mohammadi and Naderi, 2016, Patil, 2016, Hejazi, Abdovland and Harandi, 2016). However, Puklavec, Oliveira and Popovič (2016) point out the lack of research in the field of the BIS adoption at the level of the entire company, emphasizing the need for further research in this area.

2.2. SMEs needs for BISs

Since the most common organizational size in each country are SMEs, the research area of this paper focuses on the adoption of BISs in SMEs. According to Vrdoljak Raguž, Krželj Čolović and Milić Beran (2015), new working positions, in large number of countries, are mainly created by SMEs. In Croatia, the value of SMEs is evident from the greater representation and higher employment rate in relation to large companies, present even in periods of negative GDP growth (CEPOR, 2015).

The key to success is based on well-chosen decisions about the adoption and use of BISs (Zhu, Kraemer and Xu, 2006). Choosing and applying the best adoption determinants is crucial for a company's success (Puklavec, Oliveira and Popovič, 2014).

However, large companies are natural nominees for BISs implementation because of their financial ability and their better reaction on adopting technological innovation.

While business practitioners recognized that stronger efforts must be put into the BISs implementation in SMEs, a lack of academic research in this area is evident. Academic researches in the field of BISs adoption in SMEs are worryingly neglected since researches are being focused only on large companies. (Popovič et al., 2012; Wixom and Watson, 2010; Yeoh et al., 2008; Muang Sang, Xu and de Vrieze, 2016).

3. TOE Framework

For several decades, business practices and scientific literature have been indicating the importance of technological innovations for a successful business. At the same time, researchers have shown interest for exploring the factors that affect the success of adopting and using technological innovations in companies.

TOE framework describes the influence of technology, organization and environment on the adoption and use of technological innovations (Baker, 2012). TOE framework was developed by Rocco DePietro, Edith Wiarda and Mitchell Fleischer in a book "The Processes of Technological Innovation" (1990) edited by Tornatzky and Fleischer. There are three dimensions of this framework: technological, organizational, and environmental (Figure 1).

The technological dimension includes all technologies that are important for the implementation of planned innovations, whether they are technologies that are already in use within the company or technologies that will be adopted in the future. This includes the company's current practices and internal equipment, as well as a set of available external technologies. (Khandwalla 1970, Hage 1980).

The organizational context is determined by the company's size, features, resources, organizational structure, and communication processes. The organizational context refers to the company's size, degree of formalization and centralization, managerial structure and amount of slack and human resources, and linkages among employees (Acheampong and Moyaid, 2016).

The environmental dimension includes the impacts of the macroeconomic policy, size and structure of the company's business industry, changes in regulatory and legislative policy, and a degree of infrastructure development (Baker, 2012; Tornatzky and Fleischer, 1990).

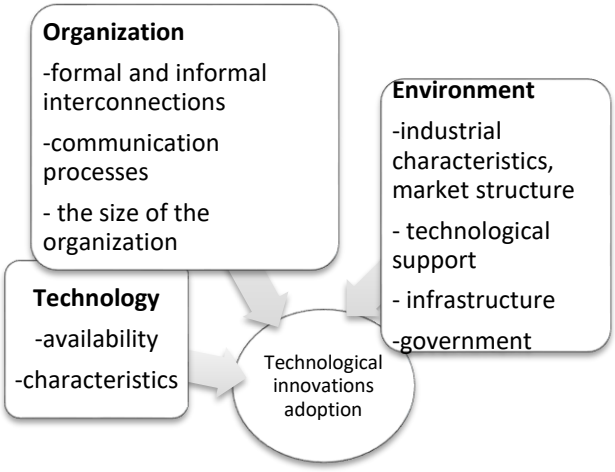


Figure 1. TOE framework (source: Tornatzky and Fleischer, 1990)

4 TOE and BISs adoption in SMEs

This section analyses specific determinants within 3 dimensions of the TOE framework for which the impact on the adoption and use of technological innovations is recognized in both fields: BIS adoption and IT/IS innovations adoption in general.

4.1. Data Collection, Research Method and Results

For this study, the literature review was done on relevant extant academic studies covering fields of BIS adoption and IT/IS innovation adoption. The main reason and sequence of creating the following tables is: (1) to specify the most frequently mentioned variables for each of the 3 dimensions of the TOE framework (the first column of the table) based on previously researched literature; (2) to specify the papers that are described in the context of IT / IS implementation in general (the second column of the table) for each of these variables and (3) to find and list papers describing the impact of the variables on the success of the BISs implementation (the third column of the table) for each of these variables.

Afterwards, a comparison of the number of found papers describing the mentioned variables in general, i.e. in the context of IT / IS innovation, has been made with the number of papers describing the TOE variables in the context of BIS implementation. The results of the comparison are also presented in the table in subsection 4.2. Research results: analysis and discussion.

The variables are categorized into three distinct dimensions based on the three elements from the TOE framework. These elements are technological, organizational and environmental factors and each of them creates one of the following tables. Within each dimension a variable was chosen due to the frequency of appearance in scientific papers, being a significant variable in the process of adopting BIS or IT / IS innovations. Each of them is attached to a scientific paper in which the variable is mentioned as crucial for adopting BIS or IT/IS in general.

For the purposes of this study, a preliminary literature analysis was conducted. The key words "BIS adoption + TOE + SMEs", "IT/IS adoption + TOE + SMEs" "technological innovation + adoption + TOE + determinants + SMEs" were searched for in the title, abstract, key words and body text of all papers through the Google Scholar database. The searching process is limited to the papers published from 1990 to 2017. Any paper published before 1990 was not included in the process. In the next step, some of the available databases such as ScienceDirect, Emerald, Hrcak, SpringerLink, ProQuest will be researched.

The search was conducted using the Google Scholar database in May and June 2017. Given the limited availability of full versions of papers in the Republic of Croatia, and considering this was an initial collection of data on selected determinants of BIS adoption, author considered best to use Google Scholar database in this initial phase of research. Also, it is planned to conduct the research in some of the aforementioned databases in later phases of this study. Since the IT/IS adoption and the adoption of technological innovations are very broad concepts, author decided to focus only on those papers closely related to the selected determinants within the TOE framework in this study. Considering the availability of full versions of articles and their closeness to the topic discussed in this paper, 50 articles have been selected in this initial phase of research.

The results of the literature review are presented in Tables 1-3.

Table 1. Technology dimension

Variable	General IT/IS innovation	BIS	Definition
Relative advantage	Ifinedo , 2011; X. L. Li et.al., 2011; Oliveira and Martins, 2011; Oliveira et.al., 2014; Premkumar i Roberts, 1999; Tsai et.al., 2010; Chong i Chan, 2012; Chong et.al., 2009; Quaddus i Hofmeyer, 2007; Moore and Benbasat, 1991; Grandon and Pearson, 2004; Cragg and King, 1993; Iacovou, Benbasat and Dexter 1995; White et.al., 2007	Acheampong and Moyaid, 2016; Puklavec et.al., 2014; Hatta et. al., 2015; Ipomai, 2016; Boonsiritomachai, 2014;	The degree to which an innovation is perceived to be better than the idea it supersedes or existing systems (Acheampong and Moyaid, 2016; Rogers, 2003).
Complexity	Chong and Chan, 2012; Rogers, 2003; Chong et.al., 2009; Premkumar and Roberts, 1999; Grandon and Pearson, 2004; X. L. Li et al., 2011; Ifinedo, 2011; White et.al., 2007	Acheampong and Moyaid, 2016; Puklavec et.al., 2014; Boonsiritomachai, 2014; Hatta et. al., 2015;	The degree to which an innovation is perceived as difficult to understand and use (Acheampong and Moyaid, 2016; Rogers, 2003).
Compatibility	Chong and Chan, 2012; Chong et.al., 2009 Grandon and Pearson, 2004; Ifinedo, 2011; Oliveira et.al., 2014; White et.al., 2007	Hatta et. al., 2015; Acheampong and Moyaid, 2016; Puklavec et.al., 2014; Boonsiritomachai, 2014; Rostek, 2013	The degree to which an innovation is perceived as being consistent with existing values, past experiences and needs of potential adoption (Acheampong and Moyaid, 2016; Rogers, 2003).
Trialability	Ling, 2001; Moore i Benbasat 1991; Park and Chen 2007;	Hatta et. al., 2015; Boonsiritomachai, 2014; Puklavec et.al., 2014	The degree to which and innovation can be pilot tested or experimented (Ling, 2001).
Observability	Moore and Benbasat 1991; Ling, 2001; Oliveira, 2014; Mehrtens et al., 2001; Igbaria et al., 1997; Hsu et al., 2006;	Hatta et. al., 2015; Boonsiritomachai, 2014; Puklavec et.al., 2014	The extent to which relative advantage or gains of an innovation are clear (Ling, 2001).
Financial resources and costs	Grandon and Pearson, 2004; Premkumar and Roberts, 1999; Chong i Chan, 2012 ; Chwelos et al., 2001; Y. Lee and Larsen, 2009; Hameed et al., 2012; Caldeira and Ward, 2002	Hatta et. al., 2015; Puklavec et.al., 2014; Rostek, 2013	Cost effectiveness, i.e. where the benefits of adopting new technology exceed the costs of such technology (Premkumar and Roberts, 1999).

Table 2. Organizational dimension

Variable	General IT/IS innovation	BIS	Definition
Availability of organizational resources	Duan, Deng and Corbitt 2012; Kim and Garrison 2010; Iacovou, Benbasat and Dexter 1995; Oliveira and Martins, 2011	Boonsiritomachai, 2014; Hatta et. al., 2015; Puklavec et.al., 2014	Partial synonym for the readiness of the company to adopt innovation, i.e. to measure the degree of availability of financial and technological resources in the company (Duan, Deng and Corbitt 2012; Kim and Garrison 2010; Lee and Cheung 2004; Iacovou, Benbasat and Dexter 1995).
Customer demand	Ifinedo, 2011, Mehrtens, Cragg and Mills, 2001; Daniel and Grimshaw, 2002	Hatta et. al., 2015	Refers to the pressure of clients for adopting technological innovations (Ifinedo, 2011, Mehrtens, Cragg and Mills, 2001) as well as the company's desire to provide improved customer service with the help of new technology solutions (Daniel and Grimshaw, 2002).
Top management support	Premkumar i Roberts, 1999; Grandon and Pearson, 2004; Ling, 2001; Tsai et.al. 2010; Quaddus i Hofmeyer, 2007; Igbaria et al., 1997; Al-Qirim, 2014; Reich and Benbasat, 1990; Hwang et.al., 2004; Thong et.al., 1999; Jarvenpa i Ives, 1991; Bruque Camara et.al., 2004; Damanpour and Schneider, 2006	Acheampong and Moyaid, 2016; Hatta et. al., 2015; Puklavec et.al., 2014; Boonsiritomachai, 2014; Rostek, 2013	The degree of "active engagement of top management with IS implementation" (Thong et.al., 1996.)
Organizational readiness	Hameed et.al., 2012; Ifinedo, 2011; Grandon and Pearson, 2004; Iacovou, Benbasat and Dexter 1995; Oliveira and Martins, 2011; Quaddus i Hofmeyer, 2007	Hatta et. al., 2015; Acheampong and Moyaid, 2016; Puklavec et.al., 2014	The degree of organizational readiness is defined as the availability of the necessary organizational resources for the adoption of the information system. It is measured through the level of organizational awareness, commitment, organizational resources and management for the adoption of BIS (Iacovou et al., 1995; Hameed et al., 2012).
Collaboration	Ling, 2001; Bruque Camara et.al., 2004; Oliveira and Martins, 2011;	Hatta et. al., 2015; Puklavec et.al., 2014	It represents internal and external communication and cooperation for the dissemination and acquisition of knowledge necessary for the adoption of BIS (Puklavec 2016; Ling, 2001).

Table 3. Environmental dimension

Variable	Other IT/IS innovation	BIS	Definition
Business partners	Chwelos et.al., 2001; Ifinedo, 2011; Iacovou et al., 1995; Soares-Aguiar and Palma-dos-Reis, 2008; Oliveira and Martins, 2011; Wymer and Regan, 2005	Puklavec et.al., 2014; Hatta et. al., 2015	Refers to the potential strength of a business partner to encourage the adoption of technological innovations (Chwelos et al., 2001).
Competitive pressure	Chan and Chong, 2012 ; Grandon and Pearson, 2004; Chong et.al., 2009; Chwelos et.al., 2001; Premkumar and Roberts, 1999; Soares-Aguiar and Palma-dos-Reis, 2008; Wymer and Regan, 2005; Oliveira and Martins, 2011; Zhu et.al., 2003	Acheampong and Moyaid, 2016; Puklavec, 2016; Hatta et. al., 2015; Ipomai, 2016; Rostek, 2013	Competitors is the group that reflects competitors' pressures to adopt an innovation. Intense competition can cause a company to look for new ways of doing business (Ifinedo, 2011; Puklavec, 2016).
Providers availability	Chaveesuk 2010; Hwang et al. 2004	Boonsiritomachai et.al. , 2014; Puklavec et.al., 2014; Hatta et. al., 2015	Defines the criteria for selecting companies that produce/sell ICTs and provide education and customer support services (Boonsiritomachai et al., 2014).
Availability of technological infrastructure	Premkumar and Roberts, 1999; Lee and Larsens, 2009; Quaddus and Hofmeyer, 2007; Wymer and Regan, 2005	Hatta et. al., 2015; Rostek, 2013	Refers to the development of the existing technological infrastructure as well as the degree of external support in the implementation and use of innovative technological solutions (Premkumar and Roberts, 1999, Quaddus and Hofmeyer, 2007).
Market trends	Chan and Chong, 2012; Chong and Ooi, 2008; Chong et.al., 2009; Wymer and Regan, 2005	Puklavec et.al., 2014; Hatta et. al., 2015	Different market trends that can influence the company to adopt technological innovations (Chong et al., 2009).
Regulatory body	Ling, 2001; Quaddus and Hofmeyer, 2007; Ifinedo, 2011; Grandon and Pearson, 2004; Teo et.al., 1997; Bose and Luo, 2011; Wymer and Regan, 2005	Acheampong and Moyaid, 2016; Hatta et. al., 2015	Refers to the level of assistance provided by government institutions to encourage the expansion of IT innovations into the businesses (Ifinedo, 2011).
Collaboration with other companies	Premkumar and Roberts, 1999; Oliveira and Martins, 2011	Hatta et. al., 2015	Refers to the vertical relationships with affiliated companies. It includes situations in which the parent company introduces technological innovations and then transfers them to their affiliates (Premkumar and Roberts, 1999).

4.2. Analysis and Discussion of Research Results

Based on the review of previous studies, 18 specific determinants were extracted for BISs adoption within the TOE framework.

Six key determinants for BIS adoption were chosen within the technology dimension, five in the organizational dimension, and seven in the environmental dimension within the TOE framework. Based on those specific determinants, the number of scientific papers focused on determinants in the BIS and IT/IS innovation adoption research field was compared. Table 4 presents the results of the comparison of scientific papers belonging to those two fields that were found while reviewing the literature according to the chosen fields of literature retrieval.

Table 4. Results of comparison between the fields of research

Variable	BIS	General IT/IS innovation
Relative advantage	5	14
Complexity	4	8
Compatibility	5	6
Trialability	3	3
Observability	3	6
Financial resources and costs	3	8
Availability of organizational resources	3	4
Customer demand	1	3
Top management support	5	13
Organizational readiness	3	6
Collaboration	2	3
Business partners	2	6
Competitive pressure	5	9
Providers availability	3	2
Availability of technological infrastructure	2	4
Market trends	2	4
Regulatory body	2	7
Collaboration with other companies	1	2

Several papers describing BIS adoption through the frame of chosen determinants were found, but their number is relatively small in comparison to the number of papers focused on other IT/IS innovation. From the results, it is obvious that the most common determinants in the BIS adoption research field are within the technology dimension, especially determinants such as "Relative advantage" and "Compatibility". It is followed by the environmental dimension "Competitive pressure" as the most common determinant. Within the organizational dimension the most common determinant is "Top management support".

In the scientific papers written about the general IT/IS innovation adoption determinants within the TOE framework, most important determinants are from technology, then environmental and finally from organizational dimension. Most common determinants in this field of research are very similar, as it was in the case of BISs adoption; these are: "Relative advantage" within the technology dimension and "Top management support" within the organizational dimension.

5. Conclusion

As it was mentioned before, benefits of BIS can be limited if it is not properly and widely adopted so it is crucial to understand the determinants of BIS adoption to achieve desired business success. The value of this paper is in the result of the literature review which identifies determinants for BISs adoption within the TOE framework. Besides, the comparison that has been made between the abovementioned two fields of research shows that there is a lack of papers in the BIS adoption field of research. Very similar results obtained by searching for determinants for BIS adoption and IT / IS adoption point to the need for additional research on the specificities associated with the use of BISs.

Limitation of this paper is that the papers have been searched on Google Scholar rather than on the databases of scientific papers. That will be done in the next research.

Hopefully, the determinants which will be tested in SMEs in Croatia, will examine the current state of BIS adoption in Croatia. The results which will be obtained through the future testing of these determinants within TOE framework would be beneficial for the academic researchers, BIS vendors and SMEs itself, so as for Croatian SMEs and both their opportunities and concerns regarding the BIS adoption.

For that reason, author encourages academics to focus more on exploring and analysing determinants for adopting BISs in SMEs. Hopefully, all the phases of this work will stimulate future efforts to develop more determinants for the successful adoption of BIS.

Acknowledgments

This paper is funded by the Croatian Science Foundation under the project PROSPER – Process and Business Intelligence for Business Excellence (IP-2014-09-3729).

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A Machine Translation Model Inspired by Code Generation

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Abstract. *In this paper we present our machine translation model that is based on bilingual linguistic phrases and their lexical attributes. Developed model partly arises from our previous work in the field of Generative Programming, and the working prototype was made for Croatian-French and French-Croatian translation. The model is aimed for the general language domain, but it is so far mostly trained for some limited domains like cooking recipes, weather forecast and user manuals for different devices. The proposed model was evaluated according to the matched phrases and by using the BLEU machine translation evaluation method.*

Keywords. machine translation, phrase based translation, BLEU

1 Introduction

In our previous work, we have acquired a lot of experience in a field of Generative Programming (GP) that resulted in SCT generator model (Radošević & Magdalenić, 2011) and its special implementation named Autogenerator (Magdalenić, Radošević & Orehovački, 2013). The idea in the base of SCT was to connect three model elements (Specification, Configuration and Templates), as described in (Radošević & Magdalenić, 2011) to generate the source code of the target program application. Considering that maintaining of configuration rules and code templates represents a kind of background work, remains that the purpose of a generation system is to translate the Specification in the higher level language into a program code (lower level language).

On the other hand, some important experiences in natural language processing were acquired in the development of natural language dictionaries and their use in the education process (Fara & Radošević, 2016). These efforts have resulted in, among others, the Croatian-French and French-Croatian online dictionary[1], with currently 11400 records containing words, their types, pronunciation and examples of use. Within this project, an appropriate search engine for finding translations was developed. Also, the system enables collaboration of more authors in gathering of dictionary terms.

The idea in a base of our machine translation model was to transform the code generation model into a natural language translation model, by using of the developed dictionaries, the search engine and the other findings from our previous research. For this purpose, a prototype[2] of our translation system was made. It can translate in both directions (from Croatian to French and vice versa), but for now it is mostly trained for French to Croatian translation, as well as the conducted tests within this paper. Training and testing in the opposite direction is planned for the future work.

2 Related Work

For machine translation, we can use rule-based, statistical, or hybrid machine translation approaches (Trujillo, 1999). Phrase-based statistical machine translation is the most popular approach in a machine translation research community (Koehn, Och & Marcu, 2003). Koehn et al. (Koehn, Och & Marcu, 2003) have created translation model and decoder to evaluate and compare various translation methods, and their results showed that phrase translation has better performances than word-based methods. Furthermore, Chand (Chand, 2016) has performed an empirical survey of machine translation tools. The tools have tested include rule based systems and statistical based machine translation systems, and it was shown that statistical systems have better performances. Och and Ney (Och & Ney, 2004) have presented the alignment template approach as an extension of a phrase-based machine translation approaches. Their translation approach allows many-to-many relations between words to take the context of words into account.

[1] Croatian-French and French-Croatian online dictionary is available at http://lana.foi.hr/dictionnaire/

[2] Prototype of Croatian-French translator is available at http://lana.foi.hr/traducteur/

Munteanu and Marcu (Munteanu & Marcu, 2005) have proposed a method for discovering parallel sentences in comparable, but non-parallel corpora. They showed that a good-quality machine translation system can be built from scratch by starting with a very small parallel corpus (100,000 words) and exploiting a large non-parallel corpus. Chiang (Chiang, 2005) presented a statistical phrase-based translation model that uses hierarchical phrases (phrases that contain sub-phrases). Cho et al. (Cho et al., 2014) proposed a neural network model called RNN Encoder-Decoder for statistical machine translation. They use the aforementioned model to score each phrase pair in the phrase table, and found that it improves the translation performance in terms of BLEU scores. Och (Och, 2003) analyzed various training criteria that directly optimize quality of statistical machine translation. Maučec and Brest (Maučec & Brest, 2003) offer a comprehensive survey of approaches to coping with Slavic languages in different aspects of statistical machine translation. They claim that languages with a rich morphology pose an especially difficult challenge for machine translation research.

There are some existing tools for statistical machine translations. Apertium (Forcada et al., 2011) is open-source platform for rule-based machine translation. The mentioned platform provides a language-independent machine translation engine, tools to manage the linguistic data necessary to build a machine translation system for a given language pair, and linguistic data for a growing number of language pairs. Moses (Koehn et al., 2007) is an open source toolkit for statistical machine translation that supports linguistically motivated factors, confusion network decoding for the translation of ambiguous input, and efficient data formats for translation models. Morphological, syntactic, or semantic linguistic information are integrated into pre-processing or post-processing steps. Stanford Phrasal (Green, Cer & Manning, 2014) is statistical phrase-based machine translation system written in Java that provides API for implementation of new decoding models, ability to translate phrases with gaps, and also enables the conditional extraction of phrase tables and lexical reordering models.

A similar approach of the phrases-based translation was offered by Zens at al. (Zens, Och & Ney, 2002) as a limited-domain speech translation task from the German to the English language. The authors used bilingual phrases instead of single words in the translation model because the contextual information in single-word based models was excluded for the translation decisions. Some of the today's most commonly used metrics for the evaluation of machine translation are BLEU, ORANGE, METEOR and LEPOR. The basic assumption of all evaluation metrics for machine translation is that the referent translations must be "good" translations and the more a machine translation is like its referent translations then the score is higher. BLEU (Papineni et al., 2002) is a machine translation metric that uses the range from 0 to 1 to evaluate the translation where the referent translation must be provided. Translations will only attain a score of 1 if they are identical to the referent translation. Unlike BLEU the ORANGE (Lin & Och, 2004) machine translation evaluation metrics doesn't require human involvement at all. It uses a set of referent translations automatically, without extra intervention. Generally, a "good" translation should be ranked higher than a "bad" translation based on their scores. Contrary to BLEU, the METEOR (Lavie & Denkowski, 2009) machine translation evaluation metrics uses and emphasizes recall in addition to precision which is in high correlation with human judgments. METEOR also addresses the problem of referent translation variability and features parameterized ingredients. To address some of the weaknesses in the existing machine translation evaluation (non-English to target language translation, low resource language pairs, etc.), Han has proposed the LEPOR metric (Han, 2017). This metric can be easily employed to different language pairs, or new language pairs due to the concise external resources utilization.

3 Machine Translation Model

The idea in a base of our translation model arises from the general code generation model as described in (Czarnecki & Eisenecker, 2000). In such model, the generator is a mechanism that uses some program artifacts like metaprograms and a set of configuration rules to transform the program specification (usually written in some Domain Specific Language, DSL) to produce the program code in a target programming language. In case of the machine translation of natural language, there are some similarities with a code generator, but also some specifics:

- the specification language and the target language are natural languages, both very complex,
- the translation process requires a very big database of translation artifacts (like words, phrases and attributes) and
- configuration rules that lead the translation process are not totally deterministic i.e. depend on probabilities.

Our translation model (Fig. 1.) uses a **bilingual dictionary** in its base. Such dictionary includes words, lexical tags, pronunciation, different meanings and examples of use with phrases. The dictionary is maintained manually, by more editors that mutually collaborate. Each word in a dictionary has one or more meanings in the opposite language, where the order of these meanings determines the ***priority value*** that is used in a translation process to find the most probable translation.

Apart from the bilingual dictionary, there is a **translation phrase database**. This database is also maintained manually, by using of appropriate editor's interface (Fig.2) which is an addition to the translator interface, as shown in Fig. 3. The attributes of the phrases are not entered manually, but updated automatically by updating script. This script uses some attributes inherited from bilingual dictionary (like word type, gender, and number) as well as the attributes extracted from word endings like cases. An example of the phrase record with attributes is as follows:

```
Phrase_HR:prati posuđe Phrase_FR:faire la
vaisselle ATTR: fe:sl fe:inf fd:nf he:gen
```

In the example, the attribute names of Croatian phrases start with '**h**', while the attribute names of French phrases start with '**f**'. The second letter represents the way how the attributes were obtained. Some attributes are inherited from the dictionary (marked by '**d**') and the others were extracted by word endings (marked by '**e**'). Marks after the colon have their meanings as follows: ***sl*** - singular, ***inf*** - infinitive, ***nf*** - feminine noun, ***gen*** - genitive case.

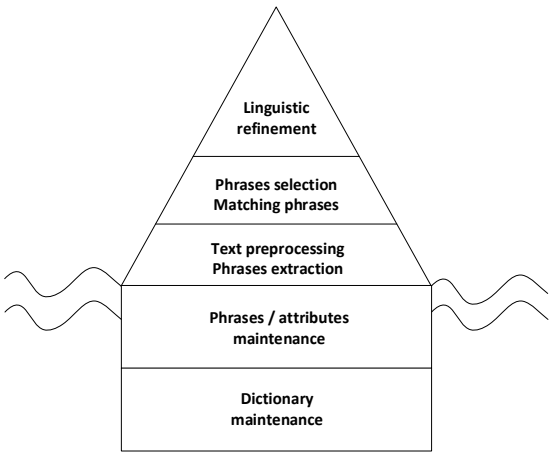


Figure 1. Translation model

The translation process starts by text preprocessing. In this phase, the text for translation is being transformed into a list containing words and separators. Apart to that list, another list, containing attributes of words is also being created, for the purpose of later linguistic refinement.

Phrases extraction is the process of cutting text into phrases of different lengths. The phrases start from each word in the text, containing 1-5 words. **Matching phrases** tries to find the longest phrase with the translation in the translation phrase database. Such phrase is observed as the **candidate for translation**. In some cases, there are more candidates, so a list should be created. The order inside the list depends on the **priority value** of the phrase. If the phrase is inherited from the dictionary, the priority depends on the order of meanings, but if the phrase is entered by translator editor's interface, the priority value is equal to zero (highest priority). Another factor that impacts the order of candidates is the **similarity value** that is used for phrases containing only one word. This value is expressed by the similarity of strings (based on the Levenshtein distance between strings), on a scale 0 - 1, between the candidate for translation and a word from translation phrase database.

Some candidates for translation have to be excluded because of the overlapping problem. In some cases, the phrase can include the beginning of another phrase (but not the whole another phrase). In that case, the general strategy is **shortening the first phrase**, except in a case when the first phrase is in the list of non-shortening phrases. In that case, the second phrase will be excluded.

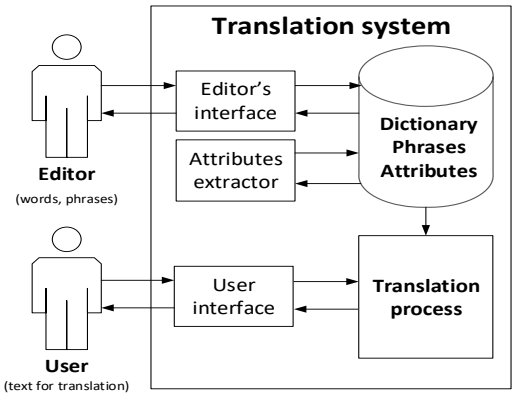


Figure 2. Translation system

After aforementioned phases of translation, there are still some issues to be solved in order to obtain a better translation. It's the **refinement phase**. The refinement is made by changing the priority values of translation candidates. There are, for now, two ways to do that:

- **by increasing the priority of shortened phrases.** In the case of shortening phrases (in order to avoid the overlapping), it's possible to **increase the priority of shortened phrases** according to the similarity between shortened phrases and non-shortened phrases. This enables the usage of phrase context in order to find the most appropriate translation.
- **by using of lexical attributes**. As mentioned before, the phrases have their lexical attributes according to word types, genders, cases etc. Such attributes are also extracted from text to be translated, in a preprocessing phase. Depending on the matching of that attributes with attributes of phrases that are candidates for translation, their priority values can be increased or decreased. This kind of **linguistic refinement** enables translation system to put translations into the right form, according to word type, gender, number or case.

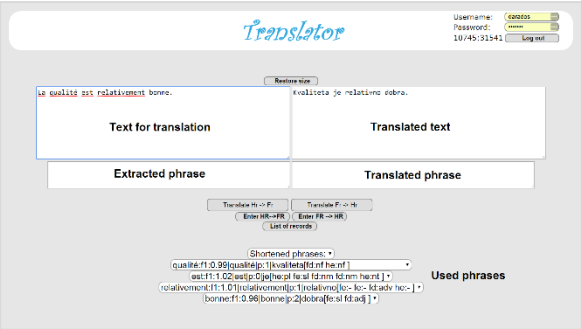


Figure 3. Translation interface

4 Model Evaluation

In order to evaluate our up today's efforts in the building of an effective translator, some tests were provided. There were two groups of tests. The first group was based on the internal measures of the translator, like **coverage of the original text by translation phrases** of different size (containing one or more words). These tests have been carried out on documents that belong to seven different categories to see the differences among them. The second group of testing was carried out using widely accepted **BLEU metrics**[3] (Papineni et al., 2002) (Seljan, Vičić & Brkić, 2012). The purpose was to find the indications of the relationship between internal measures from the first group of testing and the BLEU score, as well as the relationship of the BLEU score achieved by our translator and the widely used Google Translator[4]. The total number of phrases in translator's database was 40000, where 31000 were inherited from the dictionary, and the rest of 9000 were entered by using the editor's interface. The direction of translation process was French to Croatian for all testing.

[3] The tests have been conducted using Tilde Interactive BLEU score evaluator, https://www.letsmt.eu/Bleu.aspx

4.1 Testing using internal measures of translator

There were seven categories of articles (recipes, news, user manuals, fashion and clothes, weather forecasts, computer programming and song lyrics) included in a test, with 10 articles per category, where the size of the documents were around 200 words, with the purpose to find out some information about the phrases used in the translation process. The phrases were categorized into seven types:

F1a - unrecognized word (could be a name or doesn't exist in the translator's database)
F1b - the word exceeds the similarity threshold with the one that exists in the database
F1c - the word is exactly the same as the one that exists in the database
F2, **F3**, **F4**, **F5** - the phrase consisting of 2-5 words were found in the translator's database

The results are shown in Fig.4:

[4] Available at https://translate.google.hr/

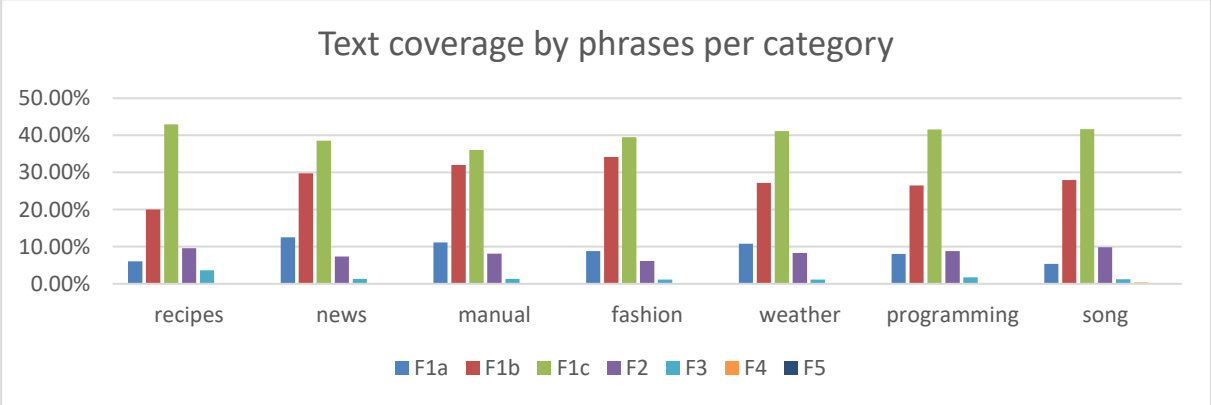


Figure 4. Coverage of text by phrases per category

The results show the high level of words coverage by translator database, because only **5-12%** of words were unrecognized, which includes the names. The most frequent category was ***F1c*** (exact match of words), with **36-43%** of the whole texts, followed by ***F1b*** (words that exceed the similarity threshold), with **20-32%**, and ***F2***, phrases consisted of two words, with **12-20%**. Phrases consisting 3 or more words were relatively rare used (**3-11%** of text for ***F3***, and ***0-1%*** for ***F4*** and ***F5***).

Coverage of text by particular words (***F1a***, ***F1b*** and ***F1c***) and phrases (***F2-F5***) is shown in Fig. 5:

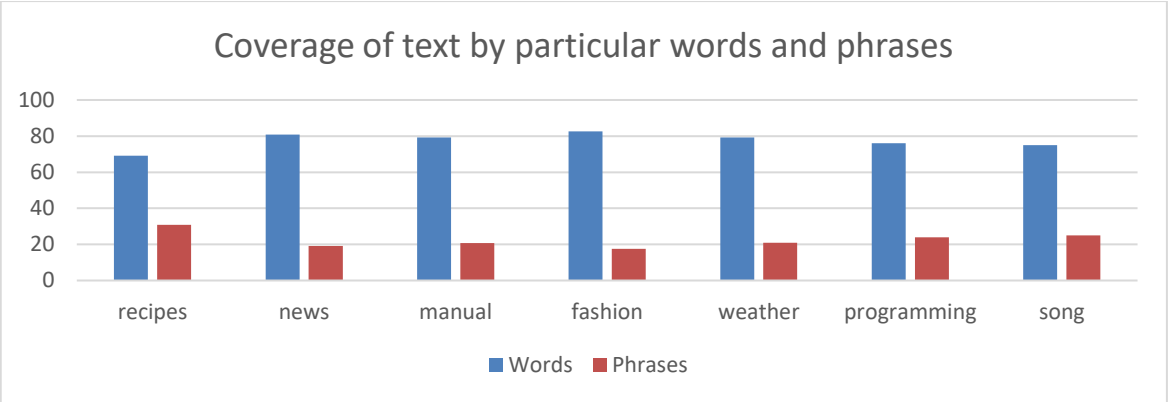


Figure 5. Coverage of text by particular words and phrases per category

The results vary, depending on the category, from **17%** (fashion) to **31%** (recipes). It could be connected with the translator database training, as well as the wideness of vocabulary for different categories.

4.2 Testing by BLEU Score

The BLEU method of machine translation evaluation relies on the similarity between the machine translation and the referent translation (usually human made), giving a score between 0 and 1 (Papineni et al., 2002). Coverage with phrases (***F2-F5***) for the category 'songs' was **25,01%** in the average (Fig.5). Table 1 shows results on a level of particular songs:

Table 1. Coverage by phrases and BLEU score on a level of particular songs

Song	Words	Phrases %	BLEU_test	BLEU_Google
song 01	201	32,84	5,48	27,37
song 02	508	40,16	7,14	15,27
song 03	307	19,54	2,85	7,40
song 04	536	26,12	4,44	10,33
song 05	280	7,86	1,89	10,86
song 06	**252**	**25,79**	**22,74**	**20,46**
song 07	547	17,92	1,47	4,13
song 08	**255**	**24,31**	**10,23**	**6,45**
song 09	355	24,79	11,27	18,17
song 10	181	28,18	3,59	9,60

0,27 Correlation Phrases - BLEU_test
0,48 Correlation BLEU_test - BLEU_Google

It can be seen in Table 1. that the BLEU score of Google Translator was better in 8 of 10 cases. The Pearson correlation between coverage of the translation in phrases and the BLEU score was **0,27**, while the correlation of BLEU scores of the tested translator and Google Translator was higher, **0,48**. These results should be observed as preliminary, because of the very small testing set.

5 Conclusion

This paper presents our machine translation model and prototype of its implementation on the example of croatian-french and french-croatian translation. The model partly arises from our previous work in a field of Generative Programming and our work on building online bilingual dictionaries.

There were some tests performed on the prototype of our translation system. Some tests have used internal metrics of the translation system, like usage of different length phrases, while the others were based on widely used BLEU machine translation evaluation method. The results of the internal metrics show that there are significant differences in the translator's coverage of different categories (e.g. results were much better for cooking recipes than for the other categories). The results of the testing using BLEU method show some positive correlation with the results of internal metrics (0,27), and some positive correlation between results of our translation system and the widely-used Google Translator (0,48).

In our future work, it's planned to include some more elements of our SCT generator model (Radošević & Magdalenić, 2011) into the translation model. For example, using of translation phrases that include some variable parts, like code templates, could significantly reduce the necessary number of such phrases. Some improvements are also possible in the linguistic refinement of translation, including the usage of more phrase context.

Acknowledgments

We would like to thank prof. Višnja Fara and prof. Biljana Grubačević for their work on the online dictionaries and their help in the linguistic part.

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Large-Scale Multi-Agent Modelling of Massively Multi-Player On-Line Role-Playing Games – A Summary*

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Abstract. *An overview of the Large-Scale Multi-Agent Modelling of Massively Multi-Player On-Line Role-Playing Games (ModelMMORPG) project financed by the Croatian Science Foundation is provided. ModelMMORPG aimed on studying Massively Multiplayer Online Role-Playing Games (MMORPGs) using a combined computer science Multiagent System (MAS) and a social science Agent-Based Modelling (ABM) methodology. The main results, performed activities, developed software as well as published papers are described and discussed. In the end a critical evaluation of the project is given.*

Keywords. mmorpg, agent based modeling, agent organizations, modelmmorpg, sna, nlp

1 Introduction

MMORPGs give us the opportunity to study two important aspects of computing: (1) large-scale virtual social interaction of people (players) and (2) the design, development and coordination of large-scale distributed Artificial Intelligence (AI). A common denominator for both aspects are the methods used to study them: social interaction can be described and simulated using ABM (Bonabeau, 2002) representing a social science perspective whilst distributed AI is commonly modelled in terms of MASs (Van der Hoek and Wooldridge, 2008) from a computer science perspective.

The important question to ask in both perspectives is how do agents organize in order to perform their tasks and reach their objectives? Project ModelMMORPG, briefly summarized herein, has employed a combined empirical and theoretical approach towards finding the answer to this question.

From the empirical side, we have studied human behaviour on a dedicated gaming server in order to find most suitable structures, cultures, processes, strategies and dynamics employed by most successful player communities.

From the theoretical side, we have tested a multitude of organizational architectures from organization theory in various MMORPG settings, and compared them with methods found in empirical research.

Our research was therefore aimed towards enriching the organizational design methods for the development of MMORPGs to foster the development of self-organizing and adaptable networks of Large-Scale Multiagent Systems (LSMASs). The main objectives of ModelMMORPG were:

1. To identify and formalize adequate organizational design methods for developing LSMAS in MMORPGs.

*This work has been supported in full by the Croatian Science Foundation under the project number 8537.

2. To couple them with real-life and future scenarios from industry.

3. To provide open and accessible tools, which will allow for design, development, implementation, control, simulation and maintenance of LSMASs in MMORPGs.

In this paper we will provide a summary of activities, developed software and published papers during the last three years of the project.

2 Activities

The initial project work plan consisted of six individual work packaged: (1) Initialization, (2) Player organization analysis, (3) Modelling tool development, (4) Large-scale experiments, (5) Dissemination, and (6) Management. Work packages (2), (3) and (4) roughly correspond to the three phases of the project: firstly we have analyzed the behaviour of human organizational behaviour by analyzing literature as well as by observing players on a dedicated MMORPG server with a specially designed test-bed quest; secondly we have been developing a LSMAS modelling tool based on these results including an end-point plug-in that would allow us to test the models in a concrete MMORPG; and thirdly we have experimented with various models in various settings.

During the initialization package the open source MMORPG The Mana World (TMW) was chosen as the main test bed. In order to define an actual quest that will push players to collaborate and compete with each other a 3-day brainstorming session was organized. Participants were the members of the ModelMMORPG project as well as a number of interested students and faculty from the Faculty of Organization and Informatics where the meeting has been held. During the session a number of creative group problem solving techniques was employed (including idea writing, mind mapping and the 6 thinking hats technique) in order to get valuable results. Idea writing and mind mapping provided us with very good results, while the 6 thinking hats technique showed to be to complicated for the task to be of any value. The hand drawn mind maps (the one actually chosen for the quest in the end is shown on figure 1) have been of particular values, since they provided clarity and focus on what is to be achieved.

The brainstorming session yielded a detailed description of the quest to be implemented which was published as a deliverable on the project website.[1]

During the second work package the quest was implemented on a dedicated TMW server. Additionally, data collection services as well as a modified client application were implemented as well, to allow for data gathering. A dedicated social website, which displayed player statistics was also setup to facilitate competition between the various player teams. Later, data about player behaviour was collected during a period of one month (mostly students from various faculties were playing the game). The collected data was analyzed using using various Social Network Analysis (SNA) (Scott, 2017) and Natural Language Processing (NLP) (Chowdhury, 2003) techniques in order to provide us with insights especially about players' organizational behaviour.

In the third work package insights from the previous packages were used to design a meta-model for a modelling tool based on two ontologies: (1) an organization theory ontology build from a large corpus of organization theory literature (Schatten, Grd, et al., 2014), as well as (2) a MMORPGs based domain ontology. Building on this meta-model a graphical modelling tool for LSMASs was implemented. In parallel, an end-point plug-in for TMW was implemented that allowed us to implement artificial players which were able to play the game autonomously.

In the fourth work package a number of models were build using the developed modelling tool for various computer gaming, especially MMORPGs, as well as smart city (Caragliu et al., 2011), Internet of Things (IoT) (Xia et al., 2012) and migrant crisis (Berry et al., 2016) simulation related scenarios. The experiments with this models have been successfully performed, but their detailed analysis, at the time of writing this paper, is still to be carried out.

The last two work packages dealt with the usual project activities of dissemination and management, and won't be described in detail herein.

3 Developed Software

During the project a number of software programs and packages have been developed which we shall summarize in (more or less) chronological order:

Dragon egg quest for TMW The implementation of the quest into TMW was the first major programming task of the project. TMW uses a custom script language to formalize quests which we had to extend (using C++) in order to add additional functionality needed by our quest. Additionally, a number of graphics had to be developed for the various new characters that we had introduced into the game.

Data gathering web services In order to provide a central place to gather player data during the data gathering phase a number of web services were implemented in Python to collect and store the data appropriately.[2]

[1] See http://ai.foi.hr/modelmmorpg for more details.

[2] These services were to the most part implemented by a very talented student Lovro Predovan.

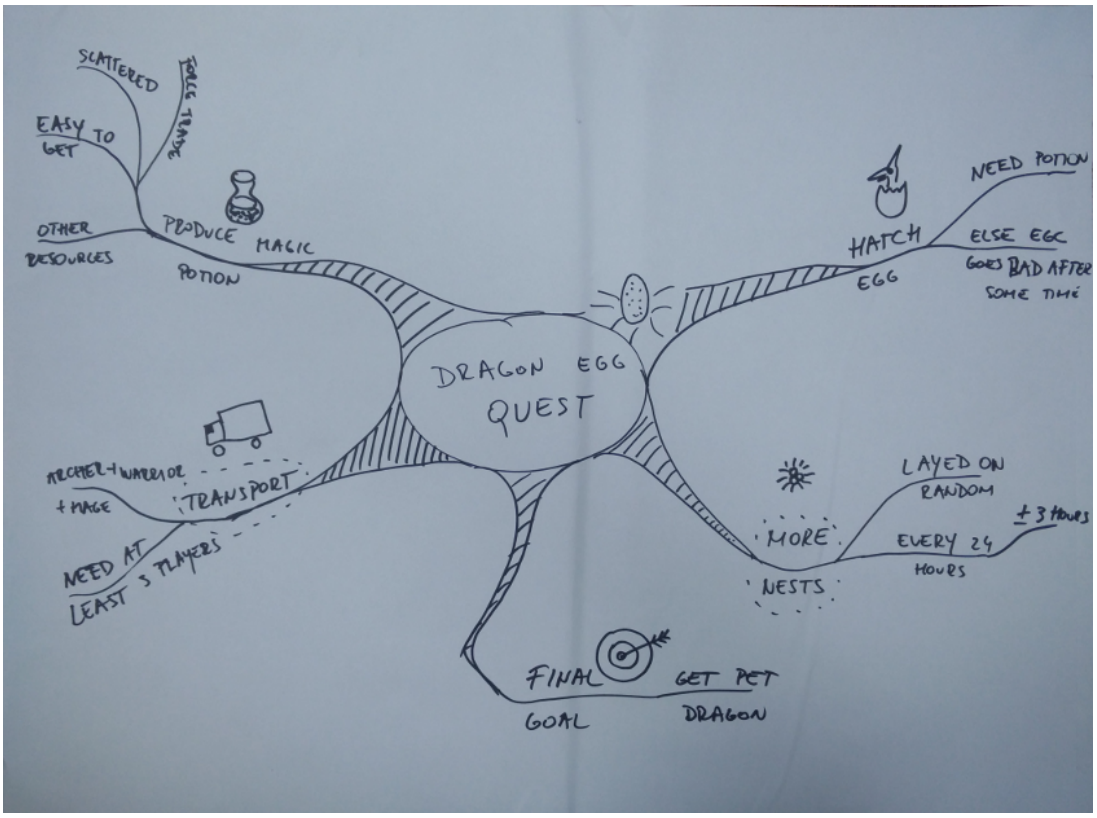


Figure 1. Hand drawn mind map of the developed quest

Custom TMW client Since part of the data about player behaviour wasn't available in the TMW server logs, but on the client side, we have implemented a custom client in Python that sent these data to the above mentioned web services.

Social web site In order to facilitate competition between the various player teams, a social web based on Wordpress site about the game was established. The website[3] featured live updates of player and party statistics implemented in PHP and was well visited during the data collection phase.

SNA scripts/tools In order to analyze interaction between players especially from a social stricture perspective, a number of smaller scripts and tools was implemented mostly in Python to preprocess, analyze and visualize the data using SNA techniques.

NLP scripts/tools Additionally, a number of smaller Python scripts and tools for NLP analysis was implemented as well.

LSMASs ontology & meta model In order to formalize the domain of organization theory applicable to LSMASs and MMORPGs and number of ontologies was developed in Protégé/OWL. These ontologies were the building blocks for a meta-model developed in AtoM^3.

LSMASs modelling tool Based on the meta-model, a graphical modelling tool for LSMASs was developed in AtoM^3. The modelling tool has a code generation module that generates code for the Smart Python Agent Development Environment (SPADE) platform.

TMW low-level interface In order to interface a TMW server and allow the implementation of artificial players, we firstly developed a lower-level interface in Python which implements the client-server network protocol of TMW. The interface allowed us to perform basic player actions (move, attack, talk, pick up item etc.) programmatically.

TMW map knowledge base To allow artificial players to navigate through MMORPG world we created a formal description of the world in SWI Prolog. This description was mostly generated from the actual map files through a Perl script.[4]

TMW automated planner Since we wanted to implement Belief-Desire-Intention (BDI) agents, an automated planning engine based on the STRIPS

[3] Available at http://dragon.foi.hr

[4] This Perl script was implemented by another very talented student Marin Rukavina.



Figure 2. A TMW screenshot showing possible choices a player can make in a conversation, from (Schatten, Tomičić, et al., 2015)

algorithm was implemented in SWI Prolog which featured formalized quests of TMW.[5]

TMW high-level interface In order to integrate the low-level interface, the knowledge-base and the planning system into a coherent end-point plugin, a high level interface using the SPADE platform was implemented. This high-level interface is also the connection to the modelling tool.

Test models In the end a number of test models for TMW, smart cities, IoT and migrant crisis simulation were implemented using the modelling tool. At the time of writing this paper, they have yet to be evaluated in detail.

4 Published Papers

At the time of writing this paper, during the project a total of 23 various papers and presentations were published. In the following we will provide a short summary.

In (Schatten, Tomičić, et al., 2015), agent-based approaches to modeling MMORPG's agents including human players, artificial players and non-playing characters were presented and an overviewed was provided. A special focus was put on useful agent behaviors, coordination and consensus mechanisms, as well as organization and social network structure of agent societies, which would be utilized in the ModelMMORPG project. Showcase of decision making approach of TMW is shown in Fig. 2.

