International Journal for Quality Research 7(3) 3–14
ISSN 1800-6450

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Article info:
Received 17 May 2013
Accepted 25 August 2013

UDC – 65.018

ADAPTING E-COURSES USING DATA MINING TECHNIQUES – PDCA APPROACH AND QUALITY SPIRAL

Abstract: *This paper presents an approach to adapting e-courses based on original PDCA (Plan, Do, Check, Act) platform and quality spiral. An algorithm for the adaptation of e-courses was proposed and implemented into the Moodle Learning Management System at the Faculty of Technical Sciences, Čačak. The approach is primarily based on improving LMS (Learning Management Systems) or e-learning systems through modifying the electronic structure of the courses by predicting the behaviour patterns of the users. The prediction of user behaviour patterns was done using data mining techniques. Future research will focus on modelling of excellence of continuous advancement of the original system based on the evaluation results carried out at the end of each PDCA cycle. Additionally, future work will aim at evaluating the effects of the system based on the achievements and positive feedback of the users.*

Keywords: *e-courses, adaptation, data mining, PDCA, spiral quality*

1. Introduction

The expansion of e-learning has resulted in increased usage and advancement of learning management systems. The need for individualisation of learning has imposed new demands on learning management systems and their adaptation to the individual users' needs. In order to determine the characteristics of users' online behaviour (hereafter 'behaviour patterns') it is necessary to analyse all previous users' activities within a particular course and to make decisions accordingly.

Virtual learning environments in the form of a learning management system are becoming more prevalent in universities and provide a variety of features in the organization of the blended learning, but also in the implementation of all the classes online and through the facilitation of the process of lifelong learning. These systems have been recognized as a good pedagogical support for most of the activities that a student needs to carry out, with less effort, time and money, as well as the limitations of the approach. These systems provide many opportunities to work with students, and a variety of activities with the possibility of cooperation and verification of acquired knowledge through electronic tests. There are numerous commercial learning management systems Blackboard and WebCT. And there are free systems such as Moodle, Claroline and so on. One of the most popular free system is Moodle.

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Learning Management Systems (LMS) allow course administrators and teachers to access the statistics and usage of individual courses and to track users' activities on a course (Brockbank, 2003; Hollander, 2000; Mendoza *et al*., 2006; Naveh *et al*., 2010). The data existing in the learning management system log files undergo the analysis, which requires the use of specialised tools. Data mining has become a universal solution to successful screening of user behaviour patterns. Data mining or knowledge discovery in databases (KDD) represents an automatic extraction of implicit and interesting patterns from large databases (Klosgen and Zitkow, 2002).

User behaviour patterns discovered by data mining techniques provide a basis for e-courses adaptation. According to (Despotović-Zrakić *et al*., 2012), the adaptation of e-courses, which involves characteristics, knowledge, expectations etc., is the next stage in the development of the learning management system. The major objective is modifying a course so as to meet individual users' needs.

Quality spiral and the PDCA cycle ensure continuous improvement of e-courses in this study through their adaptation.

In this paper PDCA approach and quality spiral are used in order to improve e-courses of programming languages courses.

The structure of the paper is as follows. Section 2 includes a preview of similar investigations. Section 3 presents the framework. Section 4 provides purpose, tasks and goals. Section 5 presents a methodology for creating an adaptation system. The proposed adaptation algorithm and the implementation are given in Section 6. Final considerations are presented in Section 7.

2. Related Work

There are a large number of studies on the adaptation of electronic courses based on users' needs. In this chapter, we have singled out some of the studies involving data mining techniques and/or conventional PDCA approach and quality spiral. We have also provided similarities and differences resulting from the comparison between our study and other individual studies. The most significant similarities and differences are presented at the end of this chapter.

In their study on e-courses adaptation, (Despotović-Zrakić *et al*., 2012) used data mining techniques, more specifically clustering. The technique relies on membership of LMS users to some learning styles. Based on the characteristics of learning styles, the authors performed the course adaptation by offering teaching material, different activity types and deadlines for completion of tasks. The results of the group of students attending the adaptive courses were compared with those of the control group.

Compared with the study of Despotović-(Zrakić *et al*., 2012), in the investigation presented here the neural networks technique was used, and the students were not classified into groups. Data mining techniques enabled the improvement of the reporting system. The improved reporting allowed us to make an e-course adaptation according to a predetermined algorithm. In addition, the PDCA approach was included in order to improve continuously quality of E-learning.

