The Architecture of the Personalized Adaptive E-Learning System

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Abstract. The current freely available learning management systems do not provide adaptation options. An e-learning system suitable for learners' needs can improve the learning process results. This paper presents the architecture of a personalized adaptive e-learning system based on the learner model. The system is based on three main components: learner model, content model, and adaptation model. The learner model is based on the lifetime of the learner's data in the system and is used in the context of lifelong learning. The content model is based on diverse use of learning resources and activities. The adaptation model is based on three developed methods: the learner group classification method, the optimal topics sequence creation method, and topic sequence organization method. Implementation of the system was based on Moodle system. Some components were added to Moodle system code as extensions that were designed to complement the operation and adaptation of the system. Architecture of the developed system was implemented and experimentally approved. As a result, target audience suitable for the developed system was determined.

Keywords: System, Architecture, E-learning, Adaptation

1 Introduction

Nowadays the learning has following pronounced tendencies: (i) the amount of the information to be acquired increases (i.e. information overload problem [6]), (ii) the necessity for the lifelong learning grows, (iii) the necessity for the professional reorientation and the self-learning increases, (iv) the use of ICT in the education including e-learning for providing the learning process grows, (v) different attitude towards the use of ICT can be observed in the society (digital natives and digital immigrants [7]), (vi) the necessity for the more individualized learning approach increases [5], (vii) the necessity for the "All individuals to learn, Anywhere, Anytime, through Any device, with the support of Anyone" [4].

The use of the personalized adaptive e-learning system can positively influence

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with the learning connected above-mentioned tendencies. Scheuermann and Pedró [8] emphasize that "ICT as a tool for the support of personalisation strategies in teaching and learning".

This paper is built on the different recearches [10-15] and offers a thorough design, implementation and testing of a Learner Model based Personalized Adaptive e-Learning System (LMPAELS). LMPAELS architecture is based on three models: a learner model (LM), a content model (CM), and an adaptation model (AM). The LM describes an adult learner and is applicable to the lifelong learning. The CM supports the use of various learning resource formats. The system implements (i) the adaptation of the course structure, (ii) the adaptation of the course content, and (iii) the adaptability of the acquired topic sequence. The proposed system architecture was experimentally tested. The results of the experimentation confirm the utility and appropriateness of the proposed system for a specific target audience.

The remainder of the paper is structured as follows. Section 2 presents related work. Section 3 describes the components of the system architecture. Section 4 describes the system implementation. Section 5 presents the experiment of the system approbation and obtained results evaluation. Discussion on the use of the developed system is given in the Section 6. Finally, conclusions and future work are given in the Section 7.

2 Related Work

Many papers have been dedicated to the adaptation of e-learning and these studies have a long history, but with the development of technology and the needs of society, new opportunities are emerging. Few latest and most relevant approaches were chosen to characterize the novelty and capabilities of the proposed system.

The paper [2] describes the adaptive e-learning model that consists of four components: (1) the CM, (2) the LM, (3) the AM, and (4) communication interface (between the learner and the system). The CM is based on the SCORM that consists of chapters. Each chapter is created according to three levels of complexity. Three stereotypes are used to classify a learner. The learner is offered the content (chapters) of the corresponding difficulty level depending on the stereotype assigned to him. In [2] the emphasis is on the automatic allocation and change of stereotypes depending on the learning results.

The study [1] describes adaptive e-learning system using three main models: a domain model (DM), the LM, and the AM. Additional components are interaction module (for communication between the learner and the system) and data modeller (for the LM data update). The DM consists of instuctional units that contain learning object (LO). All LOs are divided into two groups: abstract LOs (include concepts, mathematical notations) and concrete LOs (include examples and practical tools). Depending on the learning style (LS), all learners are divided into two groups: sensing and intuitive learners. In [1] the emphasis is placed on the automatic adaptation of the learning path based on the learner's learning style. For sensing learners, a specific LO is given first and an abstract LO is given afterwards. For intuitive learners it is the other way around – the first is an abstract LO and a specific LO follows.

In [9] the adaptive learning system "E-school" is described. Learner groups (LG) are created by the system administrator based on the characteristics of the learners. Different LGs have access to specific lectures. In [9] the emphasis is made on the ability of learners to monitor their own learning progress. Teachers are able to assess the progress of a learner. A tree of lectures is created for each learner. Knowledge of learners is tested using a quiz. Different quizzes are generated for the same content.

The paper [3] offers the best sequence of the course learning activities. The sequence is based on the correspondence between learner characteristics (background knowledge and learning objectives) and course activities defined in the system.