[5]A number of quests were formalized by the student Dario Belinić

The work presented in (Bogdan Okreša Đuric and Konecki, 2015) resulted in a quick overview of the observed behavior of TMW players who tested the quest devised for this project. The content emphasizes various forms of behavior, such as communication, coalition forming (grouping), and in-game activity (e.g. successful log-in attempts), avatar (in-game character) similarity, etc. These data were commented in context of creating an intelligent assistant e.g. in the form of Non-Player Character (NPC), or any other form, that would help players throughout the game.

Analysis of social ties and player behavior is present in (Schatten and Bogdan Okreša Đuric, 2015) as well, but in a somewhat different context and on a different level of detail. This paper presented findings using various methods of SNA, thus offering visual and qualitative analysis of social aspects of player cooperation in the observed game (TMW), such as forming of communities or coalitions (in-game parties), character relations (most common being friend relations), and intensity and timing of private in-game communication (where periods of (non)activity are clearly visible).

An initial ontology comprising key concepts for modeling TMW domain is presented in (Bogdan Okreša Đurić and Konecki, 2015). The said ontology is based on several other published ontologies concerning digital or video games.

Paper (Maliković and Schatten, 2015) presented an initial implementation of artificial players that would be able to play MMORPGs and interact with other players. The implementation is based on an automated planning system and a belief-desire-intention (BDI) agent model, and was coded in Prolog. The developed artificial player is able to receive tasks from NPCs, and solve them according to its internal planning mechanism.

The state-of-the-art overview of self-sustainability-related research and argued grounds for the development of an agent-based modelling and simulation tool, which could be used for modelling self-sustainable human settlements, or even self-sustainable organizations in MMORPG games, was presented in (Tomičić and Schatten, 2015).

The used SNA features during the ModelMMORPG project led to an extended analysis of various SNA features combined with NLP, in the context of analyzing political attitudes and mentalities using social semantic web mining and big data analysis, presented in (Schatten, Seva, et al., 2015). The paper offers an overview of various SNA and NLP techniques that are welcome in political attitudes and mentalities research, with examples.

Building further on the context of SNA, web mining and big data analysis (including NLP), the extended version (Schatten, Ševa, and Okreša-Đurić, 2015) of the above mentioned paper features a set of steps combined into a tutorial on gathering, analyzing, and visualizing data using various tools and techniques. The



Figure 3. Wordcloud of hashtags used in gathered and analysed tweets, from (Seva et al., 2016)

provided tutorial can easily be followed and applied to various domains, although the tutorial and examples are based on analysis of politically active content. These findings were made even more clearer in (Schatten, 2016).

In (Schatten and Terna, 2016) and overview of the project was presented with possible ties to the SLAPP simulation shell. Some of the main hypotheses of the project were outlined.

Following the preliminary work presented in (Tomičić and Schatten, 2015), the real-world case-study and simulation results with the agent-based framework for modelling and simulation of resources in smart self-sustainable human settlements was presented in (Tomičić and Schatten, 2016), arguing and demonstrating the framework's capability to maintain and prolong the self-sustainability of the settlement regarding the simulated resources' management.

Further improvement of comprehension of politics in the hands of various SNA and NLP tools is published in (Seva et al., 2016), where the SNA features used in the ModelMMORPG project motivated an analysis performed on a set of data gathered approximately at the time of Croatian governmental elections of 2015. The paper offers possibilities and examples for retrieving public opinion, in political context, publicly available on social network applications. Data gathering, analysis, and visualization are shown on a real example, a part of which is shown in Fig. 3.

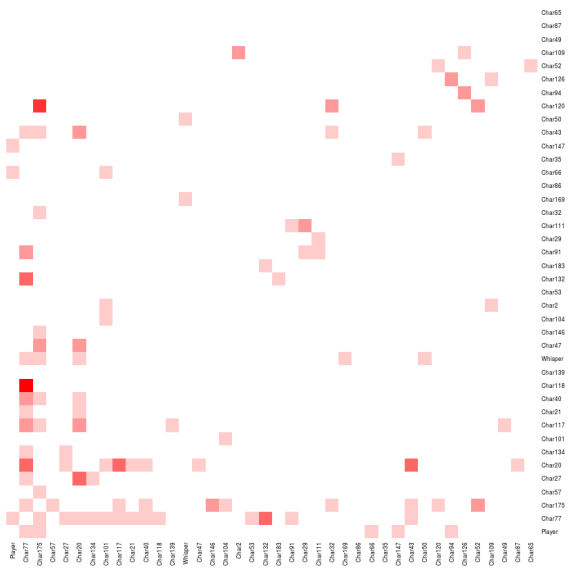


Figure 4. Heatmap showing showing intensity of private communication for every pair of players, where higher saturation shows stronger intensity, from (Schatten and Bogdan Okreša Đurić, 2016)

Analysis of data gathered from TMW, in the context of player to player communication and interaction is presented in (Schatten and Bogdan Okreša Đurić, 2016). The results show interesting findings based on private communication of players and their in-game activity, such as timing and intensity of player communication, their perceived activity in the game, and their interaction with other players using in-game social components. An excerpt of visualized results is shown in Fig. 4.

The paper (Bogdan Okresa Đuric et al., 2016) presented the recipeWorld developed by Fontana and Terna as a possible solution for simulation of large-scale social networks, and provided two conceptual examples of modelling, based on MMORPGs, and the migrant crisis in the EU. Our main objective was to establish a decision making support for potential decision makers confronted with large-scale systems steering.

An overview of the state-of-the-art on organizational design techniques for potential use in large-scale MAS was presented in (Schatten, Ševa, and Tomičić, 2016), together with identifying missing advancements and providing a roadmap of six future development areas of importance, including inter-organizational adaptability, self-reorganization, fault-tolerance, cooperation and competition, strategic management and organizational memory.

The initial idea of the metamodel that is to be used in the final stages of the ModelMMORPG project was firstly published in (Bogdan Okreša Đurić, 2016). The paper presents, shortly, the planned features of the metamodel, the methodology for reaching it, and the key steps that have to be conducted in order to reach the

developed metamodel, e.g. devised ontology comprising organizational concepts for LSMAS. Being a part of a doctoral consortium, this paper set initial pathway for a PhD thesis. The meta-model and the modelling tool were further enhanced in (Đurić, 2017).

Application of the idea of agent organizations on MMORPGs, along with the idea of automated intelligent agents, led to an increased interest in observing self-sustainability of such organizations in the mentioned LSMAS application domain, presented in (Tomicic et al., 2016). Some guidelines on integrating the self-sustainability framework used in the mentioned paper (Smart Self-Sustainable Human Settlements (SSSHS)) with TMW MMORPG are given in the referenced paper.

In this paper we have researched the possibility of using a recent agent-based framework called Smart Self-Sustainable Human Settlements (SSSHS) in agent based organizations, and provided a conceptual framework for integrating SSSHS into a modelling tool that is being developed as part of the ModelMMORPG project. We've argued that it is possible to use the SSSHS framework for building agent organizations in the context of MMORPGs

The initial attempt of combining an ontology comprising organizational concepts applicable to LSMASs with an ontology featuring concepts applicable to MMORPGs is presented in (Bogdan Okreša Đurić and Schatten, 2016). The resulting ontology is built of concepts that can be applied to a specific MMORPG, such as TMW.

The paper (Schatten, Tomicic, et al., 2017) discusses an agent-based automated testing environment for massively multi-player role playing games that is utilizing the game-logic approach, not only for load and stability testing, but also for testing of actual quests in a given MMORPG. The paper partially presents the architecture of the developed framework, including low and high level interfaces and a modelling tool, discusses the chosen LSMAS approach, TMW game as the chosen test bed, and the model developed for testing purposes.

The paper (Schatten, Bogdan Okreša Đurić, et al., 2017) reported on the current state of development of a model driven and agent based MMORPG development platform, discussing the platform's architecture and the example model in more detail. Also, further development plans for a few unfinished components of the framework were discussed.

The work (Schatten, Bogdan Okreaša Đurić, et al., 2017) is a demonstration of the developed agent-based framework for automated testing of MMORPG, that allows for a model-driven development of tests using a graphical user interface, implementation of automated artificial players and their use in testing the quests of the game.

In (Schatten, 2017) a presentation of the findings of the project was given to a larger (especially industry related) audience. There were numerous questions and a large interest for the project findings, resulting in a number of post-presentation meetings and discussions.

5 Discussion and Conclusions

In this paper we have provided a summary of the ModelMMORPG project financed by the Croatian Science Foundation under project number 8537. We firstly provided and overview of performed activities. These activities resulted in a number of developed software programs described later in this paper. Until the time of writing this paper, all results that were published have been summarized as well.

The authors of this paper have no knowledge of a similar research being conducted at the moment, or in the past. Papers detailing on a similar research line exist though, yet they mostly refer to aspects of MMORPGs domain not covered by the ModelMMORPG project, for example: devising an ontology to represent the information that agents store, in the context of MMORPGs (Aranda et al., 2009), analysis of players' behavior in MMORPGs (Lofgren and Fefferman, 2007), or evaluating MMORPG elements using agents (Go et al., 2007).

The project is soon coming to an end, but a lot of new open questions have arisen, that shall be subject to future research of the established research group.

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A Review on Application Domains of Large-Scale Multiagent Systems*

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Abstract. *The paper summarizes a number of recent application domains (ADs) for large-scale multiagent systems (LSMASs) including the Industry 4.0, cooperative intelligent transport systems (C-ITSs), smart grids, smart cities, virtual & augmented reality (VAR) and electronic sports (eSports). These ADs intentionally overlap to show some of the basic building blocks of modern large scale applications - organization, cooperation, competition, robustness and (collective) intelligence. Benefits of using organization-centred LSMASs are outlined and a discussion is provided.*

Keywords. large scale multiagent systems, internet of everything, cyber-physical systems, application domain

1 Introduction

The term large-scale multiagent systems (LSMASs) represents novel framework for modelling, implementation and maintenance of massively distributed systems (M. Schatten et al., 2016; Okreša Đurić, 2017; Okreša Đurić, 2016). LSMASs allow us to not only address the various components of such systems as agents (which is by itself a very strong metaphor) (Garcia et al., 2003), but allow us to group them together into organizations facilitating model overview and modelling even more complex interaction (Markus Schatten, 2014). While holonic (Fischer et al., 2003), multilevel (Gil-Quijano et al., 2012) and swarm-based (Minar et al., 1996) multiagent system (MAS) approaches in most cases address exclusively organizational structure within agent organization, organization-centered multiagent systems (OCMASs) (Ferber et al., 2003) address much more: processes, objectives, interaction, communication, learning etc.

LSMASs go even further: they address interorganizational processes (competition, mergers, spinouts, joint ventures etc.) as well as higher order organizations (organizations of agents which are themselves composed of lower order organizations) (Markus Schatten, 2013). In this way very complex systems can be modeled, by using only simple concepts like organizational units, roles, processes, objectives, strategies etc.

In recent times, engineering complex large-scale systems has become a major challenge. A lot of various initiatives, which might be grouped under the term Internet of everything (IoE), have become the major focus of both scientific and engineering endeavours. The IoE which can be simply described as the process on connecting everything, including devices, processes, services, living beings etc. to the Internet is shaping our current reality.[1] Another common term is the term cyber-physical systems (CPSs) which "refers to a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities" (Baheti and Gill, 2011) and "is defined as transformative technolog[y][...] for managing interconnected systems between its physical assets and computational capabilities" (Lee et al., 2015). The result of these initiatives is a complex sociocybernetic system of systems which itself is becoming increasingly hard to understand in its entirety. Thus, it is necessary to develop new and better modelling techniques based on greater and more concise metaphors. LSMASs are one such metaphor as has already been contemplated in (M. Schatten et al., 2016) and as shall be shown in more detail herein.

In the following sections we will provide more detailed examples of how LSMASs can facilitate the modeling and implementation of complex sociocybernetic systems through a number of application domains: Industry 4.0 in section 2, cooperative intelligent transport systems (C-ITSs) in section 3, Smart Grids in section 4, Smart Cities in section 5, virtual & augmented reality (VAR) in section 6 and electronic sports (eSports) in section 7. In 8 we provide a brief discussion of our findings and draw our conclusions in the ending section 9.

*This work has been supported in full by the Croatian Science Foundation under the project number 8537.

[1] Internet of things (IoT) on the other hand focuses mostly on connecting various devices, but often IoE and IoT are considered synonymous.

Table 1. Conceptual analysis of Industry 4.0 AD

Key concepts	robots, cloud services, big data, sensors, people, products, plants, companies, corporations, industries
Objects	services, data, products
Agents	robots, people, sensors
Agent organizations	plants, companies, corporations, industries

Table 2. Conceptual analysis of C-ITS AD

Key concepts	vehicles, sensors, assistant systems, infrastructure
Objects	infrastructure, data
Agents	autonomous or smart vehicles, sensors, traffic services
Agent organizations	groups of vehicles, sensors, and traffic services

2 Industry 4.0

Industry 4.0, a term used to denote the fourth industrial revolution, "focuses on the establishment of intelligent products and production processes" (Brettel et al., 2014) through the integration of CPSs with current industrial production, logistics and services (Lee et al., 2015). Such systems include (industrial) robotics, integrated cloud services, and big data analytics due to myriads of sensors generating data.

Having the organizational background of industrial companies in mind, Industry 4.0 seems like a natural application domain (AD) for LSMASs which focus on organization. Additionally, robots are the physical incarnation of agents, and thus perfectly suitable to be modelled and implemented in this way. Besides the obvious (robots, services, and people grouped into agent organizations), such organizations of agents have to cooperate (exchange data, services, products etc.) on plant, company, corporate, and industry level. Whilst systems on plant level are mostly connected and integrated, this is an increasingly infrequent case on the higher company, corporate, and industry levels. Such cooperation between organizations of higher level can be modelled and implemented using LSMASs and thus can be made more autonomous and robust. A summary of key concepts and various examples of objects, agents, and agent organizations in Industry 4.0 AD is presented in Table 1.

3 Cooperative Intelligent Transport Systems

C-ITSs or car-2-X communication systems commonly denotes the ability of vehicles, traffic sensors, traffic assistant systems, and roadside infrastructure to communicate and exchange information (Festag, 2014). Especially in the current domain of ad-hoc vehicular networks (Boban et al., 2011) as well as autonomous vehicles (Falcone et al., 2007) and the rising flying vehicle and drone traffic momentum (Markus Schatten and et al., 2015) communication and cooperation facilities become increasingly important.

Traffic systems have been, and are still, considered a natural AD for multiagent development approaches (see for example (Gaud et al., 2008)). LSMASs can extend this tradition with additional and important features: groups of vehicles, sensors, and traffic services can be considered organizations that cooperate or compete with other (agent) organization and deal with complex traffic situations that might emerge on a daily basis. Two detailed modeling examples in this regard are given in (M. Schatten et al., 2016). Key concepts, along with particular examples of objects, agents, and agent organizations for the C-ITS domain are shown in Table 2.

4 Smart Grids

Smart grid is a term referring to the electric grid that is "enhanced" with the ability to deliver electricity from a producer to consumers in an electronically controlled environment, with consumers being the integral part of the smart grids, since they can modify their behaviours and patterns based on the grid feedback (Siano, 2014; Li and Yao, 2010; Initiative et al., n.d.). Smart grid intelligently integrates actions of all parties involved in the network for the purpose of an efficient delivery of "sustainable, economic and secure electricity supplies" (Tamilmaran and Dwarkadas Pralhadas, 2011).

Demand side management is considered to be an integral part of smart grids, including automated metering, sensors, communication systems, intelligent devices and specialized processors (Siano, 2014), primarily aimed to reduce the power consumption at consumer side during peak periods. A multiagent development approach towards energy manipulation in the demand side management context has been implemented in the agent-based framework for modelling and simulating smart self-sustainable systems (Tomičić and Markus Schatten, 2015; Tomičić and Markus Schatten, 2016), where producers, consumers, and storage systems are modelled as reactive agents that are able to connect, communicate, and negotiate between themselves, and modify their own behaviours based on the current information perceived from the environment, in order to prevent the loss of resources within the system.

There are many other examples of using the multiagent systems in the smart grid domain. The use of multiagent systems to control a distributed smart grid

Table 3. Conceptual analysis of Smart Grid AD

Key concepts	electricity, consumer, producer, storage systems
Objects	infrastructure, data, electricity
Agents	consumer, producer, storage systems
Agent organizations	smart grid comprising consumers, producers, and storage systems

Table 4. Conceptual analysis of Smart Cities AD

Key concepts	structures, materials, sensors, electronics, appliances, networks, people, data
Objects	data, materials, structures
Agents	sensors, appliances, people
Agent organizations	smart- flats, buildings, neighborhoods, cities, and various similar groups

in a simulated environment is presented in (Pipattanasomporn et al., 2009), with the architecture that includes control agent, user agent, database agent and distributed energy resource agent, each with their own unique objectives and responsibilities. Other works include multiagent smart grid automation architectures (Zhabelova and Vyatkin, 2012), distributed control concepts using multiagent technology (Hommelberg et al., 2007), multiagent system architecture for smart grid management and forecasting of energy demand in virtual power plants (Hernández et al., 2013), agent-based restoration with distributed energy storage support in smart grids (Nguyen and Flueck, 2012) and others, all pointing to appropriateness of smart grid AD for multiagent development approaches.

Table 3 contains a summary of key concepts, followed by basic objects, agents, and agent organizations, identified in the smart grid AD of LSMASs.

5 Smart Cities

Smart cities present a concept only dreamed about not a long time ago, and envisioned in numerous pieces of popular literature and video as a proof of the coming future and technological advancement. The rising popularity of the idea of IoE encourages research of this particular application domain of LSMAS. The idea of smart cities is put nicely by Hall and associates in (Hall et al., 2000):

> "The vision of 'Smart Cities' is the urban center of the future, made safe, secure environmentally green, and efficient because all structures - whether for power, water, transportation, etc. are designed, constructed, and maintained making use of advanced, integrated materials, sensors, electronics, and networks which are interfaced with computerized systems comprised of databases, tracking, and decision-making algorithms."

The potential of organizational modeling in the domain of smart cities is somewhat underlined in Sec. 4 of this paper. Further motivation for organizational approach to building smart cities is found in the benefits of OCMAS - emphasizing processes, resources, communication, interaction, learning, etc. Having imagined a smart city as a rich society in a broad sense of the word, comprising urban elements, safety, various sorts of structure, sensors, electronics, and information, one can easily deduce that organizational features might improve the effectiveness of such a society.

Organizational features may be incorporated in forming organizations of individual flats agents live in (both artificial (i.e. computer) and natural (i.e. human)), or higher level organizations, such as those comprising individual flats grouped in a building, or numerous buildings in an organizational unit of a neighbourhood or a whole city. Furthermore, it is clear that organizational concepts and ideas from intelligent transport systems (Sec. 3) and smart grids (Sec. 4) can be applied to the domain of smart cities as well, as its integral parts.

Several of the key concepts of the smart cities AD are listed in Table 4, followed by selected examples of objects, agents, and agent organizations of the same AD of LSMASs.

6 Virtual & Augmented Reality

While virtual reality uses completely virtual surroundings based on computer-generated graphics and animations, augmented reality utilizes real-world surroundings augmented with virtual objects in real time (Tang et al., 1998). Virtual reality offers a potential for rich interactive experiences aimed at entertainment, education and training (Traum and Rickel, 2002).

Face-to-face dialogues with virtual humans, i.e. embodied agents, are a common challenge in virtual and augmented realities, where intelligent agents are used for multi-party dialogues (Traum and Rickel, 2002), simulating instructors (Evers and Nijholt, 2000) and substitutes for missing team members (Rickel and Johnson, 1999), simulating fighter pilots in large battlefield simulations (Hill et al., 1997), simulating crowd evacuation management under terrorist bomb attacks in public areas with a BDI software agents (Shendarkar et al., 2008). Other work is also related to disaster management, employing both virtual/augmented real-

Table 5. Conceptual analysis of VAR AD

Key concepts	experience, dialogue, emergency situation management
Objects	data, experience, situations
Agents	artificial agents, people
Agent organizations	various grouping possibilities in a multitude of simulation scenarios

Table 6. Conceptual analysis of eSports AD

Key concepts	cooperation, competition, players, teams
Objects	data, computer games of various genre
Agents	players, artificial agents
Agent organizations	teams of players or artificial agents

ity and multiagent systems. In (Uno and Kashiyama, 2008), authors have presented a simulation system for disaster evacuation based on a multiagent model, using virtual reality as a visualization technique. DrillSim (Massaguer et al., 2006) is an augmented reality simulation environment based on a multiagent simulation, where the simulation of the disaster response activity can be achieved "by modeling each person involved as an agent".

Multiagent systems are also used for pedagogical purposes in virtual environments (Buche et al., 2003), and virtual environments can provide test beds for creation and evaluation of multiagent systems (Kaminka et al., 2002). A toolbox for performing alternative experimentation on complex biological systems was designed on the framework of multi-agent systems and virtual reality (Desmeulles et al., 2006), presenting a new type of investigation for the complex systems study called the *in virtuo* experiment. The virtual and augmented realities thus can be seen as a "natural habitat" for multiagent systems, that can be practically utilized for a number of purposes.

Table 5 offers a conceptual analysis of the key concepts, along with examples of objects, agents, and agent organizations, of the VAR AD.

7 Electronic Sports

It was evident that computers will play a big role in various digital and analogue games, ever since IBM DeepBlue beat the world chess champion after a six-game match (Corporation, 2012), and more recently AlphaGo successfully won a game of Go against top-tier players (Hassabis and Silver, 2017). Modern computer games are more aligned with a different idea of gaming - cooperative and competitive computer gaming in human versus human matches. Such games, generally classified as first-person shooters (FPSs) and multiplayer online battle arenas (MOBAs) include various titles, the most popular being League of Legends, World of Tanks, Call of Duty, HearthStone, and DOTA2[2]. Even though competitive gaming is not an entirely new idea, it has gained immense popularity in the last decade, both in the context of audience and revenue (Armstrong, 2017).

Seen as an AD of LSMASs, various currently popular games could benefit from organizational features of intelligent agents that would operate from inside a game. A general idea visible from the time of BigBlue and AlphaGo is a competition of computer versus human players. Since most popular games in eSports are based on team-play, no single agent can beat human players who cooperate. That is where organization of artificial intelligent agents shines - the advancing technology poses questions such as would a team of artificial agent players win in a competitive team game against a team of human players, where teammates in both teams cooperate?

Selected key concepts of the eSports AD of LSMASs are shown in Table 6, accompanied by several chosen examples of objects, agents, and agent organizations of the said AD.

8 Discussion

As has been shown in the previous few examples, various IoE and CPS initiatives can greatly benefit from LSMASs. The main benefit of using an organizational approach (as LSMASs do) to such complex systems is the possibility of modeling higher order organizations which are then considered as single entities. This metaphor allows us to develop even more complex distributed and concurrent systems, by approaching their subsystems as (simplified) entities.

It is simpler to model a situation in which two (possibly higher order) organizations cooperate with each other, then to model all the interacting components of two complex systems. For example, it is easier (for a human) to grasp that two industrial plants A and B need to exchange information to synchronize production pace, then that operating stations X_1 to X_{25} from line L_1 and stations Y_1 to Y_{17} from line L_2 need to send their current production data to a control station G which in turn analyzes the data, generates synchronization deltas and sends them to the adequate operating station. In the end effect, the system that operates the plants might be implemented this way, but on a higher-level of abstraction one might understand the

[2]Statistics data from 19 July 2017, available at https://www.statista.com/statistics/506923/esports-games-number-players-global/

operation quite easier and even detect possibilities for optimization.

9 Conclusion

In this paper we have presented a number of contemporary ADs of LSMASs which are closely related to the IoE and CPSs initiatives. It has been contemplated that an organization-centred LSMASs approach which has been mostly developed during the ModelMMORPG[3] project can highly benefit the modelling and implementation of such complex sociocybernetic systems. Detailed modeling examples of such systems are subject to our future research.

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Model Driven Game Quest Scenario Development for Massively Multi-Player Role-Playing Games: A Case Study*

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Abstract. *In this paper, a new application case of the novel organizational metamodel for Large-Scale Multiagent Systems (LSMASs) being developed is going to be presented. The mentioned metamodel is being tested on a new computer game of Role-Playing Game (RPG) genre by developing a game quest scenario through the model-driven approach. This new application of the said metamodel will further enhance the feature of general applicability of the metamodel to various LSMAS domain examples.*

Keywords. mmorpg, agent based modeling, agent organizations

1 Introduction

The graphical modeling tool for modeling and building a system comprising agents, groups of agents, roles (special types of grouped constraints), actions (inherently bound to specific roles), sets of actions designated as processes, and quests (composed of a series of sub-goals or tasks), used in this paper, was presented in (Okreša Đurić, 2017; Okreša Đurić, 2016), and the initial application case on The Mana World (TMW) Massively Multi-player Online Role-Playing Game (MMORPG) was introduced in (Schatten, Tomičić, et al., 2017; Schatten, Okreša Đurić, et al., 2017b; Schatten, Okreša Đurić, et al., 2017a). Although the existing body of research has considerably contributed in bringing the model driven approaches into the game development domain (e.g. in modeling narratives, spatial and temporal relationships, gameflow, game modes and similar), the novelty of our approach is given via the organizational aspects of in-game quests that are inherently bound to organizational behaviours of players and Non-Player Characters (NPCs). By applying the organizational metamodel for LSMASs on the second test-bed and developing the game quest scenario with organizational aspects in mind, the general applicability of the metamodel would be further argued.

*This work has been fully supported by the Croatian Science Foundation under the project number 8537.

2 Related Work

According to (Dormans, 2012), model-driven engineering "is a suitable approach to deal with the dynamic process of designing games." A state-of-the-art in model-driven game development, summarizing the developments in "game design languages, game software modelling languages, game models, game software models, model-driven game frameworks, game software frameworks, model-driven engineering tools and assistive user interfaces", is presented by (Tang and Hanneghan, 2011). In their work, authors provide an extensive overview of given subjects, supported by illustrative examples, advantages and shortcomings of reviewed languages, tools and frameworks.

Adams proposed the so called "flowboard" for the purposes of documenting game structure (Adams, 2004). The word "flowboard" is derived from a combination of the words flowchart and storyboard, using both approaches in modelling by using a number of pictures (rectangles) in a non-linear series, presenting a mockup of the screen in one of the gameplay modes (for example, menu screen, high score table, splash screen, etc.). The arrows in the flowboard denote constraints of progressing from one gameplay mode to another, with text labels describing events' triggers that are required for the transition to take place. The flowboard is a simple tool for modelling various gameplay modes, that might be adapted for a certain level game scenario dynamics, but lacks the expressiveness for describing more details about game quests, organizational structure and game role constraints.

Onder proposed the story beat diagram for modelling the progression of a story (Onder, 2002). The elements of the diagram include ovals (representing activities/tasks) and arrows (representing progressions), and are able able to describe available routes for the game player, which are possible to explore within the game story. While providing an ordered overview of the game-play scenario flow, the story beat diagram does not provide additional details on players, organizational context, spatial data, interactions of players/NPCs and similar.

Unified Modelling Language (UML) has also been

used in the context of game design. In their work (Taylor et al., 2006), authors have adapted the use-case diagram language defined in UML in order to create a custom modelling language for the description of the game flow, intended for the design of individual game levels, and have demonstrated its application in practice. Their "Computer Game Flow Design Diagram" uses arrows do denote directions of a game-flow, rectangles for objects that are fixed within the game spatial context, and ovals for objects that can move throughout the game space. Although their model additionally uses pseudo-code for the description of various details of the game (responses, interactions, etc.), the graphical modelling language itself lacks the expressiveness for describing details of characters, roles, quests, organizational aspects, etc.

Finite State Machines (FSMs) have also been utilized in modelling games, but mostly in modelling game AI (Kienzle et al., 2007). Although FSM diagrams have considerable potential in modelling games, considering that games often include various states that can change by certain triggers (rules, interactions, events), they lack the ability to describe the quests in an organizational context (hierarchy, roles, etc.).

Natkin et. al (Natkin et al., 2004) proposed a "new formal approach for the design process of computer games", involving the modelling of combined spatial and temporal relationships in games. Authors used hypergraphs for spatial (topological) relationships' modelling, and logical and temporal relationships are modeled by using Petri nets. By using this approach, game developers could model game flow and game events, but couldn't tackle characters, their roles/behaviours, quest details or organizational aspects of the game quests.

Although the existing body of research within the model-driven game development field showed promising results on various aspects of game development (narratives, spatial and temporal relationships, game flow, game modes), there is a lack of research involving organizational aspects of more complex games that include quests and foster organizational behaviour, such as MMORPGs.

3 Organizational Metamodel for Large-Scale Multiagent Systems

The novel organizational metamodel for LSMASs that will, in the end, include working with organizational dynamics as a feature of human organizations translated to LSMAS domain, was initially presented in (Okreša Đurić, 2017) and is being developed as an integral part of the ModelMMORPG project[1]. The main idea of the mentioned metamodel is organizational modeling of complex multiagent systems comprising large numbers of agents, thus referring to the idea of LSMASs. The *meta* prefix is based on the fact that the metamodel can be used for various purposes, i.e. for organizational modeling of models pertaining to various application domains, all of which are based in the general concept of LSMAS. This multi-application statement is an intention to show various application domains that can be modeled using the said metamodel through a number of case-studies. An example of a model is shown in Sec. 4.1 of this paper.

The general idea of the metamodel is to provide a tool for organizational modeling of LSMAS concepts in a manner similar to that of organizing human organizations, but with a special emphasis on seven perspectives which are argued to be invaluable for the ongoing research of LSMASs (Schatten, 2014):

- organizational structure,
- organizational culture,
- strategy,
- processes,
- individual agents,
- organizational dynamics,
- context and inter-organizational aspects.

The stated is set to be achieved through a basically two-step process initially presented in (Okreša Đurić, 2016), and further discussed in (Okreša Đurić, 2018): an established ontology comprising concepts of organizational modeling, and based upon it a metamodel containing all the necessary concepts of the mentioned ontology that are deemed needed and necessary for the main goal of the metamodel - organizational modeling of LSMAS.

As stated before, the metamodel is being developed as a part of the ModelMMORPG project, and is therefore mostly related to its main purpose - modeling of MMORPGs. The metamodel was envisioned with generality and wide spectre of possible use though, and is therefore created to be applicable to a wider array of LSMAS application domains. Being originally built for the application in MMORPG domain, but with general use in mind, the metamodel prominently features several key concepts:

- organizational unit - this concept that represents a class of agent that can play various roles contains some key actions (such as ChangeRole action used for changing roles the agent plays at the moment), and is knowledgeable of some norms of the system;
- role - a normative concept of the system, every norm is a set of constraints that can be posed on

[1]Large-Scale Multi-Agent Modelling of Massively On-Line Role-Playing Games; Artificial Intelligence Laboratory at the Faculty of Organization and Informatics, University of Zagreb; for further information visit http://ai.foi.hr/modelmmorpg.php

an agent, i.e. an agent can play a norm and thus apply a set of conditions of the system upon itself, such as a set of available actions;

- process - actions that can be performed by a role are grouped into sets called processes - the set of actions is not constrained to a single role though, and can consist of actions from various roles, all of which can be coordinated to achieving a common goal;

- objective - the concept of objective represents a goal that is to be reached by the agents of the system using available actions of the roles individual agents can play.

The mentioned core elements of the metamodel are applicable to the MMORPG domain, although for a more detailed description of a specific application example further concepts would be welcome (e.g. various types of items). This omitting of concepts that would foster detailed modeling is motivated by generalization of the use of the metamodel. Relation of MMORPG concepts and generalized LSMAS concepts can be noted in various examples not related to the domain of MMORPG, since the metamodel elements are general enough to be used in application domains other than MMORPG, e.g. smart cities, the Internet of Everything (IoE), etc.

Another interesting feature of the metamodel is its application template generator that is described in (Schatten, Okreša Đurić, et al., 2017a). This feature of the metamodel generates application template based on Smart Python Agent Development Environment (SPADE), thus providing the users with agent templates and their possible actions (or behaviours in SPADE language) as defined using the modeling tool. A sample listing of the generator is shown in Sec. 4.2, based on the example shown in this paper. SPADE was chosen as a tool that is based on Python programming language, and is rather simple to use, along with the fact that it is the basic Multiagent Systems (MASs) development environment used in the ModelMMORPG project.

4 Game-based Example

Minion Wars is an open source, browser-based alternate reality game based on usage of Google Maps and Google Places Application Programming Interface (API). User interacts with virtual world through map interface and is given a wide variety of actions that it can perform in immediate vicinity of its location which is tracked and updated in real time. Goal of the user is to gather experience points and resources by visiting specific locations called nodes. Nodes are either randomly generated or retrieved from Google Places API and are defended by NPC agents called minions. In order to access nodes, user is supposed to defeat enemy minions through use of its own minions. Some of the actions available to the user are:

- spend experience points to upgrade abilities - abilities are personal characteristics that define aspects such as amount and strength of users minions, number and range of minions it can send away on missions to remotely access nodes and speed of camp upgrades.

- build and upgrade camps - camps can host minions that then automatically gather resources from nodes in certain radius. Upgrading camps allows it to host more minions and access nodes in larger area.

- manage minions - organize minions in groups, decide which minions remain with user, which are stationed in camps and which are sent away on missions.

4.1 Example Quest Description

Landmark Quest is a special type of quest available to a user. User can earn rewards by completing sets of specific tasks that are geofenced to areas in certain radius of locations assigned to Landmark Quests. These quests can be started by simply entering the designated quest area. Some of the tasks that user can complete are as follows:

- defeat certain amount of enemies,

- defeat specific enemy with help of other users (e.g. a “boss” enemy),

- solve puzzles,

- visit specific locations within the area.

Users can perform any of the tasks available at the moment in any order. For each task completed, the user is awarded participation points. Upon getting certain predetermined amount of participation points, the quest is considered completed.

As the user progresses with tasks, smaller rewards are continuously awarded. The rewards can come in form of experience points, in-game currency, or resources and information. Upon completion of designated set of tasks, the user receives a much more substantial reward.

A particular example of such a quest within the context of Minion Wars would require for user to visit the Tower of London.

To start the quest, the user needs to enter the area in direct vicinity of the Tower of London. They are immediately presented with initial backstory and how the area is filled with hostile minions led by a minion chief. The user is tasked with visiting specific areas within the Tower (Inner Ward, Outer Ward, Innermost Ward). Between each visit, the user is also required to defeat several hostile minions that roam the area.

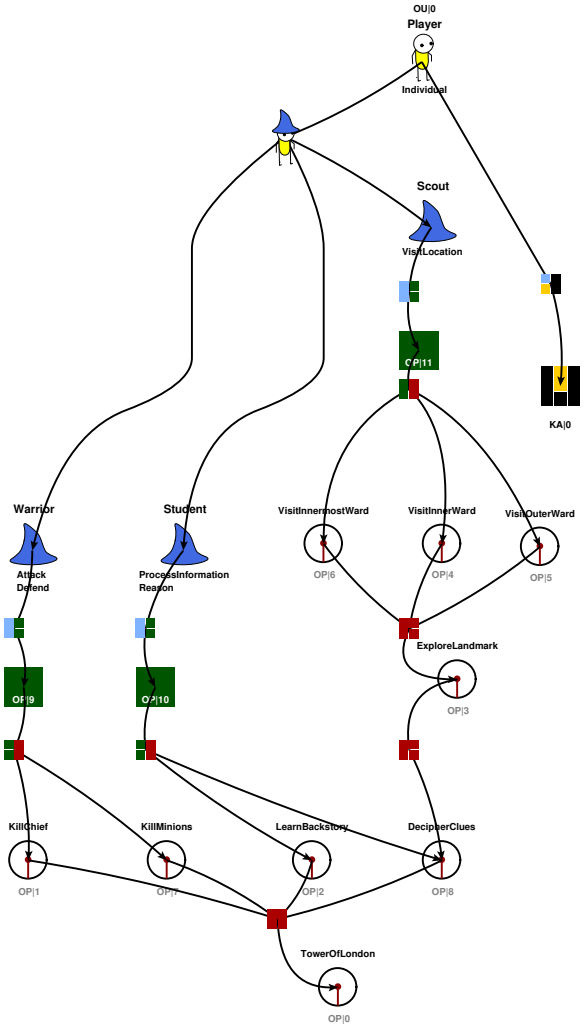


Figure 1. Model of the example quest using the described metamodel

Upon visiting each of the areas, the user is presented with information about the visited location and bits of information regarding the local minion chief. Upon visiting all the key locations, the user is tasked with finding the definite final location (the White Tower) by deciphering the clues from previous tasks. Upon entering the final location, the user is able to confront the minion chief in combat. After defeating the minion chief, the user is awarded further pieces of information about the Tower of London and significant in-game monetary reward.

4.2 Example Quest Modeling

The described example quest derived from the Minion Wars game can be modeled using the described metamodel as is shown in Fig. 1. It stems from the quest description, given in Sec. 4.1, that the player (yellow stickman in Fig. 1) has to play several different roles in order to be able to fulfill the given quest, and complete it successfully. These roles (blue hats in Fig. 1) can be, in the manner of MMORPGs, named as follows: Scout, Warrior, and the unusual one - Student. Furthermore, each agent has some individual knowledge modeled as an individual knowledge artifact seen as a yellow-black square in Fig. 1.

Since the game is envisioned as not only a fun-related experience, but an educational one as well, the Student role contains actions necessary for the agent (the human player in this case) to learn the knowledge the game provides them with, and use it when the game demands it. Therefore, the Student role is useful when completing knowledge-related tasks of the given quest example - The Tower of London (quests and tasks are shown circular in Fig. 1). The second important role emerging from the given quest is the Scout role, which enables the player agent (either artificial or human) to conduct actions (actions are grouped in processes shown as green squares in Fig. 1) pertaining to scouting the given area and moving through space. Such actions are necessary for the exploring tasks of the quest. Finally, the Warrior role is self-explainable, since the quest demands the player to best a number of minions, and their chief.

Only through the combination of the mentioned three roles, and their actions, the player can successfully complete the given quest. Upon finishing the quest, the player is presented with an award of some kind, depending on the quest, and their performance while solving the given quest.

Using the provided model, and the modeling tool being developed, which is described earlier in this paper, a developer can generate application template of the modeled system, along with the logical dependencies built based on the set relations of the defined roles, their actions, processes, and the tasks of the given quest. Such an initial programming code can boost the rapidity of modeled system development. An excerpt of such a template is shown in Lst. 1, which shows the SPADE agent template along with its single action for changing roles, and an excerpt from its knowledge base regarding the Scout role, its actions and tasks that can be achieved by playing it.

```
import spade
from RoleBehaviours import *

class Player(spade.Agent.Agent):

  class ChangeRole(spade.Behaviour.
      OneShotBehaviour):
    def _process(self):
      [...]

  def _setup(self):
    self.addBehaviour(self.ChangeRole(), None)

    self.configureKB('SWI', None, 'swipl')
    self.addBelieve('canReachGoal(Scout,
        VisitInnerWard)')
    self.addBelieve('canReachGoal(Scout,
        VisitOuterWad)')
    self.addBelieve('canReachGoal(Scout,
        VisitInnermostWard)')
    [...]
    self.addBelieve('hasAction(Scout,
        VisitLocation)')
```

Listing 1. Part of the generated code template for SPADE Player agent

It should be noted here that the application template generator part of the metamodeling tool provides the user (the developer of the modeled system) with basic programming code pertaining to the idea of implementing agents that follow the modeled organizational features (including roles and coalitions), and the basic knowledge base necessary for utilizing the said organizational features. Therefore, the extent to which the code is generated is limited to core elements needed for SPADE agent definition, along with their behaviours (actions), role playing features, and individual agent knowledge bases that allow the agents to enact various roles based on reasoning about quests, tasks, and behaviors. Reasonably, the amount of generated code depends on the complexity of the modeled system.

5 Discussion and Conclusions

Using the quest decomposition on several lower-level tasks that have to be fulfilled in order for the main quest to be achieved, the shown model gives a clear picture of the actions and roles, i.e. constraints of the system and norms, that are needed for a player to successfully finish the given quest. The addition of the application template generator is useful inasmuch as the defined model can be easily transferred to an implementation-ready code that can be used for testing the defined quest.

In this paper we have presented a new application case of the novel organizational metamodel for LSMASs that is being developed. The metamodel was tested on a new RPG computer game that was chosen as a test-bed primarily because of its quest-oriented design, by developing a game quest scenario through the model driven approach. The new application of the metamodel is an argument in favor of its feature of general applicability to various LSMAS domain examples.

As argued in Section 2, the existing body of research, dealing with game quest development questions, lacks organizational aspects of more complex games that deal with quests and utilize organizational behaviours. The research approach proposed within this paper encompasses expressiveness used to describe more details about game quests, quest hierarchies, organizational structure, game role constraints and interactions of players and NPCs.

The future work will orient towards improving the general readability of the metamodel in more complex game/organizational designs. Indeed, the metamodel has to be made more legible and easier to be read, which is an idea planned to be achieved through the use of multi-model modelling method.

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Agent-Based Simulation Model for Real-Time Traffic Analyses

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Abstract. *Densely populated areas usually have problems with commuting, especially during morning rush hours. This paper presents an agent-based simulation model for real-time traffic analyses. The built simulation model is representing the part of Belgrade during morning rush hours with major traffic participants involved. The model is used to conduct simulation experiments and based on results, improvement measures are suggested.*

Keywords. agent-based model, agent-based simulation, traffic analyses, real-time decision-making

1 Introduction

Citizens in big cities are making a lot of traffic-related decisions during the day. Some of the most important ones are made during the morning rush hours. Most of these decisions are made based on experience and not based on current traffic data.

In this paper, the model of smaller part of Belgrade during morning rush hours is presented. The model includes a proposal for a system that enables real-time traffic information sharing and drivers' real-time decision making based on that information. The main purpose of this model is to conduct traffic analyses and suggest the measures for shortening the time needed to travel from one distanced point to another. The agent-based modelling and simulation (ABMS) is chosen as the most appropriate methodology.

Over the last two decades, the application of ABMS is making vigorous development. Taking into account only papers indexed in Science Citation Index Expanded (SCI-EXPANDED) and Social Sciences Citation Index (SSCI), their number increased from 15 to 449 in period 2000-2015 (Markovic & Zornic, 2016).

Agent-based modelling and simulation can be used to reproduce systems related to economy (Čavoški & Marković, 2016; Marković, Čavoški, & Novović, 2016; Shafiei et al., 2012), ecology (Gerst et al., 2013), agriculture (Rebaudo & Dangles, 2013), medicine (Kasaie, Andrews, Kelton, & Dowdy, 2014), to solve optimization problems (Nikolopoulou & Ierapetritou, 2012), and many others.

Meignan, Simonin, and Koukam (2007) used ABMS to model bus-networks, including a road traffic model and showed that this approach is able to give solution for authorities to design new transportation solutions. Hashmi Syed et al. (2017) presented traffic route analyser together with the custom-built mobile application for collecting the traffic data.

Every agent-based model has three elements (Macal & North, 2010):

- A set of agents with their attributes and behaviours.
- A set of agent relationships and types of interaction.
- The agent's environment, as agents interact with their surroundings in addition to other agents.

The most important characteristic of the agent, also often used in literature to justify the usage of ABMS over other methods, is its independence and capability to act autonomously (Macal & North, 2014; Wooldridge & Jennings, 1995).

After defining agent-based modelling and simulation, the paper is organized as follows. Model for real-time traffic analyses is presented in section two, including the description of model variables and analyses of simulation results. Finally, conclusions and some directions for future research are provided in section three.

2 Model for real-time traffic analyses

As it can be seen in Figure 1, the presented traffic model features two parts of the route from *START* to *FINISH*, each with two alternative sub-routes. The first part, from point *A* to traffic light 14 (*TL14*) can be travelled using the blue route (2.0 km) or the red route (2.7 km). The following part, from point *B* to *TL12* can be travelled using the green (2.5 km) or the brown (3.1 km) route.

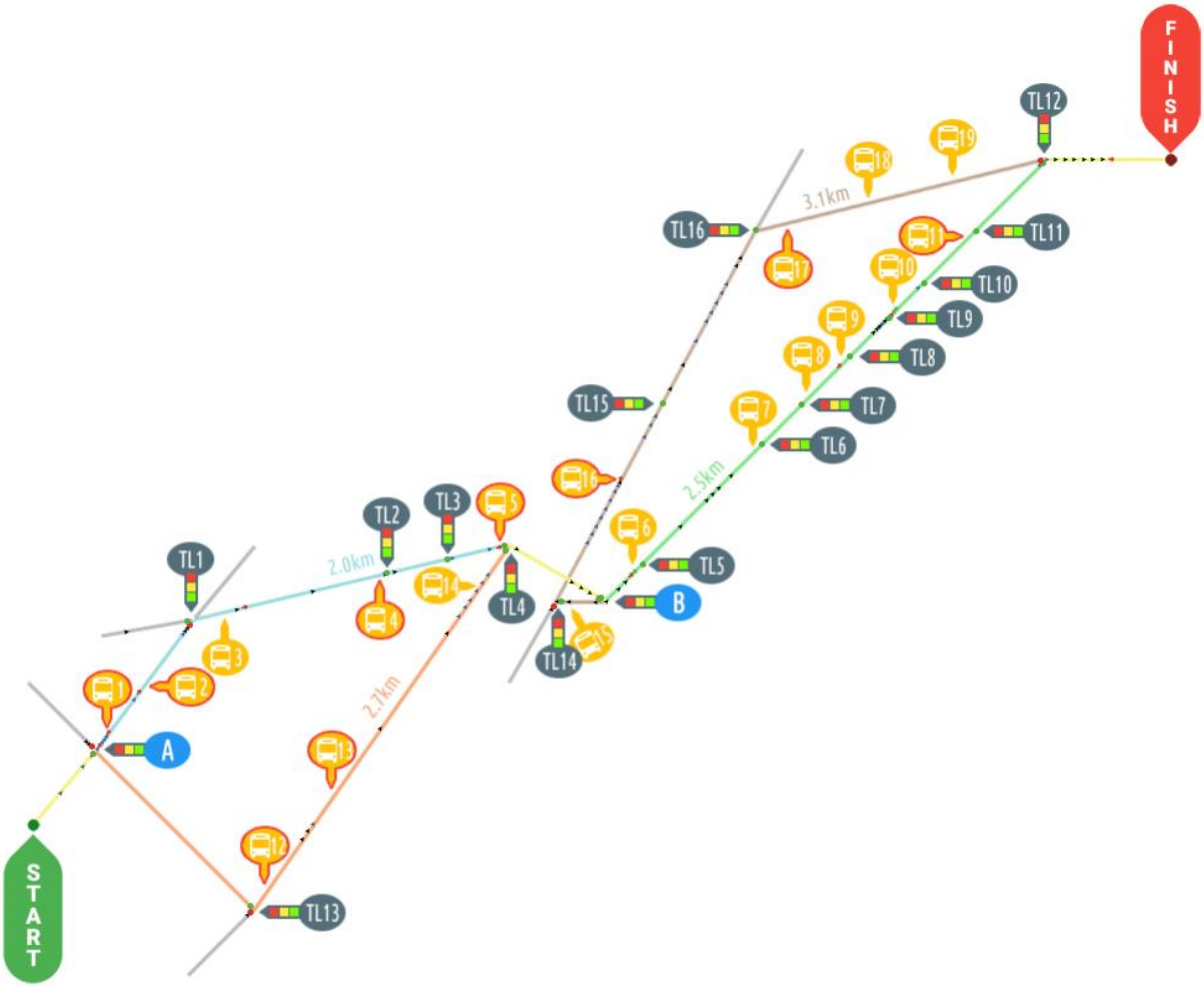


Figure 1. Traffic model

Besides roads, the model features 18 traffic lights (*TL*) and 19 bus stops (bus icon). Bus stops with a red border are stops on-street and buses are blocking the traffic while passengers are boarding. Yellow-only bus stops are bus turnouts, where two buses can board passengers without blocking the traffic.

While modelling the behaviour of traffic participants, the abilities of agents are well-employed. Namely, every car is aware of its surrounding: other cars, traffic lights, and buses. The same accounts for buses, they are aware of cars, other buses, traffic lights and bus stops. The model is built keeping flexibility in mind. Namely, the behaviour of model participants is described using more than 400 adjustable variables.

Besides observed cars travelling from *START* to *FINISH*, other cars are present also. It is assumed that all the cars are respecting the speed limit in the populated area of 50 km/h and there is no overtaking. Speeding up and slowing down is modelled, also.

There are multiple bus lines present in the observed traffic system but also included in the model. Those are presented in Table 1.

The model includes the possibility for drivers to receive information about routes to their destination. Herrera et al. (2010) proved that only 2-3% penetration of cell phones in the driver population is enough to provide accurate measurements of the velocity of the traffic flow.