Romero *et al*. (2007) suggested that the use of data mining in e-learning is an iterative procedure, which retrieves useful information by using a large number of data, and thus facilitating decision-making. The authors described in detail the procedure of application of data mining techniques in e-learning and provided the references. Special emphasis was on the Moodle learning management system. As in (Romero *et al*., 2007), our study was done using Moodle LMS, the iterative procedure being shown via the PDCA cycle.

In (Guo and Zang, 2009) a framework is proposed that utilises data mining algorithm

for representing and extracting a dynamic learning process and learning pattern to support students' deep learning, as well as to improve tutoring and collaboration in a web-based learning environment. Experiments proved that it was feasible to use the method to develop a valuable individual web-based learning system.

In their study of e-courses adaptation, (Guo and Zhang, 2009) used data mining algorithm for representing and extracting dynamic learning process and learning pattern to support students' deep learning, and to improve tutoring and collaboration in a web-based learning environments. Experiments proved that it was feasible to use the method to develop a valuable individual web-based learning system. Their study, the results of which are presented for the given case, points to the improvement of the existing learning management system, which is enabled to perform the adaptation, contrary to the system currently used.

Learning management system can also be adapted so as to meet the abilities and preferences of the participants (Markovic *et al.*, 2011). In their paper, the authors apply a system that does not involve evaluation according to predetermined standards, but depends on the individual characteristics of students. This paper highlights another dimension of adaptation which, in addition to adjusting teaching materials, encompasses the adaptive way of evaluation of students' achievements. According to the report of (Markovic *et al.*, 2011), such an approach allows modernisation of both learning and teaching. Similarly, in our research, after a single PDCA cycle within the quality spiral, it is possible to change the adaptation algorithm if necessary, so that each subsequent cycle depends on the results of the previous evaluation.

Wang and Liao (2011) used both data mining and neural networks techniques for adaptive language learning. The created system segments and transforms teaching materials into modular learning objects, according to users' features, such as gender, personality types and anxiety level. In our investigation, identical techniques were also employed. However, the adaptation was correlated with the activities on the course and their utilisation over the previous period.

In contrast to (Chen, 2008) and (Seters *et al.*, 2011), this paper does not address the adaptation of learning paths. However, similarly to (Chen, 2008) it uses an intelligent system, which makes inferences based on previous behaviour of the users. The similarity in the approach to Chen refers to the adaptation of teaching material and the presentation, whereas the difference is reflected in the approach. Chen (2008) uses pre- and post-testing, whereas in this examination the results are grounded only on the records of student activities.

In addition to the studies above, there are a number of papers addressing the adaptation of e-learning via conventional PDCA cycle and quality spiral, as shown in this paper.

Walasek *et al*. (2011) propose conventional PDCA approach for planning, description, design, implementation and evaluation of e-courses. They suggest that documents be created using Deming cycle, which is a precondition for high-quality e-courses. The study of Walasek et al. bears a large number of similarities to our study in terms of the PDCA cycle implementation. The stages above and the contents are in agreement with stages in this paper, the only difference being that the creation and evaluation do not apply to materials but to the adaptation of e-courses by presenting the appropriate modules.

In their study of learning management systems, (Tsubaki *et al.*, 2012) report that conventional PDCA cycle is one of the relevant methods for learning management. In addition, the paper presents the model for designing effective learning activities by using the PDCA cycle. Compared with the study of Tsubaki et al., in our examination PDCA was used for the same purpose (obtaining effective learning activities), the

emphasis being on adaptation of teaching materials already created.

The PDCA approach was also used in (Blagojević and Micić, 2012) (in press) for the creation of an intelligent system for reporting on the activities on the Moodle Learning Management system. This approach permitted proper evaluation of the system, which provided a basis for this study. Based on the system, this paper presents a segment addressing the adaptation of teaching materials, i.e. their presentation in e-courses, towards the realisation of an adapted model of excellence.

The analysis of papers dealing with the application of the original PDCA model and quality spiral and adaptation of e-learning in respective scientific fields highlights some similarities and differences.

