Towards An Intelligent Model for Web Systems Development

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Abstract. *In recent years several studies were conducted exploring state of the practice and different issues in web and multimedia systems development. Data analysis in all studies were conducted using classical statistical methods giving limited insight into principles of web project management.*

This paper provides results of an additional analysis of data obtained in national study among over hundred web development companies. The data was analyzed with the advanced techniques like linear regression and learning in neural networks. Those techniques enabled us to identify new validity of the web project outcome in dependence on variables such as complexity of the web system, planned duration, existence of development process, etc.

Further, an intelligent model for web systems development is proposed which suggests desirable approaches to different web development phases, useful to both developers and clients. Our research results can also contribute to domain knowledge repository.

Keywords. intelligent model, data mining techniques, web project management, generative programming

1 Introduction

Nowadays the use of web sites goes beyond providing information, and enables users to do something (like buying a book), to collaborate (using blogs and wikis), to improve business operations (through intranets and extranets), or to access different online services with multimodal devices.

Thus, depending on the purpose and goals of the web site, its complexity has grown in terms of size, requirements, functionality, maintenance, and many of the technologies used. Web design aspects other than just graphic design are also taking place (e.g. information structure, user interface, program design, usability and accessibility), so that one person generally does not have all the necessary skills to build high quality large-scale web-based systems.

Still, among inexperienced designers and users the opinion is held that the web design and development process includes media editing and authoring, as well as some web-site testing. Many authors claim that such an ad hoc or "implement, test, release" approach is appropriate merely for developing simple brochureware web sites, but for building complex web-based systems it fails in many cases to deliver systems of acceptable quality [11], [15], [19]. Thus, the resulting web-based systems could experience low performance and/or failures, highlighted in the following problems [8], [15], [19]:

- the information needs of web-based system stakeholders (different visitors, organizations, persons who maintain the system) are not met;
- unsatisfactory level of aesthetic appeal;
- insufficient level of functionality and security;
- the system is not easily scalable and maintainable;
- development is behind schedule and exceeds budget estimates.

The reasons for these failures might be a lack of vision and planning, short-sighted goals, the absence of proper development approaches, methods and techniques, as well as poor project management [8], [19].

Managing projects has always asked for skills that enable project manager and its team to achieve goals with limited resources. Good balance of the three key elements, cost, time and quality, is essential to finalize the project succesfully. That principle is also applicable to web project management. Moreover,

web projects differ from software, advertising or traditional projects in several characteristics [2], [7] that make them even more complicated to manage.

Burdman [2, p.3] and Friedlein [6, p.8] outline the following web project characteristics:

- shorter project life cycle;
- project scope changes during all project stages, even during the implementation phase;
- standard pricing model for web projects does not exist;
- development approach is iterative and parallel (e.g. user interface design and programming can be done at the same time by different team members);
- new technologies are used, often with little or no technical support;
- fewer industry standards, lossely defined and prone to changes;
- project manager's skills and responsibilities are broader;
- team members perform multiple tasks and roles;
- communication problems with the client and within the project team because of different discipline background.

Considering all these characteristics, especially constant change in web projects, managing risks is fundamental to achieving good project outcomes. It is important to identify, analyze and assess the risks to override their negative implications [3, p.2].

Risks should be considered from the earliest project stages on both sides, clients and developers, because they can impact on project contract specifications. Clients need to make sure that they are hiring competent web development company and the web company's project manager needs to make sure that it has resources and knowledge to implement required web system.

Having all the above in mind, two research questions arose:

- can we anticipate web project outcomes based on project's characteristics and development phases and activities,
- is it possible to identify principles that are specific to web projects with the advanced datamining techniques, and create an intelligent model for the web systems development.

Our research is additionaly motivated by studies on different issues in web and multimedia systems development that enabled us to gain broader view of web development practice. One of the study was performed by authors of the paper among over hundred web development companies in Croatia. Results of that study, further presented in [17] and [18], and our experience in web projects, encouraged us to more deeply explore the context of the web systems development and to provide a richer understanding of web project principles.