Table 1. Bus lines

No.	Route	Interval [minutes]	Deviation ± [minutes]
23	*START-TL1*	6	0.5
37	*TL1-TL4-B-TL14*	7.5	1
42	*TL13-TL4-B-TL14-TL16-TL12-FINISH*	14	1
47	*B-TL12-FINISH*	6	0.5
48	*TL8-TL12-FINISH*	7.5	1
50	*TL1-TL4-B-TL12-FINISH*	6	0.5
53	*START-TL1*	8	1
59	*START-TL1-TL4-B-TL12-FINISH*	7.5	1
89	*START-TL1*	12	1
94	*TL6-TL12-FINISH*	11	1

In Serbia in 2015 35% of individuals aged 16 to 74 were using mobile devices to access the internet on the

move (Eurostat, 2016). Thus, we suggest introducing the mobile application for real-time traffic information sharing. This application should be able to provide the driver with information about alternative routes to their destination and travel time for each route. Based on this information driver is able to choose the faster one. In the model, the average travel time for a selected number of cars is calculated every time the new car finishes the section.

The model is built using NetLogo software (Wilensky, 1999).

Some of the most interesting variables are made adjustable using graphic input elements, switches and sliders and are explained in order from Fig. 2:

- *speed-limit*, for setting the speed limit for cars and buses.
- *add-car-constantly*, for controlling the creation of new cars in the model.
- *add-car-unobserved*, for enabling/disabling the appearance of unobserved cars from different parts of traffic grid.
- *add-bus-constantly*, for controlling the creation of new buses.
- *get-traffic-info* is controlling whether drivers will get information about mean travel time when choosing the sub-route.
- *mean-time-last-cars* is slider for defining for how many last cars that finished the specific sub-route we will calculate the mean travel time.
- *blue-over-red*, chance to choose blue route, and not the red one.
- *green-over-brown*, chance to choose green route, and not the brown one.
- *bus-stop-{1, 2, 4, 5}-turnout*, for adding the turnout to corresponding bus stops.
- *tl-12-brown-side-green-light* is for controlling the duration of green light on the brown-route side for *TL12*.

Most of the input variables are set based on authors' approximation (like introduction of new cars to the model, *blue-over-red* and *green-over-brown*, and bus boarding time on bus stops) and some based on system observation (most of the traffic lights' green/red light duration). Additionally, bus departure times are taken from official timetable (Sekretarijat za javni prevoz, 2017).

As stated in the introduction, the purpose of this model is to conduct traffic analyses and suggest the improvement to shorten the time needed to travel from *START* to *FINISH*, including all the route subsections. We conducted a series of experiments and will present some of the interesting results and conclusions in the following section.

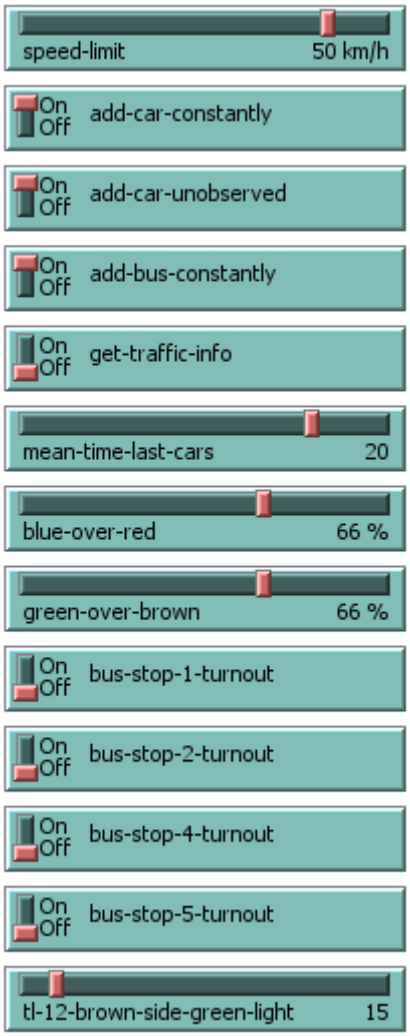


Figure 2. Model controls

2.1 Simulation results

Simulation experiments are run for the approximate duration of morning rush hours (from 07:00 to 09:00).

Input variables for the first (*base case*) experiment are presented in Figure 2. From the *base case* experiment results, we noticed that the blue route had a problem with most of the bus stops being on the traffic lane, while the part of this route from *A* to *TL1* has four buses with interval 6-12 minutes each. Besides this, the average waiting time is 3.38 minutes and travel time (from start to finish) is 10.26 minutes. Selected indicators for all experiments are presented in Table 2.

In the next experiment (*traffic info*), the *get-traffic-info* switch is turned on, meaning that drivers coming from *START* are getting information about average time needed to travel from point *A* (using blue/red route) and from point *B* (using green/brown route) for the last 20 cars (*mean-time-last-cars* slider). Based on that information they are taking a faster route. The slight improvement is visible in the system. Namely, the average travel time from start to finish is now 9.85 minutes and average waiting time is 2.67 minutes. This

is mostly because majority of the cars avoided blue and used a red route instead. The red route is burdened with only one bus that has interval of 14 minutes.

During the previous simulation experiments we noticed that bus stops 1, 2, 4, and 5 are causing traffic jams. In experiment *bus stop turnout 1* we turned on the switch *bus-stop-1-turnout* to check the influence of adding turnout to this bus stop on travel time. Results presented in Table 2 show that there is slight improvement regarding the blue route. This is expected, as bus stops 1 and 2 are ones with most buses operating and longest boarding times. What we noticed during this experiment is that bus stop 2 is one of the major bottlenecks in the system. The next experiment will consider introducing turnout to the mentioned bus stop.

Table 2. Simulation results

Experiment	Average waiting time [minutes]	Average travel time (start - finish) [minutes]	Blue route average travel time [minutes]	Red route average travel time [minutes]	Green route average travel time [minutes]	Brown route average travel time [minutes]
base case	3.38	10.26	4.47	3.25	4.11	4.77
traffic info	2.67	9.85	4.00	3.30	4.23	5.79
bus stop turnout 1	3.05	9.96	3.76	3.23	4.34	4.63
bus stop turnouts 1&2	2.73	9.59	3.32	3.26	4.30	4.53
bus stop turnouts	2.08	8.85	2.27	3.25	4.07	4.65

In experiment *bus stop turnouts 1&2* both *bus-stop-1-turnout* and *bus-stop-2-turnout* are switched on. This resulted in a reduction of average waiting time to 2.73 minutes and average travel time to 9.59. At this point, we can say that the similar result is achieved by equipping drivers with a mobile application for traffic information sharing and by introducing one or two mentioned turnouts.

With the next experiment, *bus stop turnouts*, we are analysing the influence of adding turnouts to bus stops 1, 2, 4 and 5 to travel time – *bus-stop-{1, 2, 4, 5}-turnout* switches are turned on. This experiment showed the best results. Namely, the average waiting time is 2.08 minutes now and average travel time from start to finish is 8.85 minutes (more than a minute, or 14% less than in the *base case*). The result is improved mostly because bus turnouts keep buses off the road during boarding time and cars can freely pass by.

Based on presented experiments bus turnouts should be introduced wherever possible and in the case of bus stops 1, 2, 4 and 5 it certainly is. This investment would greatly shorten the time needed to reach the desired destination, but also decrease gas consumption and CO_2 emission (Shang, Zheng, Tong, Chang, & Yu, 2014).

3 Conclusion

This paper is presenting the usage of agent-based modelling and simulation for analysing traffic system. Traffic system is modelled keeping in mind possible improvements, both those depending on drivers and policy makers. Namely, drivers can be equipped with a mobile application capable of receiving traffic information and choosing the faster route in real time. This solution can shorten the time needed to reach the destination by 5% in regular conditions. On the other side, policy makers can use the model to analyse the impact of bus stops on traffic overall.

The flexibility of the model enabled us to conduct series of experiments and notice bottlenecks of the traffic system. In some of our experiments, we suggested improvements which demonstrated that small changes could have a great impact on system efficiency. Namely, the introduction of only four bus turnouts resulted in 14% reduction of time needed to pass the same route.

We can conclude the designed model for traffic analyses is providing a better insight into problems of reaching a desired destination during rush hours. Future research will be devoted to model even more complex systems with larger number of participants.

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Quality of Software and Services

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Quality Factors for Mobile Medical Apps

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On-Line Behaviour of Users With Different Privacy Concerns

Acceptance of Open Peer Review by Scientific Publishers

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Abstract. *The paper consists of two parts. The first part describes the importance and problems of the current peer review process and characteristics of open peer review. The second part provides results of the research study of the 100 top scientific publishers about their acceptance and possible implementation of the open peer review. Public documents about open peer review were sought on publishers' Web sites and the research showed that there are very few of them available. The research confirmed that open peer review is still not widely accepted even at the major publishing houses.*

Keywords. Scientific publishing, peer review, open peer review, scientific publishers

1 Introduction

The paper is divided into two parts. The first part presents a brief introduction and overview of the current peer review process and describes characteristics of open peer review. The second part of the paper presents results from the research of the 100 top scientific publishers and their acceptance and possible implementation of open peer review, one of the latest developments in scientific publishing.

Scientific publishing is one of the most important activities because it transfers new research based knowledge and innovation to the global scientific community and the general population. Scientific publications "are the end-products of the scientific work, and their quantity and citability are keys to the promotion of scientists" (Masic, 2012). The principal media for dissemination of information about scientific discoveries are still scientific journals. "For more than 350 years, journals have played a pivotal role in the transmission of scholarly communications among academics and researchers" (Greco, 2016). To verify the quality of scientific information, scientific community has invented peer review. Peer review process as we know it today is burdened with problems and scientists in cooperation with scientific publishers seek new solutions which would significantly improve (or possibly replace) the current peer review system with a new one. A recent attempt to made such an improvement is introduction and experimental implementation of open peer review.

Broadly defined, open peer review is "a process in which the names of the authors and reviewers are known to one another" (An Introduction to Open Peer Review, 2014). Furthermore, open peer review process is open to experts conducting the review but also potentially to anyone else willing to participate in the review process. Open peer review is part of open access publishing initiative which supports "content free online to readers while supporting operations by financial models that permit this free electronic distribution" (Overview of Open Access Publishing). Open access publishing provides "an opportunity to those researchers whose work is commendable, but cannot pay high charges for publishing in the leading scientific journals" (Janodia, 2017). When mentioning charges for publishing in open access scientific journals as obstacles for dissemination of scientific information for some scientists, one must have in mind two types of scientific journals: a type which charges a fee called the article-processing charge (APC) which covers the publisher's costs and is paid by the author, research funder or sometimes by the author's institution (Overview of Open Access Publishing). Another type refers to journals charging nothing at all and being supported through sponsorship, advertising, are run using voluntary labour or by selling subscriptions to the printed form of the journal (Overview of Open Access Publishing). More than half of open access journal publishers do not charge the APC (Overview of Open Access Publishing). Regardless of the type, scientific journals almost universally accept peer review as a basic mechanism for evaluation of article manuscripts submitted by scientists. Peer review is therefore, still a pillar of trust in science and remains to be present in most scientific journals in the world.

2 Peer review process

Peer review is a "an official and legitimated mechanism for evaluating and controlling scientific production" (Meruane, Gonzales and Pina-Stranger,

2016), it is a cornerstone of scholarly communication and a guard against the publication of flawed research and assuring that research meets a standard of rigor (Wang, Wolfram, Hoyt, Ingwersen, Pöschl, Smith and Bates, 2016) and it provides feedback to the author(s) so as to improve the article (Sandewall, 2012). The first peer review was done the in Medical Essays and Observations published by the Royal Society of Edinburgh in 1731 (Post-publication peer review). However, some other authors like Nassi-Calò (2017) and Csiszar (2016) suggest that the first peer review was done later, "in 1831 by William Whewell to the Royal Society of London, suggesting that a committee of eminent scholars produced reports on articles submitted for publication to the Philosophical Transactions journal". Since then, the term per review has become a symbol of "an admirable aspiration to intellectual integrity, calm deliberation, and detached evaluation in the accumulation of human knowledge" (Iannone, 2013). Today, peer review is accepted by most scientific journals worldwide (except in journals which state explicitly that they don't go through peer review process). Since its first implementation, peer review process has gone through many changes. Some of those changes were not ideal and the current peer review system is now burdened with problems well documented in literature. Because of the problems, peer review is "currently facing a transition moment, and many believe that it is necessary to redefine its principles and practices so as not to delay or hinder the progress of science" (Nassi-Calò, 2017).

3 Peer review problems

Problems with peer review include slowness, journal editors not being pro-active in favour of controversial or challenging articles, light-touch peer review where authors want rigorous peer review, the variable quality of reviewing, authors are sometimes misunderstood by the reviewers, a lack of transparency in reviewing, reviewers coming up with conflicting criticisms, open refereeing because it inhibits reviewers, authors proposing referees, authors suggesting their friends as reviewers (Watkinson et. al, 2015), editors not informing reviewers about the final status of the paper after the review process (Lahiri, 2006), censorship, inhibiting or delaying a new work (Wheeler, 2011), expensive, wasting academic time, highly subjective, something of a lottery, prone to bias, and easily abused (Smith, 2006).

This process also suffers from plagiarism, self-citation, conflicts of interest and sometimes it holds back competing research (Tattersall, 2015). Some reviewers also take the advantage of their position and do the review only because of the sense of power and vulnerability in relations to others (Lipworth, Kerridge, Carter and Little, 2011).

Peer review can be manipulated and article rejected even if its contents actually merit publication and this mistake can be hardly ever corrected (Sandewall, 2012).

Peer review employs reviewers who are experts in all aspects of a paper and thus can evaluate both its impact and validity and can evaluate the paper prior to obtaining answers from the authors or other referees (Lee, 2012). Lee (2012) analysed peer review from various aspects and he pointed out, among many other things, that peer review in which experts participate may create a big obstacle for innovative papers because one negative opinion about the paper could mean that a single review could determine the future of the paper. In contrast, the same author reminds that successfully published papers are evaluated by the whole scientific community and that evaluation is much more valuable than the single man's opinion.

One of the most frequent problem for journal editors is a short list of reliable peer reviewers (How is research publishing going to progress in the next 20 years?, 2014) because many researchers decline to participate in peer review on the grounds of being too busy (Lajtha and Baveye, 2010).

Some reviewers are motivated for participation in the peer review process by self-interest protecting their own work that submitted article manuscript is challenging; they can also be motivated by a desire to "look good" to the editor promoting overly critical reviews; they can make cognitive errors and have limited capacity to process information; they perform unfair review (Cooper, 2009).

The referees can also fail to be sufficiently expert, informed, conscientious or fair (Harnad, 2000). Reviewers are also criticized for their inability to discover fraud, plagiarism, repetitive publication and for being anti-innovative, non-constructive and causing unacceptable delays in publishing (Lipworth, Kerridge, Carter and Little, 2011).

Because of the enumerated problems with the peer review process, academic community is searching for new modes of improvement of the peer review process. One such attempt is open peer review.

4 Open peer review

The idea of open peer review is present in scientific publishing since 1990s as an attempt to increase "the transparency of the article selection process for a journal, and for obtaining a broader basis for feedback to the authors and for the acceptance decision" (Sandewall, 2012). In spite of the two decades of its existence, it is quite difficult to find a straightforward and universal definition of open peer review. Ross-Hellauer (2017) suggests that open peer review "has neither a standardized definition nor an agreed schema of its features and implementations". He collected the corpus of 122 definitions and analysed them for their content.

As a result, he proposed the following definition: "Open peer review is an umbrella term for a number of overlapping ways that peer review models can be

adapted in line with the ethos of open science, including making reviewer and author identities open, publishing review reports and enabling greater participation in peer review process" (Ross-Hellauer, 2017).

4.1 Open peer review complexities

Since open peer review is a rather new concept, literature explaining models, concepts, scenarios and details about it is neither abundant nor extensive. The following part of this chapter provides an insight into the most interesting thoughts about open peer review in their integral form without intervening into the original text. Ross-Hellauer (2017) offered the full list of open peer review traits: "1.) Open identities: Authors and reviewers are aware of each other's identity 2.) Open reports: Review reports are published alongside the relevant article 3.) Open participation: The wider community to able to contribute to the review process 4.) Open interaction: Direct reciprocal discussion between author(s) and reviewers, and/or between reviewers, is allowed and encouraged 5.) Open pre-review manuscripts: Manuscripts are made immediately available (e.g., via pre-print servers like arXiv) in advance of any formal peer review procedures 6.) Open final-version commenting: Review or commenting on final "version of record" publications 7.) Open platforms: Review is de-coupled from publishing in that it is facilitated by a different organizational entity than the venue of publication". Open peer review comes in several flavours or scenarios, depending on the publisher and / or scientific journal. For instance, The Royal Society proposed 4 different scenarios: "Author agrees to open peer review - referee agrees to open peer review: Signed referee report made public; Author does not agree to open peer review - referee agrees to open peer review: Referee name only disclosed to author, referee report is not made public; Author agrees to open peer review - referee does not agree to open peer review: Referee name not disclosed to author or made public, referee report made public and Author does not agree to open peer review - referee does not agree to open peer review: Referee name not disclosed to author, referee report is not made public" (Open peer review in Royal Society Open Science). Ford (2013) reviewed characteristics of open peer review and offered the following extensive list of the implementations of open peer review: "Signed review refers to submitted reviews signed by the referee that are either published alongside articles at the time of publication or are signed when an author receives them; Disclosed review refers to a process in which referees and authors know each other's' identities during peer review process, enabling them to engage in discussion or discourse; Editor-mediated review is a characteristic found in most open peer review processes. Editor mediation is any work done by a journal editor to facilitate open peer review. This may include editorial pre-selection of articles and/or final decision-making for acceptance or rejection of articles; The editor-mediated portion of any open peer review process may or may not be publicly disclosed; Transparent review refers to complete openness to a distinct com-munity or the public. It allows a public community to watch peer review unfold. Authors and the public know referees' identities, and referees know authors' identities; Author responses to referee comments are public. In transparent review the public can see manuscripts, reviews, and replies from authors and public reviewers as well as the published articles.; Crowd-sourced review is a public review process in which any community member may contribute to the article review. In crowd-sourced review there is no limit to the number of comments or reviews an article may receive. In some proposed implementations of crowd-sourced review, there is little editorial mediation of article reviews. Rather, authors may simply submit papers to a pre-print server or other community for crowd-sourced commentary; Pre-publication review occurs prior to article publication, and typically occurs in a public space such as a pre-print server; Synchronous review occurs at the same time as publication of the article. In the literature, synchronous review is approached only theoretically, as part of a novel and completely iterative publishing model.; Post-publication review occurs after an article is published, much like commentary on a blog post". Wang, Wolfram, Hoyt, Ingwersen, Pöschl, Smith and Bates (2016) analysed the current open peer review models and concluded that they aim at different levels of transparency and openness: "1.) Optional open peer review, in which reviewers are encouraged, but are not required, to provide their identity in review reports; and authors may choose, but are not required, to publish review histories alongside the articles. In a published review history, all versions of the manuscripts, reviewer reports, and author's rebuttals with time-stamps are accessible and linked to the article. 2.) Mandatory open peer review, in which the review process is open to the public and review histories are accessible to all. Reviews may be conducted prepublication so that there is a clear delineation between the under review versions and the final accepted version. Mandatory open peer review may also be conducted post-publication, in which, articles are published first and the review process is ongoing". There are also other views on open peer review which actually try to facilitate the implementation process itself and make it better. For instance, one of the harshest criticism of the peer review process is often directed towards choice of reviewers especially when journal editors are not sure whom to ask to be a reviewer because they could create a conflict with author(s). In such cases, some people are not suitable to be the reviewer and open peer review would allow authors to request a different reviewer (Bali, 2015) when not satisfied with the review.

5 Research

The research part of the paper is focused on scientific journal publishers and their acceptance and possible implementation of open peer review.

It must be noted that the development of peer review is an on-going process with not so many researches or practical experiences published and explained.

In the last 15 years, open peer review or its equivalents were experimentally implemented in very few scientific journals. In 2004 the Nursing Research inaugurated open peer review for the first time. Three years later, 32 papers were published accompanied with the corresponding reviews (Dougherty, 2004). Dougherty suggested the value of peer review itself and open peer review in hands of capable experts possessing specialized knowledge in the are addressed by paper manuscripts supporting the development of science (in journal's discipline) with their assessments and recommendations.

Journal Nature also started a trial in open peer review "to explore the interest of researchers in a particular model of open peer review, whether as authors or as reviewers" (Nature's Peer Review Trial, 2006). The result was that "despite the significant interest in the trial, only a small proportion of authors opted to participate" (Nature's Peer Review Trial, 2006). One of the most famous examples is journal Atmospheric Chemistry and Physics which experimented with the two stage open peer review (Koop and Pöschl, 2006). In January 2012 Agricultural and Forest Meteorology began publishing PDFs of editor-selected peer review reports alongside to the published articles. Finally, Elsevier started a pilot study of open peer review in 5 of its journals: Agricultural and Forest Meteorology, Annals of Medicine and Surgery, Engineering Fracture Mechanics, Journal of Hydrology: Regional Studies, International Journal of Surgery (Mehmani and van Rossum, 2014).

Mehmani and van Rossum (2014) reported that from the 1990s onwards, a number of scientific journals began to trial new approaches: BioMed Central asked reviewers to sign their reviews and publishes them alongside the author's response; F1000 (Faculty of 1000) launched F1000 Research which publishes review reports alongside with the submitted articles and eLIFE publishes parts of the post-review decision letters and the associated author responses (if they agree).

The Nature publishing reported in 2016 that three journals: PeerJ, the BMJ and F1000Research embraced open peer review in various different forms, while Nature Communications is experimenting with this type of peer review (Callaway, 2016). Ross-Hellauer, Deppe and Schmidtthe (2017) presented findings of an online survey conducted in 2016 for the OpenAIRE2020 about attitudes of editors, authors and reviewers towards and levels of experience with open pee review. The findings showed that the majority of respondents (total of 3,062 full responses were collected) to be in favour of open peer review becoming mainstream scholarly practice. The same survey showed that three out of four (76.2%) respondents reporting having taken part in open peer review.

The purpose of the research in this paper was to establish whether scientific journal publishers offer publicly available documents (policies, author guidelines etc.) which explicitly describe a publisher's views and stand on open peer review and its implementation. Content analysis and comparison were applied as main research methods. The source of data about scientific publishers for analysis and comparison was the Top publishers list at http://www.scijournal.org/top-international-journal-publisher.shtml where 1600 journal publishers were listed publishing anything from 1 journal to over 2500 journals.

The research questions were:

RQ1: Do scientific publishers support open peer review by publicly announcing their support in form of a publicly available document(s)?

RQ2 Is there a difference between big and small publishers (in number of scientific journal owned by a publisher) in accepting the open peer review?

The main hypothesis of the research is that despite not so short existence of open peer review, it is still not widely accepted and implemented.

During the period of June 14th till June 19th 2017 Web sites of the first 100 scientific publishers from the Top publishers list were visited, searched and browsed (read) for information about publicly available documents (policies, guidelines etc.) which contained explanation about what type of peer review is applied in journal(s) of a particular publisher.

Table 1. The first 100 publishers on the Top publishers list and number of journals they publish (information retrieved in June 2017 from http://www.scijournal.org/top-international-journal-publisher.shtml)

Publisher	**# of journals published**
Elsevier	2571
Springer-Verlag	2209
Taylor and Francis	1803
John Wiley and Sons	1604
Sage Publications	742
SciELO	684
Walter de Gruyter	683
Redalyc	447
RMIT Publishing	415
Inderscience Publishers	391
Hindawi Publishing Corporation	366
Project MUSE	361
Cambridge University Press	329

Oxford University Press (OUP)	310
Revues.org	309
Emerald	308
Wolters Kluwer - Lippincott Williams and Wilkins	287
Biomed Central Ltd.	268
African Journals Online	230
Scientific Research Publishing	214
Sabinet Online Ltd	185
Medknow Publishers	177
Institute of Electrical and Electronics Engineers (IEEE)	174
Informa Healthcare	166
Thieme Publishing Group	157
SpringerOpen	150
Brill Academic Publishers	146
IGI Global	146
De Gruyter Open	135
Dove Medical Press	129
MDPI	124
World Scientific	114
Nature Publishing Group	110
Bentham Science	109
Scientific and Academic Publishing (SAP)	105
Karger	104
Ã‰rudit	99
ISRN International Scholarly Research Network	96
Intellect	95
IOS Press	93
Bangladesh Journals Online	87
Libertas Academica	87
OECD - Organisation for Economic Co-operation and Development	83
Mary Ann Liebert	81
ScopeMed	77
Universidad Complutense de Madrid	75
Academic Journals	73
Science and Education Publishing	72
FrancoAngeli	70
Institute of Physics (IOP)	70
American Psychological Association (APA)	68
PAGEPress	64
Akademiai Kiado RT	62
STM Journals	61
Nepal Journals Online	60

Palgrave MacMillan	60
Frontiers Media	57
University of Chicago Press, The	57
EDP Sciences	55
Horizon Research Publishing	55
Duke University Press	54
Science Alert	52
SciTechnol	50
PePSIC	48
American Chemical Society (ACS)	47
Science and Engineering Publishing Company	47
BMJ Publishing Group	46
Brepols Publishers	46
OMICS Publishing Group	45
Annual Reviews	44
Association for Computing Machinery (ACM)	44
John Benjamins Publishing Company	44
Sri Lanka Journals Online	44
Royal Society of Chemistry, The	42
Canadian Center of Science and Education	41
OA Publishing London	40
Edinburgh University Press	39
M.E. Sharpe	39
Morgan and Claypool	38
Peeters Publishers	37
University of California Press	36
American Society of Civil Engineers (ASCE)	35
Consejo Superior de Investigaciones CientÃficas	35
Berghahn Journals	34
Co-Action Publishing	34
Herbert Publications	34
Future Medicine	33
Institution of Engineering and Technology (IET)	33
MIT Press	33
Copernicus Publications	32
Hogrefe and Huber Publishing Group	32
ICE Publishing	32
Penn State University Press	32
Maney Publishing	31
Multiscience	31
American Institute of Physics (AIP)	30

Asian Network for Scientific Information (ANSInet)	30
International Institute for Science, Technology and Education (IISTE)	30
OpenJournals Publishing	30
Tehran University of Medical Sciences	30

It must be said that with some publishers, journals have an autonomy to decide which type of peer review will be applied. Consequentially, the content of publishers' Web sites was carefully analysed to find the proper and accurate information about the peer review process. Individual scientific journals were not analysed because the first 100 publishers from the Top publishers' list own the total of 20053 journals (Table 1.). However, such a significant number of journals presents a real possibility of implementation of open peer review (something that can be analysed in future research). Publishers' Web sites were analysed for publicly available documents explaining open peer review acceptance and / or implementation in a journal or journals owned by a particular publisher. In spite of possible deficiencies (some publishers tend to avoid clarity about the peer review process in their journals or give different names to the peer review types in order to achieve better marketing effect for their journals) it is the best approach for discovering the actual and current situation regarding the acceptance and implementation of open peer review process at the major scientific publishers.

5.1 Research results

After the careful analysis of the Web sites of the first 100 publishers from the Top publishers list, the results are presented in the Table 2.

Table 2. Publishers offering open peer review

Publisher	**Open peer review**	**# of journals**	**Publication type and title**
Elsevier	Yes	5	Journals: Agricultural and Forest Meteorology, Annals of Medicine and Surgery, Engineering Fracture Mechanics Journal of Hydrology: Regional Studies,
			International Journal of Surgery
Oxford University Press	Yes	1	Journal: Giga Science
Biomed Central Ltd.	Yes	2	Journals: BMC Infectious Diseases, Journal of Inflammation
Springer Open	Yes	?	?
MDPI	Yes	1	Journal: Life
Nature Publishing Group	Yes	1	?
Palgrave MacMillan	Yes	?	Books
BMJ Publishing Group	Yes	2	Journals: BMJ Open, BMJ
Copernicus Publications	Yes*	?	?

* Open peer review is called Interactive Public Peer Review

? Information not available

Three publishers stated they implement open peer review but didn't provide the number of journals in which they implement open peer review and two publishers didn't provide the titles of journals in which they implement open peer review. These results clearly indicate experimental nature of open peer review because of the small number of scientific publishers implementing this type of peer review. The remaining publishers which Web sites were analysed in this research stated that they apply "standard peer review", "classic peer review" or more specifically "single-blind peer review" and "double-blind peer review". Though modest, the results are significant because big publishing houses have a substantial influence on development of the scientific publishing market in general and can lead other publishers into the new phase of development of peer review if they decide to share their results of implementation of open peer review publicly which might become a key issue regarding the improvement of peer review process. The results must contain transparent explanation of the implementations and their good and bad sides. By doing so, the major scientific publishers will help other publishers, journal editors and authors to decide whether to implement open peer review or not. Since many scientific journals publishers promote open access on their Web pages, it is safe to assume that they will be more interested in open peer review in future if it demonstrates positive impact on quality of peer review in general.

6 Future research

After this initial research about the current state in implementation of open peer review, more detailed research is planned to discover details about what scientific publishers expect and want from open peer review. The focus of the future research will primarily be on publishers of the Croatian scientific journals, journal editors and authors. While small scientific communities are naturally part of the global scientific community, they still have their particularities and are often not included in scope of experiments of the world major scientific publishers because of the size of their market. Being a big or small community does not presume the outcome of implementation of open peer review and could provide a valuable insight into effects of implementation of open peer review in the process of transformation of the scientific information publishing. Such research should be specially focused on reasons why some publishers or journals should or should not accept open peer review.

7 Conclusion

There is no doubt in any researcher's mind that the peer review process should be improved. The question is – in what direction? The literature shows that little has changed in the peer review process in the last few decades. The latest development in this process is invention of open peer review, a process which should be transparent and open to anyone interested in it. The research study in this paper showed that only few major scientific publishers have commenced an experimental implementation of open peer review in their journals. The research study answered the both research questions. RQ1: Scientific publishers support open peer review in a small number of cases. This is not encouraging but one should have in mind that the system of scientific publishing has always been changing very slowly as well as the system of scientific information in general, and that changes have not often been immediately visible. This doesn't mean that changes shouldn't be done but instead, it means that they should be better documented and presented and the information about changes should be made publicly available. RQ2: The research study showed that major publishers are more inclined towards experimenting and acceptance of open peer review but are also very careful about extent and way of its implementation. Future research which will include direct contact with scientific publishers of different sizes would presumably provide more answers. The main hypothesis of the research that open peer review is still not widely accepted and implemented has been confirmed. At this moment, open peer review is not researched enough so there are still many uncertainties surrounding it. As Harnad (1997) pointed out: "Peer review is imperfect; it can no doubt be improved upon, but alternatives should first be tested; and in testing, one is well-advised to manipulate one variable at a time: Here we are dealing with a change in medium (paper to electronic), a change in economic model (subscription to author-side payment) and a change in quality control mechanism (peer review to open peer commentary)".

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Quality Factors for Mobile Medical Apps

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Abstract. *The increased use of mobile phones, smartphones, tablets, and connected wearable devices has fostered the development of mobile medical applications (apps) in the last few years. Mobile medical apps are developed to extend or replace some existing applications that run on a desktop or laptop computer, or on a remote server.*
If mobile apps are used, for example, to diagnose, mitigate, treat, cure, or prevent human diseases, patient safety is at potential risk if the apps do not function as intended. Therefore, such apps need to be cleared, approved, or otherwise regulated in order to protect public health.
There are many papers that have been published about the quality attributes of mobile apps. Less is known about quality factors of mobile medical apps. In this paper we provide key definitions and examples of regulated mobile medical apps, and identify factors that influence the quality of mobile medical apps.

Keywords. quality attributes, quality factors, medical device software, mHealth, mobile medical apps

1 Introduction

Consumer demand for wearable medical devices and personal monitoring devices continues to rise. The results of research2guidance's (2015) annual study with 5,009 respondents indicate that 85% of mobile health practitioners rate smartphones as a primary target device. Fox & Duggan (2012) summarized the results of a survey of 3,014 adults living in the United States. They found that 52% of smartphone owners use their devices to get health information and 19% of them have at least one health app on their phone (e.g., exercise, fitness, heart rate monitoring, diet, calorie counter, weight apps, etc.).

According to Business Insider ("Internet of Things in healthcare: Information technology in health", 2016), 646 million IoT (Internet of Things) devices (not including wearable devices such as fitness trackers) will be used for healthcare by 2020. The Deloitte Center for Health Solutions (2016) identified biosensors in wearables and medical devices as one of ten innovations that will most likely achieve more for less in healthcare. According to a report from the business consulting firm Grand Review Research, Inc. (2016), the global connected health and wellness devices market is expected to reach USD 612.0 billion by 2024.

The results of the sixth annual study on mobile health app publishing done by research2guidance (2016) are based on 2,600 plus respondents who participated in the online survey. As displayed in Fig. 1, remote monitoring, diagnostic, and medical condition management apps are the top three mHealth app types offering the highest market potential in the next five years. In 2016, 32% of total respondents predicted remote monitoring apps as the app category that offers the highest market potential for mobile health apps in five years' time.

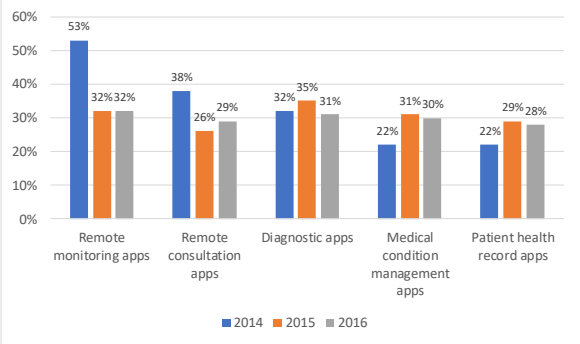


Figure 1. mHealth app types offering the highest market potential in the next 5 years (research2guidance, 2014-2016)

Typical users of mobile medical apps are health care providers and patients. Although mobile devices and apps provide many benefits for healthcare professionals such as convenience, better clinical decision-making, improved accuracy, increased efficiency, and enhanced productivity (Ventola, 2014), there are still some challenges that need to be addressed. The following are some of challenges facing users using mobile medical apps: concerns related to false claims in app stores, concerns about app quality, safety, security, privacy, availability, and training. Aungst et al. (2014) emphasized that clinicians seeking to identify mobile medical applications for use in their individual practice should

use a combination of app stores, published literature, web-based resources, and personal review to ensure safe and appropriate use. Hanrahan et al. (2014) identified the following criteria for evaluating mobile medical applications in clinical practice: usefulness, accuracy, authority, objectivity, timeliness, functionality, design, security, and value.

2 Key Definitions

This chapter provides definitions of the key terms used in this paper.

The World Health Organization (2011, p. 6) defines mHealth as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices".

The United States Food and Drug Administration (FDA, 2015, p. 7) defines mobile platforms as "commercial off-the-shelf (COTS) computing platforms, with or without wireless connectivity, that are handled in nature". Examples of such platforms include smartphones, tablet computers, smartwatches, laptops, convertibles, etc.

The FDA's final guidance on mobile medical apps (2015) defines a mobile application or mobile app as a software application that can be executed on a mobile platform with or without wireless connectivity, or a web-based software application that is tailored to a mobile platform but is executed on a server. Mobile apps can be grouped into three categories:

1. Native apps: developed using a specific programming language (Knott, 2015). For example, Java/Kotlin/C#/Python/C/C++ for Android apps, Objective-C/Swift for iOS apps, and C# for Windows Phone apps. They are usually distributed through app stores, run directly on a mobile device, have full access to the device hardware and features, and can store data offline. The latest smartphones could be considered a mini computer having a number of sensors and other features (e.g., cameras, microphones, Bluetooth, Bluetooth Low Energy (BLE), GPS, NFC, Wi-Fi, pedometer, heart rate monitor, magnetometer, barometer, air humidity sensor, fingerprint sensor, proximity sensor, temperature sensor, sensor detecting harmful radiation, touchscreen, speakers, push notifications, e-mail, storage, etc.). Smartphones can be also used with adapters. For example, using low cost smartphone adapters invented by Myung, et al. (2014), a smartphone can capture high-quality images of the front and back of the eye.
2. Web apps: websites usually hosted on the Web servers and accessed through the mobile device's Web browser. Mobile web apps are built with HTML/HTML5, CSS3, and JavaScript technologies. They can run on many different platforms, are independent of the mobile platform, and no installation through app stores is required. However, they have limited access to the device hardware and features.
3. Hybrid apps: "apps that consist of different Web technologies such as HTML or JavaScript" (Knott, 2015, p. 20). Hybrid mobile apps are built using a hybrid development framework such as Ionic, Mobile Angular UI, Sencha Touch, Intel® XDK, Titanium® SDK, or PhoneGap.

According to the FDA (2015), a mobile medical app is a mobile app that meets the definition of a device as defined by the Federal Food, Drug, and Cosmetic Act (FD&C Act) and either is intended to be used as an accessory to a regulated medical device, or to transform a mobile platform into a regulated medical device. The Medicines & Healthcare products Regulatory Agency (MHRA) (2014) considers some apps, which are used on smartphones and computers, as a medical device in their own right if they have a medical purpose.

According to the FDA (2015, p. 9), a mobile medical app manufacturer is "any person or entity that manufactures mobile medical apps in accordance with the definitions of manufacturer in 21 CFR Parts 803, 806, 807 and 820". It does not include persons who exclusively distribute mobile medical apps without engaging in manufacturing functions (e.g., owners and operators of mobile app stores like Google Play, iTunes App store, Windows Phone Store, BlackBerry World) (FDA, 2015).

The FDA (2016) defines general wellness products as products that are intended for only general wellness use, and present a low risk to the safety of users and other persons. Such products may include exercise equipment, audio recordings, video games, software products, etc. (FDA, 2016).

The IEC 82304-1 (2016) standard defines health software as software intended to be used specifically for managing, maintaining or improving the health of individual persons, or the delivery of care.

3 Regulations of Mobile Medical Apps

Using a risk-based approach to regulation of mobile medical apps, the FDA released in July 2011 draft guidance for developers of mobile medical apps. The FDA's initiative aimed to indicate which mobile medical apps fall under medical device regulatory requirements. An updated guidance document issued in 2013 was superseded by a final guidance (FDA, 2015) issued in February 2015. According to the final guidance, mobile apps may fall into one of three categories: 1) mobile apps that are not medical devices, 2) mobile apps that are medical devices, but pose a lower risk, and 3) mobile medical apps.

Mobile apps which do not meet the definition of a medical device of the FD&C Act are not regulated by

the FDA. Examples of unregulated mobile apps are: apps to provide access to electronic copies of medical textbooks or other reference materials, apps for health care providers to use as educational tools for medical training, apps for general patient education, apps that are generic aids or general purpose products, etc. (FDA, 2015).

For mobile apps that meet the definition of a medical device of the FD&C Act, but pose a lower risk, the FDA (2015) intends to exercise enforcement discretion which means that it will not enforce requirements under the FD&C Act. Examples of such apps are: patient self-management apps which do not provide treatment or treatment suggestions, apps to organize and track patient's health information, apps to automate simple tasks for health care providers, etc. (FDA, 2015). In July 2016, the FDA (2016) issued a guidance document to address low risk products that promote a healthy lifestyle (i.e., general wellness products).

Mobile medical apps are different from wellness, diet, and fitness apps. Mobile apps which are marketed, promoted, or intended for use in the diagnosis of disease or other conditions, or in the mitigation, treatment, or prevention of diseases, or otherwise meet the definition of a medical device, are regulated by the FDA. Manufacturers of mobile medical apps are subject to civil and criminal penalties for compliance failures. Like other medical devices, mobile medical apps are subject to some or all of the regulatory controls, depending into which category they fall. A mobile medical app may be classified by the FDA as:

- Class I (low risk): no FDA review is needed,
- Class II (moderate risk): FDA clearance is required via Premarket Notification 510(k), or
- Class III (high risk): FDA approval is required via Premarket Approval (PMA) review process.

In September 2013, Australia's medical device market regulator, the Therapeutic Goods Administration (TGA), published on its website a guidance on the regulatory arrangements for medical software and mobile medical 'apps' ("Regulation of medical software and mobile medical 'apps'", 2013).

In October 2014, the International Society for Pharmaceutical Engineering (ISPE) published a new GAMP (2014) guide that provides a risk-based approach to implementing and supporting regulated mobile applications. The new guide applies to mobile medical apps that meet the definition of a medical device and mobile apps that are used as part of GxP operations at a regulated organization (e.g., manufacturing, post marketing, distribution, clinical trials, maintenance/calibration, etc.).

The Federal Institute for Drugs and Medical Devices (Bundesinstitut für Arzneimittel und Medizinprodukte (BfArM)) is an independent federal higher authority that is involved in detecting and evaluating the risks of medical devices in Germany. The institute published a guidance on medical apps on their website ("Guidance on "Medical Apps"", 2015).

The MHRA regulates medical devices in the UK. In August 2014, the agency has published guidance on medical device stand-alone software including apps on their website to help identify the health apps which are medical devices and how to comply with the regulatory requirements. Updated guidance was issued in April 2017 ("Guidance: Medical device stand-alone software including apps (including IVDMDs)", 2017).

New European regulation on medical devices was published in May 2017. It states that software "that is intended to be used in combination with mobile computing platforms shall be designed and manufactured taking into account the specific features of the mobile platform (e.g. size and contrast ratio of the screen) and the external factors related to their use (varying environment as regards level of light or noise)" ("Official Journal of the European Union L 117", 2017).

The IEC 82304-1 standard was published in October 2016. This standard focuses on demonstration of development processes to ensure safety and security of standalone health software products. It extends the IEC 62304 standard by adding validation. Unlike IEC 62304, it does not apply to software embedded in medical devices or embedded in devices with specific hardware. The second edition of IEC 62304 (Health software – Software life cycle processes) is currently being drafted. This edition will enlarge the scope of IEC 62304 to align with the IEC 82304-1 standard. A final version is expected to be published in December 2019.

4 Examples of Regulated Mobile Medical Apps

There are thousands of apps classified as "Health & Fitness" or "Medical" in mobile app stores. Ventola (2012) provided examples of uses for mobile devices and apps by healthcare professionals grouped in the following categories: 1) information and time management, 2) health record maintenance and access, 3) communication and consulting, 4) reference and information gathering, 5) clinical decision-making, and 6) medical education and training. Table 1 provides some examples of mobile medical apps that have been cleared or approved by the FDA.

Table 1. Examples of regulated mobile medical apps cleared or approved by the FDA

Device name	Summary
AirStrip Remote Patient Monitoring (RPM)	Displays to clinicians physiologic and other patient information generated by other medical devices and patient IS.

Device name	Summary
AliveCor Heart Monitor	Records, displays, stores and transfers single-channel electrocardiogram rhythms.
Mobile MIM	Used for the viewing, registration, fusion, and/or display for diagnosis of medical images from SPECT, PET, CT, MRI, X-ray and ultrasound devices.
MobiUS Ultrasound Imaging System	Used for ultrasound imaging, measurement and analysis of the human body for various clinical applications.
Customized Sound Therapy (CST)	Enables qualified professionals to identify, with the patient's verbal input, the CST sounds that most closely match the patient's tinnitus.
Eko Electronic Stethoscope System	Mobile, wireless, and EHR-connected stethoscope. It can electronically amplify, filter, and transfer sounds to the app for storage and sharing.

5 Quality Factors for Mobile Medical Apps

As more people use mobile devices as integral part of their daily lives, design and development of high-quality, safe, and effective mobile medical apps plays an increasingly important role for mobile medical app manufacturers. Inukollu et al. (2014) investigated the role of mobile app development life cycle as one of the factors influencing quality of mobile apps. They found that traditional software approaches and methods as well as object-oriented concepts and methodologies can be applied to mobile application development. However, they recommended following the process-oriented approach while developing a mobile application. Trektere et al. (2016) have extended the MDevSPICE® process framework for medical device software to assist organizations developing mobile medical apps. The extended framework combines processes from various medical device software standards and agile practices for the development of mobile medical applications.

Unlike applications designed for standard desktop computers, mobile medical apps that run on mobile platforms have some limitations that need to be considered early in the design and development process. For example, smaller screen size, limited processing power/memory/storage capacity, slow and error-prone typing, decreased accuracy of clicks, poor connectivity, battery issues, interruptions during usage (e.g., phone calls, text messages, push notifications, etc.), usage in unusual places, etc. Meulendijk et al. (2014) performed research to explore what non-functional requirements of medical apps potential users view as most important. They identified the following non-functional requirements: accessibility, certifiability, portability, privacy, safety, security, stability, trustability, and usability.

The ISO/IEC 9126-1 standard was published in 2001. The purpose of this standard is to evaluate software quality using a hierarchical quality model in terms of internal quality, external quality, and quality in use. Internal and external quality is defined by the following six characteristics: functionality, reliability, usability, efficiency, maintainability, and portability. Quality in use is defined using four characteristics: effectiveness, productivity, safety, and satisfaction. Characteristics are further divided into sub-characteristics. This quality model can be tailored to the specific needs of an organization and applied to evaluate quality of any software product. For example, it has been used to evaluate: source code internal quality (Kanellopoulos et al., 2010), quality of software in ERP systems (Al-Rawashdeh et al., 2013), Internet of Things (IoT) applications (Kim, 2016), mobile environments (Idri et al., 2013), etc. Hörbst et al. (2005) introduced the ISO/IEC 9126-1 quality model to support the development process of a patient information web service.

In March 2011, ISO/IEC 9126-1 was replaced by ISO/IEC 25010. The ISO 25010 standard describes eight main characteristics to specify and evaluate the quality of a system/software product: functional suitability, performance efficiency, usability, security, portability, maintainability, compatibility, and reliability. Main quality characteristics are further defined into sub-characteristics. Most of software quality characteristics and sub-characteristics of ISO/IEC 25010 can be applied to the mobile medical app quality model with appropriate modification. For example, Idri et al. (2016) used four quality characteristics (i.e., functional suitability, operability, performance efficiency, and reliability) of ISO/IEC 25010 to evaluate the quality of free mobile personal health records for pregnancy monitoring.

5.1 Safety

Safety is defined as "freedom from risk which is not tolerable" (ISO/IEC Guide 51, 2014, p. 2).

Like other medical devices, mobile medical apps must be safe as people rely on these devices every day. When a medical app provides inaccurate or unreliable information, the worst-case scenarios can be life-threatening (Tripp, 2015). Huckvale et al. (2015) assessed 46 smartphone apps (21 Android, 25 iOS) for calculating insulin dose. The authors found that 67% of apps carried a risk of inappropriate output dose recommendation that violated basic clinical assumptions, did not match a stated formula, or correctly update in response to changing user inputs. Apple's emphasis on safety starts in their App Store review process. For example, if a medical app has

received regulatory clearance, the developer of the app has to submit the app and a link to regulatory documentation to Apple. Other apps like drug dosage calculators must come from approved entities, or receive approval by the FDA or one of its international counterparts ("App Store Review Guidelines", 2017). In case of app-related critical incidents, the user should be aware of the availability of qualified support personnel.

5.2 Security and Privacy

Internet-connected medical devices that run on old machines with outdated software are vulnerable to cybersecurity threats and may pose a security risk with safety impact. For example, some medical devices were recently hit by WannaCry ransomware attacks in the U.S. and U.K. hospitals ("Medical Devices Hit By Ransomware For The First Time In US Hospitals", 2017). When malware infects a medical device's operating system, the most pressing risks are the unavailability of patient care and the lack of health data integrity (Fu & Blum, 2013). Mobile operating systems may also have multiple security issues/vulnerabilities that may be misused by the attackers (Hodeghatta & Nayak, 2014).

Protecting mobile medical apps against the consequences of attacks requires a number of wireless security and mobile security measures. Strong security and penetration testing is one method to reduce the potential for attacks and can be applied during development. Knorr & Aspinall (2015) proposed a security testing method for Android mHealth apps to address three aspects: security, privacy, and safety. The method uses threat analysis and considers possible attack scenarios and vulnerabilities that are specific to the domain.

The FDA and notified bodies for medical devices are increasingly interested in cybersecurity. In October 2014, the FDA issued final guidance on cybersecurity and provided examples of cybersecurity documentation that is expected for premarket submissions (FDA, 2014). Two years later, the FDA issued final guidance on postmarket management of cybersecurity in marketed and distributed medical devices (FDA, 2016).

Clause 5.4 of the EN 45502-1 standard (2015) requires evaluation of information security through the risk management process when communication with the implantable part of an active implantable medical device is provided through wireless communication channels. Therefore, mobile medical app manufacturers are expected to provide documented evidence of adequate consideration for the information security threats such as compromised confidentiality, integrity, and availability of data. Situations like no detection, response, and recovery of information security threats have to be considered too. Mobile medical apps should be available for download/update from the app stores in countries in which they were approved. They should be available for the target operating system of the clinician's or the patient's mobile device. In addition, the app's functionalities should be available for offline use.