Similarities:

- Our study has improved the existing systems through the stages of the PDCA model, as presented in (Walasek *et al.*, 2011; Tsubaki *et al.*, 2012; Blagojević and Micić, 2012).
- The PDCA model was used to improve e-learning.
- The improvement was made in the area of e-learning adaptation as presented in the papers of Despotović-Zrakić *et al.*, 2012; Romero *et al.*, 2007; Markovic *et al.*, 2011; Wang and Liao, 2011; Seters *et al.*, 2011; Chen, 2008).

Differences:

- Unlike (Despotović-Zrakić *et al.*, 2012; Romero *et al.*, 2007; Markovic *et al.*, 2011; Wang and Liao, 2011; Seters *et al.*, 2011; Chen, 2008), we used the neural networks technique for the adaptation of teaching materials.
- Compared with the papers above, the adaptation refers exclusively to the method of displaying teaching materials.
- Based on the original PDCAdapting model, a modified model of excellence was designed comprising of 12 key elements (including EFQM innovation and standardisation platform in IT, in compliance with the E-learning standards, or more specifically *ISO/IEC 19796-1* and other ISO/IEC JTC 1/SC 36 standards).

3. Framework and proposed quality spiral

The establishment of a quality system is essential in all areas of human endeavour, particularly in education, which has a major influence on the development of society as a whole. The expansion of e-courses at universities raises the question of providing quality e-courses and their continuous advancement. According to (Jara and Mellar, 2009), ensuring quality e-learning has received much attention.

Higher education institutions in Serbia are using standards that are directly related to quality insurance, i.e.

- Self-evaluation and quality assessment standards in higher education institutions
- Standards and procedures for external quality assessment in higher education institutions

The standards above require ensuring quality in e-learning environments, i.e e-courses. Besides, quality insurance needs to be in compliance with the European standards and regulation available on the website of the Institute of Standardization of Serbia (http://www.iss.rs). The models proposed in our study refer exclusively to higher education institutions in Serbia.

The proposed model of quality insurance is based on conventional Deming PDCA cycle (Deming, 1982) and quality spiral.

The existing Moodle learning management system provides neither intelligent reporting nor e-courses adaptation. The introduction of an intelligent reporting system and subsequent adaptation of courses allows continuous improvement of e-courses, ensuring quality through the PDCA cycle. Figure 1 shows the proposed quality spiral

using the PDCA cycle as well as the activities in each phase of the cycle. Each of the phases (Plan, Do, Check Adapting) shows the starting point, i.e. P_{t1}, D_{t1}, C_{t1} i A_{t1} in time t1. The spiral follows the cumulative costs and current state at every stage and point on the spiral.