2 Background

2.1 Predicting software project outcomes

Identifying success or failure factors in early stages of development lifecycle enables project managers to predict software development project outcomes. Researchers and practitioners have been searching for prediction models and tools that can accurately identify critical factors and provide advice to managers.

There are number of studies conducted on the technical and managerial aspects of software development projects. Most of them tested different case-based reasoning techniques to assess how well they performed with the datasets. Case-based reasoning (CBR) is the tool for predicting the outcomes of new problems based on the solutions of similar past problems. Here, two approaches are presented.

Mendes and associates explored in several studies [12], [13], [14] the usage of case-based reasoning techniques for estimating web/hypermedia development effort. In one study they generated prediction models on quantitative case study evaluation, measuring attributes of web applications (web application size, design and authoring effort, and confounding factors [12]). Further researches included using a dataset containing 37 web hypermedia projects developed by postgraduate students to predict the accuracy of three CBR techniques [13] and eight CBR techniques [14]. The emphasis of their studies is on comparison of CBR techniques on different research questions and identifying the best CBR approach (e.g. the technique that gave the most accurate predictions was Stepwise Regression, for all measures of prediction accuracy [14]).

Weber et al. [28] addressed qualitative managerial factors in predicting project outcomes by applying CBR techniques and logistic regression. Apart from identifying the most accurate technique, they detected potential predictor variables for project success.

2.2 The role of Generative Programming

Generative programming (GP) [4] is a discipline of Automatic Programming (AP) introduced, under this name, in the late 1990's. According to a definition, GP represents "...designing and implementing software modules which can be combined to generate specialized and highly optimized systems fulfilling specific requirements" [7]. GP strives to make application and the generator development process flexible and generated program code optimized.

We found GP as useful technique for automation of web systems development, because of their characteristics, which make them suitable for generating web systems modules:

- Web applications are usually splited into many program modules, containing different kinds of code: HTML, scripts in PHP and other scripting languages, CSS, XML, JavaScript, etc.
- There are usually many repeating parts in web applications: data entry forms are similar, just like associated program modules, data manipulation operations are same for different database tables, same way of information display using different templates and data structures. The repeating part of particular web application could also be repeating for many different web applications, so generators become some kind of knowledge base for making new applications,
- There is a problem of maintaining of such complex applications - change in one module often cause change in the another one, which could be managed by generator.

GP allows flexibility in web application development, so there is a possibility of making applications using more generators, each of them dedicated for appropriate task, like:

- User database administration,
- Data representation using templates,
- Specialized task like web questionnaires, different feedback forms, web tests etc.

The whole web application process based on GP implements Barry Boehm's spiral model of software development [1], as shown on Fig. 1.