The described approaches have some common features: (i) the systems are based on three main models: the CM/DM, the LM and the AM; (ii) LGs are implemented to provide adaptation; (iii) there is a relationship between the structure of the LM and CM. These features can also refer to the system proposed in this paper.

LGs in the viewed approaches are defined by the system's administrator [1-2, 9]. In LMPAELS system the LG is created by the course creator or teacher. This approach ensures that each course has its own LGs and the creation of the LG takes into account not only the learner characterizing data, but also the pedagogical experience of a teacher and the course features.

In the viewed approaches the learning path is created within one LO [1] or one topic [3]. LMPAELS system has implemented learning path creation at the course topic level. The learner has the opportunity to make multiple choices between three topic sequences (TS): the teacher TS, the optimal TS, and the learner TS.

3 Components of the System Architecture

This section describes the conceptual architecture of the developed LMPAELS using following models: a *Learner Model*, a *Content Model*, and an *Adaptation Model* (see Fig. 1).

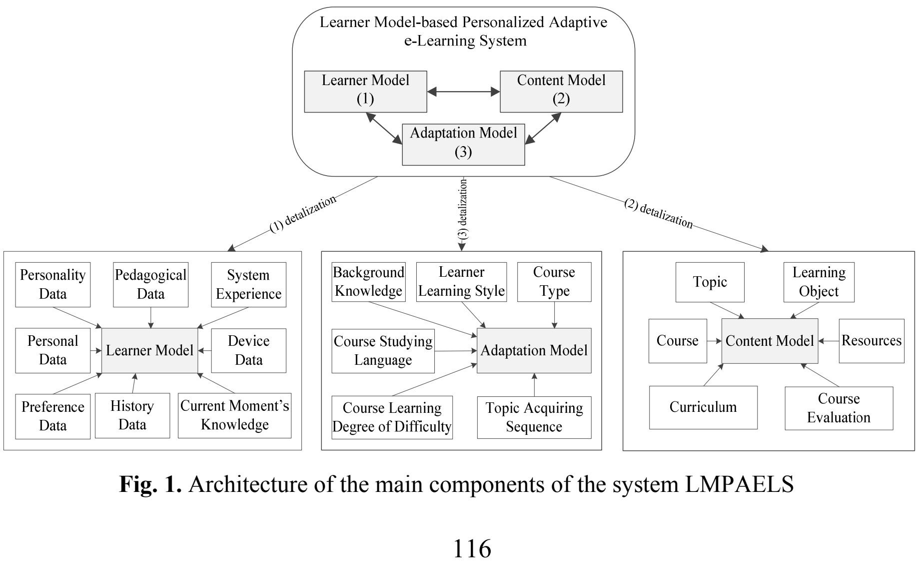

Fig. 1. Architecture of the main components of the system LMPAELS

The learner model contains data about the learner in the system. The content model contains the content offered by the system and its logical structure. The adaptation model describes conditions and rules used in the adaptation.

3.1 Learner Model

Learner model (LM) in the LMPAELS system describes the adult as a learner. LM is used in the context of lifelong learning. The system's learner characterizing data are divided into eight data categories: *Personal Data*, *Personality Data*, *Pedagogical Data*, *Preference Data*, *Device Data*, *System Experience*, *Current Moment's Knowledge*, and *History Data* (see Fig. 1). The choice of data categories for the LM is based on the results published in [11].

As LM describes the learner in the lifelong context according to the data lifetime in the system the learner data are divided into three big groups: (i) basic data; (ii) additional data, and (iii) learning process data. The *basic data* include data values that do not change over time, for example, *personal data*. The *additional data* include data values that tend to change over a longer period of time, for example, *personality data, pedagogical data, preference data, system experience,* and *device data*. The *learning process data* include data values that are constantly changing like *history data* and *current moment knowledge*.

The complete LM description can be found in the paper [12]. The LM implementation is described in the Section 4.1.

3.2 Content Model

The content model (CM) of the LMPAELS system is based on the use of learning objects (LO) and various resource formats. A learning course (*Course*) of the offered LMPAELS CM (see Fig. 1) consists of one or more topics (*Topic*). Each topic consists of one or more LO. Each LO consists of four parts: description part, theoretical part, practical part, and evaluation parts.

The *description part* explains the essence of the particular learning object, its tasks and place in the course structure. The *theoretical part* contains the provided knowledge for learning. The knowledge is represented using activities and resources (*Resources*). The *practical part* contains activities aimed at strengthening the acquired knowledge. The *evaluation part* contains activities that are used to assess the knowledge acquired by a learner such as a task/quiz.