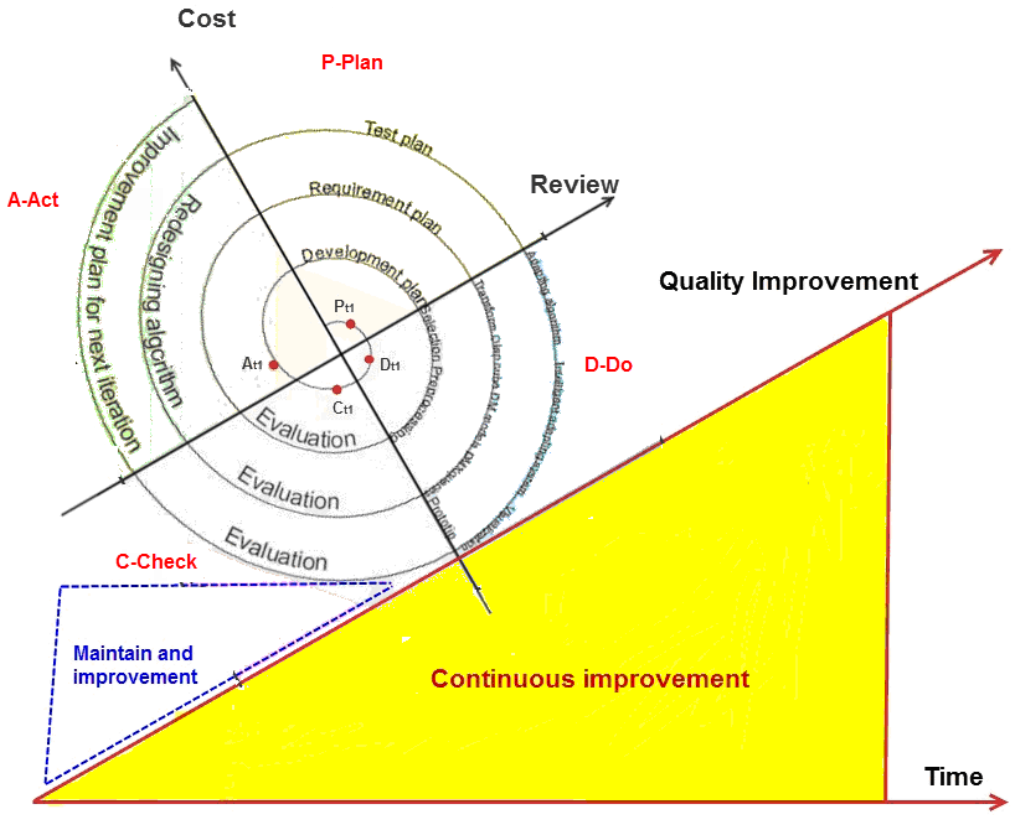

Figure 1. Quality spiral

Figure 1 shows the dynamic presentation of quality spiral and the PDCA cycle. Through the stages of the PDCA cycle, spiral quality moves towards improving quality over time, while maintenance and innovation ensure quality and prevent it from deterioration.

Plan phase includes the creation of plans for development and testing purposes. In Do phase, after creating a data mining model which pre-processes the data collection, selection, transformation, is created an algorithm for adaptation. In addition, at this stage is implemented adaptation algorithm. In Check phase evaluation is done while under Act may be made redesigning the algorithm and making plans for the next iteration of the PDCA cycle.

4. Purpose, tasks and goals (P-PLAN)

Numerous e-learning systems such as LMS Moodle do support course adaptation. Given the method of functioning of e-courses within blended learning platform, the need for more accurate reports as well as for course adaptation by teachers has been

evidenced.

Some specific tasks that are carried out via PDCAdapting cycle have been defined.

The stage P (Plan) defines the specific tasks of research:

1. Creating the model of quality spiral
2. Selection
3. Pre-processing
4. Transformation
5. Creating dimensions and OLAP cube
6. Creating data mining model
7. Writing DMX query
8. Creating a system for intelligent reporting
9. Creating the adaptation algorithm
10. Dynamic modelling of usage case of 'e-course adaptation'
11. Creating an adaptation algorithm
12. Implementation of the adaptation algorithm and PDCAdapting model
13. Visualisation of results
14. Evaluation

The purpose of research is to expand the capabilities of the existing system, with the addition of capabilities to adapt electronic courses. The system is designed on the basis of students' activities within the Moodle learning management system, and can be applied to other systems for e-learning. The target group of this research is students and pupils of primary and secondary schools, as well as all the other participants and users of electronic courses.

Goals of research:

- Improvement of the existing reporting system, in this case Moodle learning management system, creating a new system that includes intelligent features using the techniques of data analysis, which involve predicting future behaviors, with the adaptation of courses;
- Establishment of recommendations for adjusting the electronic courses prescribed patterns of behavior. Recommendations are given course administrators and teachers to help them in the future to adjust structure and organization of electronic courses for increased activity of the participants and the effectiveness of the use of electronic courses.

5. Methodologhy of creating an adaptation system (D-DO)

The adaptation of the learning management system has been applied to the Moodle platform at the Faculty of Technical Sciences, Čačak (www.ftn.kg.ac.rs). The Moodle learning management system at the Faculty has been in use for five years as a support to blended learning. More than 100 courses have been developed within this system over the period. More specifically, e-courses have been created in the areas of Electrical Engineering and Information Technology. There are about 2,000 active users on the system. The Moodle LMS database records users' activities, and the Log file contains more than one million records over the study period.

In stage D (DO), each of the tasks stated (from phase P) is carried out by precise methodology.

1. **Creating the model of quality spiral.** In order to continuously improve the PDCA methodology and quality spiral are used. The spiral of quality encompasses all the activities carried out, ensuring the quality and maintenance of the created system.

2. **Selection**. Data selection is performed from the data downloaded from the server holding the Moodle Management System. The selection includes the creation of the target data set, i.e. the data set that will be analysed (Lloyd-Williams, 1997). Our study is based on records selected from the areas of Electrical Engineering and IT. Selection refers to the level of courses participating in the analysis, and the level of the system, because the Faculty of Technical Sciences Cacak there are two independent Moodle learning management systems. One is meant to support traditional teaching, while other

supports distance learning. At this level of selection, the selected system used to support traditional teaching, while the second-mentioned system is not analyzed.