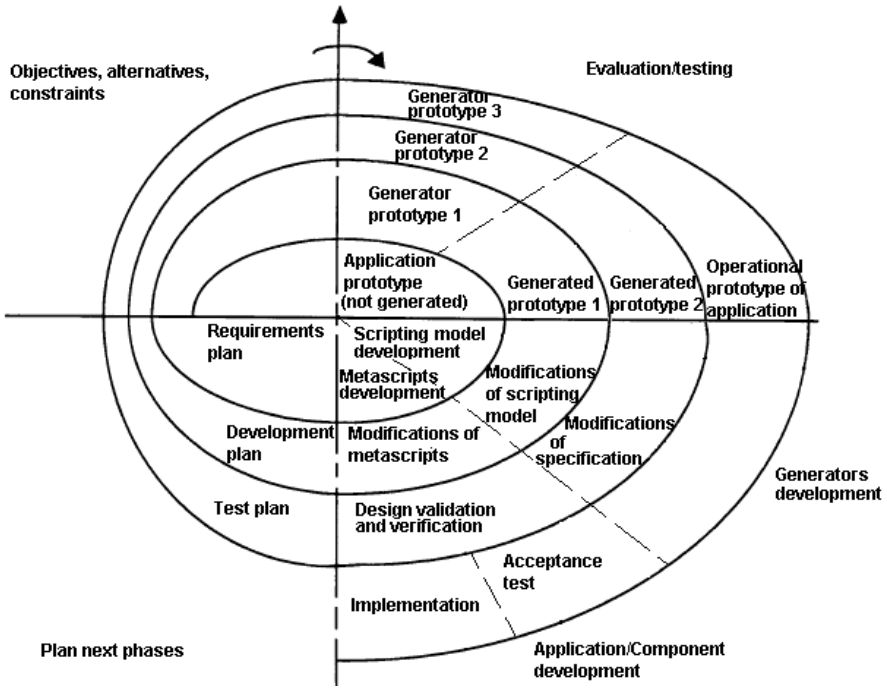

Figure 1: Generative application development as spiral development using the Boehm's model [22]

The main idea is to use existing generators as a knowledge base for development of new web applications. This could start from different starting point on a spiral (Fig. 1.) depending of the size of required modifications:

- in most usual cases modifications in application specification (sometimes could be performed by non-programmer) will fulfill all the needs,
- in more complex cases there is a need of program templates modifications. That does not affect the generator model (we used Generator Scripting Model, GSM [20]).

Changes in generator model (specification structure and configuration knowledge) are needed only if problem domain changed in a way that affect the program specification structure.

3 Research method

In order to deeply explore the paterns in the web systems management, we analysed data collected in our previous study on web/hypermedia systems development practice [17], [18] (research method for the study is also expained in those references). The objective of that study was to profile Croatian web designers/developers, to explore the characteristics of their projects, and to identify the development process and the activities and methods used in the development of web/hypermedia systems.

Although the study was national oriented, it can be comparable to a number of similar studies conducted worldwide, especially to one performed in Ireland [10], because it used the same but adopted and broadened Irish questionnaire.

The study provided quality data collected by a web survey from 101 web designers, developers and project managers from Croatia (23.7% response rate). The majority of 101 respondents answered to all 27 questions provided on 14 online screens. The answers were recorded in 171 fields and analysed with several techniques.

For the scope of this paper two analyses were conducted:

1. the first analysis – classical statistical methods were used to explore characteristics of web projects and to identify the level of problems that occur during web project life cycle;
2. the second analysis – advanced data mining techniques were used to validate the concepts of the first analysis.

Data mining is described as "... the principle of sorting through large amounts of data and picking out relevant information. It is usually used by business intelligence organizations, and financial analysts, but it is increasingly used in the sciences to extract information from the enormous data sets generated by modern experimental and observational methods. It has been described as 'the nontrivial extraction of implicit, previously unknown, and potentially useful information from data' and 'the science of extracting useful information from large data sets or databases' " [25].

Although, data mining techniques were used for predicting software project outcomes, as reviewed in the heading 2.1, their usage were not identified in neither of previous worldwide studies on web development practice [9], [22], [23], [24], [26], [27], [29].

Thus, for the the second analysis two data mining techniques were used: linear regression and neural networks.

Linear regression is used to unveil possible relationships between variables in number of fields, e.g. biological, behavioral and social sciences. We used multiple regression to determine the dependent variable as a linear function of the independent variables.

Neural networks [16] are being used as a tool for prediction and classification problems in wide variety of fields, e.g. accounting and finance, health and medicine, engineering and manufacturing, marketing, or for different decision making problems. They are gaining popularity in recent years and replaces traditional statistical techniques applied for prediction and classification.