In June 2016, the Association for the Advancement of Medical Instrumentation (AAMI) issued the technical information report that provides medical device manufacturers with guidance on developing a cybersecurity risk management process for their products (AAMI TIR57, 2016). The FDA has added this report to its list of recognized standards. New EU regulation on medical devices requires risk management including information security ("Official Journal of the European Union L 117", 2017).

Similar to risk management and usability engineering processes, security needs to be incorporated into the early design and development of mobile medical apps. Yusop et al. (2016) emphasize the need of eliciting security-related requirements such as authentication, authorization, encryption, and non-repudiation at the early stage of mobile application development. A comprehensive security program might also include security trainings and certifications, vulnerability assessment and reporting, and handling of security incidents. Employees shall be trained on technologies, regulations, standards, and corporate policies related to privacy and security (Robichau, 2014).

In general, medical devices may create, collect, process, store, or transfer a lot of data such as medical findings, vital signs, patient records, patient monitoring data, login data, etc. According to a recent study from the Ponemon Institute (2016), healthcare organizations have the most costly data breaches due to fines and the higher than average rate of lost business and customers. "Privacy issues related to using health apps include a breach of consumer confidentiality, data privacy shortcomings and security problems." (Scott et al., 2015, p. 3).

Personal data is protected by the General Data Protection Regulation (GDPR) and the data protection law in the EU. To protect data, mobile medical app manufacturers can use encryption for passwords, patient data, configuration data, backups, and the identifiable data in transit. We recommend using the privacy by design approach that takes into consideration the protection of personal data throughout the whole life cycle of a mobile medical app. If a mobile medical app uses patient data, we recommend implementing a function to obtain the patient's consent before using the app. Anonymization and pseudonymization of collected personal data could also be used to protect the privacy rights of individuals.

5.3 Usability

Usability is defined as "characteristic of the USER INTERFACE that facilitates use and thereby establishes EFFECTIVENESS, EFFICIENCY and

USER satisfaction in the intended USE ENVIRONMENT" (IEC 62366-1, 2015, p. 10).

The functionality and user experience play a very important role when it comes to the evaluation and success of any mobile app. Typical app's functionalities include to inform, alert, treat, track, instruct, communicate, diagnose, analyse, display, etc. During the early stages of designing a new user interface we recommend using paper prototypes and/or professional wireframe tools. The Healthcare Information and Management Systems Society (HIMSS) published a guide for evaluating the usability of native apps. Usability of mobile medical apps can be assessed through formative and summative evaluations according to IEC 62366-1.

HIMSS (2012) recommends that the interface of a well-designed mobile app should be simple, intuitive, and easy to learn, with minimal or no training involved. Important information should stand out, and function options should be easy to understand. The app should have a clear, clean, and uncluttered screen design. In addition, the graphic design, layout, terminology, and data entry fields should be consistent and unified across the app.

5.4 Interoperability

Interoperability is defined as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" (ISO/IEC/IEEE 24765, 2010, p. 186).

Interoperability with other systems is an important aspect which should be considered when developing mobile medical apps. Mobile medical apps should operate adequately online and offline. App designers and developers should carefully choose when to require network connectivity and when to enable offline operation. Exchanging data between a mobile platform and other computerized systems in medical institutions can be very challenging. Since mobile apps have limited processing power, memory, and storage capacity, they need the back-end applications.

5.5 Learnability

Learnability is defined as "degree to which the software product enables users to learn its application" (ISO/IEC CD 25010, 2008).

"As the development of mHealth apps and the number of users of mHealth technologies increase, there is a need to understand the usability and learnability of these mobile devices and applications." (Al-Mardini et al., 2014, p. 252). Typically, when a patient installs a mobile medical app on his mobile device, the patient does not receive a practical training. Therefore, it is very important to design and develop the app in a way that the user can learn to use the app quickly and effectively.

The instructions for use should be integrated into the app in electronic form and be kept up-to-date.

5.6 Reliability

Reliability is defined as "the ability of a system or component to perform its required functions under stated conditions for a specified period of time" (ISO/IEC/IEEE 24765, 2010, p. 297).

Heffey et al. (2013) evaluated the accuracy and reliability of 23 smartphone apps for conversion of one opioid to another at equianalgesic dose. The authors found high variability in opioid calculator conversion outputs between apps, an overall lack of stated medical professional involvement in app creation, and a general lack of data sources on which the calculations were based.

5.7 Portability

Portability is defined as "the ease with which a system or component can be transferred from one hardware or software environment to another" (ISO/IEC/IEEE 24765, 2010, p. 261).

Mobile medical apps are used on different mobile platforms (e.g., Android, iOS, Windows Phone, BlackBerry). A number of mobile platforms increased the need for cross platform mobile app development in order to create, deploy, and maintain mobile apps which ran on all of the main mobile platforms. The majority of cross platform tools (e.g., Sencha Touch, Xamarin Platform, Qt) support iOS and Android.

6 Conclusions and Outlook

Motivated by efforts to improve human health and well-being, the mobile health market is growing and driving digital growth. Some mobile medical apps may pose the risk of a physical injury or damage to health if they do not work as intended. Such apps are subject to regulatory requirements.

This paper identifies factors that influence the quality of mobile medical apps. Mobile medical apps must be safe, functional, usable, operable, learnable, portable, reliable, responsive in terms of speed, and robust against security vulnerabilities. At the same time, the apps must be protected against unauthorized access or breaches of privacy/confidentiality. Recent studies show that there are still some challenges with mobile medical apps. Considering quality factors when developing a mobile medical app is a key to successful, safe, and effective app.

A next step would be to apply the identified quality factors to one or more medical app development projects and to enhance them based on identified best practices and key learning points. A survey with questions covering each quality factor could be also designed and sent to medical app developers.

Acknowledgments

The authors would like to thank Neil James and two anonymous reviewers for their valuable comments on an earlier version of this paper.

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An Overview of Cybersecurity Regulations and Standards for Medical Device Software

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Abstract. *This paper discusses current cybersecurity regulations and standards for medical device software set by government agencies and agencies developing industry and international standards such as the FDA (Food and Drug Administration), CFDA (China Food and Drug Administration), ISO (International Organization for Standardization), IEC (International Electrotechnical Commission), UL (Underwriters Laboratories), and others. The concepts described within this paper can be utilized by medical device manufacturers in order to establish a cybersecurity program as part of their quality management systems. In general, there are three complementary ways based on the NIST (National Institute of Standards and Technology) cybersecurity framework that can be used to remove gaps in the organization's cybersecurity. The first way focuses on designing software products that take cybersecurity into account (i.e., prevention). The second way is to perform security and penetration testing and to apply other cybersecurity controls to reduce attacks and vulnerabilities that could be exploited (i.e., detection). The third way emphasizes maintenance plan in case of a cyberattack (i.e., response and recovery).*

Keywords. cybersecurity, FDA, information security, medical device software, security risk management

1 Introduction

This paper is divided into five sections. The first section focuses on history and cybersecurity in the context of medical devices. Definitions of the key terms used in this paper are provided in the second section. The third section provides an overview of the cybersecurity regulations, standards, and guidelines for medical device software. The fourth section investigates how to incorporate cybersecurity into the quality management system. Some conclusions are drawn in the final section.

Cybersecurity is a complex, multidisciplinary computing-based discipline that has its roots in the 1960s. First paper on security and privacy in computer systems was published by Ware (1967). In 1970, Ware finalized a report about security controls for computer systems and emphasized that design of a secure system must provide protection against the various types of vulnerabilities such as accidental disclosure, deliberate penetration, active infiltration, and physical attack (Ware, 1970). Ware (1970) stated the following general characteristics as desirable in a secure system: flexible, responsive to changing operational characteristics, auditable, reliable, manageable, adaptable, dependable, and assuring configuration integrity.

Burns et al. (2016) identified four periods in the history of medical devices which evolved from the non-networked and isolated equipment to networked devices incorporating remote access, wireless technology, and complex software. The first period (1980s–present) involved concerns about the complex systems and accidental failures. The second period (2000–present) involved concerns about the security and reliability of implantable medical devices. The third period (2006–present) raised questions about the vulnerability of medical devices to unauthorized parties. In the fourth period (2012–present), attention has turned to the cybersecurity of medical devices. A recent KPMG's survey (2015) of 223 healthcare executives revealed many information security concerns: malware infecting systems, HIPAA (Health Insurance Portability and Accountability Act) violations/compromise of patient privacy, internal vulnerabilities related to employee theft/negligence, medical device security, and aging IT hardware. According to a recent study from the Ponemon Institute (2016), healthcare organizations experience, on average, a cyberattack almost monthly as well as the loss or exposure of sensitive and confidential patient information. Arxan's (2016) study on application security reveals that 90% of 126 mobile health and finance apps tested had at least two critical security vulnerabilities.

In January 2017, the U.S. Food and Drug Administration issued a safety communication confirming cybersecurity vulnerabilities found in St. Jude Medical's Merlin@home wireless transmitter that could affect the company's line of implantable cardiac devices ("Cybersecurity Vulnerabilities

Identified in St. Jude Medical's Implantable Cardiac Devices and Merlin@home Transmitter: FDA Safety Communication", 2017). Two months later, the FDA issued a warning letter to Abbot. The company failed to confirm that all required corrective and preventive actions were completed to correct and prevent recurrence of potential cybersecurity vulnerabilities associated with its Merlin@home device, originally manufactured by St. Jude Medical ("Abbott (St Jude Medical Inc.) 4/12/17", 2017). In August 2017, the FDA issued another safety communication confirming a firmware update that was needed as a corrective action to reduce the risk of patient harm due to potential exploitation of cybersecurity vulnerabilities for certain Abbott implantable cardiac pacemakers ("Firmware Update to Address Cybersecurity Vulnerabilities Identified in Abbott's (formerly St. Jude Medical's) Implantable Cardiac Pacemakers: FDA Safety Communication", 2017).

2 Key Definitions

This section provides definitions of the key terms.

Asset is "a person, structure, facility, information, and records, information technology systems and resources, material, process, relationships, or reputation that has value" ("A Glossary of Common Cybersecurity Terminology", 2017).

Availability aims to keep information accessible when it is needed (Svensson, 2016).

Confidentiality aims to prevent sensitive information (e.g., medical records) from falling into the wrong hands (Svensson, 2016).

Cybersecurity is "the process of preventing unauthorized access, modification, misuse or denial of use, or the unauthorized use of information that is stored, accessed, or transferred from a medical device to an external recipient" (FDA, 2014, p. 3). "Cybersecurity ensures that appropriate safeguards are in place to reduce the risk of failure because of cyberattack, which could be initiated by the introduction of malware into the medical equipment or by unauthorized access to configuration settings in medical devices" (ANSI/AAMI CI:86, 2017, p. 30).

Data and systems security is defined as "operational state of a medical device in which information assets (data and systems) are reasonably protected from degradation of confidentiality, integrity, and availability" (AAMI TIR57, 2016, p. 2).

Information security is "protection of information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to provide confidentiality, integrity, and availability" (AAMI TIR57, 2016, p. 3). ISO/IEC 27000 (2016) defines information security as preservation of confidentiality, integrity, and availability of information.

Integrity seeks to prevent information from being altered by unauthorized users (Svensson, 2016).

Security is "protection of information and data so that unauthorized persons or systems cannot read or modify them and authorized persons or systems are not denied access to them" (ISO/IEC 12207, 2008, p. 7). The most common security objectives are as follows: data confidentiality, data integrity, access control, authentication, authorization, and non-repudiation.

Threat is "a circumstance or event that has or indicates the potential to exploit vulnerabilities and to adversely impact (create adverse consequences for) organizational operations, organizational assets (including information and information systems), individuals, other organizations, or society" ("A Glossary of Common Cybersecurity Terminology", 2017).

Vulnerability is a "weakness in an information system, system security procedures, internal controls, or implementation that could be exploited or triggered by a threat source" (AAMI TIR57, 2016, p. 5).

3 Cybersecurity Regulations and Standards for Medical Device Software

In this section we provide an overview of currently published cybersecurity regulations, standards, and guidelines in the context of medical device software. This overview can serve as an input to establish and maintain procedures that address cyberattack prevention, detection, and response/recovery.

3.1 FDA and CFDA Guidance Documents, ISO/IEC 29147, and ISO/IEC 30111

The FDA has issued three guidance documents on cybersecurity listed in Table 1. The FDA guidance documents (2014, 2016) are applicable to devices that contain software (including firmware) or programmable logic, and to software that is a medical device, including mobile medical applications.

Table 1. FDA guidance documents on cybersecurity

Title	Year issued
Guidance for Industry – Cybersecurity for Networked Medical Devices Containing Off-the-Shelf (OTS) Software	2005
Content of Premarket Submissions for Management of Cybersecurity in Medical Devices – Guidance for Industry and Food and Drug Administration Staff	2014
Postmarket Management of Cybersecurity in Medical Devices – Guidance for Industry and Food and Drug Administration Staff	2016

According to the FDA guidance (2005), computer software changes to address cybersecurity vulnerabilities should be validated. The agency (FDA, 2005) also recommends developing a single cybersecurity maintenance plan.

When preparing FDA medical device premarket submissions, the manufacturers have to demonstrate an effective cybersecurity management. The FDA (2014) recommends establishing a cybersecurity vulnerability and management approach as part of the software validation and risk analysis. Such approach contains the following activities: 1) identify assets, threats, and vulnerabilities associated with medical devices, 2) assess the impact of threats and vulnerabilities on device functionality and end users/patients, 3) assess the likelihood of a threat and of a vulnerability being exploited, 4) determine risk levels and mitigations, and 5) assess residual risk and risk acceptance criteria (FDA, 2014). The FDA premarket submission documentation should include the following information related to the cybersecurity of the medical device: 1) hazard analysis, mitigations, and design considerations, including a specific list of all cybersecurity risks and cybersecurity controls for the device; 2) a traceability matrix that links the actual cybersecurity controls to the cybersecurity risks that were considered in the design of the device; 3) a plan for providing validated software updates and patches as needed throughout the lifecycle of the medical device; 4) controls ensuring integrity (e.g., remain free of malware) of the medical device software from development to device delivery; 5) device instructions for use and product specifications related to recommended cybersecurity controls appropriate for the intended use environment (e.g., use of anti-virus software, how to configure a firewall) (FDA, 2014).

The FDA guidance (2016) on postmarket management of cybersecurity in medical devices recommends implementing a proactive, comprehensive cybersecurity risk management program. Such a program can be established as part of the risk management process and may include: monitoring cybersecurity information sources (e.g., CVE (Common Vulnerabilities and Exposures) standard for information security vulnerability names (https://cve.mitre.org)); robust software lifecycle processes; assessing and detecting presence and impact of vulnerabilities; definition of communication processes for vulnerability intake and handling; using threat modeling on a regular basis; adopting a vulnerability disclosure policy and practice; deployment of mitigations that address cybersecurity risk early and prior to exploitation (FDA, 2016). For example, the Common Vulnerability Scoring System (CVSS) version 3.0 (www.first.org/cvss) can be used for vulnerability assessment.

The FDA guidance documents (2014, 2016) recommend the use and adoption of the voluntary NIST cybersecurity framework's five core functions: Identify (ID), Protect (PR), Detect (DE), Respond (RS), and Recover (RC). In January 2017, NIST issued a draft cybersecurity framework version 1.1. Table 2 provides the NIST framework core functions and corresponding cybersecurity outcomes.

Table 2. NIST cybersecurity framework core functions and outcome categories (NIST, 2017)

Function identifier	Outcome categories
ID	Asset management, business environment, governance, risk assessment, risk management strategy, supply chain risk management
PR	Access control, awareness and training, data security, information protection processes and procedures, maintenance, protective technology
DE	Anomalies and events, security continuous monitoring, detection processes
RS	Response planning, communications, analysis, mitigation, improvements
RC	Recovery planning, improvements, communications

The CFDA published the guidance on the technical reviews of the cybersecurity registration of Class II and III medical devices that connect to networks for the purpose of exchanging or storing data, or for remote control ("CFDA Spells Out Cybersecurity Requirements", 2017).

ISO/IEC 29147 (2014) and ISO/IEC 30111 (2013) standards are recognized by the FDA. ISO/IEC 29147 can be used as a guideline to address issues related to disclosure of potential vulnerabilities in products and online services. ISO/IEC 30111 gives guidelines how vendors should investigate, triage, and resolve potential vulnerabilities in products and online services.

3.2 BS EN 45502-1

BS EN 45502-1 (2015) defines the requirements that are generally applicable to Active Implantable Medical Devices (AIMD). There are also standards for particular AIMDs. For example, ANSI/AAMI CI:86 (2017) standard for cochlear implant systems requires security protection of wireless links and risk management, interoperability, and cybersecurity of the medical device.

Subclause 5.4 of BS EN 45502-1 standard requires adequate consideration of data security and protection from harm caused by unauthorized information tampering. "When communication with the implantable part of an ACTIVE IMPLANTABLE MEDICAL DEVICE through wireless communication channels is provided, the MANUFACTURER shall evaluate INFORMATION SECURITY through the RISK MANAGEMENT

PROCESS, and apply the appropriate RISK CONTROL measures to protect the patient from HARM. *Compliance is checked by the inspection of the RISK MANAGEMENT FILE*." (BS EN 45502-1, 2015, p. 13)

As part of medical device regulatory submissions, the manufacturers shall provide documented evidence that safety risks due to IT security threats which may compromise confidentiality, integrity, and availability of data have been adequately assessed and managed. The manufacturers shall also consider no detection, response, and recovery of IT security threats.

3.3 IEC 62304+AMD1, IEC 82304-1, and IEC 60601-1+AMD1

IEC 62304+AMD1 (2015) defines the requirements for medical device software life cycle processes. This standard requires including security requirements in the software requirements. For example: security requirements related to the compromise of sensitive information, authentication, authorization, communication integrity, audit trail, and system security/malware protection. Furthermore, when a problem is detected in the medical device software, a problem report shall be prepared. The standard requires including a statement of criticality with respect to effect on performance, safety, or security. The second edition of IEC 62304 is currently being drafted to align with IEC 82304-1. This edition will require a process for managing risks associated with data and system security, including privacy.

IEC 82304-1 (2016) provides requirements for the safety and security of health software products. According to this standard, potential sources of harm include breach of security and reduction of effectiveness. As part of general requirements definition and initial risk assessment, the manufacturers of the health software products can use the following sources of information on security vulnerabilities: publicly available reports from authorities, publications by suppliers of operating systems and third party software (IEC 82304-1, 2016). Table 3 lists requirements of IEC 82304-1 standard with respect to security. The requirements apply throughout the whole life cycle including design, maintenance, postmarket communication, decommission, and disposal of health software products.

Table 3. IEC 82304-1 (2016) requirements for health software products with respect to security

Clause	Requirement
4.1 b)	As part of general requirements definition and initial risk assessment, the manufacturer shall determine and document the characteristics related to the safety and/or security of the health software product and identification of hazards and estimation of the associated risk(s).
4.2 d)	When defining use requirements, the manufacturer shall determine and document privacy and security requirements addressing areas such as authorised use, person authentication, health data integrity and authenticity, and protection against malicious intent.
4.2 f) 3)	When defining use requirements, the manufacturer shall determine and document requirements to support timely security patches and updates.
4.5 f)	When defining system requirements, the manufacturer shall include the functionality for intended use and features that allow for security compromises to be detected, recognized, logged, timed, and acted upon during normal use, as applicable.
4.5 g)	When defining system requirements, the manufacturer shall include the functionality for intended use and features that protect essential functions, even when the software security has been compromised, as applicable.
4.5 h)	When defining system requirements, the manufacturer shall include the functionality for intended use and methods for retention and recovery of product configuration by an authenticated privileged user, as applicable.
7.2.2.2 c)	The instructions for use shall contain any operational security options for the use of the health software.
7.2.2.3	The instructions for use shall list all warnings and notices for safety and/or security related to the use of the health software product and explain or expand them when they are not self-explanatory.
7.2.2.4 c)	The instructions for use shall contain operational security options for the health software to be set at installation time.
7.2.2.9	The instructions for use shall contain all information necessary for the user or the responsible organization to safely decommission and dispose of the health software. This shall include, where appropriate, safeguarding personal and health-related data in connection with security and privacy.
7.2.3.1 g)	The technical description shall provide all data that is essential for safe and secure operation, transport and storage, and measures or conditions necessary for installing the health software, and preparing it for use. This shall include any technical security options that can be configured within the health software

Clause	Requirement
	product, and that are available to the responsible organization. Such security may include: 1) configuration options (e.g., minimum list of network ports and computer services that are required), 2) software options (e.g., turn on encryption settings, change default login credentials), 3) operational options (e.g., auditing and logging management settings).
7.2.3.1 h)	The technical description shall include a description of what the software does when a failure to maintain security is detected. The description shall include any impact to patient care, data or clinical workflow.
7.2.3.1	The manufacturer shall provide instructions in the technical description for the user and/or the responsible organization on how to deal with changes of the hardware and software platforms (e.g., with patches/updates of antivirus/firewall software, system libraries, firmware, and others), and how to select appropriate platform settings to support the security goals and security capabilities.
7.2.3.2 b)	If the health software is intended to be used in an IT-network that is outside the control of the health software manufacturer, the manufacturer shall provide, as part of the technical description, instructions necessary for this use, including the technical specifications of the IT-network necessary for the health software to achieve its purpose, including security specifications and protection against malware or similar.
8.2	Where the manufacturer decides that software maintenance is relevant or necessary, for instance, due to detected errors that can have an impact on safety and/or security, the manufacturer shall develop the modification of the health software product in compliance with Clause 5 of IEC 82304-1.
8.4	The manufacturer shall inform users of the health software product and impacted responsible organizations about the security vulnerabilities the manufacturer has become aware of, and of changes in regulatory requirements that impact the use of the health software product.
8.4 c)	In the case of software maintenance, the manufacturer shall make information available to users and to the responsible organizations of the availability of the updated version of the health software product, and provide information about any impact on safety and/or security of the
	modified software, where appropriate.
8.5	The user or the responsible organization shall be able to safely decommission and dispose of the health software product at the end of its useful life, including, where appropriate, safeguarding personal and health-related data in connection with security and privacy.

IEC 60601-1+AMD1 (2012) is a product safety standard for manufacturers of medical electrical equipment and systems. As part of the risk management process for Programmable Electrical Medical Systems (PEMS), subclause 14.6.1 of the standard provides examples of possible causes for hazards associated with PEMS. These examples include consideration of lack of integrity of data, lack of data security, including its effects on data privacy, and particularly vulnerability to tampering, unintended interaction with other programs and viruses (IEC 60601-1+AMD1, 2012). If the PEMS is intended to be incorporated into an IT-network that is not validated by the PEMS manufacturer, subclause 14.13 d) requires from the manufacturer to make available instructions for implementing such connection including the technical specifications of the network connection of the PEMS including security specifications. Viruses, worms, unauthorized software updates, or upgrades can lead to hazardous situations associated with IT-networks (IEC 60601-1+AMD1, 2012).

3.4 AAMI TIR57, ISO 14971, and NIST SP 800-30 Revision 1

AAMI TIR57 (2016) supports medical device manufacturers by providing guidance on methods to perform information security risk management for a medical device. The main goal is to "manage risks from security threats that could impact the confidentiality, integrity, and/or availability of the device or the information processed by the device" (AAMI TIR57, 2016, p. vii). This technical information report follows the basic structure of ISO 14971 (2007) standard and recommends "the creation of a separate risk analysis process focused specifically on impacts that are identified by a security analysis" (AAMI TIR57, 2016, p. 5). It also incorporates some principles from NIST SP 800-30 Revision 1 (2012), a guideline for conducting risk assessments of federal information systems and organizations.

AAMI TIR57 (2016) distinguishes between security risks that include breach of data and systems security and reduction of effectiveness, security risks with potential safety impact, and safety related risks that are covered by ISO 14971 standard. "Security risk is based on an assessment of the likelihood that a threat will successfully exploit a device vulnerability,

an event that could lead to an adverse impact due to a compromise of system confidentiality, integrity, and/or availability" (AAMI TIR57, 2016, p. x).

The security risk management process recommended by AAMI TIR57 (2016) consists of the following activities: 1) security risk management plan, 2) security risk analysis, 3) security risk evaluation, 4) security risk control, 5) evaluation of overall residual security risk acceptability, 6) security risk management report, and 7) production and post-production information.

To support the manufacturers to identify characteristics related to the security of their medical devices, Annex D of AAMI TIR57 (2016) provides a list of questions that cover the following areas: essential performance of the device, data storage of Personally Identifiable Information (PII)/private data assets and non-PII data assets, data transfer, authentication and authorization, logging and auditing, physical security, device/system updates, hardening, emergency access, malware/virus protection, backup/disaster recovery, and labeling (i.e., instructions for use with respect to security).

3.5 IEC 80001 Family

IEC 80001-1 (2010) defines the following key properties for medical IT-networks: safety, effectiveness, data and systems security.

IEC/TR 80001-2-2 (2012) provides a framework for the disclosure of security-related capabilities and risks necessary for managing the risk in connecting medical devices to IT-networks. This technical report assists the health delivery organizations, medical device manufacturers, and IT vendors in the application of risk management when creating or changing a medical IT-network.

IEC TR 80001-2-8 (2016) provides guidance to health delivery organizations and medical device manufacturers how to apply the framework outlined in IEC/TR 80001-2-2 (2012). This technical report identifies the following security controls: automatic logoff, audit controls, authorization, configuration of security features, cyber security product upgrades, health data de-identification, data backup and disaster recovery, emergency access, health data integrity and authenticity, malware detection/protection, node authentication, person authentication, physical locks on device, third-party components in product life cycle roadmaps, system and application hardening, security guides, health data storage confidentiality, transmission confidentiality and integrity.

IEC TR 80001-2-9 (2017) provides guidance to health delivery organizations and medical device manufacturers for identifying, developing, interpreting, updating, and maintaining security assurance cases for networked medical devices. It also provides guidance for the selection of appropriate security controls listed in IEC/TR 80001-2-2 (2012) to establish security capabilities.

3.6 Medical Device Regulation (MDR)

New European regulation on medical devices requires IT security, protection and confidentiality of personal data at various development stages (refer to Table 4).

Table 4. MDR requirements addressing security and data protection ("Official Journal of the European Union L 117", 2017)

Page	MDR requirement
101	Manufacturers shall set out minimum requirements concerning hardware, IT networks characteristics and IT security measures, including protection against unauthorised access, necessary to run the software as intended.
107	The instructions for use shall contain for devices that incorporate electronic programmable systems, including software, or software that are devices in themselves, minimum requirements concerning hardware, IT networks characteristics and IT security measures, including protection against unauthorised access, necessary to run the software as intended.
121	Minor software revisions shall require a new UDI-PI and not a new UDI-DI. Minor software revisions are generally associated with bug fixes, usability enhancements that are not for safety purposes, security patches or operating efficiency.
171	Description of the arrangements to comply with the applicable rules on the protection and confidentiality of personal data, in particular: • organisational and technical arrangements that will be implemented to avoid unauthorised access, disclosure, dissemination, alteration or loss of information and personal data processed; • a description of measures that will be implemented to ensure confidentiality of records and personal data of subjects; • a description of measures that will be implemented in case of a data security breach in order to mitigate the possible adverse effects.
264	For devices that incorporate software or for software that are devices in themselves, the software shall be developed and manufactured in accordance with the state of the art taking into account the principles of development life cycle, risk management, including information security, verification and validation.

3.7 UL 2900 Family

In 2016, the Underwriters Laboratories launched a Cybersecurity Assurance Program (CAP) that provides testable cybersecurity criteria for assessing software vulnerabilities, malware, and security controls in network-connectable products and systems. Here are some examples of network-connectable products and systems: medical devices and their accessories, medical device data systems, in vitro diagnostic devices, health IT, wellness devices, automotive, industrial control systems, smart home, fire systems, alarm systems, IoT (Internet of Things), etc.

Table 5 provides a list of UL's 2900 series of cybersecurity standards. UL 2900-1 (2017) specifies general product requirements for network-connectable products and systems, whereas UL 2900-2-1 and UL 2900-2-2 that were published in 2016 specify industry product requirements. New UL 2900-3 standard is currently under development and will specify general requirements for the organization and product development security life cycle processes for network-connectable products.

Table 5. UL 2900 cybersecurity standards

Identifier	Title
UL 2900-1	Standard for Software Cybersecurity for Network-Connectable Products, Part 1: General Requirements
UL 2900-2-1	Outline of Investigation for Software Cybersecurity for Network-Connectable Products, Part 2-1: Particular Requirements for Network Connectable Components of Healthcare Systems
UL 2900-2-2	Outline of Investigation for Software Cybersecurity for Network-Connectable Products, Part 2-2: Particular Requirements for Industrial Control Systems

EMERGO has recently published on its web site that a set of UL 2900 standards to address medical device cybersecurity issues will soon be adopted by the FDA ("UL 2900 Cybersecurity Standards Set for FDA Adoption", 2017).

3.8 ISO/IEC 27000 Family

The ISO/IEC 27000 family of standards helps organizations to protect their information assets such as financial information, intellectual property, employee details, etc.

ISO/IEC 27000 (2016) provides an overview and the vocabulary of Information Security Management Systems (ISMS).

ISO/IEC 27001 (2013) is an international security standard that provides the requirements for establishing, implementing, maintaining, and improving an ISMS. "The information security management system preserves the confidentiality, integrity and availability of information by applying a risk management process and gives confidence to interested parties that risks are adequately managed." (ISO/IEC 27001, 2013, p. v) ISO/IEC 27001 (2013) specifies total 114 security controls across the following areas: A.5 Security policy, A.6 Organization of information security, A.7 Asset management, A.8 Human resources security, A.9 Physical and environmental security, A.10 Communications and operations management, A.11 Access control, A.12 Information systems acquisition, development and maintenance, A.13 Information security incident management, A.14 Business continuity management, A.15 Compliance.

ISO/IEC 27032 (2012) provides guidelines for organizations to address common cybersecurity risks such as social engineering attacks, hacking, malware (short for malicious software), spyware, other potentially unwanted software. It also provides a framework for information sharing, coordination, and incident handling.

ISO 27799 (2016) provides guidelines for organizational information security standards and information security management practices including the selection, implementation and management of controls taking into consideration the organization's information security risk environment(s).

3.9 HIPAA

The Health Insurance Portability and Accountability Act of 1996 is a healthcare legislation in the United States that specifies requirements to safeguard the privacy and security of Protected Health Information (PHI). It was introduced in 1996 and become Public Law 104-191. The HIPAA legislation requires, among other things, that "e-mails to patients containing health-related information must be encrypted in transit, unless the patient has written authorization on file for the organization to send their information unencrypted" (Wittkop, 2016, p. 38). Failure to comply with HIPAA may result in civil and criminal penalties (Robichau, 2014).

The HIPAA Privacy Rule generally states that any paper/electronic PHI provided to employees of a healthcare organization must be appropriate to their job and in keeping with adopted internal policies (Robichau, 2014). This approach is called the minimum necessary standard. Subject to the HIPAA Privacy Rule are so-called covered entities. There are three types of covered entities: 1) insurance carriers or health plans (e.g., Medicare, Medicaid, Health Maintenance Organization (HMO), TRICARE, etc.), 2) health care clearinghouses that submit health care claims for a provider, and 3) any health care providers

that transmit health information electronically in connection with transactions regulated by the US Department of Health and Human Resources. Each covered entity must appoint a HIPAA officer who is responsible for HIPAA compliance and all aspects of information privacy and security.

To ensure appropriate protection of electronic PHI, the HIPAA Security Rule outlines three different safeguards: 1) administrative (i.e., security management process, security personnel, information access management, workflow training and management, periodic evaluation of security policies and procedures), 2) physical (i.e., facility access and control, workstation and device security), and 3) technical (i.e., access control, audit controls, data integrity control, transmission security) ("Summary of the HIPAA Security Rule", 2013).

4 Integration of Cybersecurity into the Quality Management System

Implementation of a cybersecurity program is a significant investment for any organization. Such a program should be designed to protect computers, mobile platforms, medical devices, networks, software, medical records, proprietary, confidential or personal information, and other information assets from unintended or unauthorized access, use, theft, transmission, storage, modification, destruction, or denial of service.

Medical device manufacturers without cybersecurity programs could use the NIST cybersecurity framework as a reference to establish one. According to a Gartner report ("Best Practices in Implementing the NIST Cybersecurity Framework", 2016), the NIST cybersecurity framework that was published in February 2014 has been adopted by 30% of US companies and is expected to grow to 50% by 2020. Robert Ford, Abbott's Executive Vice President of Medical Devices, said that their cybersecurity program was built around the following key elements: 1) a dedicated product cybersecurity multifunctional group to ensure cybersecurity is part of the design process, 2) cybersecurity medical advisory board made up of leading health care professionals to advise, counsel, and partner with Abbott, and 3) a network of reputable and experienced third-party cybersecurity research companies to challenge and validate Abbott's systems ("Focus on Cybersecurity", 2017). Adopting a coordinated vulnerability disclosure policy is encouraged (FDA, 2016).

The FDA (2014) recommends developing a set of cybersecurity controls in order to assure medical device cybersecurity and to maintain medical device functionality and safety. To reduce vulnerabilities, four security experts ("Top 10 cybersecurity must-haves for 2017", 2017) recommended the following ten measures to protect patient data and keep it out of cybercriminals' hands: 1) risk assessments, 2) disaster recovery and contingency plans, 3) dedicated security operations team to handle security, hunt threats, educate staff on latest threats, and perform penetration tests, 4) business associate/vendor scrutiny, 5) better employee training, 6) layered defense, 7) improved tech hygiene, 8) cybersecurity partnerships, 9) better software, and 10) forensic consultants to provide insights on weaknesses, liabilities, and security reports.

Performing a periodical gap analysis can be a helpful method to evaluate the policies, standard operating procedures (SOPs), and processes implemented by the organization in order to identify discrepancies between the quality management system and the requirements set forth in the cybersecurity regulations, guidelines, best practice standards, and the organization's existing information security or cybersecurity program. After identifying the gaps, a cybersecurity improvement plan can be developed. The purpose of this plan is to provide management with insight into the areas within the quality management system which need to be improved.

According to the FDA guidance document (2016), cybersecurity shall be addressed in the following aspects of quality management systems: complaint handling, quality audit, corrective and preventive action, software validation and risk analysis, and servicing.

4.1 Complaint Handling

The complaint handling process should track customer security concerns and consider cybersecurity incidents as a cause for complaints.

4.2 Quality Audit

Quality audits are useful to examine implementation of the cybersecurity program to confirm compliance with regulatory requirements, policies, and SOPs.

4.3 Corrective and Preventive Action

The Corrective and Preventive Action (CAPA) sub-system should consider analysing processes, quality audit reports, returned products, service records, complaints, and other sources of quality data in order to identify cybersecurity vulnerabilities as a cause for non-conforming products, or other quality issues. The CAPA process should plan corrective and preventive actions in order to react on cybersecurity incidents.

4.4 Software Life Cycle Processes

Cybersecurity should be considered throughout the whole life cycle of the medical device software, including design inputs, security requirements, secure software architectural design, secure coding, maintenance plans, and updates.

According to the FDA (2016), robust software lifecycle processes include mechanisms for: monitoring third party software components for new vulnerabilities throughout the device's total product lifecycle, and design verification and validation for software updates and patches that are used to remediate vulnerabilities, including those related to OTS software. Similar to the usability engineering process, the manufacturers could establish a security engineering process.

Writing secure, robust code and performing code reviews with security in mind is an essential skill for every software engineer. The Microsoft Security Development Lifecycle (SDL) could be used as a guideline to help developers build secure software and to address security requirements ("Microsoft Security Development Lifecycle", 2017). Furthermore, software engineers can use threat modeling (Shostack, 2014), the OWASP (Open Web Application Security Project) Secure Coding Practices – Quick Reference Guide (2010), SAFECode (Software Assurance Forum for Excellence in Code) checklists, and training material ("Best Practices for Security & Privacy", 2016). Further information about secure systems engineering and how to integrate security activities into software engineering life cycle processes can be found in (Goertzel et al., 2007).

Using the OWASP's annual list of the top ten security risks during development and security testing of medical device software may help to adequately address and correct the most critical security flaws. OWASP identified the following top ten application security risks in 2017: injection flaws, broken authentication and session management, cross-site scripting (XSS), broken access control, security misconfiguration, sensitive data exposure, insufficient attack protection, Cross-Site Request Forgery (CSRF), using components with known vulnerabilities, and underprotected APIs ("OWASP Top 10 Application Security Risks – 2017", 2017). The following top ten mobile security risks in 2016 were identified by OWASP: improper platform usage, insecure data storage, insecure communication, insecure authentication, insecure cryptography, insecure authorization, client code quality, code tampering, reverse engineering, and extraneous functionality ("Mobile Top 10 2016-Top 10", 2017).

Medical devices with weak security that are connected to a public network (Internet) are more exposed to ransomware attacks. For example, in May 2017, the global ransomware attack has infected and encrypted some medical devices and computers at medical facilities ("Medical Devices Hit By Ransomware For The First Time In US Hospitals", 2017). A multi-layered security model can be implemented to prevent network-based and application-based attacks. For example, when users connect their laptops to public Wi-Fi networks, they are running the risk of exposure to malware or viruses that can later infect the corporate network. A firewall can stop attacks at the network perimeter, but it may not be able to stop an attack that comes from a trusted source ("Layered security is IT's best defense", 2016). Therefore, security at each layer must work together.

Security testers are responsible for performing security and penetration testing. "Security testing is a type of vulnerability assessment. The security tester takes on the role of a hacker and tries her best to break into the organization's IT environment. The purpose of such a test is to find any vulnerabilities within an organization's IT environment and how the vulnerabilities could be exploited in a real-world hacker attack." (Svensson, 2016, p. 2) Security testing includes methods such as penetration testing with man-in-the-middle attacks, fuzzing, scanning, and auditing the software (Knott, 2015).

4.5 Security Risk Management Process

The risk management process required by ISO 14971 should begin early in the development process and also address security risks. "To manage postmarket cybersecurity risks for medical devices, a company should have a structured and systematic approach to risk management and quality management systems consistent with 21 CFR part 820." (FDA, 2016, p. 14)

The security risk management process should address the following elements: 1) identification of assets, vulnerabilities, and threats, 2) security risk evaluation, 3) implementation of security risk control measures, 4) assessment of residual risk and risk acceptance criteria, and 5) submission of relevant information to appropriate stakeholders (e.g., users, regulators, health delivery organizations).

AAMI TIR57 (2016) recommends establishing a companion security risk management process in addition to the safety risk management process required by ISO 14971 (2007). According to AAMI TIR57 (2016), top management should provide adequate and qualified personnel to perform the security risk management process (i.e., personnel should be knowledgeable in evaluating security threats and vulnerabilities, and should have experience with hardware and software architecture, design, and security test methods). In addition, top management should review the suitability of the security risk management process at defined intervals (AAMI TIR57, 2016). There are three different approaches that can be used for security risk assessment: 1) threat-oriented, 2) asset/impact-oriented, and 3) vulnerability-oriented (AAMI TIR57, 2016). "A security risk management report summarizes the evaluation, assessment, mitigation activities, and traceability to the verification reports of

security controls that ensure a device is reasonably secure." (AAMI TIR57, 2016, p. 14) A security risk management file can be created and maintained as a separate document or integrated with the overall risk management file of the medical device (AAMI TIR57, 2016).

4.6 Resources and Training

Top management should provide qualified personnel and tools to perform tasks related to cybersecurity.

Many different types of security threats have developed over time: Trojan horses, worms, computer viruses, sniffers, rootkits, backdoors/trapdoors, key loggers, spyware, malware, ransomware, social engineering, reverse engineering (undesired access to intellectual property), code tempering (changes to application behaviour), botnets, insider attacks, etc. According to Meeuwisse (2017), complex digital environments in large organizations need a range of cybersecurity experts. He identified the following six main cybersecurity tasks and skills (i.e., functions) with corresponding roles: 1) management (e.g., Cyber Risk Manager, Chief Information Security Officer (CISO)/Chief Cybersecurity Officer, Cybersecurity Architect), 2) cyber audit and assessment (e.g., Audit Manager, Auditor, etc.), 3) event monitoring and alerts (reactive operations) (e.g., Security Incident and Events Manager, Cybersecurity and Network Intrusion Analysts, etc.), 4) proactive operations (e.g., Access Administrators, Security Risk Consultants, Cybersecurity Analysts, etc.), 5) environment testing (e.g., Attack and Penetration Testers (Ethical Hackers), Vulnerability Assessors), and 6) specialists (e.g., Security Controls Designer, External Security Specialist, Digital Forensics Specialist, Cryptologist, Cryptanalyst, Anti-Malware/Anti-Virus Specialist, Software Security Specialist). Meeuwisse (2017) recommends having a CISO or Chief Cybersecurity Officer role on the main executive board of an organization to ensure that the organization has appropriate security processes, policies, practices, and procedures in place.

In December 2013, the Government in the UK held 4 workshops with 51 individuals from large businesses, small and medium-sized enterprises, and universities. The Government found that businesses looked for a wide range of professional cybersecurity qualifications and accreditations as displayed in Fig. 1 (HM Government, 2014). In addition to cybersecurity experts, companies like Bigfoot Biomedical, Inc. hire security hackers ("Security Hackers Help Bigfoot Biomedical Keep Patient Info Secure", 2017).



Figure 1. Professional cyber/information assurance qualifications and accreditations (HM Government, 2014, p. 16)

4.7 Servicing

The servicing process should ensure that validated software updates and patches that are used to remediate vulnerabilities are provided.

5 Conclusions

The explosion of the digital landscape increased the need to secure company's digital property/assets and medical devices from cyberattacks. Finding a balance between increasing development costs and investments in security controls is one of the project management challenges. Software test professionals and IT infrastructure personnel must integrate security testing in their testing procedures as well as to continuously gain knowledge about security testing tools and latest cyber vulnerabilities of hardware and software. To get a proper overview of regulatory requirements that address the security of interconnected medical devices and related software has become increasingly difficult given the number of regulations, standards, frameworks, guidance documents, technical reports, and best practices on this topic. Some standards do not contain explicit provisions on cybersecurity but they provide some guidance for the implementation of security controls.

Cybersecurity has become of paramount importance in the software life cycle processes. Cybersecurity is an iterative process that involves the full product life cycle. When designing a robust cybersecurity program, medical device manufacturers should consider the following key components: 1) designing products from the start with cybersecurity in mind (i.e., prevention), 2) performing security and penetration testing and applying other cybersecurity controls to reduce exploitable weaknesses and attacks (i.e., detection), and 3) having a maintenance plan in place in case of a cyberattack (i.e., incident response and recovery). Implementing a proactive security approach against threats can drive up the value of the company's products and services.

Disclaimer

The views and opinions expressed in this paper are those of the individual author and do not represent the approach, policy, or endorsement of the organization that is currently affiliated with the author.

Acknowledgments

The author would like to thank two anonymous reviewers for their valuable comments and suggestions which helped to improve this paper.

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On-Line Behaviour of Users With Different Privacy Concerns

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Abstract. *The paper investigate online private and business activities of users with different attitudes towards privacy. Users were categorized as "privacy pragmatic", "privacy fundamentalist" and "privacy unconcerned". Survey among 436 participants showed significant difference in activities connected to information searching, social networking, entertainment, buying/selling products or services online between privacy fundamentalist and privacy unconcerned group. For other explored activities such as financial activities, civic activities and political activities no significant difference was found between the three observed groups, as well as for use of ICT and the Internet as a routine on a daily basis for private activities.*

Keywords. Privacy concern, segmentation index, ICT usage

1 Introduction

The data has never been more important than it is today, since the increased collection of private information online and the superior capabilities of Information and Communication Technologies (ICT) for searching, tagging and aggregating this information provides. Using various data mining techniques retailers can easily extract a vast amount of customers' personal data.

On the other hand, the protection of personal data in Internet has gained significant attention, therefore it is not surprising that in recent years there has been a lot of interest in studying issues relating to privacy concerns that users have and how these might impact their online activities.

Information privacy and data security are important factors for the success of e-commerce, and usually customers connect this terms with the privacy of the information that is generated in online environment and is result of customers' online actions and behaviour. Fundamentally, it includes information collection, sharing, use, reuse, and storage of data such as transactions, personal details, and demographic information (Alharbi et al, 2013). The concern is also heightened because of the massive amount of personal information that businesses collect, and customers generally lose control over the data they provide to businesses (Akhter, 2014). From customers' perspective, privacy concern arises from not knowing how the personal information they provide will be used, shared and protected.

Users' privacy concerns is one of the primary obstacles for customers to participate in e-commerce transactions, however, gathering information about customers is also necessary, in order to gain a better understanding of their preferences (Gurung & Raja, 2016). Despite disclosing information is an increasing part of modern life, "it is necessary to ensure that privacy is protected in a way that does not prevent users from continuing using ICT" (Noain-Sanchez, 2016).

2 Privacy concerns – state of the art

Researchers have devoted much attention to understanding customers' outlooks on privacy concerns. Modern consumers increasingly embrace the personalization of service, whiles disclosure of private information to companies for benefits like receiving personalized service is largely connected to privacy invasion and breaches risks. Meanwhile, Zhu et al. (2017) proposed that personalization should not focus only on the consumers' preference of benefits, than privacy concerns should be incorporated into the analysis for tailoring the personalized services or products.

The use of consumer's personal data, any data or information that can be directly or indirectly traced back to a specific person and can identify person, is growing exponentially as organizations are becoming aware of its potential (Taylor et al, 2015).

As the use of web based transactions requires sharing personal information, the protection and authorized use of such information have become a critical. Customers are exposed to risk connected to identity theft, spyware, adware, spam, phishing, and pharming, among other things (Akther, 2014).

Alharbi et al. (2013) was dealing with understanding of customers' perceived privacy and

security (CPPS) by investigating privacy concerns, data security, and exploring the factors that elevate or minimise these concerns. The study highlights differences in the levels of concern regarding individual privacy in e-transactions, in terms of the amount of information required to complete the process. Furthermore, the importance of maintaining the privacy of customer information and ensuring data security to protect and enhance the organisation's reputation and its customer relationships is stressed.

Akhter (2014) discuss Internet self-efficacy which is focused on beliefs about skills, ability, and confidence related specifically to the use of the Internet. Internet self-efficacy and Internet involvement have a negative impact on privacy concern, but on the other hand Internet self-efficacy and Internet involvement have a positive impact on the frequency of online transactions. In addition, privacy concern has a negative impact on the frequency of online transactions.

Culture of privacy and trust, regulation, knowledge and digital competences play an essential role to mitigate privacy breaches in online mediated environments. They represent "themes linked to user's necessities to understand the functioning of digital environments in order to evaluate the possible repercussions their actions may involve for their privacy" (Sanchez, 2016).

Hargitai and Marwick (2016) considered how young adults' attitudes about privacy can be reconciled with their online behaviour. Young adults understand and care about the potential privacy risks associated with disclosing information online. They engage some privacy-protective behaviours on social media, but they feel that once information is shared, control over it is lost.

The Privacy segmentation proposed by Alan F. Westin represents one scheme for categorizing the different levels of privacy concerns and divides persons into "privacy fundamentalists," "privacy pragmatists," and the "privacy unconcerned" (Dolnicar and Jordan, 2006). Privacy Fundamentalists perceive privacy as an especially high value, they believe that more individuals should refuse to give out information (all information they are asked for). They favours enactment of strong laws to secure privacy rights and control how organization are using it. They feel that they have lost a lot of their privacy and are strongly resistant to further disclosure of themselves. Privacy Unconcerned usually have low to no levels of distrust, have no problem with disclosing their personal information to government authorities or businesses. Privacy pragmatists are very concerned to protect themselves from the misuse of their personal information by other people and organisation, have strong feelings about privacy and have medium to high levels of distrust (Urban and Hoofnagle, 2014).

Westin conducted more than 30 privacy surveys where details about used privacy indexes were not published in academic papers, but in original survey reports. Kumaraguru and Cranor (2005) reported on several privacy indexes created by Westin in order to summarize his survey results in period from 1990 to 2003. Westin surveyed the general level of privacy concern of the public and studied the attitudes about specific privacy-related topics, like confidence in organizations that handle personal information, acceptance of a national identification system, and use of medical records for research. Reports includes 14 Westin surveys that were conducted via telephone and surveyed randomly-selected statistical samples of the United States adult population. During 1994 - 2000 the percentage of Fundamentalists in the public have remained almost the same, around 25%. The number of Unconcerned had decreased from 25% in 1990 to 10% in 2003. Pragmatist group was varying between 57% in 1991 to 64% in 2003.

Jai and King (2016) researched the impact of age, gender and customer loyalty on the willingness to share personal information with third-party advertisers and data brokers, towards customer privacy groups (Westin's privacy segmentation). Younger customer are more willing to share their personal information, excluding for privacy fundamentalist group. Males have a greater willingness to disclose and to give permission to share their personal information to advertisers and data brokers. Attitudinal loyalty and behaviour loyalty were differently perceived among all groups of privacy segmentation.