A complete description of the LMPAELS CM can be found in [12]. Practical implementation of the CM is described in Section 4.2.

3.3 Adaptation Model

The adaptation model (AM) describes adaptation methods implemented in the system and methods used for adaptation. The LMPAELS system is used for adaptation of (i) the course structure, (ii) the course content, and (iii) the course topic sequence.

Adaptation of the course structure (*Course Type)* (see Fig. 1) is performed using different parts of the LO of the created CM (see Section 3.2). The system has courses of two types: practical and theoretical. In structure of the practical course all four LO parts are used. In structure of the theoretical course only three LO parts are used (excluding the practical part of the LO).

Adaptation of the course content is based on the (a) *Learner Learning Style* (see Fig. 1), (b) course *Background Knowledge*, and (c) chosen *Course Learning Degree of Difficulty*. The learning style determines displayed learning resources in the theoretical part of the LO. In this LO part, resources types of which correspond visual, aural, read, kinesthetic, and a combination of the visual-aural learning styles are used. The learner pre-knowledge of the course or its absence in the particular course determines whether additional explanations in the LO's theoretical part are shown.

The degree of difficulty of the course acquisition chosen by the learner determines the difficulty level of assignments/quizzes that are being offered to the learner and the maximum grade that the learner can receive upon finishing the course. Three levels of the course acquisition difficulty are realized in the system: (i) the lowest level – till grade 6 inclusively, (ii) the average level – till grade 8 inclusively, and (iii) the highest level – till grade 10 inclusively. The choice of the above-mentioned degrees of difficulty in based on the assessment system adopted in the Latvian education system, the pedagogical experience of the authors, and the desires of learners.

Learner Groups (LG) are used to ensure the adaptation of the course content for which the appropriate adaptation scenarios are created in the system. *Learner Group Classification Method* (LGCM) was designed for the LG creation. [12].

The inclusion of learners in a group is performed with the *Learner Group Identificator Searching Algorithm* (LGISA) made with purpose to find the most suitable LG for the learner. The algorithm is based on the highest value of the learner characteristics and matching values with the LG feature [13].

The use of the variants for the course topics acquisition sequence (*Topic Acquiring Sequence*) (see Fig. 1) gives a learner the opportunity to choose one of three topic sequences (TS): (a) a teacher-proposed TS, (b) learner TS, or (c) optimal TS.

Teacher Topic Sequence is offered by a teacher for acquisition of a specific course based on the pedagogical experience of the teacher and links between topics. *Learner Topic Sequence* is created from the learner-chosen topics during the course acquisition based on links between topics. *Optimal TS* (OTS) is based on the learning process data and links between topics of all previous learners in the course. OTS is created using the *Optimal Topic Sequence Creation Method* (OTSCM) using links between the course topics, the topic sequences used by previous learners of the course, and the obtained results (grades) of the course [14].

Topic Sequence Organization Method (TSOM), developed for this purpose, provides the opportunity to use the variants for the TS realized in the system [15]. The implementation of the AM is described in the Section 4.3.

4 System Implementation

Learning management system (LMS) Moodle serves as the basis for the development of LMPAELS (see Fig. 2). To ensure the performance of the LMPAELS system, Moodle provides user authentication, creation of the learning courses, and ensures the ability to use various types of learning resources and activities. Additional components (modules, data repositories) that are necessary to ensure the LMPAELS learner model, content model, and adaptation model have been created in Moodle.

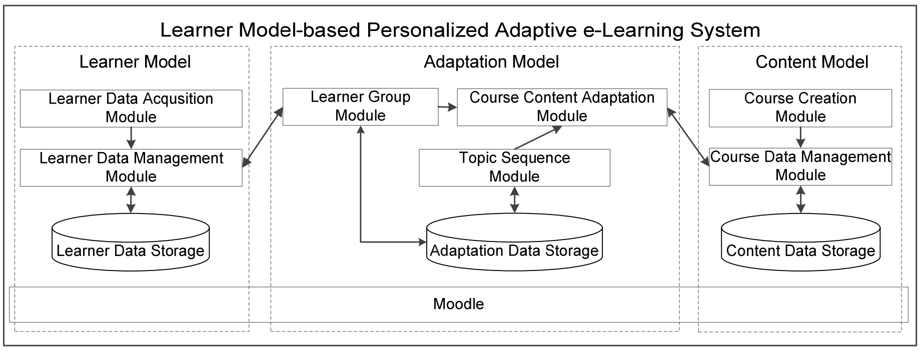

Fig. 2. The interaction of the LMPAELS system components

Fig. 2 shows the components implemented in each of the modules of the LMPAELS system. The arrows indicate the direction of the data flow between the components. These components were implemented using the following web programming technologies: PHP, JavaScript, JQuery, HTML, and CSS. With the help of SQL, the tables for storing missing data were created, data acquisition and recording into tables was implemented. Each of the LMPEALS model realizations is described below.