One should have in mind that, from the perspective of creating a neural network model, the survey in Croatia included a relatively small sample size (101) because the total number of firms connected with Web development activities were also small (418 firms compiled from 5 business databases received an email message with the link to the web questionnaire). Also, in neural network modelling the problem of overfitting must be taken into consideration. This problem occurs when a statistical model describes a random error or noise instead of the underlying relationship. This generally happens when a model is a complex one, with too many variables, and the amount of available data is relativelly small. To avoid this problem several techniques (K-Fold cross-validation, overfit penalty) and software tools were tested (SAS JMP 7.0, Neural Ware Profiler, Weka) in order to choose the one that produces reliable results. In addition, a neural network model is not an absolutely accurate representation of a typical web project, but promising results can provide a strong direction for future research.

Therefore, we demonstrate the feasibility of a datamining analysis in web systems development practice and its potentials and usability. We believe that this research can provide substanatial scientific contribution, but also can be regarded as an initial research for the new area of the project management guided by usage of intelligent methods.

4 Analyses

4.1 Results of the first analysis

Detailed results of web development practice in Croatia are presented in [17] and [18]. Here, the focus is on overall characteristics of web projects:

- almost half of the respondents (46.5%) indicated that they mostly developed small web/hypermedia systems (up to 50 online pages/screens) while 38.4% of respondents developed large-scale systems,
- features that characterize most commonly developed web/hypermedia systems include database-driven web site, dinamically generated web pages and frequently significant changes to content.
- out of 98 respondents 39.80% indicated that their projects recieved at least one web award and two third of awarded respondents recieved that recognition more than once. We assume that this is good indicator for the quality of web systems,
- about 85% of respondents indicated that their organisation used a development process that had clear tasks and/or phases: in 62.38% cases the process used were not explicitly documented while in 22.77% cases the process were explicitly documented,
- the average web project team has 3 person of which two are web developers and one is web designer, who are primarily dedicated to this formal role. Significant number of companies (41.8%) is outsourcing additional developer, as well as audio/video producers (49.4% companies) and animation specialist (42,7% companies),

- the average web company is a small sized company with up to ten employees (80.20% of respondents),
- the average planned delivery time of web/hypermedia system was 8 weeks (5% trimmed mean = 7.8, median = 5.5), while the actual project duration was 11 weeks (5% trimmed mean = 11, median = 6). It was found that 60.61% of projects exceeded planned schedule, while project costs are far better managed than project schedules, with one-third of projects being delivered within the agreed costs and one-third of projects experienced cost over-runs.
- preparing accurate time and cost estimates is considered as major to the greatest problem for 38.3% respondents.
- out of 94 respondents, 51.1% reported written requirements specifications for the most recently completed project,
- only 37.2% of 94 respondents indicated that their companies use documented procedures or guidelines for web/hypermedia development.

These research results give only partial insight into the principles of web project management. Using only descriptive statistic techniques, it is not observable how critical is a particular factor on achieving project outcomes. Thus, second analysis was performed.

4.2 Results of the second analysis

For the purpose of the second analysis, which was performed with data mining techniques, we eliminated records with missing data in order to minimize data errors and provide more reliable predictions and learning. That reduced initial 101 dataset records to 76 records.

The goal is to model and analyse relationships between one dependent variable and more predictors, to get new validity in web projects. Based on the available data we try to explore how:

a) development activities outcomes depend on basic project characteristics,
b) web projects outcomes depend on basic project characteristics and development activities outcomes.

Dependencies are presented in Fig. 2.