Hann et al. (2007) investigated the differences in privacy preferences. They categorized respondents in to three distinct segments (according their rankings of the various benefits and concerns connected to privacy): privacy guardians, information sellers, and convenience seekers. Privacy guardians were sensitive to concerns connected to online information. Information sellers are usually willing to provide information in exchange for money. Convenience seekers are willing to provide information in exchange for convenience.

The purpose of this paper is to advance our understanding of how persons that have characteristic of privacy fundamentalist, privacy pragmatics or privacy unconcerned perceive issues connected with online privacy.

3 Research problem

With the aim to investigate the differences in usage of ICT and the Internet for daily private/business activities among three groups of respondents, towards Westin's privacy segmentation: 1) the privacy unconcerned 2) the privacy pragmatists and 3) the privacy fundamentalists, first we have created a measurement instrument (questionnaire) for data collection. Further in the paper, "privacy unconcerned respondents" which characterizes no or low concern and distrust represents Group 1, the "privacy pragmatists" which characterizes mid-level concern and distrust represents Group 2,

while the "privacy fundamentalists respondents" which characterizes high privacy concern and high distrust in government, business, and technology represents Group 3.

Measurement instrument (questionnaire) comprising 10 items related to daily private activities of people such as searching information, learning activities, communication activities, social networking, entertainment, commercial activities, financial activities, civic activities, political activities, usage of ICT and the Internet on daily basis as a routine, 4 questions related to company general information in which respondents are working and 3 items related to concerns about privacy in the online environment. Items were coded on a 5-point semantic ordinal scale ranged from "1-not at all" to "5-very frequently" and "1-strongly disagree" to "strongly agree". Selection of respondents in the above mentioned three groups was performed on the way to taking the mean value of the three questions that have been referred to concerns about privacy in the online environment. Group 1 - mean value from 1.1 to 2.3, Group 2 - mean value from 2.4 to 3.6 and Group 3 - mean value from 3.7 to 4.9.

Data collection lasted for a period September - December 2015 on sample of SMEs and large Croatian companies. The database of Croatian Chamber of Economy called BIZNET was used for collecting Company contacts (2017). All companies in the category of SMEs and large enterprises from all counties in the Republic of Croatia were included in the sample, while small enterprises were collected clustered by counties, with the availability of contacts separated by those companies that have e-mail contact.

The self-administered online survey approach was used, an online questionnaire was designed through free online survey and questionnaire tool KwikSurveys (2017). The link on online questionnaire was sent to the 23,805 e-mail addresses of SMEs and large companies. After data collection, in the analysis of data in addition to standard descriptive statistics, to determine whether there were any differences between three groups (privacy unconcerned, privacy pragmatists and privacy fundamentalists) of users/employees the analysis of variance was used (Stevens, 1992).

4 Discussion

After research conducted on Croatian SMEs and large companies correctly filled out the questionnaire a total of 436 respondents/employees (i.e. 1.83% of the sample), of which 406 respondents/employees was from small, 25 from medium and 5 from large companies. Of 436 respondents 74 were selected in Group 1 (privacy unconcerned), 196 in Group 2 (privacy pragmatists) and 166 in Group 3 (privacy fundamentalists). Statistical analysis was performed using statistical tool STATISTICA.

As can be observed from the presented results of analysis of variance (Fig. 1) for activities related to "information searching" a significant difference is confirmed between the first (privacy unconcerned) and third group (privacy fundamentalists) of respondents (df1=2, df2=433 F=2.460, p=0.005), wherein the group so-called privacy unconcerned use ICT and the Internet for information searching most frequently, 97% (Group 1 n=72) of them use "frequent" or "very frequent".

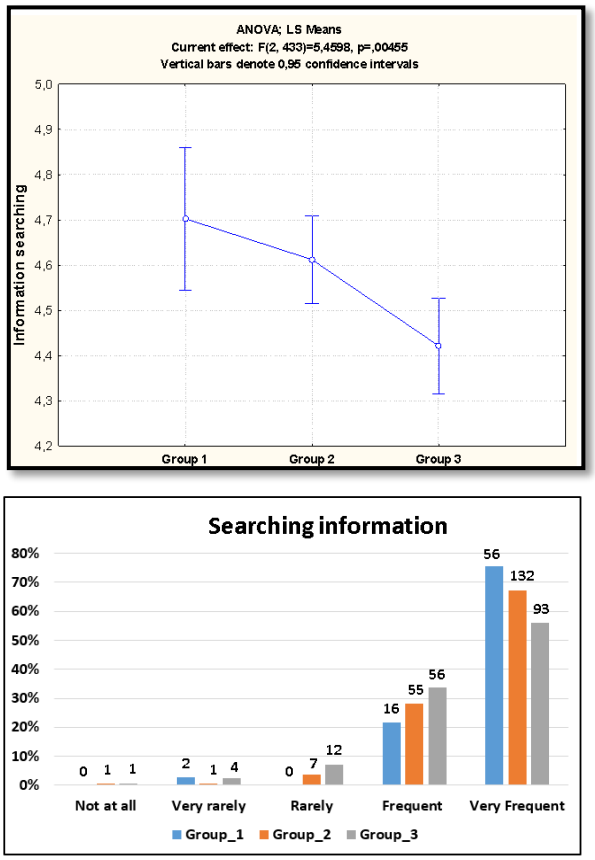


Figure 1. The use of ICT and the Internet for information search

As well as for "information search", in "social networking" (Fig. 2) via ICT and the Internet (Facebook, Twitter, YouTube) significant difference can also be noticed among the first and third group of respondents (df1=2, df2=433 F=3.028, p=0.049). From the group which characterizes high privacy concern (Group 3, privacy fundamentalists), it does not work at all or rarely or very rarely, as many as 50% (Group 3 n=83) of respondents, unlike a group that is not concerned about security and privacy (Group 1, privacy unconcerned), nearly 70% (Group 1 n=51) of respondents declared that doing "frequent" or "very frequent".

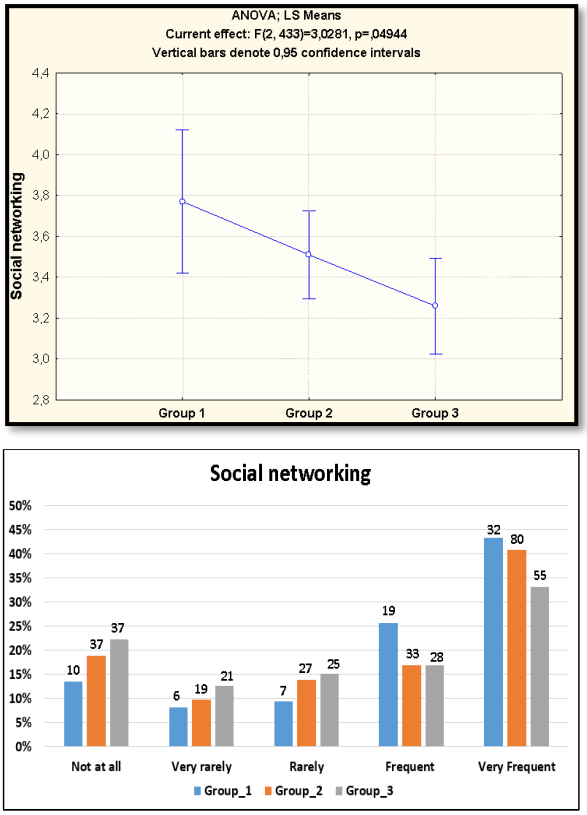


Figure 2. The use of ICT and the Internet for social networking

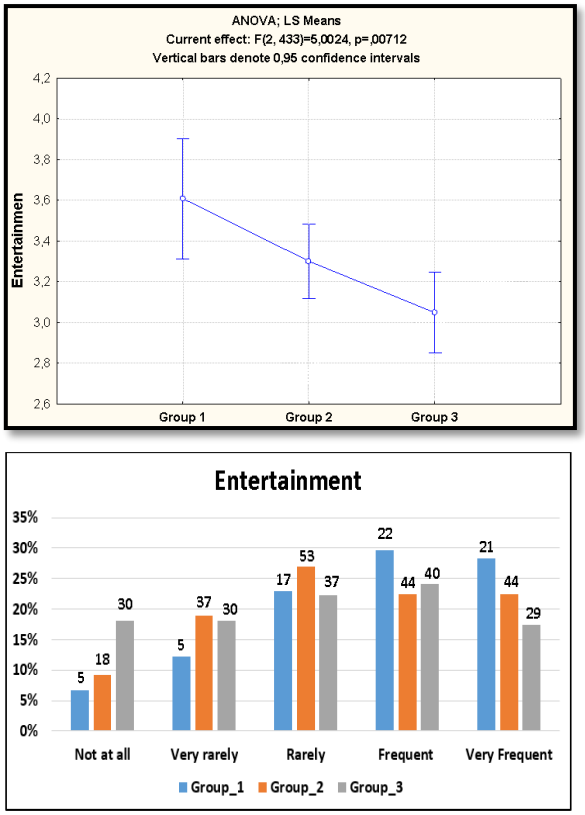


Figure 3. The use of ICT and the Internet for entertainment

When researching the use of ICT and the Internet from the aspect of "entertainment" (Fig. 3), one can notice that significant difference was also confirmed between the first and third group of respondents (df1=2, df2=433 F=5.002, p=0.007) and that the group so-called privacy unconcerned (Group 1) use ICT and the Internet for entertainment most frequently, 58% (Group 1 n=43) of them have declared that they do that "frequent" or "very frequent".

Fig. 4 shows that significant difference was also confirmed among the first and third groups of respondents when researching the use of ICT and the Internet for "commercial activities" such as buying / selling of products and services, searching for information about products and services, comparing products and services (df1=2, df2=433 F=3.363, p=0.036), and in this case the group so-called privacy unconcerned (Group 1) use ICT and the Internet for commercial activities most frequently, even 78% (Group 1 n= 58) of them have declared that they do that "frequent" or "very frequent".

For other explored aspects of using ICT and the Internet such as activities", "financial activities", "civic activities" and "political activities" no significant difference was found between the three observed groups of respondents, as well as for "use of ICT and the Internet as a routine on a daily basis for private activities". Since no significant difference was confirmed for the aforementioned activities, therefore, for these activities, the results of the research are shown only descriptively (Fig. 5).

As can be seen from Fig. 5 in relation to communication activities (e-mail, text messaging, chat and forum), all three groups of respondents prefer to communicate via ICT and the Internet, because more than 95% of respondents stated that they do it "frequent" or "very frequent" (Group 1 n=72, Group 2 n=190, Group 3 n=159). Financial activities (banking, investment activity) is used by more than 75% (Group 1 n=56, Group 2 n=159, Group 3 n=132) of respondents "frequent" or "very frequent", and also learning activities (educational materials, employment opportunities, training courses), more than 65% (Group 1 n=53, Group 2 n=126, Group 3 n=107) of respondents stated that they do it "frequent" or "very frequent".

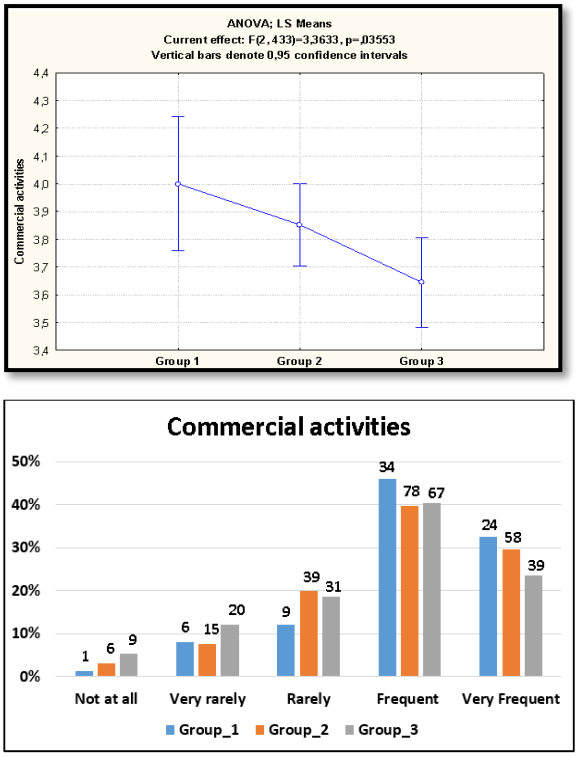


Figure 4. The use of ICT and the Internet for commercial activities

Taking part in "civic activities", such as signing petitions, voting or discussions, is not customary via ICT and the Internet in all three groups of subjects, because more than 89% (Group 1 n=66, Group 2 n=176, Group 3 n=148) of respondents in all three groups stated that "do not use" ICT and the Internet for purposes of civic participation, or use it "rarely" or "very rarely".

A similar situation can be observed in relation to "political activities" (contacting politicians, participation in political parties), in this regard, more than 95% (Group 1 n=70, Group 2 n=192, Group 3 n=160) of respondents from all three groups arguing "not" to participate or "rarely/ very rarely" in political activities via ICT and Internet.

Lastly, the aim was to investigate whether there is a significant difference in the use of ICT and the Internet between the three groups of the respondents regarding the "use of ICT and the Internet as a routine on a daily basis for private activities". It has been found here that there are no significant differences between the three groups of respondents. There is a significantly larger percentage of examinees in all three groups declared themselves that using ICT and the Internet for private purposes has become their daily routine. Most of the respondents in all three groups (almost 90% Group 1 n=68, Group 2 n=183, Group 3 n=145) have argued that ICT and the Internet on a daily basis for private activities use "frequent" or "very frequent"

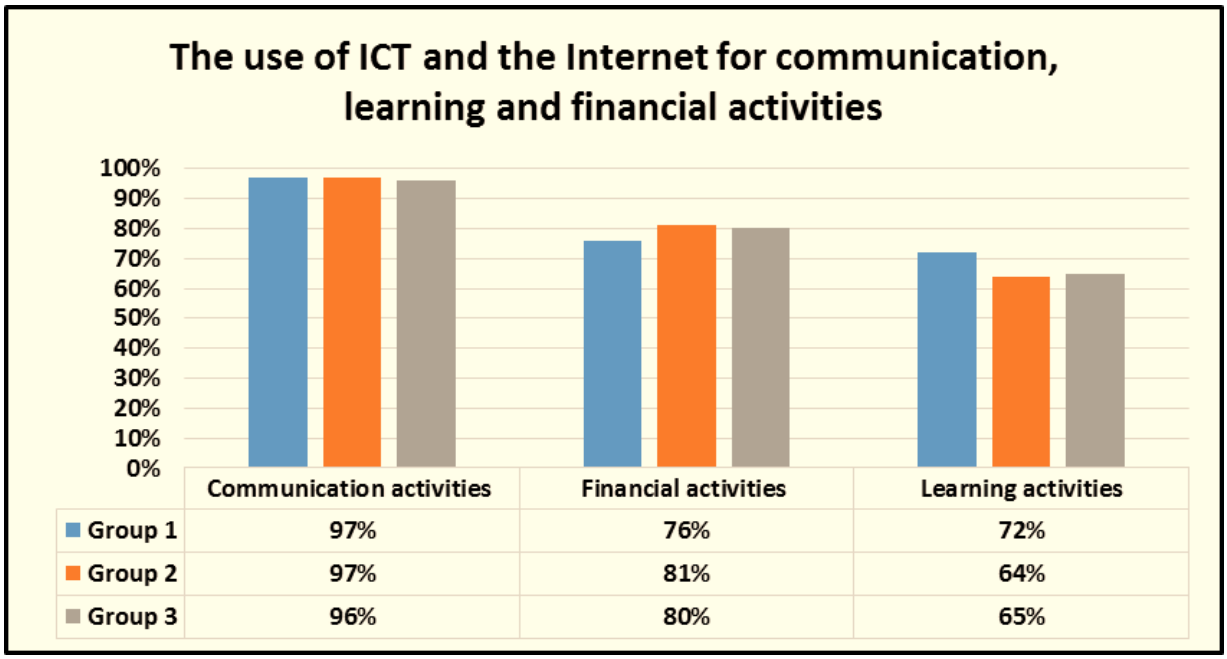


Figure 5. The use of ICT and the Internet for communication, learning and financial activities

5 Conclusions

Understanding the relationship between values and attitudes toward privacy in general and their online privacy concerns is important because it expands understanding of the way that values influence behaviours in the online context. This research attempts to further elucidate the nature of privacy concerns by examining privacy towards three privacy group. Of 436 respondents 74 were selected in group privacy unconcerned (16%), 196 in group privacy pragmatists (45%) and 166 in group privacy fundamentalist (39%). In addition, survey showed significant difference in activities connected to information searching, social networking, entertainment, buying/selling products or services online between privacy fundamentalist and privacy unconcerned group.

According to the Westin's survey (2003), the public could be classified on the basis of their different attitude toward privacy: the privacy unconcerned constitutes 20% of the public, privacy fundamentalists constitute about 25%, and about 55%, are privacy pragmatists. In our research we didn't use the same items as Westin in order to categorize respondent, yet we get the same structure – most of respondents were privacy pragmatic, but we have more respondents in privacy fundamentalist group, and less in privacy unconcerned group. Result presented in this paper can be interpreted in manner that difference in profile structure (more fundamentalist, less privacy unconcerned) can be explained with change in individuals' privacy awareness. Recent research suggest that Westin categorization can be expand on individual privacy behaviours and awareness of related privacy controls where Wisniewskia et al. (2017) propose six privacy management profiles: Privacy Minimalists (22% of participants), Self-Censors (11%), Time Savers/Consumers (17%), Privacy Balancers (36%), Selective Sharers (5%), and Privacy Minimalists (22%). Next step in our investigation is to explore the correlation of privacy concerns and usage of various e-services for private and business activities.

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Software Engineering

Paula Kokić, Boris Tomaš
Enhanced Drone Swarm Localization Using GPS and Trilateration Based on RF Propagation Model

Daniel Strmečki, Ivan Magdalenić
Towards an Ontological Model for Modelling and Automatic Code Generation of Complete Web Information Systems

Miroslav Stefanović, Đorđe Pržulj, Darko Stefanović, Miloš Vukmanović, Sonja Ristić
OCL Specification of Inter-Register Integrity Constraints in Land Administration Systems

Enhanced Drone Swarm Localization Using GPS and Trilateration Based on RF Propagation Model

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Abstract. *GPS system can provide information about location of any device that has embedded GPS receiver. However, when using swarm of drones, that information may not be enough for precise tasks. Using given GPS location error values, trilateration technique and radio frequency propagation model, an algorithm is developed, trying to minimize provided GPS location of an individual drone inside a swarm. Every drone in a swarm is observed as GPS referent node, receiving the data from RF visible nodes and forwarding data to other nodes via communication channels. Simulation results have shown that given algorithm can lower the location error of each node in a swarm, giving more precise location of a node.*

Keywords. IoT, drone, trilateration, localization.

1 Introduction

Drones combine achievements in electronics and aeronautics. Precise positioning is of the essence if drones should be used in a simple scenarios like delivery or complex scenarios like search and rescue missions. GPS and alternatives, do provide positioning solution; however, precision varies from several decimetres to several meters. Use of existing technologies like radio communication for distance measurements is widely used in space exploration, making its use interesting for researchers.

This research combines GPS and RF technologies in drone swarm to generate information valuable for each drone in the swarm.

2 State of the Art

2.1 Global Positioning System (GPS)

GPS is American space-based system which provides localization, navigation and time services in all weather conditions, anywhere on the Earth.

The system is divided into three work segments: space segment, control segment and user segment. Space segment consists of 24-31 satellites that circle around the Earth and transmit the signal. Control segment consists of global network that monitors GPS satellites, exchanges data and does analysis. User segment consists of GPS receivers in any form, whether it is a stand-alone receiver or receiver embedded in other device, like smartphones or watches ("Official U.S. Government information about the Global Positioning System (GPS) and related topics", 2016). GPS uses two types of error: by design and natural. First one is employed as different service level, where most precise service is reserved for military purpose. Second error type is caused by environmental conditions and EM fluctuations.

2.2 Radio Frequency (RF) propagation

Radio frequency is defined as any frequency of electromagnetic (EM) field that lies in range extending from 3 kHz and 300 GHz, including those used for communication or radar signals ("Dictionary – Radio Frequency", 2016). Wi-Fi signal, which is transmitted by drones, uses frequencies of 2.4 GHz and 5 GHz.

RF propagation is a term used to describe a way of spreading radio waves between two points in space and on the Earth. Because of physical properties of radio waves, signal propagation can be used to determine the distance between those two nodes. Node transmitting signal is called "signal sender" and node receiving signal is called "signal receiver". Every signal sent from a node is transmitted with a defined level of power ratio (measured in decibel-milliwats, dBm), which is weakened as it propagates through the EM field. The signal would never stop its propagation, but signal receivers can measure only defined level of power, that reaches down to -90 dBm ("Industry standard for minimum Wifi signal strength?", 2013). Therefore, if the signal at some location is higher than -90 dBm, "signal sender" is visible to the "signal receiver", which can receive signal and decode all the data that is send though that signal. (Hogg, 1993)

Distance between "signal sender" and "signal receiver" can be calculated using the value of power level which is measured by "signal receiver", through *free-space path loss* formula, as shown in (1)

$$r = 10^{\frac{\ln(10)\times(T-R-K-20\log(f))}{10n}} \quad (1)$$

where:

- R – receive power level, measured with appropriate equipment (dBm),
- T – transmit signal power level, equals 17 dBm (or individually set by each drone),
- K – path loss constant, equals -147.55,
- f – the WiFi frequency, equals 2450 MHz,
- n – the path loss exponent, equals 2, because drones are flying in a free space.
- r – distance between two nodes (result in meters, m) (Tomaš, 2013) (Dasarathan et al, 2007).

2.3 Unmanned Aerial Vehicle (UAV)

Unmanned aerial vehicle (or drone) represents an aircraft without its aircrew, i.e. its on-board pilot. The UAV can be monitored and navigated remotely. It is usually equipped with a lot of sensors, cameras, transmitters and receivers (e.g. a GPS receiver or RF antenna), depending of their purpose ("The UAV – Unmanned Aerial Vechile", 2016)

2.4 Crowdsourcing

Crowdsourcing represents a way of gathering needed services, ideas or data from undefined group of people (Frančula, 2015). Crowdsourcing systems are systems consisting of many units that exchange data independently. (Yuan et al, 2009)

In this research, crowdsourcing is employed on a drone system (swarm), where every drone is a GPS referent node for other drones. Drones are exchanging their data over WiFi network, including information about their GPS location.

3 Problem Definition

Every GPS receiver (including those embedded in drones) from GPS satellite receives lot of data. The most important data is information about location of a node. Location is given as two properties: latitude and longitude, both measured in geographic degrees, minutes and seconds. Aside location, GPS location error is received from GPS receiver in a receiving data stream. This error represents possible deviation from given location, consists of longitude error and latitude error and is measured in meters ("Official U.S. Government information about the Global Positioning System (GPS) and related topics", 2016).

GPS location error may vary up to 30 meters ("Navstar GPS User Equipment Introduction", 1996). That could be a problem if drones are located much closer to each other in a swarm so that navigating could be difficult. Lack of precision in location may cause drone to accidently collide with an object, harming either that object or itself, crashing to the ground and failing given mission.

The hypothesis of the research is:

Using RF propagation model GPS location error in crowdsourced systems can be minimized.

Aim of the research:

- simulate moving drone swarm in open space,
- using RF propagation model calculate distances between drones,
- develop an algorithm for minimizing GPS location error of drones in swarm,
- get more precise location of each drone in the swarm.

4 Solution

4.1 Drone model

Every drone in the swarm represents individual node as GPS referent beacon. Therefore, each node is simultaneously "signal sender" and "signal receiver". Each node can move in 2-dimensional space (3rd dimension is not considered in this research) and has same properties: ID, name, location (longitude and latitude) and location error (by longitude and by latitude). Each node is equipped with GPS receiver and RF antenna which allows to exchange data over WiFi network.

4.2 Algorithm

As a solution for the given problem, an algorithm for minimizing GPS location error is developed.

Input parameters of algorithm are:

- GPS location of a node (x,y) – x representing latitude and y representing longitude, measured in geographical degrees,
- GPS location error of a node (e_x, e_y) – e_x representing latitude error and e_y representing longitude error, both measured in meters,
- data (GPS location, GPS location error and received power level) of each node in the swarm that is visible by observed node.

As mentioned before, GPS location, along with its error, is received by GPS system using GPS receiver device on each node. For the purposes of simulation, GPS location and error will be generated, as described in Section 5.

Output parameter of an algorithm is specific region, i.e. surface of a geometric shape, representing the surface where observed node could be located.

Purpose of the algorithm is to return specific surface that would be smaller than the surface of an ellipse that is made using initial information about GPS location error from the input parameter.

Pseudocode of the algorithm is described through following steps:

1. Read WiFi signal power levels and determine visible nodes.
2. Calculate the surface of initial error ellipse. Initial error ellipse is created for data received from GPS component, i.e. location (x, y) and location error (e_x, e_y). Error ellipse is constructed around the location point of an observed node, on a distance that equals latitude location error (e_x) in a horizontal line and on a distance

that equals longitude location error (e_y) in a vertical line. Surface of the error ellipse represents the space where actual node is probably located. This surface would be compared to the surface calculated by the algorithm, to measure improvement of actual location precision. Figure 1. shows initial error ellipse.

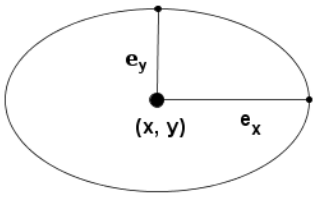


Figure 1. Initial location error elipse of observed node

3. Calculate elliptical crown around each visible node - for each visible node to the observed node, do the following:

3.a Read data of visible node: location (x, y), location error (e_x, e_y) and receive power level (R) – based on received values, determine the distance between observed node and visible node using the *free-space path loss* formula (mentioned in paragraph II).

3.b Calculate the *inner ellipse* based on calculated distance (from step 3.a) and location error of visible node. Two radiuses are determined. First radius is horizontal and is calculated by subtracting visible node's latitude location error value (e_x) from calculated distance value (r), as follows (2):

$$r_{x1} = r - e_x \qquad (2)$$

Second radius is vertical, and calculated by subtracting visible node's longitude error value (e_y) from calculated distance value (r), as follows (3):

$$r_{y1} = r - e_y \qquad (3)$$

These two radiuses are used to construct *inner ellipse* around the visible node.

3.c Calculate the *outer ellipse* based on calculated distance (from step 3.a) and location error of a visible node – following the same logic as in step 3.b. Two radiuses are determined: first radius is horizontal and is calculated by adding visible node's latitude location error value (e_x) to the calculated distance value (r), as follows (4):

$$r_{x2} = r + e_x \qquad (4)$$

Second radius is vertical, and calculated by adding visible node's longitude error value (e_y) to the calculated distance value (r), as follows (5):

$$r_{y2} = r + e_y \qquad (5)$$

These two radiuses are used to construct *outer ellipse* around the visible node.

3.d Determine elliptical crown based on an *inner ellipse* (from step 3.b) and *outer ellipse* (from step 3.d). Surfaces of those two ellipses can be recognized as two sets of points.

Set of points A and B are declared as: A is declared as surface of *outer ellipse* and B as surface of *inner ellipse*, standard difference (or exclusion) operation can be performed on those two sets. Excluding set B from set A will result in a set of point that represent surface of elliptical crown around the visible node. Figure 2. shows way of calculating elliptical crown of a visible node, using following labels:

- e_x – latitude location error of visible node
- e_y – longitude location error of visible node
- D_1 (x_1,y_1) – location of observed node D_1 (represented by blue colour)
- D_2 (x_2,y_2) – location of visible node D_2 (represented by green colour)
- r – calculated distance between two nodes

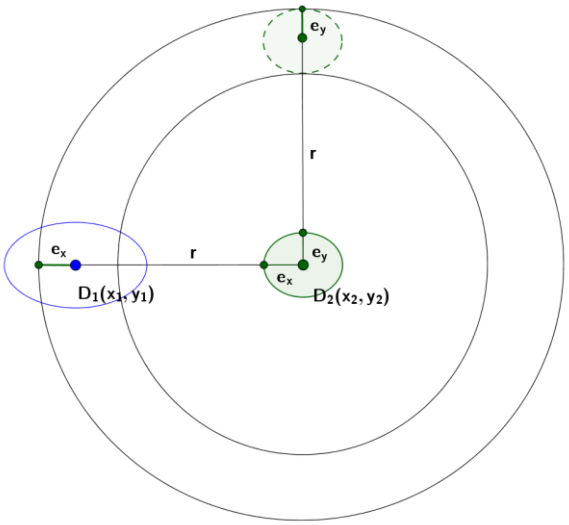


Figure 2. Eliptical crown of visible node

4. Calculate the correction surface. Correction surface is final, output value of algorithm. It is calculated through the operation of intersection between initial location error surface of observed node (from step 1) and surface of elliptical crown of each visible node (from step 3.). Formula can be presented as (6)

$$A' = A \cap C_1 \cap C_2 \cap \ldots \cap C_n, \qquad (6)$$

where:

- A' – new set, representing location correction surface (result of algorithm)
- A – initial set, representing initial surface of possible observed node location
- C_1, C_2, ... C_n – set of elliptical crowns surfaces', calculated in step 3, from the data of all visible nodes, where n represents number of visible nodes.

Figure 3. shows scenario with three nodes, where drone D_1 is the observed drone, and D_2 and D_3 are its visible drones, i.e. its referent beacons which affect correction

of its location. Final minimized location surface of observed drone is blue shaded.

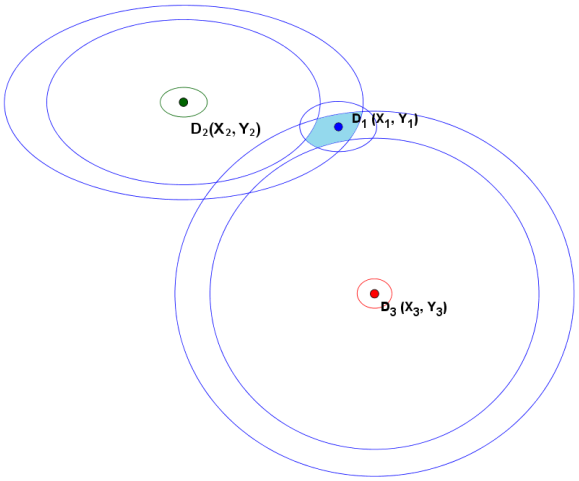


Figure 3. Blue shaded surface of observed node minimized location

4.3 Application

To test algorithm, a simple application is developed, using C# and Microsoft .NET technology. Application is used to simulate moving drones, generating location and location errors for each drone and then using, previously defined algorithm to calculate correction of drone location.

Application input parameters is data about each drone (name/ID, initial location, velocity and direction of moving). GPS location error simulation is implemented using invisible map in the background: window surface is divided by several unequal regions, and every region has different value of location error, thus making GPS error not uniformly distributed in the field. When drone enters specific region, it receives that region's location error. Receive power level (R) for each drone is simulated using the same *free-space path loss* formula, including the actual value of distance between two nodes.

For each drone transmit power is set to 17 dBm, in actual scenarios this value might vary but it is known.
Application allows user to save results of simulation in .csv format. Each loop of algorithm is recorded and results are saved.

Results include: drone ID, drone name, current location (x,y), surface of GPS location error, surface of error correction, and percent of improvement.

5 Simulation

In simulations, metric used id percentage of improvement, it is a value that describes how much (in percent) new error correction surface is smaller than initial GPS correction error surface. It is calculated using (7)

$$p = \left(1 - \frac{S_{current}}{S_{initial}}\right) \times 100\,, \qquad (7)$$

where:

- p – percent of improvement, result in %,
- $S_{current}$ – current error correction surface
- $S_{initial}$ – initial GPS location error surface

To monitoring simulation results, the same properties will be used throughout all scenario definitions, which include:

- Total – total number of information records (algorithm calls)
- Minimum – the minimum value of correction improvement percent
- Maximum – the maximum value of correction improvement percent
- Zero percent – number of improvements with value of 0%
  - Twenty percent – number of improvements with value more than 20%
  - Fifty percent – number of improvements with value more than 50%
  - Average – average improvement percent, result of sum of all improvements divided by total number of records

For the rows “Zero percent”, “Twenty percent” and “Fifty percent”, another column will be added: “Percent in total” – this describes the percent of that value in number of total records.

5.1 Scenario definition

Three scenarios are defined.

In the first scenario, number of nodes is two, which is minimal possible for algorithm to work. In the second scenario, number of nodes is increased to four (the setup for first two nodes remains the same, and second two nodes are added). In third scenario, number of nodes is increased to eight, i.e. four new nodes are added.

Every simulation lasts 30 seconds.

5.2 Results

After simulations results are shown on Table 1 for the first scenario simulation with two nodes.

Table 1. Result analysis of first scenario

Property	Result	Percent (%)
Total	1848	-
Minimum	0%	-
Maximum	63,6475%	-
Zero percent	675	36,53%
Twenty percent	470	25,43%
Fifty percent	77	4,17%
Average	11,55%	-

Table 2. shows results analysis for the second scenario simulation with four nodes.

Table 2. Result analysis of second scenario

Property	Result	Percent (%)
Total	3860	-
Minimum	0%	-
Maximum	78,7964%	-
Zero percent	583	15,10%
Twenty percent	1500	38,86%
Fifty percent	501	12,98%
Average	18,87%	-

Table 3. shows results analysis for the third scenario simulation with eight nodes.

Table 3. Result analysis of third scenario

Property	Result	Percent (%)
Total	2552	-
Minimum	0%	-
Maximum	99,1818%	-
Zero percent	167	6,54%
Twenty percent	1500	61,91%
Fifty percent	501	26,68%
Average	32,34%	-

As expected, from the given tables can be read that maximum value of improvement is increasing with the number of nodes. Furthermore, values greater than twenty and fifty percent are also increasing with the number of nodes. Average improvement percent is also increased from 11,55% in the first scenario to 32,34% in the third scenario.

Results show that using algorithm single pass improves node location by at least 11,55% in the worst-case scenario (first scenario with two nodes). Such results have confirmed hypothesis given in problem definition.

6 Conclusion

This research pointed out a problem regarding precise localization of nodes that use GPS system. The location error given by the GPS system could be very high, therefore not offering enough precise information about the location of the node. This paper observed a possible way of minimizing GPS location error in swarms of UAV nodes. According to the aim of the research, an algorithm is developed that uses trilateration theory and RF propagation model. After implementation of the algorithm, a simulation of drones moving in 2-dimensional space with same parameters but different number of nodes is run. Results of simulation have shown that algorithm gives better results when there are more drones in a swarm. Finally, it can be concluded that hypothesis given in problem definition has been confirmed, because the average improvement of node location surface in minimum swarm setup is 11,55%.

According to the simulation results, it can be concluded that algorithm satisfies given parameters and goals. However, there are areas that should be improved and researched further:

- Multiple algorithm passes, where the input would be output surfaces from this algorithm. This may or may not generate even more precise crowns and intersections and therefore more precise location of given nodes.
- 3rd dimension should be used; current research and implementation only uses 2D Cartesian coordinate system. Also, geographic coordinate system should be used instead of cartesian coordinate system.
- Ellipse was used as location estimation representation; however, actual location is not that uniformly distributed. Concept like fuzzy logic, fuzzy ellipse should be used with non-uniform location probability distribution.
- Particle filtering theory could be used, giving the algorithm different aspect of processing data from a probabilistic not geometry approach.
- Crowdsource using another source of data like sound, light, fingerprinting, landmarks, etc.
- The same principle can be applied to any group that require precise localization, for example: people or vehicle.

Acknowledgements

This work has been supported by the Croatian Science Foundation under the project IP-2014-09-3877.

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Towards an Ontological Model for Modelling and Automatic Code Generation of Complete Web Information Systems

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Abstract*. The main goal of the research, which this early findings are a part of, is to enable systems development on a higher abstraction level, by applying code generation from ontological models. In this paper we present a first step towards defining an ontological model for modelling and generating complete Web information systems. The proposed model consists of several related ontologies and includes both generic and specific system requirements and functionalities. The paper includes an experiment (proof of concept), which shows that code generation from ontological models is feasible in the Web domain on a common problem case (table and input forms). Throughout the paper we present used techniques, models, technologies and frameworks.*

Keywords. Ontology, model, generator, model-driven, development, programming, automatic, generative.

1 Introduction

Code generation has been an inspiring topic for researches since the early beginnings of software engineering discipline. Due to increasing software complexity and cycles of repeating coding on different projects, we are trying to increase software reuse by raising its abstraction level. By encapsulating knowledge about lower level operations, developers can think in terms of higher level concepts and thus become more efficient (Visser, 2008). Although this topic has been researched for decades, there are no universal solutions for automatic code generation. Some of the primary reasons for this are complicated business processes, high software complexity, number of parties involved in planning and development, abilities of the creative people who are performing development activities, desire for high customisation by the client, etc. (Musen, 2000; van Ruijven, 2013)

Although we have learned from experience that we cannot automate everything, we are still trying to automate as much as we can. For example, *Software Product Lines* (SPLs) is a discipline focused on developing software families (features, variants) using specifications and code generation.

This paper focuses on code generation based on ontological models. It is a relatively new approach used in *Generative Programming* (GP) and *Model-Driven Development* (MDD) disciplines that, we believe, hasn't received enough research attention. One could argue that UML would be better suited for modelling Web information systems, or that relational databases could also be used for storing system specifications. Our literature review showed that ontological model brings several benefits, including: providing a formal language that helps bridging the gap between business and IT, enables requirements specification in an evolutionary approach, is expressive enough for specifying system features, is well suited for the definition and description of Web components, etc. (Strmečki, Magdalenić, & Kermek, 2016).

The paper presents our early findings on code generation from ontologies and a first step towards definition, standardization and reuse of an ontological model for modelling and generating complete Web information systems.

2 Background

GP can be defined as a mapping between problem space (specification) and solution space (executable code). GP applies a code generator that uses a high level specification to yield the corresponding implementation (Magdalenić, Radošević, & Orehovački, 2013). It relies on metaprogramming techniques and it is commonly applied in other disciplines like SPLs and MDD (Strmečki et al., 2016).

SPLs focus on systematically producing a set of software products consisting of a common architecture and a set of reusable assets (Asikainen, Männistö, & Soininen, 2007). Systematic, planned and strategic reuse of software assets is used to produce multiple products that satisfy a particular market segment (Duran-Limon, Garcia-Rios, Castillo-Barrera, & Capilla, 2015). Its main goal is to avoid developing software artefacts from scratch, by reconfiguring and

reusing existing products in different projects. Although each product has some specific requirements, SPLs use variability mechanisms to develop the product timely, with low cost and high quality (Nguyen, Colman, & Han, 2015).

MDD captures the essential features of a system through models and applies code generators to automatically produce the executable code from various modelled entities (Lilis, Savidis, & Valsamakis, 2014; Magdalenić et al., 2013). In MDD, models are considered to be reusable artefacts and the final model needs to be concrete enough for executable code to be generated from it (Zimmer & Rauschmayer, 2004). The archetypal MDD is based on UML, but several studies (Bartolo Espiritu, Sanchez Lopez, & Calva Rosales, 2014; Roser & Bauer, 2006; Solis, Pacheco, Najera, & Estrada, 2013; Soylu & De Causmaecker, 2009) have shown that ontological models can be efficiently used instead.

Ontologies were first introduced to software engineering trough fields of *Artificial Intelligence* and *Semantic Web*. They were soon recognized as a convenient way to describe and organize domain and software engineering knowledge. Nowadays, ontologies can be applied to aid software development in every phase of its lifecycle (Wiebe & Chan, 2012). This includes using ontologies for description of documents, formal representation of requirements, semantic description of services and components, domain modelling, executable code and test cases generation (Happel & Seedorf, 2006).

2 Related work

Since GP techniques are used in both SPLs and MDD, we will present some of the related work in those two areas. Due to paper's size limit, in this section we will shortly present only a few papers for which we think have the greatest impact on the topic.

In their approach named *Ontology Driven Architecture for Software Engineering* (ODASE), Bossche et al. presented the results from applying ontology-driven architecture on a 250 person per month e-insurance project. The focus of their research was on formalizing the requirements in order to achieve a clear contract between business and IT. They stated that ontology provides a mechanism for business to formalize their specifications and for IT to rely on the formal semantics. The knowledge transfer from ontology to executable code was done by automatic code generation based on an internal platform named Hedwig (Bossche, Ross, MacLarty, Van Nuffelen, & Pelov, 2007). ODASE showed that application of ontologies in modelling and generative software development brings several benefits, but its remains undisclosed what ontologies were used, how they were interconnected and mapped to the code generators.

Semantic Web Builder (SWB) is an agile development platform for the Web domain, which applies ontologies in requirements modelling and automatic generation of system's infrastructure. This approach generates object-oriented code from a predefined ontology that is embedded in the platform. It is a semi-automatic development platform because the resultant platform needs to be extended in order to build complex Web systems. This means that specific functionalities, like business logic and user interface, need to be developed separately and integrated with the generated code. SWB approach has been successfully applied in the development of several government Web application in Mexico (Solis et al., 2013).

Web Information System auto-construction Environment (WISE) is a prototype platform for developing Web information systems. This approach uses two embedded ontologies (domain and behaviour ontology) from which it generates executable Java code. It also provides a graphical tool called *WISE Builder* to help its users in constructing the ontologies (Tang et al., 2006). This feature can be really helpful for non-professional users, but it also makes it hard to introduce specific functionalities. Since ontologies, graphic tool and code generators are tightly coupled, we would need to extend the platform to add custom business logic or new user interface elements.

Toti and Rinelli presented a system for semi-automatic generation of an API framework on top of a semantic repository. Their system was implemented as a desktop application written in C# that provides a number of user-supervised steps for the generation process. It produces an application logic layer on top of a RDF schema which enables CRUD (create, read, update, delete) operations for each class in the RDF schema. System generates a business entity class, a DAO class, a facade class and a SOAP-based Web service interface on top of the facade for every class. In their approach, specific functionalities are not modelled trough ontologies and need to be developed separately (Toti & Rinelli, 2015).

3 Proposal

As we have shown in the short review of related work, code generation from ontological models is quite possible, although the details of its implementation are not always disclosed. Code generation from ontological models is actually a relatively popular topic in GP, SPLs and MDD disciplines nowadays. In this paper we present a proposal for an ontological model used for modelling and automatic code generation of complete Web information systems. We believe that it is possible to model complete systems through ontologies, which includes both generic and specific functionalities (like business logic and user interface).

The conceptual model on figure 1 displays multiple ontologies (and their relations) used in the proposed ontological model of Web information systems. Our proposed ontological model consists of several related ontologies (including requirements, features,

constraints, repository, forms, components and user interface) which reduces the complexity of the model and facilitates future upgrades and maintenance. In addition to serving as a specification for generating executable code, the instances of the ontological model can be viewed as a formal representation of system's features, constraints and requirements. Connections between ontological elements ensure that requirements follow the software product throughout its entire life cycle.

In a classic Web information systems development we would probably use ERA model for data representation and UML for representation of structure and behaviour. By applying the proposed ontological model instead, we can ensure preservation and possible reuse of its elements on future projects. We can achieve high reusability of the model by mapping its elements to code generators. Imagine that one already has some database table, user interface element or Web component modelled trough the ontological model and mapped to code generators. Reusing them on a new project would be as simple as specifying a pointer to the correct ontological element. The ontological element already contains all the required specification and the code generator contains the logic for producing its implementation. Of course, if one needs to develop a new component, there are some extra steps to do, like adding it to the ontological model and updating the code generators. The process of specifying and developing Web forms and their components in shown in figure 2. Even though applying an ontological model and automatic code generation creates an initial overhead in development, a high level of ontological elements reusability can bring improvements and savings in the long term. This is especially true when developing families of systems or custom made software for SMEs, with significant number of reusable artefacts.

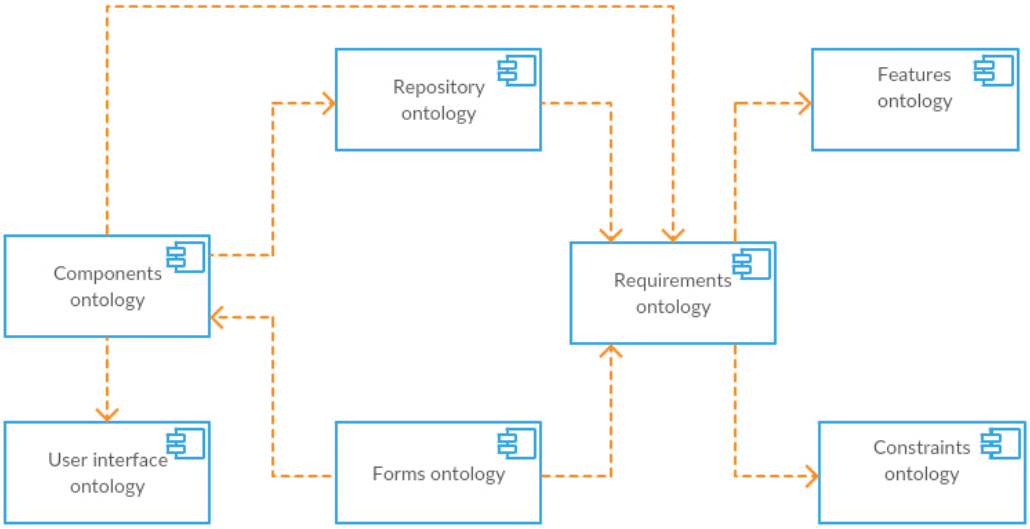


Figure 1. Ontological model – UML component diagram

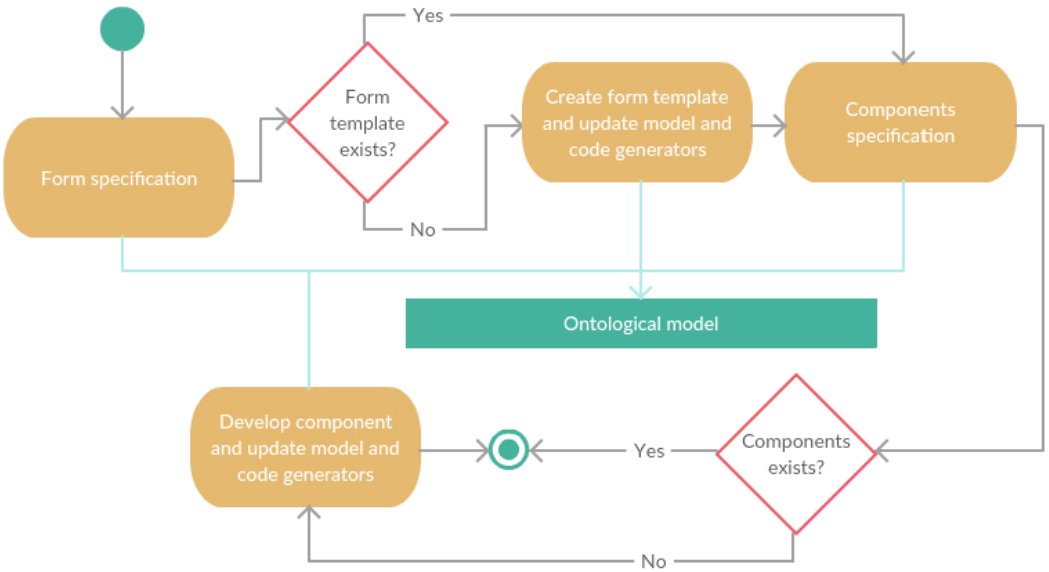


Figure 2. Process of form (and components) specification and development – UML activity diagram

4 Experiment

Our research on code generation from ontological models is still in its early stages. In this paper we will present our early findings in the form of a *Proof of Concept (*POC) application. Our POC was implemented as a Web application written in Java. It supports CRUD operations on relational database data.

4.1 Ontological model

The ontological model used in the POC shown on figure 4 is only a partial implementation of the proposed model. The focus of the POC was to demonstrate that simple, but complete Web applications can be generated from a well-defined ontological model.

The partial implementation of the proposed ontological model consist of the following ontologies: repository, forms, components and interface. The repository ontology describes the relational database domain and contains table and column definitions. The forms ontology describes the Web forms to be generated and organizes them into menu groups. The components ontology is the most complicated one, as it describes components a form can contain, as well as supported actions for clickable components. The interface ontology connects a specific component to its rendering rules (for example, the position on the page).

Ontologies were created following *Ontology 101* (Noy & McGuinness, 2001) methodology and using *Protégé 4.3.0* with *FaCT++* reasoner. The *101* methodology was selected due to its maturity, iterative nature and a large number of practical guidelines/rules for making decisions when building ontologies. *Protégé* was selected as a tool for creating ontologies because it is an open-source platform that has been proven efficient in many similar studies.