3. **Pre-processing stage**. Irrelevant records, i.e. the records relating to images and all http requests labeled as 404 (indicating that the resource was not found on the server) are excluded within this stage.

4. **Transformation.** Data are transformed into formats that can be used within different applications. The most common steps in the process of transformation are user identification, session identification, traversal path completion and learning activity mapping. In the process of transformation of certain attributes are excluded from the analysis because they have no significance for the present study. These are: ip, url and information. Upon exclusion of certain attributes approach to the transformation format, first dates and times. Date and time are given in the format "timestamp" as the final results and view user's behavior patterns would not be appropriate for the end user. This format has been changed and created the two dimensions: time and date.

5. **Designing dimensions and OLAP cube**. The basic idea of OLAP is to enable the rapid and accurate response to customer questions. OLAP provides multidimensional data analysis, which is one way of expanding the possibilities of query data. This method of analysis is replaced by analysis of a large number of queries. OLAP enables users to obtain detailed information, to make a generalization, sorting and regrouping data. OLAP end user information in a table format, and makes it easy to obtain the report.OLAP and data mining are different, but complementary activities. OLAP provides a multidimensional view of data and the ability to create a hierarchy, which is a common need in organizational analysis, and the analysis of the data does not allow.The OLAP cube and dimensions (i.e., module, activity, course, year, month, day, hour and minute) are created after pre-processing and transformation.

Microsoft Visual Studio 2008 is used for creating the OLAP cube.

6. **Designing the data mining model**. Microsoft Visual Studio 2008 was used for creating the data mining model, the Neural Networks model being used in this study.

An algorithm of neural network is used to create a network that consists of three layers of neurons. These are: input, hidden (which is optional), and an output layer.

Input layer: The input layer defines all the input attribute values for the model analysis. In this study, the input values are: course, number of students (in course), activity, hour, day, month, and year.

Hidden layer: neurons in the hidden layer receive input from the input layer and pass them on to the output layer. In this layer weights are assigned to the input neurons. Weight describes the relevance of certain neurons in the hidden layer. What is assigned greater weight neuron, the greater the importance of the value of the inputs. Weight can be negative, which means that the input value inhibits the occurrence of a specific result.

Output layer: The output neurons represent the attribute values that are anticipated. This research provides access to modules and module at the exit.

Input data are randomly split into two sets, i.e. training set and testing set, based on the percentage of data for testing and the maximum number of testing cases provided. The training set is used to create the mining model, whereas the testing set is used to check model accuracy. In this study, the percentage of the testing cases is 30%.

7. **Writing the DMX query**. Writing DMX (Data mining Extensions) queries and the testing of the model are the steps that follow. DMX query language is largely used for model creation, model training, prediction and content access (Palaniappan and Awang, 2008).

The aim of using DMX query refers to the creation of queries over the model to obtain the desired results, that is an answer to the research questions. The goal of this research is to obtain access to certain probability prediction modules.

Moreover, the above queries can be used to create a model of data analysis, however, in this study, models were created without the use of queries over the selected software.

A special type of DMX queries are predicting queries. The objective of typical projects that include data analysis is prediction. An example of DMX query used for prediction and testing neural network:

```
SELECT
 [Neuronske mreže].[Modul],
 PredictHistogram ([modul])
From
 [Neuronske mreže]
NATURAL PREDICTION JOIN
(SELECT 'add discussion' AS [Aktivnost],
 1 AS [Mesec],
 13 AS [Sat]) AS t
```

Featured is a singleton prediction query that predicts access module with entered values ("add discussion" for activity, "1" for month and "13" for hour).

8. **Creation of an intelligent reporting system**. The system was created for the purpose of obtaining the predictive behaviour patterns of students. Such reporting is not included in the learning management systems, and it allows teaching materials to be modified according to students' specific needs. The seven tasks above were implemented, and a web based intelligent e-learning reporting system was created. The creation of the system and its operation are described in detail in Micić and Blagojević, 2013. This system was designed as a self-contained and provides reporting on user activity and predict their future behaviors. It is based on the displayed data analysis techniques (neural networks). The goal of creating the system is to provide advanced reporting capabilities that the current system does not have. Is applicable to a variety of learning management systems. Creating a system can be accessed after creating the appropriate DMX query and the system presents the query results to the teacher.