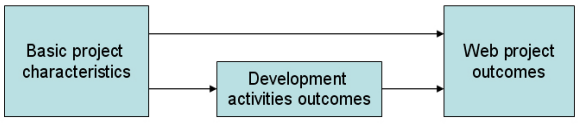

Figure 2. Basic model of dependencies in web projects

Now it is possible to create a set of models that are formalized by the following equation (eq. 1):

$$y_j = f_j(x_1, x_2, \ldots, x_i, \ldots, x_n), \text{ for } j = 1, \ldots, m. \quad (1)$$

Generally:

a) development_activities_outcomes = ***f*** (basic_project_characteristics)
b) web projects outcomes = ***f*** (basic_project_characteristics, development_activities_outcomes)

Firstly, from 171 data fields, the following variables are chosen to represent the model given in Fig. 2:

I) Basic project characteristics:

- Web company
  - organizational environment: county, type of organization (based on the description of the organization's services), number of employees,
  - usefulness of knowledge sources and learning form,
  - documented procedures or guidelines for hypermedia systems design/development,
- Web team members
  - professional discipline and role in the company,
  - experience in hypermedia design/ development: years and number of projects,
  - use of different design and development tools,
- Web team
  - size of the project team,
  - distribution of roles in the team,
- Web project
  - presence of development process,
  - usage of development methods and diagramming techniques,
  - features of the project: complexity of the web system, type of the web system, features of the web system,
  - project specification: written requirements specification (number of requirements, number of pages with requirements).

II) Development activities outcomes:

- opinions about importance of particular aspect in web development,
- problematic aspects in development and project management activities,

III) Web project outcomes:

- quality: number of awards on web competitions,
- duration (planned and actual),
- costs (planned and actual),
- secondary benefits: new knowledge, experience.

Second step is to identify useful models of dependencies among basic project characteristics, development activities outcomes and web projects outcomes. The scope of the paper limits us to present only one example of the web project outcomes, the project duration over-run, that was identified in 60.61% of respondent projects and presents great problem in web management.

Analyses were performed with classical linear regression method and then with neural networks. The software used for the analyses were SAS JMP version 7.0, which provides set of statistical tools as well as experimental design, business visualization and statistical quality control.

4.2.1 Linear regression model

One of the most common problem in web project is development behind schedule, as observed in [9], [15] and our prior research.

Our example tests how project duration over-run is related to another variables (predictors). The linear regression model is conducted from the following variables:

a) predictors: planned duration in weeks (DUR_PL), number of employees (NR_EMP), project team size (TEAM_SIZE), number of awards (NR_AWARD), complexity of the web system (COMPLEX), presence of development process (DEV_PROCESS), number of pages of requirements specification (NRSPECPAGE), documented procedures for design/development (PROC_DOC)
b) dependent variable: project duration over-run (DUR_OVER).

Formula (eq. 2) given by the linear regression is:

DUR_OVER = 1,4073355 -0,009684 * DUR_PL + 0,01828 * NR_EMP + 0,0326443 * TEAM_SIZE + 0,0073347 * NR_AWARD -0,030334 * COMPLEX -0,073223 * DEV_PROCESS - 0,001734 * NRSPECPAGE + 0,086671 * PROC_DOC (2)

Example 1. From the dataset of our prior research and eq. (2), exceeding of project duration is given. For the variables DUR_PL = 20, NR_EMP = 2, TEAM_SIZE = 6, NR_AWARD = 10, COMPLEX = 3, DEV_PROCESS = 3, NRSPECPAGE = 20, PROC_DOC = 2, estimated relative project duration over-run is 1,3474193 or 34,7%. The linear regression model Root Mean Square Error (RMSE) is 0,41794.

Parameters estimation is as follows (Table 1):

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1,407336	0,352096	4	0,0002
DUR_PL	-0,00968	0,008266	-1,17	0,2455
NR_EMP	0,01828	0,080547	0,23	0,8212
TEAM_SIZE	0,032644	0,029517	1,11	0,2727
NR_AWARD	0,007335	0,017415	0,42	0,675
COMPLEX	-0,03033	0,034199	-0,89	0,3783
DEV_PROCESS	-0,07322	0,071575	-1,02	0,31
NRSPECPAGE	-0,00173	0,004529	-0,38	0,7031
PROC_DOC	0,086671	0,115429	0,75	0,4554

Table 1. Parameters estimation of linear regression model

4.2.2 Neural network model

Many researches have been conducted to compare performance of the neural network models and traditional statistical methods. The most recent study [16] showed that neural networks outperformed the traditional methods used for prediction and classification (regression analysis, logistic regression and discriminant analysis) in about 58% of cases in various application areas. In about 49% of cases neural networks outperformed regression analysis. Additionaly, neural networks outperformed CBR techniques in all three cases being analysed.