4.2 Code generators

We implemented the POC in *Java* because it a mature, high level object-oriented programming language, with good support for code templating and working with ontologies. Besides that, *Java* is one of the most popular programming languages nowadays and its code is platform independent.

The first problem one encounters when trying to generate code from an ontological model is how to access the model data from your code generators. Fortunately, there is an open source *Semantic Web* framework for *Java* we can use. It's called *Apache Jena* and among other things, it can be used to read ontological models from files or URLs and query them using *SPARQL*. *Jena* comes with a schema generator (schemagen.bat) that is used to generate a *Java* class file with all the ontological classes and properties defined within the model. Figure 5 shows an example of a *SPARQL* query with *Jena*, used to fetch all the button components for a specific Web form.

Now that we know how to read the model and its instances, we need to map the model to executable code using code generators. Code generators can be created with *Java* and *Jena* without the need for any additional frameworks and libraries. We have however decided to use an additional framework in our POC to help us with code templating. *Apache Velocity* is a templating engine for *Java* that enables developers to use a simple templating language to reference objects defined in *Java* code. Figure 6 displays an example of how we can use *Velocity* to generate getters and setters for each column in our entity *Java* class.

We used *MySQL 5.7* database and *Hibernate* object-relational mapping framework for accessing and storing data in the database. Since *Hibernate* enables high-level object handling of relational tables and columns, it makes development of code generators much easier than it would be by writing SQL statements.

Finally, the last framework we used to accelerate the development of Web forms for our POC is *Vaadin 8*. We used *Vaadin* because it provides us with a large set of free, out-of-the-box Web components that we would need to develop ourselves otherwise. It uses a component-based user interface approach for rapid building of *Java*-based Web applications, which is exactly what we need to facilitate the development of our code generators.

Having put together all the mentioned technologies and frameworks, we have successfully mapped the ontological model to executable code and generated fully functional Web forms. An example is shown in figure 3, it is a form that supports CRUD operations for a database table representing a group of articles.

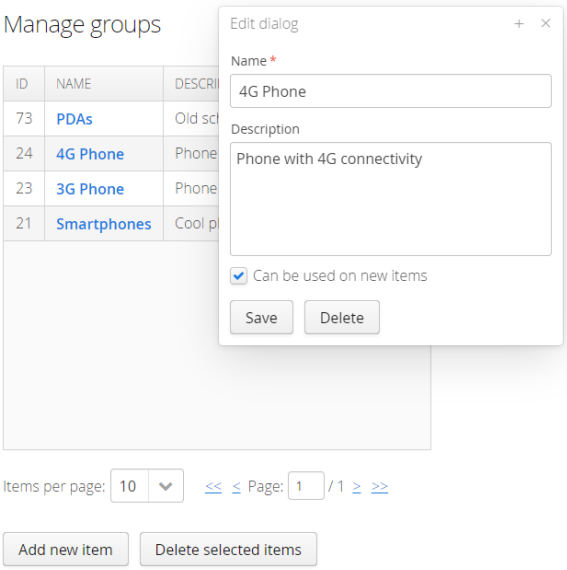


Figure 3. An example generated Vaadin Web form

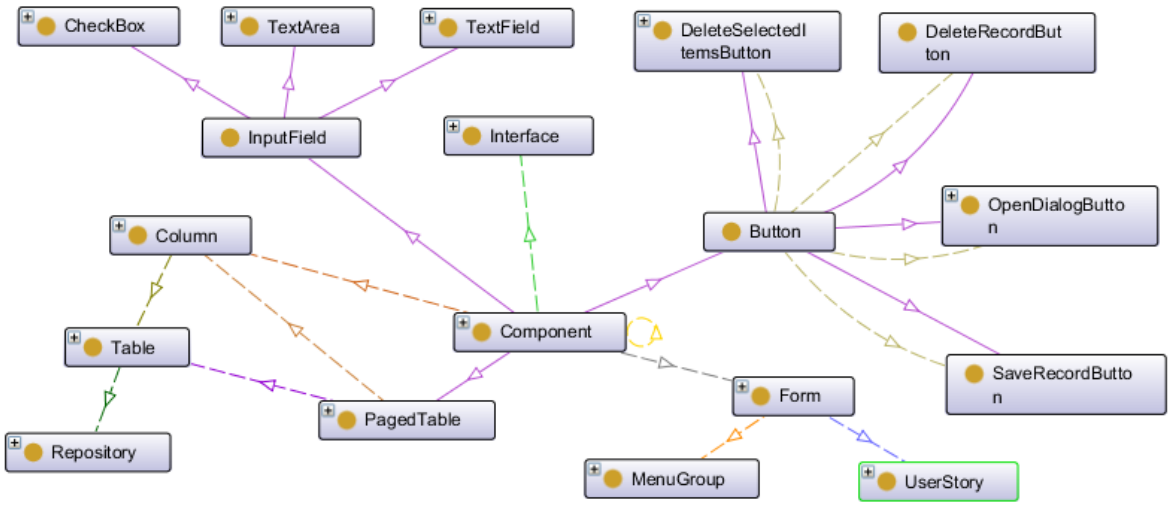


Figure 4. Ontological model used in POC – *Protégé OntoGraf*

```
StringBuilder buttonsStringBuilder = OntologyUtil.getQueryStringBuilder();
buttonsStringBuilder.append("SELECT ?resource ?type WHERE {  ");
buttonsStringBuilder.append(    "?resource rdf:type ?type . ");
buttonsStringBuilder.append(    "?resource base:componentForForm <" + formResource.getURI() + "> . ");
buttonsStringBuilder.append(    "?type rdfs:subClassOf* <" + ComponentsOntology.BUTTON + ">");
buttonsStringBuilder.append("}");
try (QueryExecution buttonsQueryExecution = QueryExecutionFactory.create(buttonsStringBuilder.toString(), model)) {
    ResultSet buttonsResultSet = buttonsQueryExecution.execSelect();
    while (buttonsResultSet.hasNext()) {
        QuerySolution buttonsQuerySolution = buttonsResultSet.next();
        Resource componentResource = buttonsQuerySolution.getResource("resource");
        Resource typeResource = buttonsQuerySolution.getResource("type");
        Button button = new Button(componentResource, typeResource);
        components.add(button);
    }
}
```

Figure 5. Querying an ontological model using SPARQL – *Apache Jena*

```
#foreach( $column in $columns )
    #if ($column.columnID != "id")
public $column.columnType get$StringUtils.capitalize($column.columnID) () {
    return $column.columnID;
}

public void set$StringUtils.capitalize($column.columnID) ($column.columnType value) {
    $column.columnID = value;
}
    #end
#end
```

Figure 6. Templating a database entity class – *Apache Velocity*

5 Conclusion

In this paper, we have presented the early findings in our research on code generation from ontological models. We presented a concept for an ontological model that can be used to model complete Web information systems, which includes both generic and specific functionalities. We reduced the complexity of the model by dividing it into several related ontologies (including requirements, features, constraints, repository, forms, components and user interface). The main goal of using an ontological model and mapping it to code generators is to achieve high reusability of modelled entities (software artefacts). We argue that in development of SPLs or custom made software for SMEs, an ontology-based generative programming approach can bring improvements and savings in the long term.

We presented an experiment, in a form of a POC, which showed that it is possible to model and generate Web forms using the proposed ontology-based generative approach. Thus, we argue that with more modelling and development effort, it is also possible to apply the same approach for developing complete Web information systems. The POC we presented relies on technologies and frameworks like *Java*, *Apache Jena*, *Apache Velocity*, *MySQL*, *Hibernate* and *Vaadin* in order to facilitate the ontological model to executable code mapping.

By applying code generation from ontological models, we are trying to enable development operations on a higher abstraction level. Ontological models helps us to move the reasoning and business logic away from hardcoded applications, which enables more efficient development and higher reusability. However, a high level of ontological knowledge reusability is required for the initial investments in ontologies and code generators to pay off. For that very reason, this paper represents a first step towards specification and standardization of an ontological model for Web information systems generative development.

6 Future work

We believe there is much more research and development to be done in this field. In our future work we will implement the complete model presented in this paper. In order to demonstrate the efficiency of this approach, we plan to carry out several case studies. Based on experience gained through all of the planned work with code generation from ontological models, we plan to define a set of guidelines for ontology-based generative development. We also plan to introduce a reasoner for our ontological model, which would help in the early detection of misspecification in the model.

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OCL Specification of Inter-Register Integrity Constraints in Land Administration Systems

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Abstract. *A great number of public services rely on data stored in land administration systems (LASs) and large investments are made to collect, record and analyze these data. Therefore, the data quality in LASs is of utmost importance. Between several data quality elements we focus on data consistency and correctness. Data consistency requirements are described by means of integrity constraints (IC). Selecting a suitable IC specification language (ICSL) to specify ICs is not straightforward. In the paper Object Constraint Language (OCL) is used as ICSL. LAS data informally can be divided in two subsets: legal data and spatial data. For each of them data consistency and correctness issues would be addressed. Besides, the so-called inter-register inconsistencies may arise between the legal and spatial data subsets. In the paper, we identify them and specify corresponding ICs as an integral part of a domain model of LAS. That way, the inter-register inconsistencies may be detected. They could be consequences of incorrectnesses in legal data or in spatial data. Therefore, presented approach enables detection of possible data correctness issues in LAS data subsets.*

Keywords. land administration systems, data consistency, data correctness, domain model, object constraint language

1 Introduction

Land represents a limited resource, and good stewardship of the land is essential. Land administration system (LAS) is a formal system to identify and locate real property and to register its ownership, value and use. LASs are frequently directed at protecting the interests of landowners, but they are also instruments of national land policy and mechanisms to support stability in society and economic development. They describe real property not only with thematic attributes (legal status, value, tax data) but also with physical, spatial or topographic ones (location, dimensions, area). LAS data informally can be divided in two subsets: data about the ownership and other rights on real properties (legal data) and data about position and shape of real properties (spatial data). To support recording of such a diversity of data a LAS contains two registers: land register and cadastre. These registers complement each other.

Land register is an official record of rights on land or of deeds concerning changes in the legal situation of defined units of land. It gives an answer to the questions who owns certain property and what legal document is that ownership based on (Henssen & Williamson, 1990).

Cadastre represents a public inventory of data regarding properties within a certain country or district. Data in cadastre is based on a survey of property's boundaries. It represents register of spatial data used for describing properties and answers questions about location of certain property (Henssen & Williamson, 1990). Data that may appear in a cadastre include: geometric data (coordinates, maps), property addresses, land use, real property information, the nature and duration of the tenure, details about the construction of buildings and apartments, population, and land taxation values.

There are differences between the LASs in different countries. Land registration system may be based on deeds or titles. LAS may be realized as dual system with separate land book (title holders on real property) and land cadastre (real property) or as unified system with one register (in some countries it is called Real estate cadastre). In both cases, problem of integration of land register and cadastral data remains an important issue due to the fact that these two subsystems are poorly coupled. Also, both subsystems have their own business rules and transactions.

Different countries interpret the term "cadastre" in different ways and this can lead to some confusion. In this paper, we use previously given definitions of land register and cadastre.

The information obtained from a LAS rest upon data that represent parts of the real world. The reliability of the information and the reliability of decisions people make based on that information depends on the quality of these data. There are several

elements of data quality and in the paper, we focus on logical data consistency and data correctness.

Integrity constraints (ICs) are formal statements, definitions or qualifications for describing data consistency requirements. Some of ICs can be inherently or implicitly expressed in a data model. Other ICs are usually hardcoded in the application software for the assurance of logical consistency. This separation from the data model raises problems of ICs management, adaptability and reuse in different applications. A formal specification of such ICs would overcome these problems. The approaches for modeling and enforcing integrity constraints are diverse as well as integrity constraint specification languages (ICSL). In the paper Object Constraint Language (OCL) is used as ICSL. ISO Technical Specification (ISO/TS) 19103:2015 (ISO 19103: Geographic information — Conceptual schema language, 2015) defines Unified Modeling Language (UML) in combination with OCL as conceptual schema language for specification of geographic information. Over the years UML established a position as standard for model-centric software design and development (Gogolla, Martin, & Richters,, 2007). OCL provides a framework to define constraints on UML class diagrams. As a specification language OCL is independent from its actual implementation and is universal concerning the time when constraints are enforced. Nonetheless, the tools exist that generate code in different languages (SQL, C#, Java) from OCL specifications. That enables the generation of integrity checking mechanisms automatically and eases the process of ICs implementation in a great extent.

Data are inconsistent if they violate implemented integrity constraints. Data correctness is the question of data correspondence with actual situation (legal e.g.) in reality. Detailed description of data consistency and data correctness in the context of LASs is given in Section 3. In a LAS data are recorded in two registers. Even if the registers are unified there are two parts of the register aimed to record legal and spatial data, respectively. For each of them data consistency and data correctness issues would be addressed. In addition, inconsistencies may arise between the legal data and spatial data. Such kind of inconsistencies and corresponding ICs in the paper are called inter-register inconsistencies and inter-register ICs. If integrity constraints are implemented within a data model, recorded data must not violate them. In reality, it is possible to record incomplete or incorrect data. The enforcement time of OCL constraints could be adjusted to the requirements of real world situation. Therefore, they can be enforced immediately, deferred or conditionally disabled or deferred. In the paper, we identify possible inter-register inconsistencies between legal and spatial data. OCL is used to specify inter-register ICs as an integral part of a domain model of LAS. Presented OCL ICs are specified in the context of the domain model that is result of previous research project partially reported in (Pržulj et al., 2017). The approach to modeling and enforcement of inter-register ICs presented in this paper enables detection of possible data correctness issues in two LAS data subsets. Their automated detection is very important since they may be consequences of incorrectnesses in legal data, in spatial data or in both of them. Elimination of those incorrectnesses is the first step in data quality improvement in the context of land administration.

Apart from Introduction and Conclusion, this paper is organized as follows. In Section 2 a short review of related work on subject of land administration is given. Issues of data consistency and data correctness in LASs and most common related problems are discussed in Section 3. Methodology used in this research is presented in Section 4. The extension of land administration domain model that includes OCL specification of ICs is given and discussed in Section 5.

2 Related Work

In 1998, FIG (Fédération Internationale des Géomètres) has published Cadastre 2014 after extensive research. It is based on Object–Right–Subject approach proposed in (Henssen & Williamson, 1990). Results of research are systematized in statements about cadastre for year 2014. Some of them recommend that LAS should be able to present data for complete legal situation, including public rights and restrictions on real property. There is a suggestion to abolish separation between maps and registers (Kaufmann & Steudler, 1998).

For purpose of developing information systems for land administration, International Organization for Standardization (ISO) published ISO 19152:2012 Geographic information – Land Administration Domain Model (LADM). As stated in (ISO 19152: Geographic information — Land Administration Domain Model (LADM), 2012) this model is not a complete solution for any given country, instead it should be used as foundation, permitting extensions to facilitate country's special needs.

Over the years papers proposing LADM country profiles have been published for different countries, such as (Bydlosz, 2011) for Poland, and (Govedarica et al., 2011) for Republic of Srpska. In (Vučić, Markovinović, & Mičević, 2013) data are presented showing that in Croatia only 5% of data are harmonized between two land administration registers thus clearly stating a need for creation of LADM for Croatia.

In 2001 the European Commission initiated the Infrastructure for Spatial Information in Europe (INSPIRE) that became effective in 2007 (D2.8.I.6 INSPIRE data specification on cadastral parcels – Guidelines, 2010). One of the main INSPIRE principles is the provision of access to relevant, harmonized and quality geographic information. Open

Geospatial Consortium (OGC) has paid attention to data quality by establishing a new Data Quality Working Group (DQWG) in 2007. Use of model-driven architecture in creating LAS in accordance with (ISO 19152: Geographic information — Land Administration Domain Model (LADM), 2012) and (D2.8.I.6 INSPIRE data specification on cadastral parcels – Guidelines, 2010) for Greece is discussed in (Psomadaki, Dimopoulou, & van Oosterom, 2016).

The ISO defines six data quality elements (ISO 19157: Geographic information — Data Quality, 2013). In this paper we focus on logical consistency and integrity constraint specification.

Approaches to categorizing ICs for LASs combine general database constraint types and specific constraint types for spatial and temporal databases.

(Elmasri & Navathe, 2011) divide constraints on databases into three main categories: i) constraints that are inherent in the data model – implicit constraints; ii) constraints that can be expressed in database schemas of the data model by means of data definition language (DDL) – explicit constraints; and iii) constraints that must be expressed end enforced procedurally by the application program – semantic constraints.

Approaches to classify spatial ICs can be found in (Cockcroft, A taxonomy of spatial data integrity constraints, 1997), (Cockcroft, The design and implementation of a repository for the management of spatial data integrity constraints, 2004), (Servigne et al., 2000) and (Borges, Laender, & Clodoveu Jr., 1999). Formal classification of integrity constraints in spatiotemporal database applications is given in (Salehi et al., 2011) and (Rodríguez, 2005).

A formal description of ICs is very important, especially for ICs which cannot be inherently or implicitly expressed in the data model. It enables the transfer of the integrity rules between different systems and system components. Approaches aiming at ICs' formalization can be based on different specification languages. An extensive overview of existing approaches to the formalization of ICs is given by Werder in (Werder, 2009). A general comparison of specification
languages, which also includes natural languages, can be found in (Salehi et al., 2007).

Here we mention just some of them. An integration of ICs in a data modelling notation called OMT-G is presented in (Borges, Laender, & Clodoveu Jr., 1999). The paper (Bravo & Rodríguez, 2009) introduces a formalization of a set of spatial semantic integrity constraints on an extended-relational database model. The formalization extends traditional notions of functional and inclusion dependencies by adding interaction with spatial attributes. UML and OCL with corresponding spatial extensions as ICSL is used in several cases. In (Werder, 2009) GeoOCL is analyzed, and in (Bejaoui et al., 2010) SpatialOCL is proposed as ICSL.

Although consistency is a desirable property of LAS data, enforcing integrity constraints might not be always feasible. In the paper (Brisaboa et al., 2015) an importance of data-cleaning tools to detect and remove, if possible, inconsistencies in large datasets is emphasized and some solutions are presented.

Problem of maintaining consistency between spatial and non-spatial data, is pointed out in (Cockcroft, A taxonomy of spatial data integrity constraints, 1997). The same problem in the context of land register and cadastre data is addressed in (Pržulj et al., 2017) were terms geoaggregate and polygon are introduced, representing parcel and part of parcel on cadastral maps respectively. These terms are discussed in more detail in Section 5.

Even with existing standards major problem for different LAS is how to sustain correctness of data stored in those systems. In (Bittner & Frank, 2002) correctness is recognized as major issue of a land register. In the same paper, issue of differences between incorrectness and inconsistency are discussed.

The aforementioned papers in this section deal with 2D constraints. Formalization of 3D spatial ICs opens a number of new issues as it is pointed out in (Xu, van Oosterom, & Zlatanova, 2017). Specification of inter-register 3D constraints in LAS and inter-register inconsistencies in the presence of 3D constraints will require further research.

3 Consistency and correctness of LAS data

In this paper, we address two elements of data quality in LAS: data correctness and data consistency.

Data are said to be incorrect if they are not in accordance with reality. Let's suppose that in a database that holds cadastral data -100 is stored as the area of a land parcel. It is for sure incorrect because there is no land parcel with negative area. On the other side, one could misspell the area and insert 102 instead of 120 as the area of a land parcel. It is possible for a land parcel to have such an area, so area data 102 conforms to any rule in relation with allowed values for land parcel's area. The value, however, is not correct because this value is not in accordance with reality. Besides, the incorrect value may not be misspelled, but it could be incorrectly measured due to the human error or due to the measurement tool error.

In order to improve the data quality, integrity constraints have to be specified. They represent the rules to which data should adhere. Data are said to be inconsistent if they do not satisfy specified integrity constraints. At the same time, inconsistent data are by definition incorrect. If an IC specifies that the attribute area has to be positive rational number then area value –100 is inconsistent and incorrect, too. Although it is important that the ICs are specified, they won't solve the entire problem of incorrect data. It is impossible to specify the IC that detects misspelled or incorrectly measured area value that is represented with positive

rational number. It is obvious that the set of inconsistent data is the proper subset of the incorrect data set. In eq. 1 let *IDBS* (incorrect data in a broader sense) denotes the set of all incorrect data of a LAS, and *ICD* (inconsistent data) denotes the set of all inconsistent data of the LAS. Let

$$IDNS = IDBS \backslash ICD \quad (1)$$

where *IDNS* stands for incorrect data in the narrow sense. In this paper we will use the term ”incorrect data” to address only the data from *IDNS* set. They are not in accordance with reality and it is not possible to detect that discordance by means of ICs that are specified within only one register (land register or cadastre). Data consistency according to the ICs specified within one register in the paper is called internal consistency.

Bittner and Frank in (Bittner & Frank, 2002) define inconsistency as internal property that could be consequence of human errors or violation of property rules, while on the other hand, incorrectness is defined by situation in which information stored in cadastre does not match legal situation in reality.

Example of inconsistency of land register could be a case in which parties are registered as owners of property and sum of their shares is not equal to 1. Incorrectness of land register could be represented with an example when certain property is sold to a new owner and that transfer of ownership is still not recorded in land register.

Cadastral data can also be checked in terms of inconsistency and incorrectness as it was already mentioned for land register. In case of spatial data, correctness of geometry and topology should be checked (Vranić & Matijević, 2015). Inconsistency could be represented by an example of invalid topological relations. For example, if building is positioned outside the boundaries of parcel it belongs to. This is shown in Fig. 1 where annotation 275 represents parcel label and 1 is sequence number of building on the same parcel. On the other hand, incorrectness could be a case when, for example, shape of certain parcel, does not match the real shape measured ”in field”.

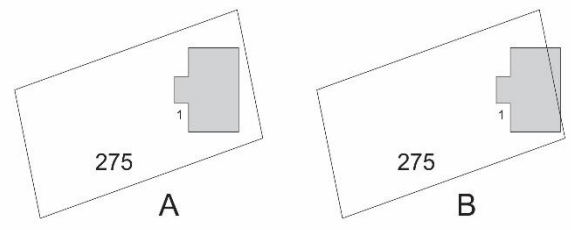


Figure 1. Cadastral data: A consistent - B inconsistent

Correctness of both registers is a problem whose origins could be traced to the fact that they are based on old ”pen and paper” systems. Although these two parts of LAS should have been consistent with each other, with ”pen and paper” system it was an impossible task. Also, process of digitalization was often done based on analog cadastral maps that were not of adequate quality or were of unknown provenance (Congalton & Macleod, 1994).

LAS can also be checked in terms of inconsistency and incorrectness. Inconsistency of LAS represents a case when data about a property in land register and data about the same property in cadastre do not match. For example, in land register there are data showing that on certain parcel there should be two buildings, while in cadastre there are spatial data representing only one building.

As for incorrectness, it could be said that LAS is in incorrect state when it is not representing true legal situation. This could happen only in case when data in at least one of two subsystems, land register or cadastre, are incorrect. It is not possible for LAS to be incorrect, while both land register and cadastre data are in correct state.

In general, inter-register inconsistency would always signal that there is an incorrectness in a broader sense in a system. In the case when both of LAS subsystems are internally consistent, the existence of an inter-register inconsistency in LAS is a signal that there is an incorrectness (in the narrow sense) in at least one of two subsystems.

For example, a parcel is recorded in land register as a parcel covering area of 1000m2. That data is consistent with all other data stored in land register. At the same time, in cadastre, the same parcel is registered with area of 900m2 and this data is consistent with all other data that are stored in cadastre. Unfortunately, a consistency problem exists between these two registers. Namely, the parcel covering area recorded in land register differs from the covering area of the same parcel that is recorded in cadastre. This is an example of inter-register inconsistency and, as mentioned before, it signals that there is an incorrectness in at least one of two subsystems.

There are three possible cases of incorrectness:

- land register data incorrectness – data about area are not correct,
- cadastral data incorrectness – data about area calculated from polygon shape that depicts parcel in cadastre are not correct,
- neither of data are correct.

Possible inter-register inconsistencies that could be detected in LAS and signal incorrectness in at least one subsystem are:

- for land register data about a specific parcel there are no matching data in cadastre,
- for cadastral data about parcel there are no matching land register data,
- land register data about parcel’s area do not match data about matching parcel’s area in cadastre,
- for land register data about part of parcel there are no matching data in cadastre,
- for cadastral data about part of parcel there are no matching land register data,

- land register data about part of parcel's area do not match data about matching part of a parcel area in cadastre,
- land register data about part of parcel's land use do not match data about matching part of a parcel's land use in cadastre.

4 Specification of integrity constraints

There is a large number of different approaches for modeling and enforcing ICs as well as for selecting most suitable ICSL. Main factors in process of selecting ICSL for specifying ICs are: understandability, readability, usability, and expressivity of the ICSL. In case of LAS, ISO Technical Specification (ISO/TS) 19103:2015 defines Unified Modeling Language (UML) in combination with Object Constraint Language (OCL) as conceptual schema language for specification of geographic information (ISO 19103: Geographic information — Conceptual schema language, 2015).

UML is a graphical language and in latest version (in time of writing this paper it was version 2.5 published from June 2015), 15 different types of diagrams were defined, categorized in two major groups: structural and behaviour diagrams (OMG Unified Modeling Language, version 2.5, 2015).

Over the years UML established a position as standard for model-centric software production (Gogolla, Martin, & Richters,, 2007). Yet, it is not possible to model all of the necessary restrictions simply by using class diagram, that is most widely used UML diagram. Therefore, an ICSL is needed to complement UML (Richters & Gogolla, 1998) (Dobing & Parsons, 2006).

Based on the ideas of Syntropy method, International Business Machines Corporation (IBM) developed Object Constraint Language (OCL) in 1995. OCL development was influenced by previously issued request for proposal (RFP), by Object Management Group (OMG), for standard object-oriented analysis and design language for UML. IBM led submission to OMG, that included OCL, was adopted in 1997, making OCL a part of UML 1.1 (Cabot & Gogolla, 2012).

OCL established a position as de facto standard modelling language for specifying system constraints that otherwise would not be possible to specify. Nevertheless because of difficult syntax, general usability of OCL is still low and this results in extended time and expense spent on design phase of software development (Salemi, Selamat, & Penhaker, 2016). It is common for model domain to be represented with class diagram, while constraints are defined using natural language instead of OCL. Needless to say that this is a big drawback to whole idea of dedicating less time for understanding subject model.

OCL is a platform-independent and generic method for modeling constraints and its main advantages are its declarative expression of constraints, connection to UML and possibility of interpretation by code engines, so generation of integrity checking mechanisms can be done automatically (Bejaoui at al., 2010).

Although OCL was initially used just as an ICSL, it soon became an important part of model-driven engineering (MDE) and nowadays it is used for different kind of model queries, manipulations, specification requirements, model transformations, well-formed rules or code generation templates (Cabot & Gogolla, 2012).

The OCL complements class diagrams since it is possible to write constraints that will "navigate" along associations to describe conditions on object states in class invariants and pre- and post-conditions of operations (Baumeister et al., 2001). Class invariants represent constraints connected to a class defining logical properties that features of all objects should satisfy. Operation preconditions represents constraints connected to operations defining what conditions should be true before execution of operation so operation in question
would execute correctly. Operation postconditions represents constraints connected to operations defining what conditions should be true after operation is executed correctly (Lano, 2009).

The OCL can track its roots to set theory, predicate logic and operational semantics. OCL supports set theoretic concepts cardinality (size), comprehension (select) and projection (collect) as well as algebra operation (union, intersection, etc.). Computational aspects are expressed using iterate construct thus providing possibilities that go beyond set theory and predicate logic, for example a possibility to sum up all elements in a specific set of integers (Baar, 2000).

5 Domain Model with inter-register constraints

In domain model proposed in (Pržulj et al., 2017), for representing spatial data, classes Geoaggregate and Polygon are used. Geoaggregate corresponds to GM_Aggregate class from OGC spatial scheme adopted in ISO 19107 (ISO 19107: Geographic information – Spatial schema, 2003). Geoaggregate represents a collection of primitive geometric shapes: points, line strings and polygons. Geoaggregate instance represents one parcel (with all its details) from land register on cadastral map. Polygon is planar surface that is topologically closed and has one external and zero or more internal boundaries (ISO 19125: OpenGIS Implementation Specification for Geographic information, 2005). In proposed domain model polygon representing part of parcel does not have explicit inner boundaries. Instead, geoaggregate referencing its polygons cares about their nesting. This

way inner boundaries (if any) are detected in every polygon. Polygon instance represents spatial data about part of parcel on cadastral map. Class Theme is used for representing land uses in cadastre that in practice differ from land uses in land register.

With introduction of these new terms inter-register inconsistencies that could be detected in LAS, listed in Section 3, can be redefined as follows:

- for parcel, there is no matching geoaggregate,
- for geoaggregate, there is no matching parcel,
- parcel area does not match corresponding geoaggregate area,
- for part of parcel, there is no matching polygon,
- for polygon, there is no matching part of parcel,
- part of parcel area does not match corresponding polygon area,
- part of parcel land use does not match polygon theme.

Proposed class diagram with constraints declared using OCL is show in Fig. 2. For drawing class diagram Eclipse Java EE IDE for Web Developers, Neon Release (4.6.0) with Papyrus UML Modeller 2.0.1 was used.

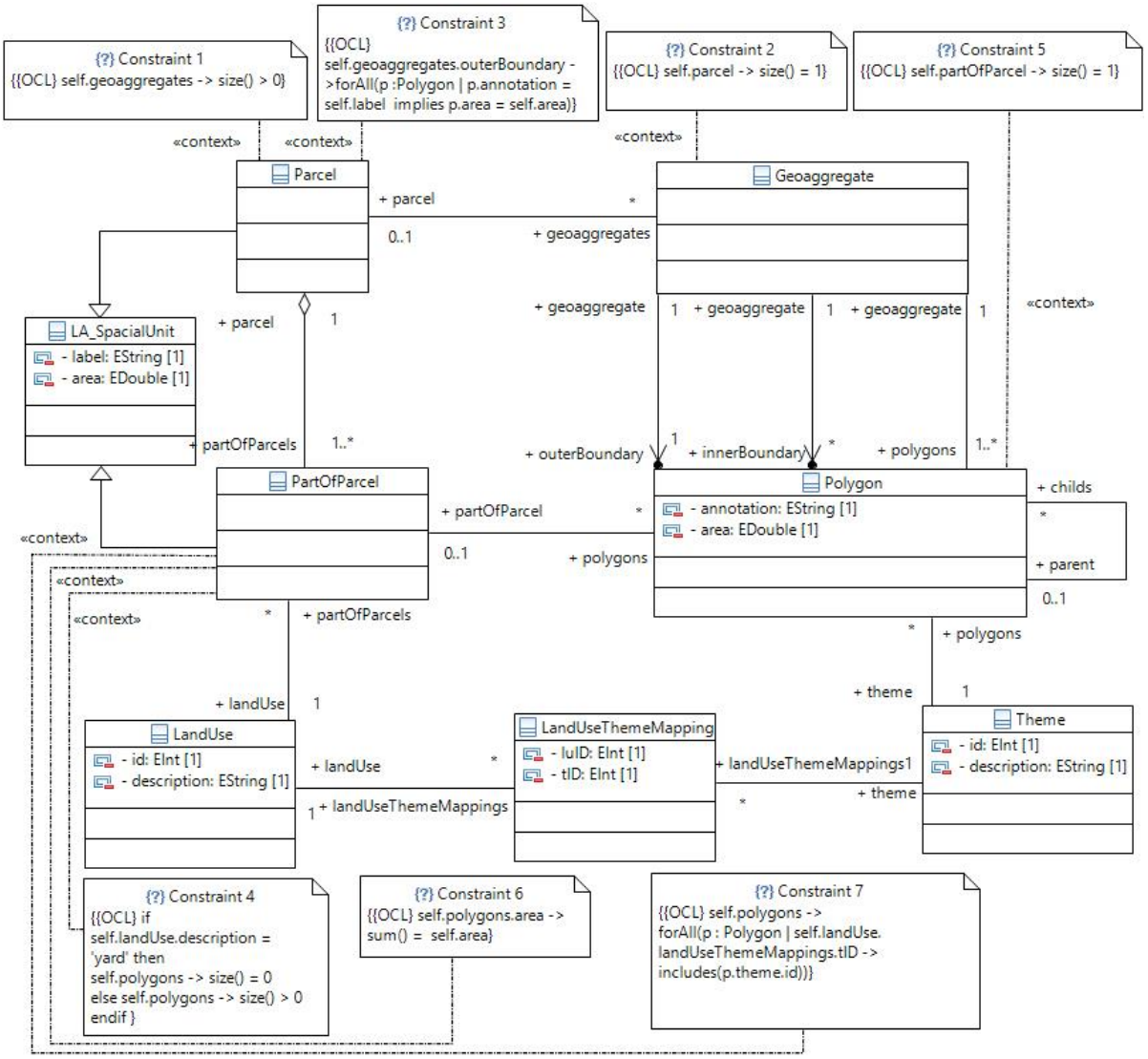


Figure 2. Class diagram for preserving data consistency in LAS

In proposed domain model classes Parcel and PartOfParcel represent abstractions of parcel and part of parcel from land register and they are both specialization of one of basic classes of LADM, class LA_SpatialUnit. Between classes Parcel and PartOfParcel aggregation is defined, modeling whole-part relation.

Class Parcel inherits attribute area from class in LA_SpatialUnit and it is used to store data about area and the same can be said for attribute area in PartOfParcel class.For every part of parcel, it is necessary to declare its land use based on class LandUse and that is why cardinality between PartOfParcel class and LandUse class is set to one. Between class Geoaggregate and class Polygon three associations are defined that represent outer and inner boundaries of parcel as well as other polygons that can appear within one geoaggregate. Following the same

analogy as between classes Parcel and PartOfParcel, every geoaggregate has one polygon that covers its entire area and that represents its outer boundaries. In cadastral systems, it is possible that one parcel is nested within another, so geoaggregate besides mandatory polygon that represents outter boundary can have polygons that represent inner boundaries if they exist. This is modeled with association innerBoundary between Geoaggregate and Polygon classes.

Attribute area in class Polygon is used to store data about area. In case when polygon represents outer boundary of a parcel, value recorded in area attribute represents true area of parcel, where areas of all inner boundary polygons, if any, were deducted. It's important to notice that certain tolerance between data representing area in land register and cadastre is acceptable. This acceptable level of tolerance is defined by countries' legislation and it should depend on technologies and tools used for surveying purposes.

Analog to association between classes PartOfParcel and LandUse, association between classes Polygon and Theme is created.

Inter-register dependencies between land register and cadastre are created through associations between classes Parcel and Geoaggregate, classes PartOfParcel and Polygon and classes LandUse and Theme through class LandUseThemeMapping. Instance of LandUseThemeMapping class is pair that maps land use from land register with corresponding theme from cadastre map.

Attribute label, that class Parcel inherits from class LA_SpatialUnit, is used for matching parcel corresponding outer boundary polygon through its attribute annotation.

Cardinality between classes Parcel and Geoaggregate allows existence of parcel that has no representation in spatial data and also a possibility for one parcel to be represented by several geoaggregates. It is necessary for model to allow a possibility of having more than one geoaggregate associated with parcel when there are data collected from different sources of spatial data about the same property. One geoaggregate can be associated with at most one parcel, while it is possible that there is a geoaggregate that is not associated with any of parcels. Minimal cardinality set to zero in both cases is necessary to allow storing of data from various sources that are often in inconsistent state.

Cardinality between classes PartOfParcel and Polygon allows possibility that part of parcel will not have a representation in spatial data and this is intended to support existence of part of parcel added to land register as a taxation deductible ('yard'). If there are multiple parts of parcel with the same land use they are represented by one part of parcel record in land register, but by multiple polygons on cadastral map.

It is evident that some constraints could not be implemented using just UML class diagram, so those constraints are defined using OCL as follows:

- Constraint 1 – It is necessary that every parcel has matching geoaggregates.

```
context Parcel:
self.geoaggregates > size()>0
```

- Constraint 2 – It is necessary that every geoaggregate has a matching parcel.

```
context GeoAggregate:
self.parcel > size()=1
```

- Constraint 3 – It is necessary that every parcel and matching geoaggregate have the same area.

```
context Parcel:
self.geoaggregates.outerBoundary
forAll(p:Polygon|p.annotation =
self.label implies p.area =
self.area)
```

- Constraint 4 – It is necessary for every part of parcel, unless its land uses description is 'yard', to have matching polygon(s).

```
context PartOfParcel:
if self.landUse.description =
'yard'
then self.polygons > size()=0
else self.polygons > size() > 0
endif
```

- Constraint 5 – It is necessary that every polygon has matching part of parcel.

```
context Polygon:
self.partOfParcel > size()=1
```

- Constraint 6 – It is necessary that every part of parcel has the same area as a sum of areas of matching polygons.

```
context PartOfParcel:
self.polygons.area >
sum() = self.area
```

- Constraint 7 – It is necessary that every part of parcel and matching polygon(s) have appropriate land use/theme mapping.

```
context PartOfParcel:
self.polygons >
forAll(p:Polygon|self.landUse.
landUseThemeMappings.tID >
includes(p.theme.id))
```

6 Conclusion

Process of establishing LAS has to support storing of all available data that have previously been held in "pen and paper" systems. Without possibility of implementing sustainable IC validation in "pen and paper" systems, it is to be expected that newly established LAS will contain data that are inconsistent and therefore incorrect.

Presented solution proposes ICs that should be implemented and used to detect inter-register inconsistencies in LAS. Detected inter-register inconsistencies indicate incorrectnesses in at least one of LAS subsystems that should be addressed and corrected by responsible authorities. Following step

towards LAS data consistency should be enforcement of inter-register ICs. LAS data that are brought to consistent state by detecting and correcting identified violations of inter-register ICs can be preserved in consistent state by enforcing those ICs.

Inter-registered ICs presented in this paper could be a starting point for future modeling of land register and cadastre internal consistency. Future research would be directed at identification of processes in LAS that could cause violation of inter-register constraints proposed in this paper.

Platform independent model of inter-register ICs expressed by means of OCL could be transformed into different platform specific models aimed at ICs' implementation. These transformations could be the subject of future research, as well as implementation and testing of proposed domain model on real world data.

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Strategic Planning and Decision Making

Antonia Bralić
Social Network Analysis of Country Participation in Horizon 2020 Programme

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Social Network Analysis of Country Participation in Horizon 2020 Programme

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Abstract. *Social network analysis has had multiple application through a variety of disciplines. This paper examines various examples of applying social network analysis and covers background of the theory. Main purpose of the paper is to use social network analysis to analyze country participation in the Horizon 2020 programme, mainly using measures of centrality. Few countries have emerged as central, and additional characteristics of those countries, like funding and beneficiaries have been evaluated. The importance of understanding formed relationships in Horizon 2020 lies in strategic decision making on partnerships, projects, and funding.*

Keywords. Social network analysis, Horizon 2020, graph theory

1 Introduction

Social network analysis (*SNA*) is "commonly used for mapping and measuring relationships and information flows among people, groups, organizations, computers, websites and other information/ knowledge processing entities" (Vrček, et al., 2013). The links between the nodes represent connections, while nodes itself can be, as stated, people, groups or other entities. (Freeman, 1984) in (Wasserman & Faust, 2009) states "the methods of social network analysis provide formal statements about social properties and processes".

The point of SNA is not only to map and measure relationships between the nodes, it is also to understand the structure of a network and to draw conclusions that can support research on the impact of the relationship on an actor. (Grunspan, et al., 2014) are for example stating that "SNA aims to understand the determinants, structures, and consequences of relationships between actors". Although the relationships SNA analyses are most often those between human beings, links among groups or organizations, as well as those among nation-states or international alliances are also examined (Freeman, 2004). Having that in mind, it is no wonder that multiple applications of SNA are discovered in literature review: (Grunspan, et al., 2014) studied social interactions between students in undergraduate education and their impact on learning outcomes, (Putnik, et al., 2016) applied the concept of social networks through an altered education process and found that the quality of students' work was better when students were between the interaction paths of other students.

Various other applications of SNA include examining and modelling social interactions between animals (Coleing, 2009), analysing team sports through SNA (Lusher, et al., 2010), as well as exploring the influence of social networks on innovation (Lewrick, et al., 2007) and understanding interactions between health professionals (Pow, et al., 2011). (Eveland Jr & Kleinman, 2013) used SNA to compare general and political discussion networks within voluntary organizations and (Johnson, et al., 2008) have explored how a network position of a non-profit organization affects its capacity level. (Chung & Paredes, 2015) have implemented SNA in analysing social learning to find that the learning is influenced by social network properties.

For the purpose of this article, connection between social network analysis and project management is interesting. Example of this kind of connection is the research of (Mohan & Paila, 2013) in which SNA was used as a visual tool to help with effectively managing stakeholders on projects. Further on, (Fitsilis, et al., 2009) have applied SNA in improving software project control with the goal of "enabling better team selection and SNA being the tool for managing project risk and improving project time and cost management". Research similar to the one in this paper was conducted by (Divjak, et al., 2010) where structure of project partnership in Eureka network was analysed using SNA. There are three main findings of that research: "countries from the same region cooperate more, country's level of development does not guarantee central position in the network, and bilateral partnerships are the most successful ones".

The purpose of this paper is to connect SNA as a powerful tool for analysing relationships in a network and the Horizon 2020 programme as the main EU

framework programme for research and innovation. Horizon 2020 was announced in 2011 after evaluating existing and past programmes on the EU level. It is an 80 billion euro programme that was developed to boost research, innovation and competitiveness in Europe (European Commission, 2011). The funding is available from 2014 to 2020 and with the political backing, has the goal to "ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation" (European Commission, n.d.). There are multiple programme sections within Horizon 2020, largest three being excellent science, industrial leadership, and societal challenges, each with specific elements. Legal entities of different kind can participate in Horizon 2020, such as universities, small and medium-sized enterprises (SMEs), large companies, research organizations, non-governmental organizations (NGOs). In Horizon 2020, bi-annual work programmes cover funding opportunities and current one is built for 2016-2017.

There are multiple applications of the provided data on Horizon 2020, such as visualization on coordinating projects, funds, and project count (Passas, 2016). The European Union Open Data Portal itself is listing applications of the open data in general, similar to the one above, but with a disclaimer that third party applications are not controlled (European Union Open Data Portal, n.d.), which is why it is important to extract relevant Horizon 2020 data directly from the European Union Open Data Portal. Using SNA is not uncommon in analyzing EU projects results and formed networks. (European Commission, 2015) has published a report on results of 7th Framework Program (FP7) participation in which "effects and outcomes of networking at the macro level" were analyzed through network analysis and at the micro level through case studies, in-depth interviews and a survey. The SNA aimed to "provide a broad view of networking activities that took place in FP7 and its different specific programmes and underlying thematic areas". Some of the findings included that 86% of collaboration pairs from Framework Programme 6 were not renewed in FP7, as well as that Universities and research organisations "derive an advantage from being centrally located in the co-participation network of framework programmes".

Based on previous research and research interests, the following research questions for this paper have been defined, that ought to be answered through the social network analysis and through available data.

RQ1: Based on centrality measures, do the largest member state countries hold central position in the network?

RQ2: Have the countries with the highest centrality measures received most funding to date via Horizon 2020 projects and do those countries have the highest success rate of applied projects?

RQ3: Among the countries with highest centrality measures, what type of institutions are the top beneficiaries?

The research findings can be of value to organizations planning to participate in Horizon 2020 projects, as well as to public in general, to gain a holistic overview of the roles of member countries in Horizon 2020 projects to this date. The paper is organized as follows: first, an overview of social network analysis is provided, as well as the connection between SNA and graph theory. After, the research method and results are presented, and finally the answers to research questions are provided, and conclusion is laid out.

2 Social network analysis method

If SNA determines and analyses relationships within actors in a network, it is important to define what a "network" is, and how the network theory is related to one of its foundations, graph theory.

(Wasserman & Faust, 2009) state that there are "three mathematical foundations of network methods: graph theory, statistical and probability theory, and algebraic methods". Also according to (Wasserman & Faust, 2009), graph theoretic, sociometric, and algebraic schemes can be adapted to represent a wide range of network data. Relevant for this paper, sociometric notation presents the relationship data in a sociomatrix, where "the rows and columns refer to the actors making up the pairs" and the sociomatrices are essentially adjacency matrices for graphs. Meanwhile, according to the same authors, graph theoretic notation is "useful for centrality and prestige methods, cohesive subgroup ideas, as well as dyadic and triadic methods".

There are different ways networks can be categorized. First, networks can be unipartite or one-mode (consist of only one type of actor), or bipartite or two-mode in which actors are linked with the groups to which they belong (Grunspan, et al., 2014). An example of a bipartite network is connecting universities to projects they participated on, while a unipartite network would connect universities to universities. Networks can also be studied from an ego-centered and socio-centered approach. Socio-centered approach is focused on the characteristics of the network as a whole, while ego-centered approach focuses on an actor in a network and is analyzing its immediate relationships.

Definition of a social network deriving from graph theory conceptualizes social network as a graph: there is a set of vertices as social actors and a set of lines representing social relations between these vertices (nodes) (de Nooy, 2008).

Same author states that social network is more than a simple graph as it covers details on social actors, as well as the nature of the relationships between the nodes. Depending on the nature of ties in a graph, it can be undirected and directed. In undirected graph, sets of nodes are not ordered pairs, while in a directed graph the pair of nodes is ordered and there is an associated direction between nodes. Example of an undirected graph is a student A studying with student B, and an example of a directed graph is student A's perception of student B as being smart (not necessarily mutual) (Grunspan, et al., 2014).

As stated, networks have developed from several foundations, one of which, often used to describe networks, is graph theory. (Brandes, et al., 2016) define elements of graphs, since it is assumed networks are represented as graphs: "an (undirected) graph $G=(V,E)$ consists of a set V of vertices (also called nodes) representing actors and a set of (undirected) edges (also called links) representing ties between actors. An edge is thus an unordered pair of vertices representing a symmetric relationship. If there exists an edge $e=\{u,v\}\in E$, we say that u and v are adjacent and that u and v are incident to e. We will use $n=|V|$ for the number of vertices and $m=|E|$ for the number of edges of a graph.

Some of the centrality measures analyzed in this paper are degree centrality, betweenness centrality, and closeness centrality. Centrality measures serve as indicators of important nodes in a network.

2.1. Degree centrality

Degree of a node is "the count of the number of ties to other actors in the network, i.e. the number of lines that are incident with it" (Divjak, et al., 2010). (Wasserman & Faust, 2009) state that this measure focuses on the most visible actors in the network (…). An actor with a large degree is in direct contact or is adjacent to many more actors".

Degree centrality formula, from (Divjak, et al., 2010):

$$C_D(n_i) = d(n_i) = \sum_{\forall j \neq i} x_{ij} \quad (1)$$

Where:
$C_D(n_i)$ = degree centrality of actor i
$d(n_i)$ =degree of node i
x_{ij} = 1 if I is incident to j; 0 if i is not incident to j
n = number of nodes in the network

2.2. Betweenness centrality

(Wasserman & Faust, 2009) state that "the important idea with betweenness is that an actor is central if it lies between other actors on their geodesics". This means that an actor must be between many of the actors to have a large "betweenness" centrality.

Betweenness centrality formula, from (Divjak, et al., 2010):

$$C_B(n_i) = \frac{\sum_{j<k, i\neq j, i\neq k} \frac{g_{jk}(n_i)}{g_{jk}}}{\frac{((n-2)(n-1))}{2}} \quad (2)$$

Where:
$C_B(n_i)$ = standardized betweenness centrality of node i
$g_{jk}(n_i)$ = number of geodesic linking j and k that contains i in between
g_{jk} = total number of geodesic linking j and k

2.3. Closeness centrality

"Closeness focuses on how close an actor is to all the other actors in the set of actors; the idea is that an actor is central if it can quickly interact with all others" (Wasserman & Faust, 2009).

Closeness centrality formula, from (Divjak, et al., 2010):

$$C_C(n_i) = \frac{n-1}{\left(\sum_{j=1, i\neq j}^{n} d(n_i, n_j)\right)} \quad (3)$$

Where:
$C_C(n_i)$ = standardized closeness centrality of node i
$d(n_i,n_j)$ = geodesic between i and j

3 Research

3.1. Research method

The research in this paper covered all EU research projects under Horizon 2020 (2014-2020), with the goal of building a social network and answering the research questions. The dataset containing projects was downloaded from the European Union Open Data portal on March 21st 2017. CORDIS datasets are produced on a monthly basis and on the date of download, there have been 13776 downloads. For each participant Cordis record number (RCN), ID, Acronym, Role, Organisation Name, Organisation Short Name, Organisation Type, Participation Ended, EC Contribution, and Organisation Country have been listed in the dataset (European Union Open Data Portal, 2016). Data has been analysed using RStudio, a tool based on R, a free software environment for statistical computing and graphics (The R Foundation, n.d.). RStudio was chosen for data analysis in this research as it supports a variety of techniques, it is well supported by packages developed for social network analysis, and it provides an environment for both analysis and visualization of the generated networks.