9. **Dynamic modelling usage case of 'E-course adaptation'.** Sequence diagram represents the mainstream of that proposed activity or module that the user chooses, and is not considered an alternative flow, and the case when the system recommends the use of the proposed activities, and requires adjustment of input parameters.

10. **Creation of the adaptation algorithm**. The capabilities of the system created and a specific procedure for possible adjustment of e-courses were taken into consideration when creating the adaptation algorithm. Dynamically modeled use case adaptation in electronic courses served as the basis for designing algorithms to adapt e-learning.

11. **Implementation of the adaptation algorithm**. Implementation of the adaptation algorithm allows for the advancement of the system created. It enables a teacher to re-organise an e-course through specific recommendations.

12. **Visualisation of results**. The visualisation of results was done in order to present the results more clearly.

13. **Evaluation.** The evaluation was conducted on an IT course, more specifically a Programming Languages course.

6. Proposed algorithm and its implementation

The proposed framework presented in section 6.1, which refers to e-courses adaptation, requires modelling for better understanding. Dynamic modelling, shown on the sequence diagram in Figure 2, helps to present the process of adaptation through message exchange among objects. Messages are presented chronologically so as to enable determining the course and timing of the

activities. A sequence diagram was made in StarUml (Staruml Software, http://www.staruml.com), representing the main course in which an activity or module is proposed, until an alternative course has been considered, i.e. the case when the system makes no recommendations for the proposed activities, and requires adjustment of input parameters.

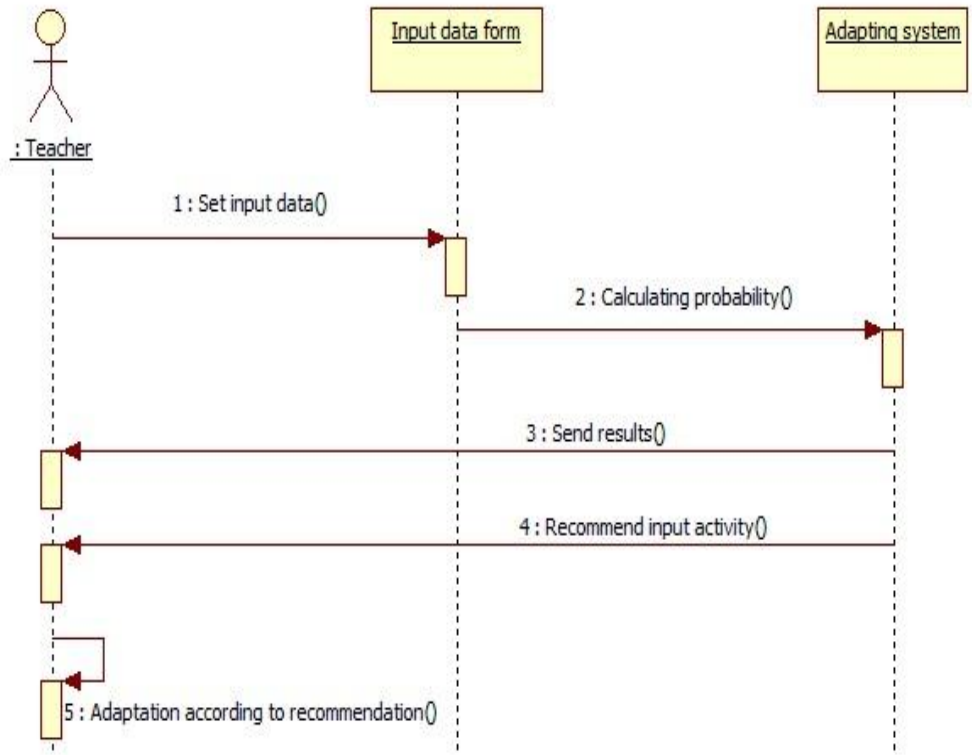

Figure 2. Sequence diagram of the usage case of adaptation on the Programming Languages course

Dynamically modelled usage case in e-courses adaptation served as the basis for creating algorithms for the adaptation of e-learning. Adaptation algorithm is shown in Figure 3.