Based on the variables from the previous example, we developed a neural network model of relative project duration over-run with 8 predictors in first layer and 3 variables in hidden layer (Fig. 3).

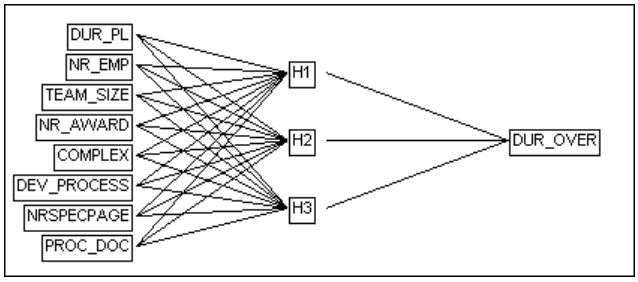

Figure 3. Neural network model of relative project duration over-run

The neural network presented as a result in this case was trained with the following parameters shown in table 2:

	Specify
Hidden Nodes	3
Overfit Penalty	0,001
Number of Tours	16
Max Iterations	50
Converge Criterion	0,00001

Table 2. Parameters of neural network model

The precision of the model is shown in table 3:

	Objective
SSE	0,000123409
Penalty	0,0392478542
Total	0,0393712632
N	13
Nparm	31

Table 3. Precision of the neural network model

The neural network error (RMSE) is 0,00196271.

By comparing results of performance in SAS JMP for both linear regression method and approximately the best neural network model, we can conclude that neural network model (RMSE = 0,00196271) outperformed linear regression method (RMSE = 0,41794).

4.3 Discussion

Using linear regression method and ”Fit Model” analysis in SAS JMP, it is possible to observe changes in dependent variable DUR_OVER.

On Fig. 4 two scattergrams illustrate correlations between variables. Note that the first scattergram shows almost none correlation of project duration over-run and number of employees, while the second scattergram illustrates small to medium positive correlation of project duration over-run and project team size, giving the prediction that biger web teams tend to exceed project schedule.

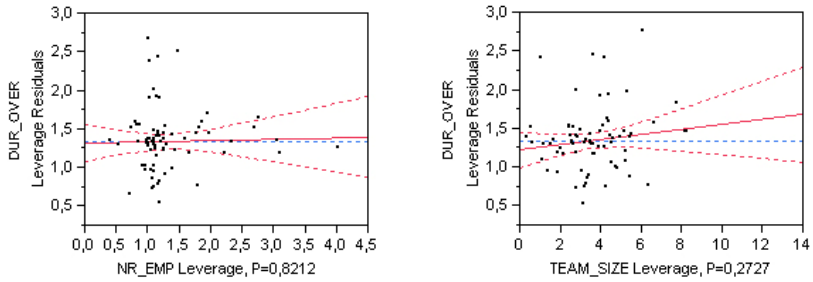

Figure 4. Correlations between dependent variable DUR_OVER and predictors NR_EMP and TEAM_SIZE

Comparing with the linear regression method, neural networks show greater ability of discovering validity in data. Fig. 13 illustrates all dependences of variable DUR_OVER for given predictors. By observing scattergrams on Fig. 4 and NR_EMP and TEAM_SIZE graphs on Fig. 5, it is notable that neural network recognize nonlinearity of the curves and more accurate render real dependence.