In RStudio, XLConnect, readxl, sna, and igraph packages were used to import and analyse dataset.

The package "sna" serves as a tool to obtain centrality degrees laid out earlier in this paper. The following steps were taken to import and analyse data:

Import dataset:

```
Horizon <- read_excel ("path")
```

Check the structure of the imported dataset:

```
str(Horizon)
```

Create matrix containing information on countries and projects:

```
Y <- as.matrix
(table(Horizon$country,Horizon$projectI
D))
```

Create adjacency $n \times n$ matrix A, where n is the number of vertices in the graph (number of participating countries):

```
A <- Y%*%t(Y)
```

Create a graph out of the created matrix:

```
Horizon.graph <- graph.adjacency (A)
```

Plot the created graph with particular, defined look:

```
plot (Horizon.graph1,
vertex.size=degree(Horizon.graph1)/30,
edge.color="light grey",
vertex.color="grey",
vertex.frame.color="grey",
vertex.label.cex=0.8)
```

In total, 131 countries centrality measures have been analysed and made it to the graph, as the research covered all country participants. To obtain good results, only basic data covering country, project ID, city, and project name remained in the sheet.

To answer the research questions, information gathered through SNA was combined and enriched with other analysis provided by European Commission on the current status of Horizon 2020 projects and countries' participation.

3.2. Research findings

The created social network where nodes represent countries and edges represent partnerships on projects was the basis to perform further analysis on the position of countries, through centrality measures. If this network is perceived as a graph, the graph is simple, undirected, and unipartite. The graph presents all countries that participated in the Horizon 2020 programme. It is visible on Figure 1 that countries with high centrality degrees are located in the centre of the network, maintaining a number of relations with other countries. Similarly, countries with smaller centrality degrees are located on the outskirts of the graph, as they are not as connected as the central countries.

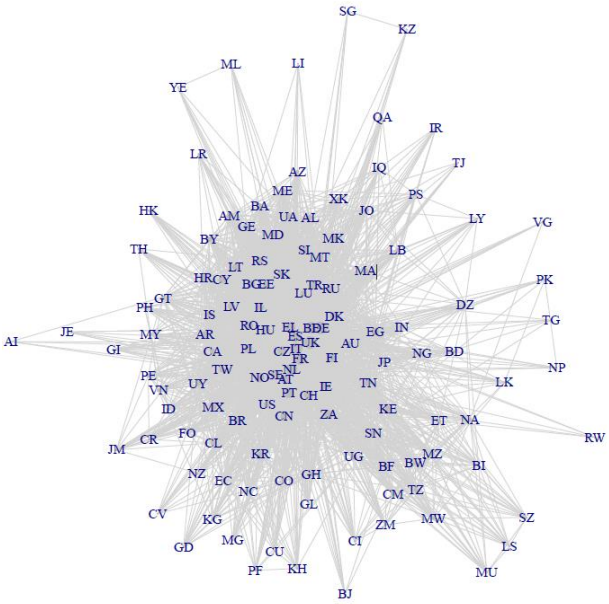


Figure 1. Social Network Analysis Graph

Degree centrality measures are laid out in Table 1, sorted from largest, showing top five countries with the largest degree centrality, which are United Kingdom, Germany, France, Italy, and Belgium.

Table 1. Degree centrality

Country	Degree centrality
United Kingdom (UK)	123
Germany (DE)	122
France (FR)	113
Italy (IT)	113
Belgium (BE)	111

These actors should begin to be recognized by others as a major channel or relational information (Wasserman & Faust, 2009). According to a similar research, conducted by (Divjak, et al., 2010), degree centrality is an indicator of "a country's activity in a network" and the countries with a higher degree centrality should be perceived as an attractive partner.

Table 2 shows top five countries in regards to betweenness centrality, which are the same as above: United Kingdom, Germany, France, Italy, and Belgium.

Table 2. Betweenness centrality

Country	Betweenness centrality
United Kingdom (UK)	566.487
Germany (DE)	562.704
France (FR)	341.199
Italy (IT)	345.845
Belgium (BE)	349.307

As mentioned, betweenness centrality is determined by the node being between other actors in a network. In this research, these are the countries that have the highest betweeneess centrality meaning they control the flows between actors in the network.

Table 3 shows countries with highest closeness centrality, which is recorded for the same set of countries: UK, Germany, France, Italy, and Belgium.

Table 3. Closeness centrality

Country	Closeness centrality
United Kingdom (UK)	0.007299
Germany (DE)	0.007246
France (FR)	0.006807
Italy (IT)	0.006803
Belgium (BE)	0.006711

For these countries it is easiest to access other actors within the network, meaning they can build contacts fast.

Looking at the positions in the network, it is interesting to look at centrality degrees of recent European Union members and how these countries have positioned themselves in this network. Table 4 shows countries that most recently joined EU and their centrality measures.

Table 4. Newest EU members and degree centrality measures

Country	Degree centrality	Betweenness centrality	Closeness centrality
Croatia	63	23.767	0.005076
Romania	74	42.546	0.005376
Bulgaria	68	30.921	0.005208

The table above shows that Romania and Bulgaria do have higher centrality measures than Croatia, which does make sense since the countries have entered the EU six years earlier than Croatia. It would be an interesting point to follow throughout time, to see whether Croatia will be earning a more central place as the time progresses.

The research questions have been answered.

RQ1: Based on centrality measures, do the largest member state countries hold central position in the network?

Four out of five most central countries in the centrality measures analysis are in the top five largest member states, based on population. Those countries are (in order from the most populated one); Germany, France, United Kingdom, Italy (eurostat, 2017). Belgium is the 9th most populated country in the EU, but is in the top five countries in our analysis, while on the other hand Spain is the 5th most populated country in the EU but has not made it to the top five most central countries in Horizon 2020.

RQ2: Have the countries with the highest centrality measures received most funding to date via Horizon 2020 projects and do those countries have the highest success rate of applied projects?

Table 5. Success rate and funding to date in Horizon 2020. Data from (European Commission, 2016)

Country	Funding to date (in million Euro)	Success rate
United Kingdom	€ 2.634,93	14,8%
Germany	€ 3.031,00	15,7%
France	€ 1.758,66	16,8%
Italy	€ 1.413,62	11,6%
Belgium	€ 808,42	17,1%
Ireland	€ 303,44	15,3%
Portugal	€ 286,89	12,4%
Spain	€ 1.509,16	13,3%
Netherlands	€ 1.329,18	16,1%
Luxembourg	€ 43,19	16,0%
Denmark	€ 425,73	15,0%
Sweden	€ 571,18	13,2%
Czech Republic	€ 106,73	13,2%
Austria	€ 491,51	16,3%
Slovenia	€ 94,48	10,0%
Croatia	€ 28,83	10,8%
Poland	€ 153,70	11,1%
Slovakia	€ 43,84	13,7%
Hungary	€ 94,51	10,0%
Finland	€ 350,07	12,9%
Estonia	€ 60,36	13,2%
Latvia	€ 19,42	11,4%
Lithuania	€ 18,82	11,3%
Romania	€ 66,25	11,4%
Bulgaria	€ 23,05	9,5%
Greece	€ 351,13	12,1%
Cyprus	€ 51,69	9,1%

It appears that countries with highest centrality measures do have high received funding. UK, Germany, and France in general have received most funding to date through Horizon 2020 projects. However, Spain and Netherlands show high received funding, higher than Italy and Belgium, although their centrality measures are not as high. When analysing success rates, based on Table 5, the highest one is the one of Belgium, followed by France, Austria, Netherlands and Luxembourg. This demonstrates that having high centrality measures (degree, betweenness, and closeness) is not necessarily an indicator of a success rate. Interestingly, Belgium was found to be

quite central in SNA, although funding received is not as high, but its success rate is the highest among the member states (17.1%). UK on the other hand, has a success rate of 14.8%, but is the most central node in the network, based on the SNA and has received most funding to date. Further deeper statistical analysis is needed to determine the exact effect of these indicators.

RQ3: Among the countries with highest centrality measures, what type of institutions are the top beneficiaries?

Analysing the top 10 beneficiaries (based on financial distribution) for top 5 countries based on the SNA, the results show that institutes/research organizations and universities are main beneficiaries in these member states

- UK: all top 10 beneficiaries are universities
- Germany: 6 institutes/research organizations, 4 universities
- France: 7 institutes/research organizations, 2 universities
- Italy: 5 institutes/research organizations, 5 universities
- Belgium: 3 institutes/research organizations, 6 universities

4 Conclusion

Social network analysis is a powerful way to determine and analyse connections between actors in a network. Understanding the nature of formed relationships is important to make data driven decisions and to gain a holistic view of the partnerships within a network. In this research, SNA served as a foundation for determining central roles of countries in the Horizon 2020 network that resulted in answering key research questions. It can be concluded that the size of the country is somewhat related to high centrality measures. UK, Germany, France, and Italy hold highest measures of degree, betweenness, and closeness centrality. Spain, which is following these countries in size does not hold high centrality measures and Belgium has taken its spot in the top five countries based on centrality. This means that these five countries are the most central, control the flow of information and resources, and can form partnership easily. Further on, high participation of universities and research institutes was detected for the five most central countries in the network, and the success rate (although all top countries listed here do have above average success rate), as well as the funding received, do not seem to follow the centrality measures. Further research should be conducted to determine deeper connection and statistical significance of the statements here, which are based on the qualitative analysis. Some of the limitations of the research include the fact that the SNA has been performed on a whole set of data and the findings present only highest centrality countries, lack of further statistical analysis to connect other research elements to centrality measures (such as funding or beneficiaries). Further, a limitation is the up to date data source, as these sources are updated regularly on Cordis website, it also means that the network might be changing. Finally, additional network analysis measures should be deployed to analyse data further.

To conclude, SNA has demonstrated to be a good choice for determining the central positions in the network created by partnerships through the Horizon 2020 projects and the ideas for expanding this research have been laid out here as well.

Acknowledgments

This work has been supported by Croatian Science Foundation under the project HigherDecision IP-2014-09-7854.

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Predicting Natural Gas Consumption – A Literature Review

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Abstract. *Natural gas is considered to be one of the most important energy sources. Due to its many advantages, demand for this energy source has increased considerably. Many authors tried to develop models for predicting natural gas consumption. The aim of this paper is to present an overview and systematic analysis of the latest research papers that deal with predictions of natural gas consumption from the year 2002 to 2017. In this paper, prediction methods, input variables used for modelling, prediction area, as well as prediction horizon will be analysed. This research could be helpful for other researchers in order to create better and more accurate prediction models.*

Keywords. Natural gas, prediction models, energy, literature review

1 Introduction

Natural gas (NG) is one of the most important energy resources that is becoming more and more popular because of its environmental benefits (lower impact on environmental pollution). Therefore, demand for this source of energy has increased considerably in recent years. According to U.S. Energy Information Administration (U.S. Energy Information Administraton, 2016), natural gas has the largest increase in world primary energy consumption, so it is projected to increase from 120 trillion cubic feet (Tcf) in 2012 to 203 Tcf in 2040. Globally, natural gas accounted for 23.8% of primary energy consumption (BP Global, 2015). Natural gas remains the main fuel in the production of electricity and in industry sector.

Many authors have tried to develop models for predicting natural gas consumption on the hourly, daily, weekly, monthly or yearly basis. The accuracy of the model is important for decision making on gas nominations. Every natural gas distributor is obliged to make a nomination of natural gas by its supplier, which is the amount of gas needed for the following day (or other future period). There is a certain regulated tolerance that is allowed. In case the actual consumption exceeds the nominated amount, the distributor must pay a certain penalty. On the other hand, if nominated amount exceed actual consumption, different type of penalty will be charged as well. Since the incorrect nominations lead to high costs, an accurate predictions of natural gas consumption for the following day are very important due to financial reasons.

The purpose of this paper is to provide an overview of predictive models of natural gas consumption in several countries in the world. In the paper, the methods used for predicting NG consumption, the input variables used for modelling, as well as the prediction area and forecast horizon will be analysed. This paper is structured as follows: in Section 2 methodology is described, Section 3 gives an overview of prediction models, Section 4 describes input and output variables, Section 5 gives an overview of prediction area and Section 6 describes prediction horizons. The key findings of this research are given in Section 7.

2 Methodology

For the research purposes, literature overview analysis was conducted using the most relevant scientific database Web of Science Core Collection (WoSCC). The keywords "natural gas consumption (prediction OR demand)" were used for searching articles. The articles were searched within three indexes: Science Citation Index Expanded (SCI-Expanded), Social Science Citation Index (SCI), and Arts and Humanities Citation Index (A&HCI) for the period from 2002 to 2017.

This search resulted with 187 papers, including article (180), proceedings paper (8) and review (7). After reviewing the title, abstracts and keywords of all found articles, articles that are not related to models for prediction of natural gas consumption for residential or commercial use were eliminated. Thereafter, 27 articles remain that met posted criteria. Those papers

were analysed according to several criteria: methods used for predictions of natural gas consumption, input variables used for modelling, prediction area and prediction horizon.

Similar literature review was conducted by Soldo (2012), who analysed natural gas consumption from the year 1949 to 2010.

As it can be seen in Table 1, in the last three years 13 papers considering natural gas prediction were published, which is more than 44% of all analysed papers.

Table 1. Number of published papers per year

Year of publication	Number of papers	%	Authors
2004	1	3.70%	Gil & Deferrari
2005	2	7.41%	Aras; Gutierrez et al.
2007	1	3.70%	Potočnik et al.
2008	1	3.70%	Brabec et al.
2009	1	3.70%	Tonković et al.
2010	3	11.12%	Azadeh et al.; Forouzanfar et al.; Ma & Li
2011	2	7.41%	Kaynar et al.; Sabo et al.
2012	2	7.41%	Demirel et al.; Olgun et al.
2013	1	3.70%	Taspinar et al.
2014	1	3.70%	Soldo et al.
2015	6	22.22%	Azadeh et al.; Boran; Izadyar et al.; Szoplik; Wu et al.; Zhu et al.
2016	4	14.82%	Akpinar & Yumusak; Bai & Li; Baldacci et al.; Zeng & Li
2017	2	7.41%	Akpinar & Yumusak; Panapakidis & Dagoumas
Total	**27**	**100.00%**	

3 Overview of prediction areas

Prediction of NG consumption can be conducted on different areas, for example on the country, region, city or individual customer area (Soldo, 2012).

NG consumption on country level was investigated by Gutierrez et al. (2005), Potočnik et al. (2007), Brabec et al. (2008), Azadeh et al. (2010), Forouzanfar et al. (2010), Ma & Li (2010), Kaynar et al. (2011), Olgun et al. (2012), Azadeh et al. (2015), Boran (2015), Wu et al. (2015), Zhu et al. (2015), Zeng & Li (2016) and Panapakidis & Dagoumas (2017). It can be seen that most of the papers dealt with the predictions on country area. Gutierrez and co-authors (2005) were predicting natural gas consumption in Spain, Potočnik and co-authors (2007) in Slovenia, while Brabec and co-authors (2008) made predictions using data about large commercial entities in Slovakia. Three papers dealt with predictions of NG consumption in Iran. Those are Azadeh et al. (2010), Forouzanfar et al. (2010) and Azadeh et al. (2015). Ma & Li (2010), Wu et al. (2015) and Zeng & Li (2016) conducted research about natural gas consumption predictions in China while the same number of papers investigated this problem in Turkey (Kaynar et al., 2011; Olgun et al., 2012; Boran, 2015). Zhu and co-authors (2015) were predicting demand of natural gas in United Kingdom. Natural gas consumption has been predicted by Panapakidis & Dagoumas (2017) in Greece.

There are only five papers that predicted natural gas consumption on regional level. Gil & Deferrari (2004) presented the results for the case of Greater Buenos Aires region in Argentina. The paper written by Tonković et al. (2009) investigated the prediction of NG consumption in the north-east region of Croatia. Several Turkish authors (Taspinar et al., 2013; Akpinar & Yumusak, 2016; Akpinar & Yumusak, 2017) tried to predict NG consumption in Marmara region (Sakarya province).

The following papers deal with predictions of natural gas consumption on city level. The predicting method based on genetic algorithms, developed by Aras (2005), has been applied by using data for Turkish city Eskisehir. Demirel et al. (2012) also made predictions of natural gas consumption in Turkish city, but in this case city of Istanbul. Sabo and co-authors (2011) proposed mathematical models of natural gas consumption for area of the city of Osijek. The residential heating demand of the Baharestan city in Iran was forecasted by Izadyar et al. (2015). Szoplik (2015) were predicting natural gas demand using NG consumption data for the Szczecin city in Poland. Bai & Li (2016) used the data of the NG consumption of Anqing city in China for modelling and forecasting. Baldacci et al. (2016) tried to predict gas consumption for a given gas network. First gas network services

Voltana, a small village, and the second gas network services Lugo, a small city. The aim of the study, conducted by Soldo et al. (2014), was to forecast residential natural gas consumption not only for the city level, but also for the house level. They used two datasets about past NG consumption. The first dataset was for two small cities with total of 4314 customers, and the second dataset was for the model house which has a heated space that covers 100 m2.

Overview of countries in which predictions of natural gas consumption were made, is shown in Table 2.

Table 2. Overview of the number of published papers by countries where predictions were made

Country	Number of published papers
Argentina	1
China	4
Croatia	3
Greece	1
Iran	4
Italy	1
Poland	1
Slovakia	1
Slovenia	1
Spain	1
Turkey	8
United Kingdom	1

4 Overview of prediction horizons

There are several prediction horizons that can be used for prediction of natural gas consumption. Large number of authors were predicting natural gas consumption on annual level. Gil & Deferrari (2004) presented a model intended to predict the annual natural gas consumption for the region in Argentina, Gutierrez et al. (2005) used the stochastic Gompertz innovation diffusion model for forecasting annual natural gas consumption in Spain, Forouzanfar et al. (2010) used a logistic based approach to predict the annual natural gas consumption in Iran, Ma & Li (2010) predicted China's gas consumption in 2009-2020, Olgun et al. (2012) presented a model in order to estimate the annual NG demand for Turkey until year 2030, Boran (2015), Wu et al. (2015) and Zeng & Li (2016) used grey prediction models to predict annual NG consumption in Turkey and China.

Forouzanfar et al. (2010) modelled seasonal NG consumption as well as Baldacci et al. (2016).

Predicting natural gas consumption on monthly level was reported by Aras (2005), who forecasted residential consumption using genetic algorithms, Azadeh et al. (2015), who proposed a hybrid method based on computer simulation and ANFIS, Izadyar et al. (2015), who predicted the residential heating demand in Iran, and Akpinar & Yumusak (2016), who forecasted NG consumption using time series methods.

There are two papers in which weekly prediction of natural gas consumption was reported. Those are papers written by Potočnik et al. (2007), who proposed a forecasting model in order to forecast risk estimation, and Kaynar et al. (2011), who used neural network and neuro fuzzy system for prediction of NG consumption on weekly basis.

Large number of authors predicted natural gas consumption on daily level. Gil & Deferrari (2004) proposed a daily prediction model in Argentina, and Potočnik and co-authors (2007) presented a risk model that is applicable to estimating the daily forecasting risk. In order to do that, they had to create a model for daily prediction of natural gas consumption. Brabec et al. (2008) forecasted a commercial NG consumption in Slovakia, Azadeh et al. (2010) predicted short-term NG demand, Demirel et al. (2012), Taspinar et al. (2013) and Akpinar & Yumusak (2017) predicted daily NG consumption in Turkey, Soldo et al. (2014) used solar radiation as an input variable in order to predict daily NG consumption, Zhu et al. (2015) tried to predict natural gas demand in United Kingdom, Bai & Li (2016) proposed a structure-calibrated support vector regression approach to forecast the daily NG consumption, Panapakidis & Dagoumas (2017) predicted daily natural gas demand.

Predicting natural gas consumption on hourly scale was reported by Tonković et al. (2009), who created a prediction model of natural gas consumption on a regional level by using neural networks, Sabo et al. (2011), who proposed mathematical models of natural gas consumption, and Szoplik (2015), who forecasted natural gas consumption in Poland using neural networks.

5 Overview of prediction methods

Natural gas consumption is predicted by using various predicting techniques and methods or even a combination of several methods. Soldo (2012) discovered that among the first tools for prediction of natural gas consumption was the Hubbert curve model used in 1950s. Since 1960s, when statistical models were developed, various statistical models have been used for predictions of NG consumption. From the late 1970s and 1980s, the artificial neural networks became very popular forecasting tool. Lately, there are new methods used in predictions of natural gas consumption such as Grey models or genetic algorithms.

In this research, the most often method used for prediction of natural gas consumption was neural network or techniques based on similar principles (like adaptive network-based fuzzy inference system). Neural networks are programs that, most often by the iterative process from the past data, try to find the connection between input and output variables of the

model in order to obtain the output value for the new input variables (Zekić-Sušac et al., 2009). Adaptive network-based fuzzy inference system (ANFIS) was presented by Jang (1993), which is "a fuzzy inference system implemented in the framework of adaptive networks". According to Azadeh et al. (2010), "ANFIS possess both the learning capability of neural networks and the structured knowledge representation employed in fuzzy inference system which is appropriate for nonlinear modelling and time series prediction".

Authors who used neural networks were Tonković et al. (2009), Kaynar et al. (2011), Demirel et al. (2012), Olgun et al. (2012), Taspinar et al. (2013), Soldo et al. (2014) Izadyar et al (2015) and Szoplik (2015). Tonković et al. (2009), Taspinar et al. (2013) and Kaynar et al. (2011) trained and tested two neural network algorithms – the multilayer perceptron and the radial basis function network with different activation functions. The first mentioned algorithm produced the smallest mean absolute percentage error in all analysed paper. Taspinar et al. (2013) also compared neural networks algorithms and time series model. In their research, Demirel and co-authors (2012) used multilayer perceptron algorithm for neural network and compared this model with 2 time series models. Olgun et al. (2012) compared neural networks with support vector machines. Taspinar et al. (2013) and Szoplik (2015) also used a multilayer perceptron algorithm in order to predict natural gas consumption. Soldo et al. (2014) investigated the influence of solar radiation on residential NG consumption. Among several different methods, they used neural networks on two different data sets. The first data set is from a model house and the second one from the local distribution company. Extreme learning machine (ELM), as a learning algorithm for feedforward neural network, was used by Izadyar et al. (2015).

Panapakidis & Dagoumas (2017) proposed an interesting model that combines the wavelet transform, genetic algorithm, adaptive neuro-fuzzy inference system and feed-forward neural network. They tried to test the robustness of a novel hybrid computational intelligence model in day-ahead predictions of natural gas demand. There was one more paper that combined two different models. Azadeh et al. (2015) created a hybrid model of adaptive neuro fuzzy inference system and computer simulation for prediction of natural gas consumption. The same authors (Azadeh et al., 2010) presented an adaptive network-based fuzzy inference system in their earlier research. The ANFIS was used by Kaynar et al. (2011) as well, in order to predict weekly natural gas consumption in Turkey.

Ma & Li (2010) predicted natural gas consumption based on the Grey system model. The same approach was using Boran (2015) – grey prediction with rolling mechanism (GPRM), Wu et al. (2015), and Zeng & Li (2016). According to Kayacan et al. (2010), "Grey models predict the future values of a time series based only on a set of the most recent data depending on the window size of the predictor".

Another commonly used techniques for natural gas consumption prediction are support vector machine (SVM) and support vector regression (SVR). Olgun et al. (2012) compared neural networks with support vector machines and they concluded that support vector machines had less statistical error for demand estimation of natural gas consumption. Soldo et al. (2014) used several linear and nonlinear models for predictions. The testing errors obtained by nonlinear neural networks and SVR models are slightly higher compared to linear models. Zhu et al. (2015) presented the method that integrated the SVR algorithm with the reconstruction properties of a time series and optimises the original local predictor by removing false neighbours. A structure-calibrated SVR approach was used by Bai & Li (2016).

Aras (2008) tried to forecast short-term demand of natural gas in residences by using genetic algorithms. Genetic programming technique was used by Forouzanfar et al. (2010) and Izadyar et al. (2015) as well.

Some authors used mathematical models in order to predict natural gas consumption. Gil & Deferrari (2004) developed a model which is able to predict the NG consumption 1 to 5 days in advance with 10% of uncertainty. Gutierrez et al. (2005) presented a stochastic Gompertz innovation diffusion model while Potočnik et al. (2007) forecasted NG consumption by using their model that is already used in several gas distribution systems. Brabec et al. (2008) developed nonlinear mixed effects model (NLME), a parametric statistical model which is later compared with two classical time series approaches. Several advanced linear and nonlinear mathematical models, such as exponential, Gompertz and logistic model, were used by Sabo et al. (2011). Forouzanfar et al. (2010) used a method based on the concept of the nonlinear programming with earlier mentioned genetic programming technique. Soldo et al. (2014) compared several linear models such as auto-regressive model with exogenous inputs and stepwise regression. Akpinar & Yumusak (2017) used multiple linear regression (MLR) for prediction of NG consumption.

There are several time series methods used for predicting natural gas consumption. Kaynar (2011) and Demirel (2012) used autoregressive integrated moving average (ARIMA). Taspinar (2013) also used type of ARIMA model, called SARIMAX, which is seasonal autoregressive integrated moving average model with exogenous inputs. Akpinar & Yumusak (2016) presented time series decomposition, Holt-Winters exponential smoothing and ARIMA.

Among other methods used for NG consumption predictions can be highlighted Baldacci et al. (2016), who defined two predicting techniques, one based on a nearest neighbour approach and one employing local regression analysis.

Table 3 shows a systematic overview of prediction methods used in predicting natural gas consumption by prediction area and prediction horizon.

Table 3. Number of papers per prediction method by prediction area and prediction horizon

Prediction method	Prediction area				Prediction horizon*					
	Country	Region	City	House	Y	S	M	W	D	H
Neural network	2	2	4	1	1			1	3	2
ANFIS	2							1	1	
Grey model	4				4					
SVM/SVR	2		2	1	1				3	
Genetic algorithms	1		2		1	1	2			
Mathematical and statistical models	4	2	2	1	3	1		1	5	1
Time series	1	2	1				1	1	2	
Hybrid models	2						1		1	
Other			1							

*Y – yearly, S – seasonal, M – monthly, W – weekly, D – daily, H – hourly

6 Overview of variables used for modelling

Various data sets were used to produce prediction models of NG consumption. Accordingly, authors used different input variables in order to create a model but it can be noticed that the most commonly used variables were past natural gas consumption and meteorological data (especially temperature). Those two input variables were used by Gil & Deferrari (2004), Sabo et al. (2011), Izadyar et al. (2015) and Baldacci et al. (2016). Following papers also used past NG consumption, but some other meteorological data as well. Potočnik et al. (2007) developed a short-term energy consumption model. The predicting model is based on observations of past gas consumption, past weather data, weather forecast, seasonal information, days of week, holidays, industrial nominations etc. Tonković et al. (2009) used similar input variables, such as month, season detection, day type (working day, holiday, day after holiday), day of the week, temperature, wind direction, wind velocity at different time and past gas consumption. Zhu et al. (2015) used past gas consumption, together with temperature, wind speed, effective temperature and pseudo seasonal normal effective temperature. Input variables used by Akpinar & Yumusak (2017) were past gas consumption, minimum, maximum and 1-day lagged average temperature, minimum and maximum humidity, holidays, number of subscribers, building size. Panapakidis & Dagoumas (2017) used past gas consumption, temperature, months and days of week. There are several papers where only past gas consumption was used as input variable: Gutierrez et al. (2005), Forouzanfar et al. (2010), Kaynar et al. (2011), Boran (2015), Wu et al. (2015), Akpinar & Yumusak (2016), Zeng & Li (2016) and Bai & Li (2016). Those authors mostly used grey modelling and mathematical models. Aras (2005) used for predictions consumer price index and average daily temperatures. Brabec et al. (2008) used temperature and day of the week. Similar variables can be found in Szoplik's paper (Szoplik, 2015). He used temperature, hour of the day, day of the week, month and day of month. For the prediction of natural gas demand, Azadeh et al. (2010) used day of week, demand of the same day in previous year, demand of a day before, demand of 2 days before as input variables. Demirel et al. (2012) used daily average temperature, squared temperature, natural gas price, number of gas subscribers, 12 lags of consumption, while Taspinar et al. (2013) used humidity, atmospheric pressure, wind speed, ambient air temperature and average cloud cover. Some authors included Gross domestic product (GDP) in their models. Ma & Li (2010) used GDP and past consumption, Olgun et al. (2012) used GDP and population, while Azadeh et al. (2015) used GDP, population, NG price, inflation rate, unemployment rate, IT/IS index, human development index and CO2 emission. Soldo et al. (2014) conducted an interesting research in which the influence of solar radiation on predicting residential natural gas consumption was investigated. The input variables they used were weather data (on hourly basis) and solar radiation.

From this analysis, it can be seen that past gas consumption is the most important input variable for prediction of natural gas consumption. It was used in largest number of papers, especially in papers where mathematical and grey models were presented. The important variables were also various meteorological data.

Table 4 shows the overview of number of papers by input variables used most frequently according to prediction method, area and horizon.

Table 4. Number of papers by input variables used according to prediction method, area and horizon

Input variable	Prediction method*									Prediction area**				Prediction horizon***					
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**Co**	**R**	**Ci**	**H**	**Y**	**S**	**M**	**W**	**D**	**H**
Past gas consumption	3	2	3	1	2	6	2	1	1	10	4	3		6	2	2	2	6	2
Temperature	6	1		2	2	6	2	1	1	5	4	7	1	1	1	2	1	10	3
Days of week	2					2		1		3	1	1					1	3	2
Month	2							1		1	1	1						1	2
Seasonal information	1			1		1				2	1						1	2	1
Wind data	2			1			1			1	2							2	1
GDP	1		1	1				1		3				2		1			
Holidays						2				1	1						1	2	
Humidity	1					1	1				2							2	
No of gas subscribers	1					1	1				1	1						2	
Gas price	1	1					1			1		1						2	

*A – neural network, B – ANFIS, C – Grey model, D – SVM/SVR, E – Genetic algorithms, F – mathematical and statistical models, G – time series, H – hybrid models, I – other

**Co – country, R – region, Ci – city, H – house

***Y – yearly, S – seasonal, M – monthly, W – weekly, D – daily, H – hourly

7 Discussion and conclusion

The aim of this paper is to present an overview of the latest papers that deal with predictions of natural gas consumption. In order to achieve this goal, the search of relevant scientific articles was conducted using scientific database Web of Science Core Collection. There was total of 27 papers that met required conditions. Those papers were analysed and then compared according to several criteria, such as methods used for predictions, input variables used for modelling, prediction areas and prediction horizons. Natural gas prediction models are complex models with high interdependency between its structural components, e.g. choice of appropriate method will be dependent on chosen prediction horizon or the use of the appropriate input variables will depend on the method used. The results of this paper show that the most common method used for predictions of natural gas consumption is neural network. Other popular methods are neuro-fuzzy inference system, time series methods, genetic algorithms, support vector machines/ regression, Grey system models, mathematical and statistical models or hybrid models based on several methods. Some researches use two or more methods in the same paper. But analysis has shown that for modelling, authors often use past natural gas consumption data and weather data (mostly temperature) as input variables. Other variables include month, days of the week, wind speed, number of natural gas subscribers, GDP, inflation rate etc. Speaking of prediction areas, it can be seen that most of the papers deal with the predictions on country level. Predictions can be made as well as on regional, city, or even house level. The analysis also revealed that authors mostly predict natural gas consumption on daily and annual level. There are only few papers that predict natural gas consumption on seasonal, monthly, weekly or hourly level.

Limitation of this study is reflected in relatively small number of analysed papers. For further research, authors plan to search more relevant scientific databases, such as Scopus or Proquest in order to obtain larger number of relevant sources. This paper could be helpful for other researchers who deal with predictions of natural gas consumption in order to create better and more accurate models.

Acknowledgments

This work has been fully supported by Croatian Science Foundation under Grant No. IP-2016-06-8350 "Methodological Framework for Efficient Energy Management by Intelligent Data Analytics" (MERIDA).

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The Mathematical Look at a Notion of the Compromise and its Ramifications

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Abstract. *This paper aims to define a measure which would capture notion of compromise on a given profile of voter preferences, about certain candidate being appointed to the certain position by some social welfare function. The goal is to define what compromise should mean, and proposes so called "d-measure of divergence" as a measure of divergence for some candidate to be positioned to certain position. Two well established social welfare functions, Borda and plurality count d-measure of divergence results are compared. Furthermore, d-measure of divergence enables us to define new social welfare functions, which would (in different ways) minimize d-measure of divergence (from the compromise): "Simple d-measure", greedy minimization and "Total d-measure" social welfare functions. Characterization for the SdM function is given, and properties of later two functions are analyzed.*

Keywords. Borda count, Plurality count, Social choice function, Social welfare function, Compromise

1 Motivation and basic definitions

Main inspiration for this article comes from following example. Let there is an election in which one hundred voters should choose between three candidates: A, B and C. Each voter places its vote by ordering those candidates. That ordering we will call a *preference*, and denote it α_i. Set of all preferences for those hundred voters, a *profile* α is given in Table 1, in which fifty one voters have preference $A \succ B \succ C$, while forty nine voters have preference $C \succ B \succ A$.

Table 1: Basic motivation profile

51	49
A	C
B	B
C	A

Given the profile α, which candidate should win? Most of the classical social choice functions would say - candidate A. Borda count would produce $A \succ B \succ C$ linear ordering, result of plurality count would be $A \succ C \succ B$ (with A winning the most first places, and B the least). Condorcet method would duel all candidates, and those duels would yield $A \succ B \succ C$ ordering. All those classical methods have one thing in common: winner should be candidate A. Nevertheless, that is a candidate that 49% of voters see as the worst choice. Should A then be a winner? What should be result if we approach to a profile α looking for *compromise*? If we want from social choice function to address notion of compromise, wouldn't it be better if candidate B is declared as a winner?

This leads us to the main topic of this article: finding a way for determining a value which should capture notion of compromise on a given profile, for placing a candidate on a certain position in linear ordering. Let us go back to the example in Table 1. If we take a look at candidate A, in a given profile he/she is placed first in 51 preferences, and placed third in 49 preferences. Therefore, in 51 preferences, distance between his position and the first place is 0 (places), and in 49 preferences that distance equals 2 (places). If we simply sum all those distances (for each candidate) over profile α, we would get a measure of distance between profile placements of a candidate and a first place. But, for a such measure, one can easily prove that ranking based on it gives result equivalent to Borda count.

What we want to do is to put some weight on those distances, so that bigger distance carries more than just its linear contribution. Therefore, we will take look on a distance with some power d, d being a real number greater than 1. If we sum such weighted distances from the first place over profile α for a candidate A, we get following expression:

$$51 \cdot 0^d + 49 \cdot 2^d, \qquad d > 1$$

We introduce notion $\beta_1^d(A)$ for such expression. For other two candidates we have:

$$\beta_1^d(B) = 51 \cdot 1^d + 49 \cdot 1^d = 100$$

$$\beta_1^d(C) = 51 \cdot 2^d + 49 \cdot 0^d = 51 \cdot 2^d$$

Value $\beta_1^d(M_i)$ for some candidate M_i we will call *a d-measure of divergence from the first position*. The idea is that smaller value of $\beta_1^d(M_i)$ captures notion of the greater level of compromise on a given profile for a candidate to be placed on a first place of linear ordering. Unlike distance function from works of (Seiford, Cook, 1978), we do not form measure of distance between preferences. Rather than that, we establish measure divergence from compromise (or consensus) that certain candidate should be positioned on certain position. But the goal is similar: it is a in society interest to minimize that measure. This leads us to the following basic definitions.

1.1 Basic definitions

Definition 1.1 (d-Measure of divergence from the first position)**.** *Let $M = \{M_1, ..., M_m\}$ be set of m candidates, and let $\alpha \in \mathcal{L}(M)^n$ be a profile of n voters over those candidates. We define* a d-measure of divergence from the first position *for a candidate M_k, $\beta_1^d(M_k)$, as a*

$$\beta_1^d(M_k) = \sum_{i=1}^{n} \left|\alpha_i^k - 1\right|^d \tag{1}$$

where α_i^k stands for a position of the candidate M_k in a preference of i-th voter α_i, and for some real value $d > 1$.

Now we can easily extend definition to a d-measure of divergence from a j-th position of the k-th candidate:

Definition 1.2 (d-Measure of divergence from the j-th position)**.** *Let $M = \{M_1, ..., M_m\}$ be set of m candidates, and let $\alpha \in \mathcal{L}(M)^n$ be a profile of n voters over those candidates. We define* a d-measure of divergence from a j-th position *for a candidate M_k, $\beta_j^d(M_k)$, as a*

$$\beta_j^d(M_k) = \sum_{i=1}^{n} \left|\alpha_i^k - j\right|^d \tag{2}$$

where α_i^k stands for a position of the candidate M_k in a preference of i-th voter, α_i, and for some real value $d > 1$.

Given the Definition 1.2, it is only natural to gather $\beta_j^d(M_k)$ values in a form of a matrix:

Definition 1.3 (d-Measure of divergence matrix)**.** *Let $M = \{M_1, ..., M_m\}$ be set of m candidates, and let $\alpha \in \mathcal{L}(M)^n$ be a profile of n voters over those candidates. We define* a d-measure of divergence matrix

$$M^d = \begin{bmatrix} \beta_1^d(M_1) & \beta_2^d(M_1) & \cdots & \beta_m^d(M_1) \\ \beta_1^d(M_2) & \beta_2^d(M_2) & \cdots & \beta_m^d(M_2) \\ \vdots & \vdots & \ddots & \vdots \\ \beta_1^d(M_m) & \beta_2^d(M_m) & \cdots & \beta_m^d(M_m) \end{bmatrix} \tag{3}$$

for some real value $d > 1$.

As we can see, in j-th column of a matrix M^d we have d-measures of divergence from j-th position for all candidates, while in i-th row of matrix M^d, we have d-measures of divergence from all positions for a candidate M_i.

1.2 Compromise as a Sorties paradox

Before we go further, let us say something about the value of parameter d. In the example given in the Table 1 we see that, if we want candidate B to have smaller d-measure of divergence from a first position than candidate A (which means, if we want candidate B to be declared a compromise winner on a given profile), it should be

$$\beta_1^d(B) < \beta_1^d(A) \quad \Rightarrow \quad d > \log_2 100 - \log_2 49$$

But, what is the value of d that should be used generally? Answering to that question requires finding an answer to the following version of a Sorties paradox (Hyde, 2014): Let us say that n voters are voting through strict linear ordering over the set of three candidates, $\{A, B, C\}$. For some $k \in \mathbb{N}$, $\lceil \frac{n}{2} \rceil \leq k \leq n$ they form profile α_{basic} given in Table 2.

Table 2: Basic definition profile

k	$n-k$
A	C
B	B
C	A

Let us accept reasoning that candidate B should be a compromise winner on profile α_{basic} given in Table 2 for $k = \lceil \frac{n}{2} \rceil$, and that candidate A should be a compromise winner on profile α_{basic} for $k = n$. Sorties paradox arises from question: what is the value of k for which we should consider candidate B a compromise winner on a given profile α_{basic}, while for value $k + 1$ a compromise winner should be candidate A?

This question can be seen as a version of a classical Sorties paradox given by Megarian logician Eubulides of Miletus about a number of grains which are (not) forming a heap. Phenomenon that lies at a heart of the paradox is recognized as the phenomenon of vagueness; the concept of heap appears to lack sharp boundaries, just as the concept of compromise winner does in our case. Nevertheless, we will approach to the issue not as to a paradox, but (same as Eubulides did) as a puzzle.

From statement that for a value of $k = \lceil \frac{n}{2} \rceil$ we have one candidate as a compromise winner on a given profile, while for a value of $k = n$ we have another candidate as a compromise winner, using the Least-number principle, we shall conclude that there is some k_0 between those two values, such that for k_0 compromise winner on a profile α_{basic} is a candidate B, and for

$k_0 + 1$ compromise winner is candidate A. Value k_0 should be result of an apriori social choice of a group which is about to use this model.

There are numerous situations in which similar social choices are being made. For instance, in a number of states two-third parliament majority is needed to make constitution changes, as opposed to simple majority needed for other type of decisions. So, why 2/3? Why not 3/4 or 4/7? Measure of majority needed for such constitutional changes represents similar social decision, as one presented in this paper – society decided where to "draw the line". Similarly, social decision should be made about value of k_0. When value for k_0 is determined, for d we have:

$$\log_2\left(\frac{n}{n-k_0}\right) < d < \log_2\left(\frac{n}{n-k_0-1}\right)$$

2 d-Measure of divergence from the first position

If we interpret d-measure of divergence from the first position as a measure of compromise for a social function choice winner selection, we can compare results of the classical social choice function. For instance, Borda count is usually considered as a social choice function that emphasize compromise candidate as a winner, especially when compared to the plurality winner. Does this thesis holds if we use d-measure of divergence from the first position as a measure for selection of the compromise candidate for a winner?

In this section we will provide an answer to that question. To do that, we will first consider three candidate scenario, followed by scenarios with more candidates. Let us consider following theorem:

Theorem 2.1. *Let α be a profile over the set of candidates $M = \{A, B, C\}$. Let W_{BC} stands for a unique Borda count winner candidate and W_{PC} for a unique plurality winner candidate (if there are such) over some profile α. For every $d > 1$ there is*

$$\beta_1^d(W_{BC}) \leq \beta_1^d(W_{PC}).$$

Equality holds iff $W_{BC} = W_{PC}$.

There is combinatorial proof of this theorem. Although there are six different preferences over the set of three candidates, number of all possible combinations of preferences that can form a profile can be reduced.

Table 3: Condorcet triplets: profiles α_1^C and α_2^C

1	1	1
A	C	B
B	A	C
C	B	A

1	1	1
C	A	B
B	C	A
A	B	C

Two profiles α_1^C and α_2^C (Table 3) we will call Condorcet triples. Those profiles consist of three preferences on which neutral and anonymous social choice function should form a tie (or a cycle) as a result. As Saari showed (Saari, 1994), all scoring point functions are invariant in regard of Condorcet triplet removal, which includes both Borda and plurality count. Furthermore, it is easy to prove that a d-measure of divergence from the j-th position preserves ordering among candidates when profile is reduced for the Condorcet triple.

Lemma 2.2. *Let A and B be any two candidates from the set of candidates M. For a d-measure of divergence from the j-th position β_i^d, and profiles α and α', α' being the profile derived from α by removal of one Condorcet triple, we have*

$$\beta_i^d(A, \alpha) < \beta_i^d(B, \alpha) \quad \textit{iff} \quad \beta_i^d(A, \alpha') < \beta_i^d(B, \alpha').$$

Since both Borda and plurality count, as well as d-measure of divergence from the j-th position relations among candidates, are Condorcet triple invariant, we can reduce a set of all possible combinations of voters preferences to a set of preferences without Condorcet triples. This means that largest profile we should analyze consists of (some number of) two preferences from α_1^C and two from α_2^C. Still, it is a large work, and here we will demonstrate it on one of such reductions.

Lemma 2.3. *Let α_1 be a profile over the set of candidates $M = \{A, B, C\}$, without any Condorcet triples. Furthermore, let α_1 be a profile of a form*

k	l	m
$\xi(A)$	$\xi(C)$	$\xi(A)$
$\xi(B)$	$\xi(A)$	$\xi(C)$
$\xi(C)$	$\xi(B)$	$\xi(B)$

ξ being some permutation over the set M. Then, for every profile α obtained as a union of α_1 and some number of copies of Condorcet triples α_1^C and α_2^C it follows

$$\beta_1^d(W_{BC}) < \beta_1^d(W_{PC}),$$

for some $W_{BC}, W_{PC} \in M$, winners by Borda and plurality count respectively over the profile α, where $W_{BC} \neq W_{PC}$ if such W_{PC} exists.

Proof: Without loss of generality, we can drop permutation function ξ. On a given profile, plurality winner can be candidate A or C. If A is plurality winner, it follows $k + m > l$. For A to be Borda winner it should have greater Borda score than C, so $2k + l + 2m > 2l + m$, ie. $2k + m > l$ which holds beacuse of plurality winning condition. Therefore, if A is plurality winner, then it is also Borda winner, which proves the Lemma.

On the other hand, if C is plurylity winner, then we have:

$$k + m < l. \tag{4}$$

For A to be Borda winner (compared to C), we have

$$2k + l + 2m > 2l + m \;\Rightarrow\; 2k + m > l. \quad (5)$$

Conditions (4) and (5) sums to $m + k < l < m + 2k$. For a profile α_1 and $d > 1$ for which d-measure of divergence form the first place for a candidate C is smaller than the one for the candidate A, must hold:

$$\beta_1^d(C) < \beta_1^d(A) \quad \Leftrightarrow \quad m + k \cdot 2^d < l.$$

But from the condition (5) follows: $m + k \cdot 2^d > m + 2k > l$, which leads to the conclusion that C can not have smaller d-measure of divergence from the first place than candidate A, which proves the Lemma. □

Similar lemmas can be proven for all combination of preferences that can form profile α' which does not contain any Condorcet triple. Together with invariance of Borda count, plurality count and d-measure of divergence from the first position, in regard to removal (or addition) of Condorcet triplets, follows the proof of Theorem 2.1.

In case with more than three candidates, similar claim can not be proven. If there is four candidates, there are profiles on which plurality count produces different winner than Borda count, and with smaller d-measure of divergence form the first position. Consider the following theorem:

Theorem 2.4. *Let $M = \{A, B, C, D\}$ be set of candidates, and let W_{BC} stands for a unique Borda count winner candidate and W_{PC} for a unique plurality winner candidate over some profile α. For every $d > 1$ there is a profile α such that $W_{BC} \neq W_{PC}$, and for d-measures of divergence from the first position there is*

$$\beta_1^d(W_{PC}) < \beta_1^d(W_{BC}).$$

It can be proven that for a profile given in the Table 4 and a given $d > 1$, there are values for m, i and j for which Borda winner (candidate B) has a greater d-measure of divergence from the first place than the plurality winner (candidate A). In such profile, values for m, i and j are determined by:

$$i > \frac{2 \cdot 3^d - 2 \cdot 2^d - 1}{3^d - 2 \cdot 2^d + 1},$$

$$\frac{2^d - 2}{3^d - 2^d - 1} \cdot i + \frac{1}{3^d - 2^d - 1} < j < i - 1$$

$$\text{and} \qquad m = 2i - j - 1.$$

Let us demonstrate construction of the profile on which Borda winner has a greater d-measure of divergence from the first position than a plurality winner in the following example:

Example 2.5. *Let $M = \{A, B, C, D\}$ be set of candidates, and let $d = 1.05$. According to Theorem 2.4, values m, i and j from a profile in Table 4, equal to $m = 44$, $i = 43$ and $j = 44$. On this profile plurality winner is candidate A, while Borda winner is candidate B (with Borda score 217, while Borda scores of candidate A and C equals to 216 and 212). d-Measures of divergence from the first place equals to:*

$$\beta_1^{1.05}(A) = (43 + 41) \cdot 2^{1.05} = 173.9245$$

$$\beta_1^{1.05}(B) = 44 + 41 \cdot 3^{1.05} = 173.9455$$

Table 4: Construction profile for Theorem 2.4

m	i	j
A	B	D
B	C	C
C	A	A
D	D	B

Construction from the Theorem 2.4 can be expanded to the arbitrary large set of candidates. With first four positions of the candidates that remain the same, all other candidates can be arbitrary placed below 4th position in preferences of the constructed profile. Analysis of such profile leads to the same conditions for construction as in the case with four candidates.

3 d-Measure social welfare functions

3.1 Simple d-measure of divergence function, SdM

As defined in Section 1, a d-measure of divergence enables new approach to the construction of the social choice and social welfare functions. Simplest, and the most natural way to use information about d-measure of divergence, is to address a d-measure of divergence from first position. In most cases, it is only important who is the winner on a given profile. Therefore, we can define social welfare function based only upon d-measure of divergence from a first position, ie. values in the first column of a d-measure of divergence matrix, M^d.

Definition 3.1. *Let $M = \{M_1, ..., M_m\}$ be set of m candidates, $d > 1$ real number, and let $\alpha \in \mathcal{L}(M)^n$ be a profile of n voters over those candidates. Let $M_\alpha^d = \left[\beta_j^d(M_i)\right]$ be a d-measure of divergence matrix. We define social welfare function $SdM : \mathcal{L}(M)^n \to \mathcal{L}(M)$ in following way: let us make strict linear ordering of d-measures of divergence from a first position for all candidates*

$$\beta_1^d(M_{i_1}) < \beta_1^d(M_{i_2}) < ... < \beta_1^d(M_{i_m}). \quad (6)$$

We define strict linear ordering implied by (6) as a result of a social welfare function SdM:

$$SdM(\alpha) = M_{i_1} \succ M_{i_2} \succ M_{i_3} \succ ... \succ M_{i_m}, \quad (7)$$

if such strict ordering exists. Otherwise, we say social welfare function SdC is undefined on a profile α.