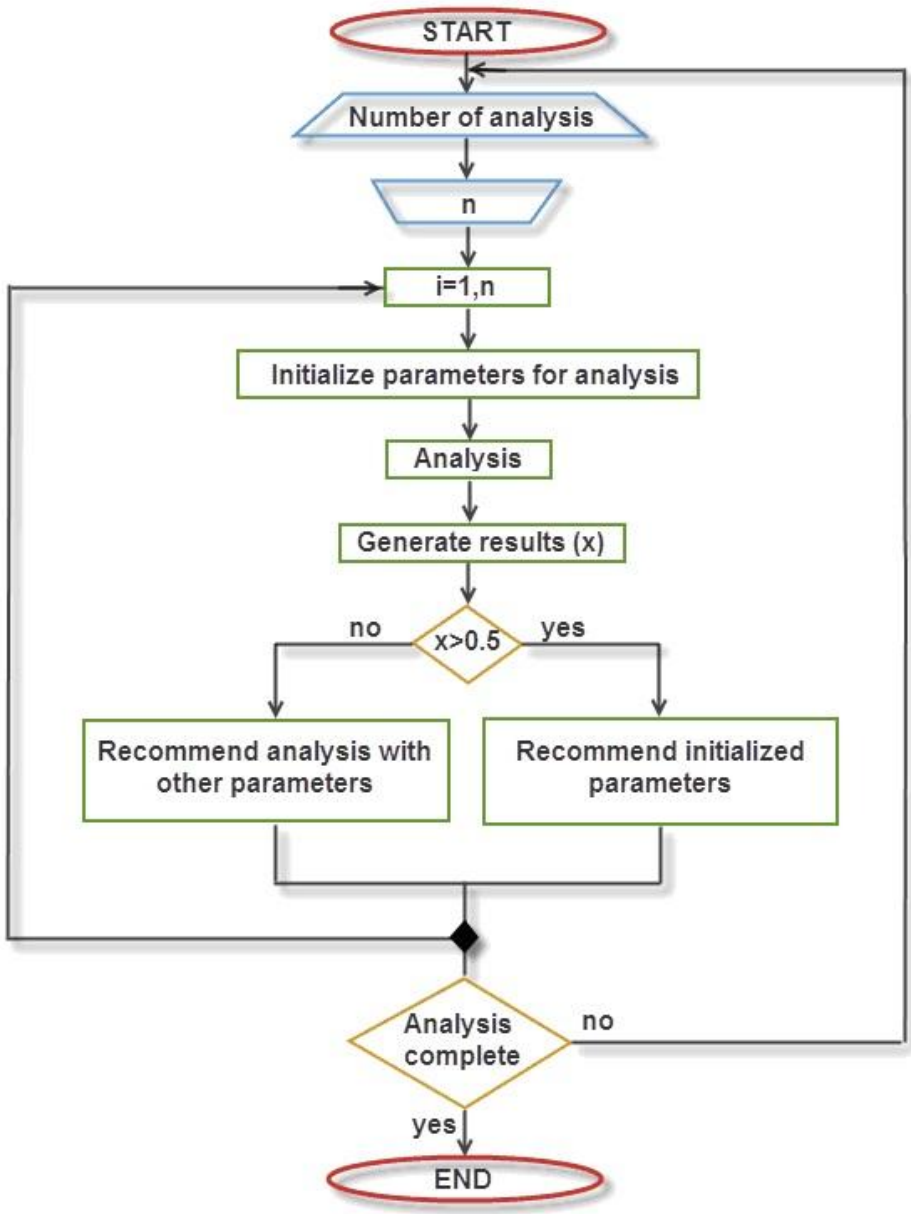

Figure 3. Algorithm for the e-courses adaptation

If the probability is higher than 0.5, the initialised parameters are suggested as appropriate for a particular activity in the selected course. If the probability is lower than 0.5, it is suggested that input parameters be re-selected. The analysis can be repeated as many times as needed by hitting 'no' to the question 'Is the analysis completed?

6.1 A possible scenario of use (C-CHECK)

This section shows the usage case scenario

on the Programming Languages course. The course is attended by second year Information Technology students at the Faculty of Technical Sciences, Čačak. It is designed to support blended learning. Besides teaching materials, the course offers self-evaluation tests, chapters that support programmed learning, links to useful websites, etc. In addition, special attention was paid to the modules enabling collaborative learning (forum, chat room, wiki pages).

In order to determine the appropriate application of a module within a course, the instructor uses a web based intelligent report e-learning system (Micić and Blagojević, 2012, in press). Based on input data, the system performs the analysis and estimates the probability of access to particular modules. The system operates according to the algorithm shown in Figure 4.