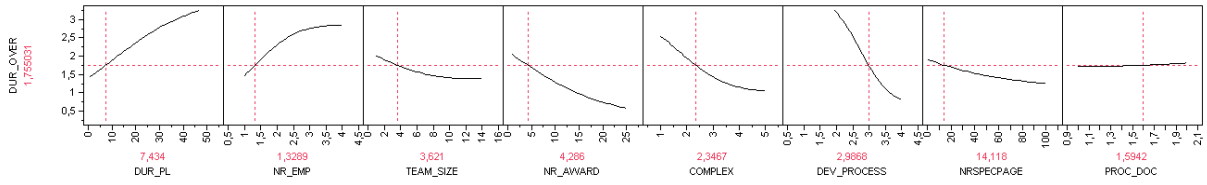

Figure 5. Dependences of variable DUR_OVER for given predictors

Usage of intelligent models has potentials in web project management for one of the crucial project management tasks: project duration planning and prediction of possible duration exceeding. Fig. 6 illustrates estimation of project duration over-run for some web team.

On the first layer parameters values are the same as in the *Example 1* (linear regression model). As a result neural network gives estimated relative project duration over-run DUR_OVER = 1,91704 or 92%.

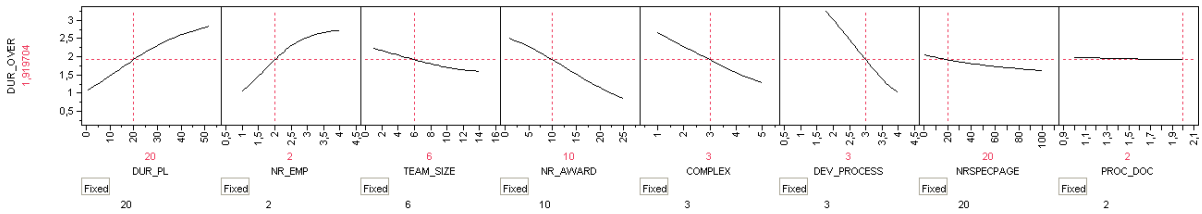

Figure 6. Estimation of project duration over-run for the web team X

With help of the presented graphs it is possible to observe which factor should be changed or influenced in order to lower the risk of exceeding project time schedule. Here, the solution is evident: by changing variable DEV_PROCESS from 3 (development process has clear tasks and/or phases, though the process used is not explicitly documented) to 4 (development process is explicitly documented), variable DUR_OVER is reduced to 1,01833 or 2%.

This example emphasis importance of managing web projects guided by documented development process.

5 Proposition of an Intelligent Model for the Web Systems Development

Web systems development is still young area with the lack of stable standards and norms as a consequence of dynamic web technology developments and specific characteristics of web systems, particularly aesthetic and cognitive ones.

Thus, there is constant need to follow current trends in web design and development, to implement some inovation and finaly, exchange the knowledge. The need for knowledge exchange is great, resulting in many forums, discussion groups, and social networks where designers and developers share common solutions, but mainly oriented to solving code or implementation problems. Project management problems are less discussed, although web project management is integral part of the web development and equaly important.

Therefore, it is essential to provide project managers with useful knowledge, not only by books or trial-and-error "learning-by-doing" on real projects, but also by providing intelligent models of best web project cases. Those models should be more useful than just descriptive knowledge because they would sumarize existing validity in web projects.

Our contribution is a proposal of an intelligent model for the web systems development based on data obtained in web survey from web developers and analyses with data mining techniques (Fig 7).

In the process of knowledge collection, solutions from discussion forums and surveys are used to build active libraries and repositories of components. Forums can help to find implicit/explicit solutions for problems in application design and management, while data mining techniques enable extracting valuable knowledge from different investigated sources.

Active libraries [Czarnecky, 1998] contain metaprograms that implement domain-specific code generation, optimizations, debugging, profiling and testing. Generative programming uses active libraries, together with feature specifications and configuration knowledge, in automating web systems building and maintenance.

Intelligent models of case problems propose the best graphic, navigation or layout design, optimization of performances etc. at design activities level and effective project management at management activities level.