Of course, social welfare function SdM induces a social choice function (we will use the same name for the function), as a function which declares a candidate with minimal d-measure of divergence from the first position as a winner on a given profile. Let us now see which properties does satisfy social choice function SdM.

It is fairly simple to prove that SdM is **anonymous** and **neutral** for all $d > 1$ (which means it symmetrically treats voters and candidates), and that social choice function SdM is **positively responsive** (**monotonic**) for all $d > 1$ (we say for a social choice function that it is monotonic, if a voters' increase of a candidate ranking in his / her preference can not prevent that candidate from winning an election).

There are two more properties of a SdM social choice function we want to point out, *reinforcement* and *continuity*. First of those two, reinforcement, Young calls *consistency*, and he proves that this property characterizes position scoring social choice functions. Later of two, continuity, is technical property needed for proof of position scoring social choice functions characterization (Young, 1975).

Definition 3.2. *Social choice function F satisfies* reinforcement *if, whenever we split the set of preferences α into two subsets α' and α'', and some candidate would win for both subsets, then it will also win for the full profile α:*

$$F(\alpha')\cap F(\alpha'') \neq \emptyset \quad \Rightarrow \quad F(\alpha) = F(\alpha')\cap F(\alpha'')$$

Definition 3.3. *Social choice function F satisfies* continuity *if, for disjoint profiles α' and α'', where is $F(\alpha') = M_1$, $F(\alpha'') = M_2$, there is a number $n \in \mathbb{N}$, such that for a profile α made (as a union) of n copies of profile α' and profile α'' we have $F(\alpha) = M_1$.*

Proposition 3.4. *Social choice function SdM satisfies **reinforcement** and **continuity** for all $d > 1$.*

Proof: Since SdM can have just one winner, we have to show that for some candidate $M_w \in \{M_1, ..., M_m\}$, $SdM(\alpha') = SdM(\alpha'') = M_w$, it follows $SdM(\alpha) = M_w$. For all $d > 1$ it follows

$$\beta_1^d(M_w, \alpha') = \min_{\text{j=1,...,m}} \beta_1^d(M_j, \alpha'),$$

$$\beta_1^d(M_w, \alpha'') = \min_{\text{j=1,...,m}} \beta_1^d(M_j, \alpha''),$$

where $\beta_1^d(M_j, \alpha)$ stands for a d-measure of divergence from a first position for a candidate M_j on profile α. On the other hand, for a d-measure of divergence from a first position for a candidate M_j on profile α, we have

$$\beta_1^d(M_j, \alpha) = \beta_1^d(M_j, \alpha') + \beta_1^d(M_j, \alpha'').$$

Now, it follows

$$\beta_1^d(M_w, \alpha) = \beta_1^d(M_w, \alpha') + \beta_1^d(M_w, \alpha'') =$$

$$= \min_{\text{j=1,...,k}} \beta_1^d(M_j, \alpha') + \min_{\text{j=1,...,k}} \beta_1^d(M_j, \alpha'') \leq$$

$$\leq \min_{\text{j=1,...,k}} \left(\beta_1^d(M_j, \alpha') + \beta_1^d(M_j, \alpha'')\right) = \min_{\text{j=1,...,k}} \beta_1^d(M_j, \alpha)$$

Therefore, M_w is SdM winner on a profile α.

To prove continuity, let us suppose that $SdM(\alpha') = M_1$, $SdM(\alpha'') = M_2$ for disjoint profiles α' and α''. Suppose $m_1, m_2 \in \mathbb{R}$ equals to corresponding d-measures of divergence from a first position for those two candidates:

$$\begin{aligned} m_1 &= \beta_1^d(M_1, \alpha') = \min_{\text{j=1,...,k}} \beta_1^d(M_j, \alpha') \\ m_2 &= \beta_1^d(M_2, \alpha'') = \min_{\text{j=1,...,k}} \beta_1^d(M_j, \alpha''). \end{aligned} \tag{8}$$

For all $d > 1$ we have that a d-measures of divergence from a first position over the profile α made of n copies of profile α' and profile α'', and for every candidate M_i there is:

$$\beta_1^d(M_i, \alpha) = \beta_1^d(M_i, \alpha'') + n \cdot \beta_1^d(M_i, \alpha').$$

Specially, for candidates M_1 and M_2 we have

$$\beta_1^d(M_1, \alpha) = \beta_1^d(M_1, \alpha'') + n \cdot m_1,$$
$$\beta_1^d(M_2, \alpha) = m_2 + n \cdot \beta_1^d(M_2, \alpha').$$

Now, we have to show, that there is a $n \in \mathbb{N}$, such that

$$\beta_1^d(M_1, \alpha) < \beta_1^d(M_2, \alpha)$$
$$\beta_1^d(M_1, \alpha'') + n \cdot m_1 < m_2 + n \cdot \beta_1^d(M_2, \alpha')$$
$$\beta_1^d(M_1, \alpha'') - m_2 < n \cdot \left(\beta_1^d(M_2, \alpha') - m_1\right)$$

Because of (8), it follows $k_1 = \beta_1^d(M_1, \alpha'') - m_2 > 0$ and α' for $k_2 = \beta_1^d(M_2, \alpha') - m_1 > 0$. Now, it is clear, that there is $n \in \mathbb{N}$ such that $k_1 < n \cdot k_2$, which proves continuity. □

With these properties, we are able to prove main theorem about SdM social choice function.

Theorem 3.5. *For all $d > 1$, social choice function SdM is positional score function over set of m candidates, with scoring vector $s = (0, -1, -2^d, ..., -(m-1)^d)$.*

Proof: Young gives characterization (Young, 1975) of the social choice functions F as a (generalized) positional scoring rule iff it satisfies anonymity, neutrality, reinforcement and continuity. Furthermore, it is easy to see that positional score for some candidate M_k over scoring vector $s = \left(0, -1, -2^d, ..., -(m-1)^d\right)$ is maximized iff d-measure of divergence from a first position $\beta_1^d(M_k) = \sum_{i=1}^n \left|\alpha_i^k - 1\right|^d$ from Definition 1.1 is minimized. □

From Theorem 3.5 we can conclude that there is a positional score function which produces a winner that has the smallest d-measure of divergence from a first position. But modeling social choice functions according to a d-measure of divergence doesn't end there. In fact, we got relatively simple result because we used only one parameter, a d-measure of divergence from a *first position*. This means that we used only data from the first column from a d-measure of divergence matrix M^d. Now, we will expand our approach, trying to interpret all M^d data through social choice (welfare) functions.

3.2 Greedy approach to a d-measure of divergence

Main goal in this section will be construction of social wellfare function through utilization of a d-measure of divergence from *all positions*, not just winning one. Probably the simplest way to do that is using greedy technique; first place in linear order we will assign to a candidate with smallest d-measure of divergence from a first position, second place we will assign to candidate with smallest d-measure of divergence from a second position (from the set of remaining candidates, of course), and so on. Although algorithm sounds reasonable, it can produce strange results. Let us examine following example.

Example 3.6. *Suppose α is a profile over the set of five candidates $M = \{A, B, C, D, E\}$ given with following table:*

38	3	10
A	E	B
B	B	C
C	A	A
D	C	D
E	D	E

and let $d = 2$. Similar example can be constructed for lower values of d, but in this case we use $d = 2$ for clarity.

In this case, candidate A is clear Borda, Condorcet and plurality winner. But, that candidate doesn't have the lowest d-measure of divergence from a first position. For $d = 2$, we have $\beta_1^2(A) = 52$, and $\beta_1^2(B) = 41$, so by SdM and greedy approach to the d-measure of divergence, candidate B will be selected as a winner. But what about other candidates in a result linear ordering of a social welfare function? Let us take look at a d-measure of divergence matrix:

$$M^d(\alpha) = \begin{bmatrix} 52 & 51 & 152 & 355 & \mathbf{660} \\ \mathbf{41} & \cancel{10} & \cancel{81} & \cancel{254} & \cancel{529} \\ 189 & \mathbf{50} & \cancel{13} & \cancel{78} & \cancel{245} \\ 351 & 175 & \mathbf{60} & \cancel{27} & \cancel{48} \\ 768 & 435 & 204 & \mathbf{75} & \cancel{3} \end{bmatrix}$$

In i-th column, lowest d-measure of divergence from the i-th place is marked bold. Therefore, result of greedy approach on this profile is ordering

$$B \succ C \succ D \succ E \succ A.$$

Intuitively, this result is just - wrong. More formally, this example clearly demonstrates lack of Pareto efficiency of greedy approach to d-measure of divergence. In a given profile, candidate A is placed higher than candidate D in all preferences. Yet, greedy approach positioned candidate A on the last place of linear ordering, and so even after candidate D.

There is a way to deal with this problem. Greedy method could be applied cumulatively. After picking a candidate with the lowest value of d-measure of divergence in first column of a matrix M^d, when one chooses a candidate for a second position in result ordering, one can choose candidate (among remaining ones) which minimize a sum of d-measures of divergence from first and second position. And so on.

If we apply cumulative greedy approach to a profile described in Example 3.6, in first column of the matrix M^d we would choose candidate B (with the lowest d-measure of divergence in the first column). After that, we would choose candidate A with cumulative d-measure of divergence in the first and the second columns equal to 103, and so on. If we proceed with that algorithm, we would end up with the final ordering $B \succ A \succ C \succ D \succ E$.

Stated such way, cumulative greedy approach offers a way of exploring the subject of social welfare functions build upon a d-measure of divergence, but we won't pursue it in this paper. Rather than that, we will try to find comprehensive method for minimizing a d-measure of divergence.

3.3 Total minimization of a d-measure of divergence

Instead of trying to minimize a d-measure of divergence from positions one by one, as we tried to do with greedy approach, we will now look at minimization of all d-measures of divergence at once. This means that we will look for linear ordering, among all possible linear orderings of candidates, which minimize sum of d-measures of divergence from all positions. Such unique ordering (if it exists) we will take as a result of Total d-Measure social welfare function, TdM.

Definition 3.7. *Let $M = \{M_1, ..., M_m\}$ be set of m candidates, $d > 1$ real number, and let $\alpha \in \mathcal{L}(M)^n$ be a profile of n voters over those candidates. Let $M_\alpha^d = \left[\beta_j^d(M_i)\right]$ be a d-measure of divergence matrix. Let* Sym($\mathbb{N}_m$) *be set of all permutations of set $\{1, 2, ..., m\}$, with elements $\xi_i, i \in \{1, 2, ..., m!\}$. We define social welfare function $TdM : \mathcal{L}(M)^n \to \mathcal{L}(M)$ ("Total d-Measure") in following way: let ξ_{TdM} be unique permutation of the set $\{1, 2, ..., m\}$ such that*

$$\sum_{i=1}^{m} \beta_i^d \left(M_{\xi_{TdM}(i)}\right) = \min_{j=1,...,m!} \sum_{i=1}^{m} \beta_i^d \left(M_{\xi_j(i)}\right) \quad (9)$$

We define:

$$TdM(\alpha) = M_{\xi_{TdM}(1)} \succ M_{\xi_{TdM}(2)} \succ ... \succ M_{\xi_{TdM}(m)}.$$

If there is no such unique permutation that satisfies equation (9), we say TdM is undefined on a profile α.

Remark 3.8. *In order to simplify notation, for a sum over a order of candidates (defined with a permutation ξ) on a given profile, and for some value $d > 1$,*

$\sum_{i=1}^{m} \beta_i^d \left(M_{\xi_{TdC}(i)}\right)$, *we will write*

$$\beta_{sum}^d \left(M_{\xi(1)} \succ M_{\xi(2)} \succ ... \succ M_{\xi(m)}\right) \quad or \quad \beta_{sum}^d(\xi).$$

For instance, if in Example 3.6, ordering of the candidates which has minimal sum of the d-measures of divergence would be $A \succ B \succ C \succ D \succ E$ with total sum 178. Notice that this ordering differs from result of SdM (and greedy) social welfare function, while it is same as result of Borda count. It is clear that TdM social welfare function doesn't have to produce winner with the lowest d-measure of divergence from the first position.

Before we go any further, let us establish basic property of TdM, that is, its asymptotic behavior. Unlike many other social welfare functions, it is not obvious that d-measure minimization over all orderings will produce an ordering which extremely dominate in a profile. In a way, following proposition is a version of the Young continuity condition, which was proven for SdM.

Proposition 3.9. *Let $M = \{M_1, M_2, ..., M_m\}$ be set of candidates, and let α be a profile, in which k_1 out of n voters have preference*

$$M_{\xi(1)} \succ M_{\xi(2)} \succ ... \succ M_{\xi(m)} \tag{10}$$

for some permutation over the set of candidates ξ, while other k_2 voters have some other preferences over the same set of candidates. If on a profile α number of k_1 voters increase (and consequently n), then there is some $k_0 \in \mathbb{N}$ such that for every $k_1 > k_0$ the result of social welfare function TdM is preference (10) for all $d > 1$.

Proof: Profile α can be written in general form:

k_1	$k_{2,1}$	$k_{2,2}$	$\cdots$	$k_{2,i}$
$M_{\xi(1)}$	$M_{\xi_1(1)}$	$M_{\xi_2(1)}$	$\cdots$	$M_{\xi_i(1)}$
$M_{\xi(2)}$	$M_{\xi_1(2)}$	$M_{\xi_2(2)}$	$\cdots$	$M_{\xi_i(2)}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
$M_{\xi(m)}$	$M_{\xi_1(m)}$	$M_{\xi_2(m)}$	$\cdots$	$M_{\xi_i(m)}$

for some number of preferences i, $i \leq k_2$, such that $k_{2,1} + k_{2,2} + \cdots + k_{2,i} = k_2, k_{2,1}, k_{2,2}, \cdots, k_{2,i} \in \mathbb{N}$. Let us now look how d-measure of divergence matrix M_α^d changes as k_1 increases. Places in matrix determined by ξ (that is, $\beta_1^d(M_{\xi(1)})$, $\beta_2^d(M_{\xi(2)})$, ..., $\beta_m^d(M_{\xi(m)})$) do not depend of k_1, so they remain the same. All other elements of M_d increases linearly as k_1 increases. Therefore, at some point $\beta_{sum}^d(\xi)$ will become minimal sum among all sums over permutations of the set of candidates M, which proves the proposition. □

Since TdM derives its result from properties of overall orderings, and not from properties of individual candidates, it is only natural to expect that properties based on a relationship between candidates would not always hold. Monotonicity is first of such properties. Suppose that α is profile over three candidates, A, B and C, which contains ordering $B \succ C \succ A$, such that A is TdM winner. If we swap positions of candidates A and C in that ordering to gain new ordering $B \succ A \succ C$, we will denote new profile with α'. Let us examine changes on a d-measure of a divergence matrix:

$$\Delta^d = M_\alpha^d - M_{\alpha'}^d = \begin{bmatrix} -2^d + 1 & -1 & 1 \\ 0 & 0 & 0 \\ 2^d - 1 & 1 & -1 \end{bmatrix} \tag{11}$$

From Δ^d we can read out changes in β_{sum}^d for various orderings (in notation, δ_{sum}^d) when we change profile from α to α'. Specialy, we have:

$$\begin{aligned} \delta_{sum}^d(A \succ C \succ B) &= 2 - 2^d \\ \delta_{sum}^d(B \succ A \succ C) &= -2 \end{aligned} \tag{12}$$

We can see that β_{sum}^d is reduced for both orderings, but reduction is greater for the ordering $B \succ A \succ C$ (for $d < 2$). So, to prove that social choice function TdM is not monotonic we should construct described profile α for which difference between β_{sum}^d of orderings $A \succ C \succ B$ and $B \succ A \succ C$ is lesser than difference between corresponding values of δ_{sum}^d.

In Table 5 non-monotonic change in one such profile (for d=1.15) is given; in the first profile TdM winner is candidate A, and after the change (in which candidate A swaps with candidate C for a higher position in one preference), TdM winner becomes candidate B.

Table 5: Non-monotonic profile for TdM and d=1.15

5	14	11
B	A	B
C	C	A
A	B	C

4	14	12
B	A	B
C	C	A
A	B	C

Example in Table 5 came from the analysis of three candidates scenario, which can be (without loss of generality) reduced to three cases, with candidate A winning on some profile α: 1) in preference $B \succ C \succ A$, candidate A swaps places with B; 2) in same preference candidate A swaps places with C; and 3) in preference $B \succ A \succ C$, candidate A swaps places with B. Analysis of the first case leads to conclusion that candidate A remains TdM winner.

Second case is described prior to Table 5. To draw a more general conclusion for all $d > 1$, we will analyze if there is a profile α such that (see (12)) difference $\delta_{sum}^d(A \succ C \succ B) - \delta_{sum}^d(B \succ A \succ C) = 4 - 2^d$ is greater than the difference $\beta_{sum}^d(B \succ A \succ C) - \beta_{sum}^d(A \succ C \succ B)$. We seek such a profile only for $1 < d < 2$, because in case of $d \geq 2$ candidate A remains winner.

Analysis of that scenario shows that such profile can be constructed for all $d \in \langle 1, 2 \rangle$, with construction rules similar to preference relations described in (Saari,

1994); each increase of certain preference in a profile does fixed change to the β^d_{sum}. This allows us to combine preferences in order to achieve certain distance in observed sums. We won't go into detail of that extensive analysis in this paper. Let us just point out that, values for d which are close to 2 yield non-monotonic profiles with much higher total number of preferences (voters). This can be interesting finding if we are considering usage of TdM social choice function in a smaller group of voters. Third case leads to similar conclusion, but this time for values of d greater than 2. Finding described profiles is relatively simple when value of d is close to 1 or very large, and it becomes more challenging when $d \to 2$. Even more, we have following result, which follows from analysis of a matrix Δ^d:

Proposition 3.10. *For d=2, social choice function TdM over set of three candidates is monotonic.*

Another important property of the social welfare functions is Pareto efficiency.

Theorem 3.11. *Social welfare function TdM is Pareto efficient for every value* $d > 1$.

Sketch of the proof: Suppose, TdM is not Pareto efficient, i.e. there is a profile α and two candidates A and B, such that is $A \succ B$ in all preferences of the profile, but $B \succ A$ in a result ordering of the TdM. Let us assume (without loss of generality) that candidate B is on the i-th position in the result ordering, and candidate A i the j-th position, $i < j$. Let us now analyze each of the preferences that form profile α. Since in each of those preferences A comes before B, we can assume that A is on the k-th position, and B is on the l-th position, with $k < l$. There are six different combinations of values i, j. k and l. For all of those combinations we analyze contribution of the analyzed preference to the β^d_{sum} for two linear orderings: one which by assumption minimizes β^d_{sum} over all preferences (with $B \succ A$ in the ordering), and one constructed from that ordering with swap of the positions for A and B. Analyzis shows that contribution to β^d_{sum} is smaller for the ordering which contains $A \succ B$, in all six preference types. □

4 Conclusion

In this paper we provided new approach to the notion of compromise on a given profile of voters preferences. For a compromise seen as a version of Sorties paradox, we provided definition of d-measure of divergence from the j-th position, which gives numerical value of divergence from a compromise that k-th candidate should be placed on j-th position in strict linear ordering of the candidates.

Even if Borda count is usually considered a social choice function which provides compromise result (especially when compared to plurality count), this statement holds only in case of three candidates scenario. If there are four or more candidates, there are profiles on which plurality count produces winner with lower d-measure of divergence from the first place than Borda count.

Next, d-measure of divergence enables us to define new social welfare functions, which would (in different ways) minimize d-measure of divergence (from the compromise): SdM, greedy minimization, and TdM social welfare functions. Characterization for the SdM function, as a scoring point social choice function is given. Since d-measure of divergence offers much richer ways for utilization, two more concept of d-measure of divergence minimization are introduced. But while greedy approach didn't produce encouraging results, there is a cumulative greedy approach which can lead to interesting results in future analyzes. Finally, we introduced concept of social choice function build upon total minimization of d-measure of divergence, and proved its basic properties: asymptotic behavior, lack of monotonicity and Pareto efficiency.

Acknowledgments

The research was supported by the University of Applied Sciences Velika Gorica.

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The ANP Representation of the BSC

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Abstract. *The development and empirical verification of the balanced scorecard (BSC) model, using the multi-criteria decision-making method (MCDM) called the analytic network process (ANP), are the key issues of the presented research. The research was based on a case study of modelling the BSC for Ydria Motors LL (YM), a manufacturing company. Findings from the empirical analysis showed that the BSC and the ANP are complementary methods. Therefore, it can be asserted that introducing the ANP to implement the BSC and vice versa, improved the decision-making approach and the quality of the obtained results.*

Keywords. analytic hierarchy process (AHP), analytic network process (ANP), balanced scorecard (BSC), decision-making, performance measurement systems (PMSs), strategy

1 Introduction

Organisations cannot successfully execute strategies if strategic analyses and formulations are poor (Hrebiniak, 2006). Among the number of approaches for measuring business performance, several have attained a dominant position, e.g. analytic hierarchy process (AHP; Saaty, 1980), analytic network process (ANP) (Leung, Lam, & Cao, 2006; Saaty, 2001) and balanced scorecard (BSC) (Kaplan & Norton, 2004).

The AHP is a theory of measurement through pairwise comparisons and relies on expert judgements to derive priority scales. The AHP helps analysts to organise theoretical aspects of a problem into a hierarchical structure, similar to a family tree. By reducing complex decisions to a series of simple comparisons and rankings, then synthesising the results, the AHP helps analysts to arrive at the best decision, and provides them with a clear rationale for the choices made (Saaty, 2008). In addition to the AHP, the ANP is a useful tool for prediction and for representing a variety of competitors with their interactions and their relative strengths to wield influence in making decisions (Saaty, 2001).

The ANP is employed to identify causal relationships (Janeš, 2014) of a BSC's strategy map (Rahimnia & Kargozar, 2016). The inclusion of a BSC provides a framework to ensure that all important criteria are examined and relevant ones are included in the decision model. The ANP provides a convenient means of including BSC indicator interactions and their prioritisation (Tjader et al., 2014). Both methods support the decision-making process (Saaty, 2001), and they have been used in combination with several additional statistical and managerial methods.

The specific objectives of this paper are:

- To briefly present methods used in developing the ANP-BSC model;
- To analyse the benefits of the proposed approach in combining the ANP and the BSC;
- To present an ANP-BSC model on a case study of Ydria Motors LL (YM).

The remainder of the paper proceeds as follows. In the next section, the conceptual background of the method used is presented. The methodology section presents construct operationalisation and validation procedures. This section is followed by the data analysis and results section, which discusses the testing of the proposed research methodology. The paper concludes with a discussion of the empirical findings and implications for research and practices.

2 Conceptual background

2.1 The Analytic Network Process

The AHP helps analysts to organise theoretical aspects of a problem into a hierarchical structure; it organises the basic rationale by breaking down a problem into smaller and smaller constituent parts. This then guides decision makers through a series of pairwise comparison judgments to express the relative strength or intensity of the impact of the elements in the hierarchy (Saaty & Kearns, 1985). The AHP faces certain limitations when the complexity of decision problems increases and interactions among criteria and sub-criteria are not implicitly covered (Saaty, 1980, 2001). To avoid these limitations, generally known as the rank-reversal problem, the ANP was developed by considering the dependency and

feedback among elements (Sipahi & Timor, 2010). The ANP is recognised as an improved or general form of AHP, and is capable of evaluating a wide range of criteria, including tangible and intangible factors that have a bearing on the outcome without bothering about their linear hierarchy. The ANP allows for complex interactions and influences among the various components of the decision problem, thus making it a better choice for studying more complex decision problems (Chung et al., 2016). The ANP brings all of the decision objectives, criteria, alternatives and actors, e.g. decision makers, into a single unified framework, and it facilitates the interaction and feedback of elements within groups-clusters (inner dependence) and between groups-clusters (outer dependence).

Building the ANP model requires defining the elements and their assignment to clusters, as well as their relationships, i.e. indicating the flow of influence between the elements. Like the AHP, the ANP is also founded on a ratio scale measurement and pairwise comparisons of elements to derive the priorities of selected alternatives (Saaty, 2001). The main function of the ANP is to determine the relationship of a network structure on the degree of interdependence. Once the measures are identified, the second most important question is the weightage that should be given to each particular measure in designing the model. For example, the BSC's measures are derived from the interrelated strategic objectives of the organisation; hence, in deriving their weightages, these relationships are quite useful (Thakkar et al., 2006). Therefore, influence is a central concept in the ANP. It is a useful tool for prediction and representation, and for representing a variety of competitors with their surmised interactions and their relative strengths to wield influence in making decisions. When the decision-making process involves attributes that have a dependency relationship, the problem should be modelled as an ANP (Saaty, 2001). Most complex real-world decision problems have numerous inter-dependent elements that can be captured and processed utilising the feedback and interaction capabilities of an ANP model (Saaty & Ozdemir, 2004; Tjader et al., 2014). According to Thakkar et al. (2006), the ANP is a multi-attribute decision-making approach based on knowledge, experience and perceptions of experts in the field. Even though it does not provide an optimal solution (from a cost perspective), it is valuable for decision making, involving intangible attributes that are associated with strategic factors (Saaty & Begičević, 2010). Use of the ANP approach provides the means to accommodate the interrelationships of organisational goals to determine the weightages for various BSC perspectives, and this makes the results more valuable and realistic.

Recently, contributors have applied the ANP in many managerial areas. Ravi, Shankar, and Tiwari (2005) combine the BSC and the ANP to conduct reverse logistics operations for end-of-life computers. Nakagawa and Sekitani (2004) utilise the ANP for supplier selection (Gencer & Gürpinar, 2007) and supply-chain performance evaluation (Jharkharia & Shankar 2007). Niemira and Saaty (2004) use the ANP for financial-crisis forecasting. Leung, Lam, and Cao (2006) use the AHP and the ANP to facilitate the implementation of BSC. Gencer and Gürpinar (2007) suggest that the user-friendly software would help managers apply the ANP more easily in decision making (Kadoić et al., 2016). Wu and Lee (2007) use the ANP for knowledge management strategy selection. Lin, Chiu, and Tsai (2008) utilise the ANP to find the most optimal dispatching method. The achievements of the ANP can be observed from its diverse applications and areas of usage such as economics, business, benchmarking, education, manufacturing, project management (Cheng & Li 2005), product development, sociology, politics, etc. (Begičević, Divjak, & Hunjak, 2007; Kuo & Lin, 2012; Moalagh & Ravasan, 2013; Tavana et al., 2013; Wudhikarn, Chakpitak, & Neubert, 2015).

2.2 The Balanced Scorecard

The most important management decision-making issues are strategic planning, strategic analysis and the evaluation of strategy execution. Organisations cannot successfully execute strategy if strategic analysis and formulation are poor (Hrebiniak, 2006; Janeš, 2014). However, managers struggle with closing the gap between strategy and actual results (Kumar Srivastava & Sushil, 2014).

Among a number of approaches for strategy execution monitoring, Kaplan and Norton (2004) achieved a dominant position with their BSC. Thus, the BSC system considers the traditional financial key performance indicators (KPIs) as well as leading KPIs of future performance. In this way, it provides key information about the activities of the managers (Janeš, 2014).

In addition to many benefits, the BSC approach has several critical deficiencies. Tangible 'proxies', such as defect and absenteeism rates, are used to capture the intangible attributes (Janeš, 2014). The BSC lacks dynamics and, consequently, lagging and leading indicators are listed at the same time; cause and effect are not separated in time; and no consideration is given to policies that could generate short-term results which may be completely different from those in the long term (Barnabè, 2011). Moreover, objective surrogate measures often inaccurately reflect intangible criteria. Nonetheless, subjective evaluations are vulnerable to accusations of favouritism, whereas objective measures may be perceived as transparent. Another critical consideration is how the weights of the subjective and objective criteria should be determined if both types of criteria are used in the BSC (Leung, Lam, & Cao, 2006).

Therefore, a number of researchers have tried to resolve some of the aforementioned deficiencies by applying a multi-criteria decision-making method (MCDM) such as the technique for order of preference by similarity to ideal solution (TOPSIS), AHP or ANP. MCDMs have a distinctive fitting to the weaknesses and complexions of the BSC, especially multiple criteria considerations (Bentes et al., 2012). Hence, the AHP has been empirically identified to add several advantages to the BSC such as multi-criteria prioritisation, comparative analysis of business performance, and qualitative and quantitative determination. It seems reasonable to suggest that the more complex the interactions, the greater the need to utilise the ANP (Leung, Lam, & Cao, 2006). Therefore, the ANP was suggested and used with the BSC to cope with the dependency issue as well as other deficiencies of the BSC. Moreover, the algorithm for the ANP accounts for all of the performance measures included in the BSC. This alleviates the negative influence of judgment biases when decision makers use the BSC as part of their performance management (Hu, Wen, & Yan, 2015).

3 Research methodology

The proposed approach uses the ANP and aims at identifying the causal relationships of a BSC's strategy map (Janeš, 2014; Rahimnia & Kargozar, 2016). Basically, what the method does is to estimate the importance of the relationships, and then select those relationships that are considered important according to a defined criterion.

The inclusion of the BSC provides a framework to ensure that all important criteria are examined and relevant ones are included in the decision model (Quezada et al., 2014; Tjader et al., 2014).

The methodological approach used in the presented research was based on a comprehensive review of academic and grey literature, a pool of the existing models, meta-analysis and a number of stakeholders' consultations. Further, it was based on background research, a literature review and an analysis of AHP, ANP and BSC characteristics.

The research was performed as a case study of modelling the BSC system for a manufacturing company and founded on the complementary use of qualitative and quantitative methods. A strategic map of the company that contains the causal relationships between its strategic goals and their respective KPIs has been set and confirmed with the YM Company's executive management (Bititci et al., 2006; Janeš, 2014).

In this paper, the objective was to analyse the benefits of the proposed approach of combining the ANP and BSC methods.

The method was carried out using the following steps (Quezada et al., 2014; Wudhikarn 2016):

1. With qualitative analysis and the designed BSC system (Janeš, 2014; Kaplan & Norton, 2004, 2012), a starting-point, i.e. identification of the strategic objectives, for the quantitative analysis was prepared.
2. Design of the ANP model. The strategic objectives (nodes) were grouped into the four perspectives (clusters) of the BSC. Only those arcs that corresponded to the identified cause-effect relationships were considered.
3. Pairwise comparisons were carried out. The objective was to obtain the importance of all nodes of one cluster in relation to every node of all other clusters.
4. The pairwise comparison process was used to build the comparison matrices and to obtain the corresponding priorities, which were input into the supermatrix. The proposed method uses the priorities of the relationships included in the supermatrix and the priorities of the nodes obtained from the limiting supermatrix.
5. Analysis of the network should be performed when the resulting network has nodes without arcs, which was not the case in the presented investigation.

4 The ANP-BSC model of the YM Company

The YM Company is organised as a competence centre that produces and develops machines, appliances and electric motors for home appliances.

The company's understanding of its business performance sustainability, which is based on comprehensive data tests and semi-structured interviews with the three YM Company's executive managers, contributed to the selection of the strategic goals in the BSC's perspectives. The strategic goals are arranged according to importance as stated by the executive management:

1. Financial perspective: Expansion of opportunities for revenue (Revenue), Cost efficiency, Net operating result, Return on assets (ROA).
2. Customer perspective: Competitiveness, High responsiveness, Reputation, Satisfied customers.
3. Internal process perspective: Development of products and devices (Development of PD), Process optimisation, Development of suppliers, Environmental protection.
4. Learning and growth perspective (LG): Competent managers, Organisation development, Innovation, Social responsibility.

The BSC model was designed with the involvement and consensus of the executive management in eight workshops (Janeš, 2014). The initial ANP model comprehended five perspectives

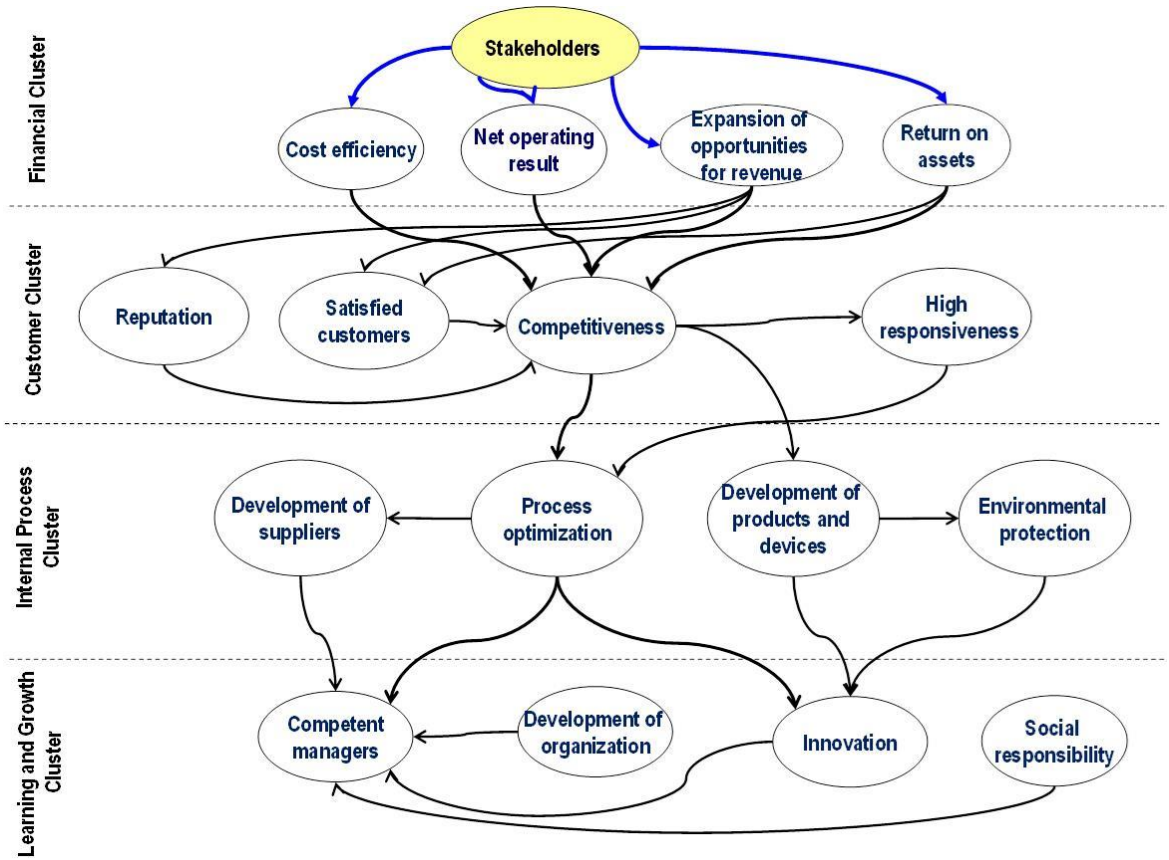


Figure 1. The ANP model with nodes and arcs

(clusters), which included strategic goals (nodes) with cause-effect relationships (arcs). The modelling process only considered relationships on the basis of grounded cause-effect relationships between strategic goals. The cluster, Vision, and its node, Stakeholders, have been added because of the financial perspective estimation, i.e. as an indicator that was comparing the goals of the top perspective. The model is designed based on the Super Decisions simple network template (Figure 1).

Table 1. Comparisons matrix of the financial perspective strategic goals in the ANP model

	Cost efficiency	Net operating result	Return on Assets	Revenue
Cost efficien.	1.0	2	3	0.5
Net operating result	0.5	1.0	2	0.3333
Return on assets	0.3333	0.5	1.0	0.25
Revenue	2	3.0	4	1.0

Note: Strategic goals (nodes) comparisons with respect to Stakeholders. Inconsistency ratio = 0.01160

In the next step, pairwise comparisons between nodes were carried out in order to obtain priorities. Pairwise comparisons were collected from the experts, i.e. with the involvement and consensus of the YM Company's executive management included in developing the ANP-BSC model. An example of the comparisons matrix of the strategic goals (nodes) is presented in Table 1. For each comparisons matrix, the inconsistency ratio was calculated, which was under the limit of 0.1 that must not be exceeded for pairwise comparisons to be reasonable. To this end, the pairwise comparisons for the nodes in each cluster that belong to a parent node were carried out for all the parent nodes in the model (Figure 1). In the presented research, all clusters that represent BSC perspectives are equally important. Thereafter, the unweighted and weighted matrixes were calculated.

In the presented simple, straightforward network of clusters, nodes and arcs, the process of obtaining the limit matrix is performed in order to raise the weighted supermatrix to powers until it stabilises, i.e. until all the columns in the matrix have the same values so the priorities of all nodes can be read from any column (Table 2).

Table 2. Limit matrix with priorities

Perspective-Cluster		Customer
	Strategic goal-Node	Competitiveness
Financial	Revenue	0.020300
	Cost efficiency	0.020300
	Net operating result	0.020300
	ROA	0.020300
Customer	Competitiveness	0.158562
	High responsiveness	0.046817
	Reputation	0.015420
	Satisfied customers	0.011165
Internal process	Development of PD	0.058423
	Process optimisation	0.042340
	Development of suppliers	0.028590
	Environmental protection	0.021127
Learning and Growth	Competent managers	0.106192
	Organisation development	0.020300
	Innovation	0.064771
	Social responsibility	0.020300
Goal	Goal	0.000000
Alternatives (fictive cluster)	ANode	0.324796

Note: The table presents only a part of the limit matrix, which actually contains all the same columns of the Priorities vector. The Vision cluster and the Stakeholders node are excluded because they only served the purpose of the financial perspective estimation. Even without the latter in the model, the priorities remain the same.

The Financial cluster with its nodes, Revenue, Cost efficiency, Net operating result and ROA, appears to have a relatively minor priority according to the limit matrix, which is not the case according to the interviews with the managers. The results from the limit matrix indicate that in the Customer cluster, the highest priority belongs to node Competitiveness (0.158562), which is the most important node among all nodes. Competitiveness is followed by High responsiveness (0.046817). This result is in accordance with the importance stated by the executive management. Reputation (0.015420) and Satisfied customers (0.011165) appear to have a relatively lower priority, which somewhat aligns with the company's ranking of the nodes. In the Internal process cluster, the highest priority node is Development of PD (0.058423), followed by Process optimisation (0.042340) and Development of suppliers (0.028590), which is in accordance with the importance stated by the executive management. Environmental protection has a low priority of 0.021127. In the Learning and growth cluster, the highest priority node is Competent managers (0.106192) followed by Innovation (0.064771), which surpassed Organisational development (0.020300). Namely, Organisation development is at the second level of importance according to executive management. Social responsibility has, according to management, a low priority. However, the analysis ranked it at the same level as Organisational development (0.020300). The cluster, Goal, and its node, Goal, were added for the purpose of ensuring that nodes from the same perspective were mutually compared in pairs, and that the clusters were compared in pairs with respect to the Goal. The fictive cluster, Alternatives, and its node, Anode, were added for the role of enhancing alternatives and, therefore, are not considered in the analysis.

5 Practical implications of the ANP-BSC model

One of the main areas that both the relevant literature and Kaplan and Norton themselves identified as critical is related to the identification, assessment and quantification of causal relationships, which are essential within the BSC (Barnabè, 2011). In this context, the causal relationships have been at the centre of survey interest, because they provide a better relationship model between the four BSC perspectives and their respective strategic goals, which are defined in a subjective way. Even though this way of working is widely accepted in practice, some studies have shown that the declared relationships are not necessarily valid. In order to overcome this situation, the proposed ANP provides a quantitative tool in order to establish the relationships between strategic objectives (Janeš, 2014; Quezada et al., 2014). After the semi-structured interviews with the executive managers, they established that the designed strategy map represented the company's strategy i.e. methods used were perceived firstly with some precaution, but later, when the findings were presented with approval and surprise. Namely the executive management was not convinced what to expect from investigation, but they confirmed that selected and empirically confirmed goals and their respective KPIs were supporting decision-making process (Figure 2; Janeš, 2014).

It should be noted that the arcs (Figure 1) were changed in the opposite direction from the BSC model cause-effect relationships. The ANP model indicated that if the managers' competencies and the development of suppliers were improved, then the process optimisation and labour productivity may improve. Similarly, to improve customers' satisfaction, it is necessary to improve the competitiveness of the optimised production processes.

The advantage of using ANP is that it allows for the inclusion of dependence and feedback on the strategic goals and perspectives in the strategic map. From a practical point of view, the presented method

is a good alternative for designing a strategy map of a company, which uses an ANP approach that has been successful in other areas of management. Therefore, it opens new possibilities for research. It should be noted that the presented ANP approach is in accordance with the findings of the Engle-Granger two-step method approach used in previous research performed by Janeš (2014).

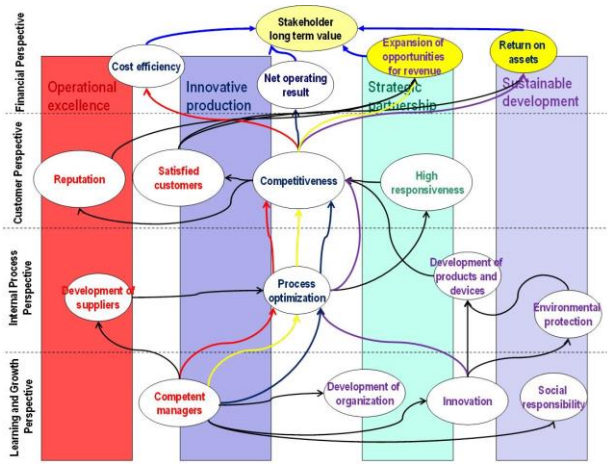


Figure 2. Strategic map of the YM Company
Source: Adapted from Janeš, 2014

6 Conclusions

The literature has identified the necessity to further define the concept of causality within the layout of the BSC, in the direction of relying on specific quantitative tools needed to convert the BSC into a mathematical model. Therefore, based on the reviewed literature, the main characteristics of this approach have been depicted and, in particular, the potentialities of using the ANP to explore the concept of causality in the BSC have been stressed.

A key finding in this research is that the development of the BSC, supported by the ANP, contributes to the explanation of causal relationships in the BSC system. However, it must be emphasised that the generalisation of the research findings was limited to only one manufacturing company. Based on the results, it is recommended that further research be oriented towards expanding the ANP-BSC to other companies, and to use the causal relationships to forecast the future trajectory of the strategy in order to generalise findings and acquire new knowledge.

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Leave one blank line after the abstract, and then begin the keywords. Use the word "Keywords." in 10-point Times, boldface type, left positioned, initially capitalized, followed by up to ten keywords in 10-point, separated by comma, as below.
Leave two blank lines after the keywords, and then begin the main text.

Keywords. CECIIS, conference paper, template

1 Introduction

This is an example of a Central European Conference on Information and Intelligent Systems (CECIIS) submission. These guidelines include complete description of the paper style including formatting, fonts, spacing, and related information for producing your proceedings manuscripts.

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All papers should be written in English, up to 8 pages long (approximately 20 000 characters), and arranged in the following order:

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- Body text (Main text)
- Footnotes
- Acknowledgements
- References

All printed material, including text and figures, must be kept within a print area of 16 cm (6.3") wide by 24.7 (9.7") high. Do not write or print anything outside the print area. Paper size is A4: 21x29.7 cm (8.3x11.7"). Margins (top, bottom, left, right) are 2.5 cm (1"). All *text* must be in a two-column format. Columns are to be 7.7 cm (3") wide, with a 0.6 cm (0.24") space between them. Text must be fully justified. Indent each paragraph by 0.5 cm (0.2").

The final submission has to be submitted in a single PDF file with all fonts that are used embedded, and also the source file (Microsoft Word, LaTeX - zip original files and images).

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The main title (on the first page) should begin 3,5 cm from the top edge of the page, centred, and in Times 18-point, bold face. Capitalize the first letter of nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, or prepositions (unless the title begins with such a word). Leave a blank line after the title.

5 Author Name(s) and Affiliation(s)

Author names and affiliations are to be centred beneath the title and printed in Times 10-point type. Author names should be in bold face. Multiple authors shall be grouped by affiliation as shown in the title above. Include also e-mail addresses in 9-point `Courier/Typewriter` face. Follow the author information by two blank lines before main text.

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As in this heading, they should be Times 12-point boldface, initially capitalized, flush left, with one blank line before, and one after. Use a hanging indent for long headings.

7.1.1 Third-order Headings (May Extend to the Next Line)

Third-order headings, as in this paragraph, are discouraged. However, if you must use them, use 10-point Times, boldface, initially capitalized, flush left, with one blank line before, and one after. Use a hanging indent for long headings.

8 Main Text

Type your main text in 10-point Times, single-spaced. Do not use double-spacing. All paragraphs should be indented 0.5 cm (0.2") except for the first paragraph in a section.

Be sure your text is fully justified—that is, flush left and flush right. Please do not place any additional blank lines between paragraphs.

8.1 Figures

All figures are to be included within the text. **Figure captions** are to be *below* the figures, in 10-point

Times (or a similar serif font), normal face. Initially capitalize only the first word of each figure caption.

Figures are to be numbered consecutively with Arabic numerals throughout the paper, for example: "Figure 1. Database contexts", and are referred to in the text as Fig. 1, Fig. 2, etc.

8.1.1 Illustrations, Photographs and Graphs

Illustrations, photographs and graphs are considered as figures. All graphics should be centred. Your artwork must be in place in the article (preferably printed as part of the text rather than pasted up). If you are using photographs and are able to have halftones made at a print shop, use a 100- or 110-line screen. Supply the best quality photographs and illustrations possible.

Pencilled lines and very fine lines do not reproduce well. Remember, the quality of the book cannot be better than the originals provided. The conference proceedings will be printed in grey scale, but you can provide images in colour since the papers will also be published on the web site of the conference.

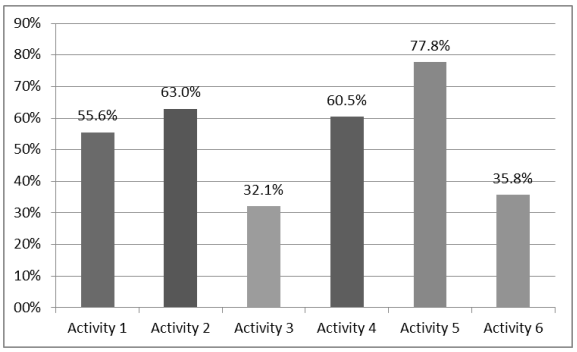


Figure 1. Times, 10 points, normal face

8.2 Tables

All tables are to be included within the text. **Table titles** are to be *above* the tables, in 10-point Times (or a similar serif font), normal face. Initially capitalize only the first word of each table title. Tables are to be numbered consecutively with Arabic numerals throughout the paper, for example: "Table 1. Input data", and are referred to in the text as Table 1, Table 2, etc. Column headings should be as brief as possible.

Table 1. Times, 10 points, normal face

	Column 1	Column 2	Column 3
Row 1	1	2	3
Row 2	4	5	6
Row 3	3	4	7
Row 4	2	6	4
Row 5	2	2	4

8.3 Equations

Equations should be numbered serially on the right-hand side by Arabic numerals in parentheses, and referred to in the text by eq. 1, eq. 2 etc.

$$3x^2 + 3x - 23 = 0 \quad (1)$$

8.4 Footnotes

Use footnotes sparingly (or not at all!) and place them at the bottom of the column on the page on which they are referenced.[1]

9 In-text Citations and Referencing

In-text citation must be used to denote all text used from another author(s) work or from authors previously published own work. When referenced in the text, enclose the author surname(s) and the publication year in brackets, for example (Surname, year) or (Surname, year, p. x) where x is the page number of the cited reference. When referenced paper has more than three authors, cite the paper as (Surname et al., year).

List and number all bibliographical references, alphabetically sorted, in 10-point Times, single-spaced, with a hanging indent, at the end of your paper. Use 6-point paragraph spacing after each reference. References should be distributed evenly in both columns as much as possible, so use a column break where appropriate.

In the References section below you will find examples of common types of bibliographical items: book (Mayer, 2009, p. 52), journal paper (Bule & Peer, 2014), journal paper with more than three authors (Shukor et al., 2014), conference proceedings paper (Steingartner & Novitzká, 2015), report or standard (*ISO/IEC 25010: Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models*, 2011) and web page ("Web Content Accessibility Guidelines (WCAG) 2.0," 2008). For other types of bibliographical items refer the **APA style guidelines**. It should be ensured that every reference cited in the text is also listed in the References section (and vice versa).

Acknowledgments

Acknowledgments, if necessary, should appear in a separate paragraph preceding the references.

[1] Use Times 8-point type, single-spaced. Avoid using footnotes altogether and include necessary peripheral observations in the text (within parentheses, if you prefer, as in this sentence).

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ISSN 1847-2001 (Print)
ISSN 1848-2295 (Online)