Fig. 4 shows the selection of input data and the results obtained from the table, i.e. hour, day, month, year, activity and course. In this case, the predictive value is activity (chosen 'view'). This case relates to a module system that predicts electronic modules within a course (module name and associated probability).

Also, figure 4 provides numerical parameters, i.e. the results pertaining both to the input data and the probability of the occurrence of modules within an e-course. The numerical result relating to the probability (ranging from 0 to 1) in this specific case amounts to 0.5645322. The system also provides the possibility of expressing the result in percentages (from 0 to 100).

With regard to a given probability (which is higher than 0.5), the user is recommended to select from the baseline activities, or 'view'. In relation to a given result, the teacher should organise an e-course so as to put emphasis on viewing teaching materials.

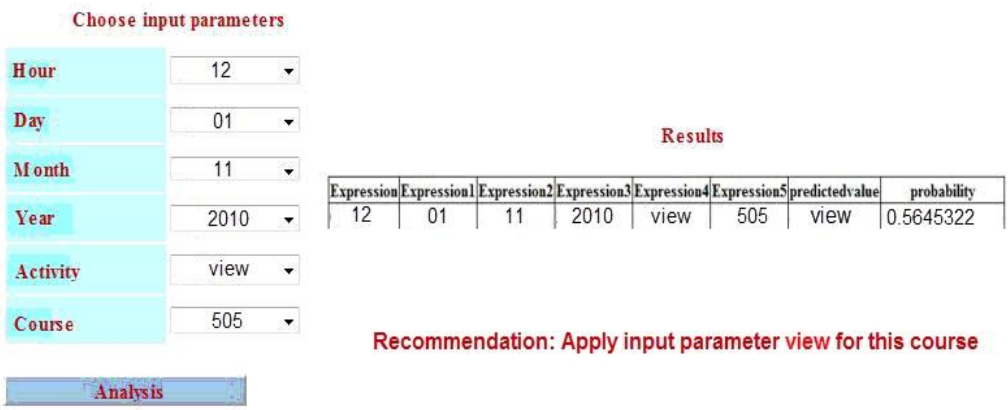

Figure 4. Results for the selected usage case

The presented usage case in the Check phase serves for the evaluation of algorithms and adaptation systems. It is performed after each DO stage of quality spiral, and answers to the question referring to the extent to which the plans are met. In this particular case, the adaptation functions as planned, i.e. the teacher, based on the entered input data, receives a recommendation for the use of the selected activity or module.

Only after the first Check stage of quality spiral, does the stage Act not include re-designing of algorithm because it operates in accordance with the established plan. This means that the algorithm is capable of re-designing in each Act stage of the quality spiral, or only in the stages in which the Check phase determines re-designing as appropriate.

7. Proposed algorithm and its implementation

The designed system which involves adaptive capabilities using data mining techniques allows for the advancement of the current system by adding web intelligence and adaptation capabilities. The significance of the research is as follows:

- The possibilities of applying data mining techniques to analyze patterns of user behavior learning management system are identified;
- An algorithm to adapt the content of electronic courses is created;
- Adaptation algorithm is implemented.

The advantages of the system primarily refer to (a) possible modification of teaching materials to meet the various needs of users, (b) individualisation of teaching and (c) improved reporting, which leads to increased efficiency of the course participants. Superior-performance server requirement can be considered as a shortage of the designed system with adaptation modules added.

The advantages of the presented approach that includes quality spiral and PDCA enables continuous improvement, as well as evaluation and verification of the effects achieved. It is expected that the PDCA approach ensures quality e-learning. Hence, the following conclusions can be made by stages:

Pt: This quality spiral stage involves continuous work on plan designing within new cycle iterations, i.e. test plan, requirement plan and development plan.

Dt: The first iteration in quality spiral and algorithm implementation is followed by the improving algorhitm in the next time interval t.

Ct: Each line in quality spiral at the Check stage includes the evaluation of the current system by testing different usage cases.

At: This stage involves advancement and re-designing the adaptation algorithm, as well as possible change of plan for the next iterations.

Future work will focus on further development of the adaptation algorithm and evaluation through identifying the effects of utilisation of the adaptive system after the elapsed time t.

Acknowledgment: This study was supported by the Serbian Ministry of Education and Science (Project III 44006, http://www.mi.sanu.ac.rs/projects/projects.htm#interdisciplinary).

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