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.

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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]

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[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.
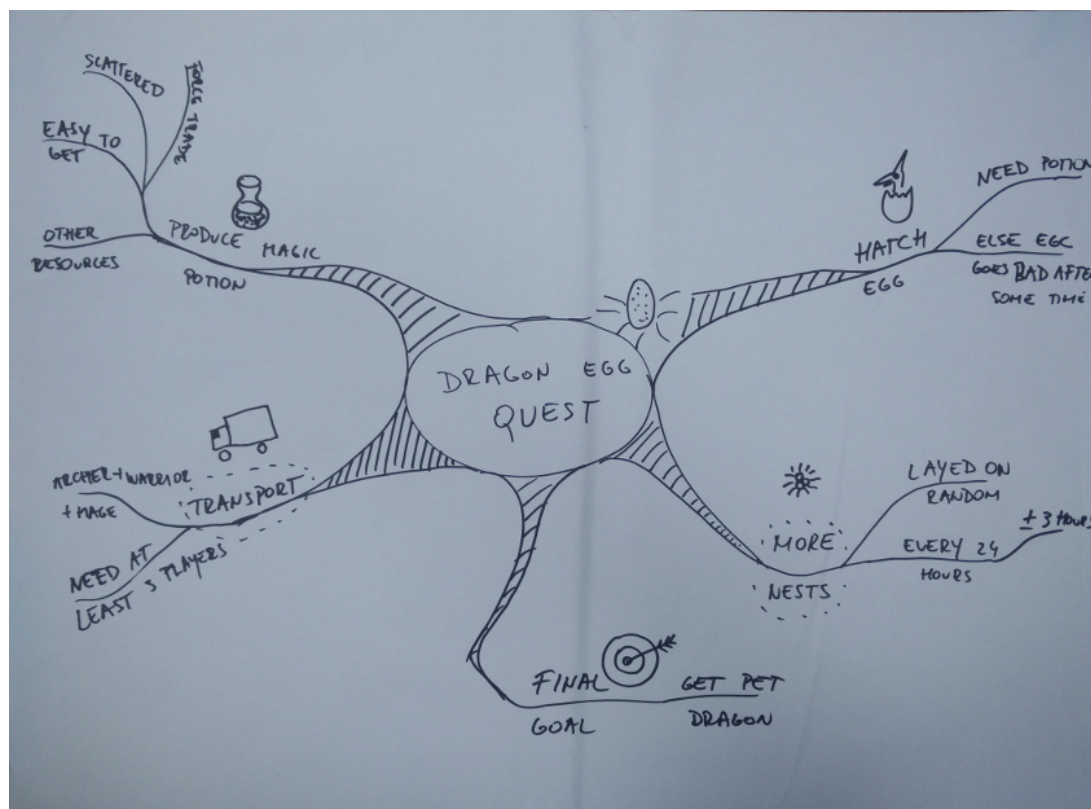
Figure 1. Hand drawn mind map of the developed quest

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

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[3] Available at http://dragon.foi.hr

[4] This Perl script was implemented by another very talented student Marin Rukavina.
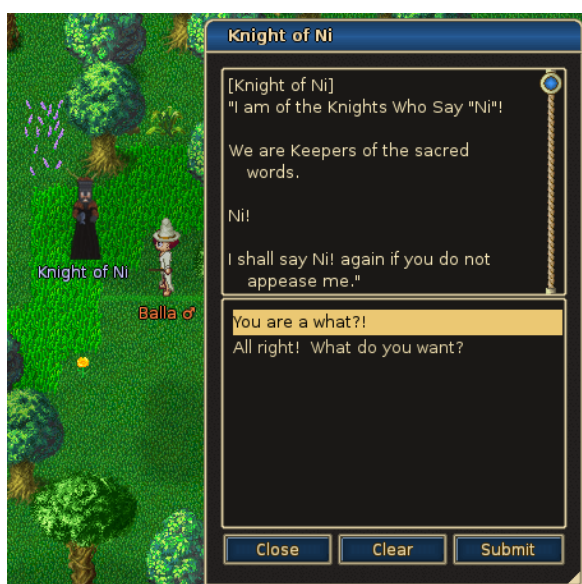
Figure 2. A TMW screenshot showing possible choices a player can make in a conversation, from (Schatten, Tomičić, et al., 2015)

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.

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[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-Đuric, 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)

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)

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.

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.

References

Aranda, G., Botti, V., & Carrascosa, C. (2009). MMOG based on MAS : The MMOG Layer. In *Proceedings of the 8th international conference on autonomous agents and multiagent systems* (Vol. 2, pp. 1149–1150). Budapest, HU: International Foundation for Autonomous Agents and Multiagent Systems.

Berry, M., Garcia-Blanco, I., & Moore, K. (2016). Press coverage of the refugee and migrant crisis in the eu: A content analysis of five european countries.

Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*, *99*(suppl 3), 7280–7287.

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in europe. *Journal of urban technology*, *18*(2), 65–82.

Chowdhury, G. G. (2003). Natural language processing. *Annual review of information science and technology*, *37*(1), 51–89.

Đurić, B. O. [Bogdan Okreša]. (2016). Organizational metamodel for large-scale multi-agent systems. In *Trends in practical applications of scalable multi-agent systems, the paams collection* (pp. 387–390). Springer.

Đurić, B. O. (2017). A novel approach to modelling distributed systems: Using large-scale multi-agent systems. In *Software project management for distributed computing* (pp. 229–254). Springer.

Đurić, B. O. [Bogdan Okreša] & Konecki, M. (2015). Specific owl-based rpg ontology. In *Central european conference on information and intelligent systems 26th inernational conference*.