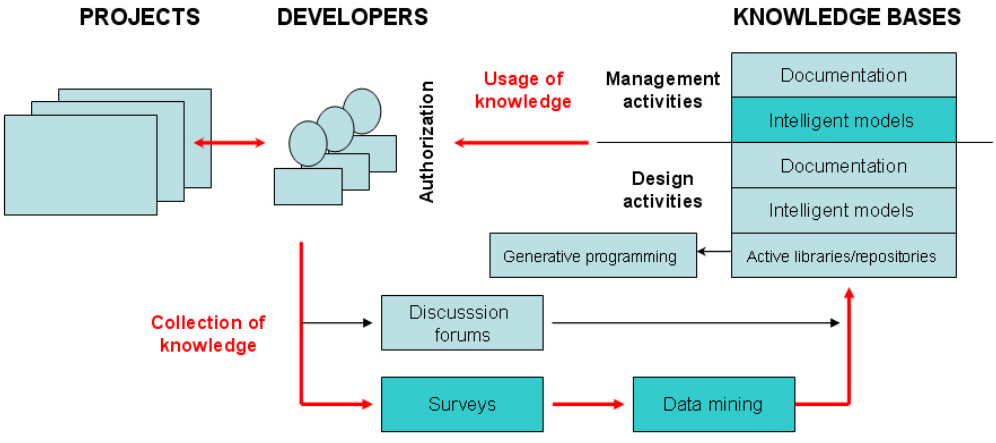

Figure 7. An intelligent model for the web systems development

6 Conclusions

This paper has outlined new analyses conducted on the data gathered on national representative survey about web development practice. The goal was to identify optimal method for determination of parameters which yield sucessful web project outcomes and was ilustrated on example of project duration over-run.

Analyses were performed with linear regression and neural networks methods. Both methods showed that it was possible to identify new validity in web project management, e.g. that web team enlargement influence on project duration over-run or that documented development process lowers project duration.

More accurate prediction is gained by neural networks and the primacy of this method has been confirmed in other researches [16]. However, since data mining techniques were performed on a dataset of study not primarily designed to discover development process variables and project management issues, but to gain a broader view of web development practice, some important parameters might have not been revealed by the second analysis. Also, some variables in the present analysis, e.g. the number of awards as one of the measures of web project quality, do not explicitly predict that a future project would gain an award. Instead, they give us tacit knowledge that in combination with other dependent variables, a future project would be of good quality and could receive recognition. Thus, a new study with specific variables that could unveil dependencies and give more acurate predictions, as well as further analyses, are needed to identify other important parameters for optimization of web project outcomes.

Another goal of the paper was proposition of an intelligent model for the web systems development based on data obtained in web survey and analyses with data mining techniques. Emphasis of the proposed model is on collection and usage of knowledge by web developers and managers. The model includes procedures for generating web systems modules, intelligent performance of complex functions and automatization of project management tasks.

Further researches of the model could include:

- additional studies of web management validities on bigger dataset and more focused research questions,
- analysis of data with different statistical and data mining methods to identify more accurate one,
- identification of the most appropriate knowledge presentation and how this knowledge is used in the process of decision making on web projects or in management activities (planning resources, managing risks etc.),
- integration with other processes in software development (conceptual design, generative programming),
- practical realization of an intelligent model to explore its usability in practice (e.g. integration in discussion forums).

In addition, future research may include a contribution to web knowledge repository creation, with knowledge on different levels and forms:

- white papers, forums, discussion groups,
- intelligent models of best web project cases, with a description of phases and activities,
- intelligent modules for generative programming.

This goal could be applicable not only to web management but to other areas as well.

We believe that the biggest challenge would be the creation of a Knowledge-Based Software Development Methodology for the acquisition of experiences and knowledge models, which would facilitate the knowledge-based economy and provide a new approach to the development of socio-technical systems.

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