Đuric, B. O. [Bogdan Okreša] & Konecki, M. (2015). Modeling mmorpg players' behaviour. In *Central european conference on information and intelligent systems* (p. 177). Faculty of Organization and Informatics Varazdin.

Đurić, B. O. [Bogdan Okreša] & Schatten, M. (2016). Defining ontology combining concepts of massive multi-player online role playing games and organization of large-scale multi-agent systems. In *Information and communication technology, electronics and microelectronics (mipro), 2016 39th international convention on* (pp. 1330–1335). IEEE.

Đuric, B. O. [Bogdan Okresa], Tomicic, I., & Schatten, M. (2016). Towards agent-based simulation of emerging and large-scale social networks. examples of the migrant crisis and mmorpgs. *European Quarterly of Political Attitudes and Mentalities*, *5*(4), 1.

Go, C. A. L., Basa, T., & Lee, W.-H. (2007). MMORPG Map Evaluation Using Pedestrian Agents. In M. S. Szczuka, D. Howard, D. Slezak, H.-k. Kim, T.-h. Kim, I.-s. Ko, ... P. M. Sloot (Eds.), *Advances in hybrid information technology* (Vol. 4413, pp. 323–332). Lecture Notes in Computer Science. Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-540-77368-9_32

Lofgren, E. T. & Fefferman, N. H. (2007). The untapped potential of virtual game worlds to shed light on real world epidemics. *Lancet Infectious Diseases*, *7*(September), 625–629. doi:10.1016/S1473-3099(07)70212-8

Maliković, M. & Schatten, M. (2015). Artificial intelligent player's planning in massively multi-player on-line role-playing games. In *Central european conference on information and intelligent systems* (p. 3). Faculty of Organization and Informatics Varazdin.

Schatten, M. (2016). Bigdata and the" new" science of networks. In *Data science croatia*.

Schatten, M. (2017). Modelmmorpg - agent-based models of massively multi-player on-line role-playing games. In *Ai with the best*.

Schatten, M., Đurić, B. O. [Bogdan Okreaša], Tomičič, I., & Ivkovič, N. (2017). Automated mmorpg testing–an agent-based approach. In *International conference on practical applications of agents and multi-agent systems* (pp. 359–363). Springer.

Schatten, M. & Đurić, B. O. [Bogdan Okreša]. (2016). Social networks in "the mana world"-an analysis of social ties in an open source mmorpg. *International Journal of Multimedia and Ubiquitous Engineering*, *11*(3), 257–272.

Schatten, M. & Đuric, B. O. [Bogdan Okreša]. (2015). A social network analysis of a massively multiplayer on-line role playing game. In *Modeling and simulation (mas), 2015 4th international conference on* (pp. 37–42). IEEE.

Schatten, M., Đurić, B. O. [Bogdan Okreša], Tomičić, I., & Ivković, N. (2017). Agents as bots–an initial attempt towards model-driven mmorpg gameplay. In *International conference on practical applications of agents and multi-agent systems* (pp. 246–258). Springer.

Schatten, M., Grd, P., Konecki, M., & Kudelić, R. (2014). Towards a formal conceptualization of organizational design techniques for large scale multi agent systems. *Procedia Technology*, *15*, 577–586.

Schatten, M., Seva, J., & Đuric, B. O. (2015). An introduction to social semantic web mining & big data analytics for political attitudes and mentalities research. *European Quarterly of Political Attitudes and Mentalities*, *4*(1), 40.

Schatten, M., Ševa, J., & Okreša-Đurić, B. (2015). Big data analytics and the social web: A tutorial for the social scientist. *European Quarterly of Political Attitudes and Mentalities*, *4*(3), 30–81.

Schatten, M., Ševa, J., & Tomičić, I. (2016). A roadmap for scalable agent organizations in the internet of everything. *Journal of Systems and Software*, *115*, 31–41.

Schatten, M. & Terna, P. (2016). From players to agents via the project modelmmorpg and the slapp simulation shell. In *Swarmfest 2016: 20th annual meeting on agent based modeling & simulation*.

Schatten, M., Tomičić, I., & Đurić, B. O. (2015). Multi-agent modeling methods for massivley multi-player on-line role-playing games. In *Information and communication technology, electronics and microelectronics (mipro), 2015 38th international convention on* (pp. 1256–1261). IEEE.

Schatten, M., Tomicic, I., Đuric, B. O., & Ivkovic, N. (2017). Towards an agent-based automated testing environment for massively multi-player role playing games. In *Information and communication technology, electronics and microelectronics (mipro), 2017 40th international convention on* (pp. 1361–1366). IEEE.

Scott, J. (2017). *Social network analysis*. Sage.

Seva, J., Đuric, B. O., & Schatten, M. (2016). Visualizing public opinion in croatia based on available social network content 1. *European Quarterly of Political Attitudes and Mentalities*, *5*(1), 22.

Tomičić, I. & Schatten, M. (2015). Towards an agent based framework for modelling smart self-sustainable systems. *Interdisciplinary Description of Complex Systems*, *13*(1), 57–70.

Tomičić, I. & Schatten, M. (2016). A case study on renewable energy management in an eco-village community in croatia–an agent based approach. *International Journal of Renewable Energy Research*, *6*, 1307–1317.

Tomicic, I., Schatten, M., Đuric, B. O., & Seva, J. (2016). Self-sustainable agent organizations in massively multi-player on-line role-playing games-a conceptual framework. In *Central european conference on information and intelligent systems* (p. 213). Faculty of Organization and Informatics Varazdin.

Van der Hoek, W. & Wooldridge, M. (2008). Multi-agent systems. *Foundations of Artificial Intelligence*, *3*, 887–928.

Xia, F., Yang, L. T., Wang, L., & Vinel, A. (2012). Internet of things. *International Journal of Communication Systems*, *25*(9), 1101.