4.1 Learner Model Implementation

Two modules were created for the LMPAEL learner model (LM) (see Section 3.1): *Learner Data Acquisition Module* and *Learner Data Management Module* (see Fig. 2). *Learner Data Storage* is used to store data about the learner.

The Learner Data Acquisition Module provides acquisition of learner's data, such as: results of surveys and quizzes, individual choices of the learner, an external system etc. Types of data mining for the LM are described in details in [13]. An external ePortfolio system Mahara was used to obtain the initial data about the learner. Retrieving data from the ePortfolio system is described in [10]. The Learner Data Management Module allows to view and process data about the learner.

4.2 Content Model Implementation

For implementation of the LMPAELS content model (CM) (see Section 3.2), many of the components existing in Moodle that are used for organizing the Moodle course, such as course structure modules, sections, activities and resources were used. In addition, a *Course Creation Module* and a *Course Data Management Module* were created (see Fig. 2). *Content Data Storage* was created for storing CM data.

The Course Creation Module is responsible for creating course content, content elements (resources and activities), and their relevance to the type of adaptation. By adding a new resource/activity, the author of the course indicates the relevance of this content element to the type of adaptation of the course content (learning style, course difficulty level, and background knowledge) (see Section 3.3). Courser Data Management Module provides content model data storage, processing and output.

Implementation of the course structure is provided by the Moodle course format. In the beginning of the new course, the course author specifies the course type (theoretical or practical) (see Section 3.2). The system creates a course structure according to the choice made.

4.3 Adaptation Model Implementation

Three modules were created for the implementation of the LMPAELS AM: (i) the *Learner Groups Module*, (ii) the *Topic Sequence Module*, and (iii) the *Course Content Adaptation Module*. AM data are stored in the *Adaptation Data Storage.* (see Fig. 2)

The Learner Group Module provides (i) the creation of learner groups in the course, (ii) the creation of adaptation scenarios for each LG, (iii) the classification of learners in existing LG. The LGCM is used to create LGs (see Section 3.3). The LGISA algorithm is used to classify learners in the already existing LGs (see Section 3.3). A more complete description of LGM is available in [13].

The Topic Sequence Module (TSM) provides the organization of TS. The main tasks of the TSM are collecting data from the learning process, creating the OTS of the course, and TS management. The OTSCM is used to create the OTS (see Section 3.3). The TSOM is used for the TS organization (see Section 3.3). A more complete decription of operation of the TSM is given in [14].

The Course Content Adaptation Module (CCAM) implements the adaptation scenario for the learner. The CCAM finds the group number assigned to the learner and the adaptation scenario of this group. Subsequently, according to the description of the scenario, the course content is adapted.

5 Experiment

5.1 Description of the Experiment

An experiment was conducted to test the developed system. The system was approbated in Daugavpils University during the learning process. In the fall semester of the study year 2016/2017, the course "Programming Foundations I" (first study year) was tested. In the spring semester, the course "Databases II" (second study year) was tested. Two versions were prepared for both courses: adaptive and non-adaptive.

The experiment was organized in a particular institution where the number of students was not sufficient to organize a proper experimentation. Therefore, participants of the experimental study had the opportunity to use both versions of adaptive and non-adaptive courses. In the case of a proper experiment, one learner group would use only the adaptive course and the second group would use only the non-adaptive course.

The goal of the experiment was to evaluate the architecture and functionality of the developed system, and to determine the target audience that finds the system suitable.

Forty-six students of the professional bachelor study program "Information Technologies" participated in the approbation and evaluation of courses. 20 of them were in their first year of studies and the remaining ones were in their second year of studies. Each student used both the adaptive and non-adaptive version of the course. After finishing studying the adaptive and non-adaptive course, students were encouraged to compare and evaluate both of these course versions. Each learner completed the course evaluation survey electronically, and the system saved the data obtained in the database. SPSS software was used to process the obtained data.

A survey consisting of two parts was created for obtaining data about the course. The first part contains 8 questions about the respondent. The second part contains 46 statements about the course. The statements were grouped into five groups (scales) that were used as course evaluable characteristics: course relevance (10 statements), course cognitive rating (10 statements), course structure (7 statements), course content (6 statements), and course topic sequence (12 statements).

The scale "E-course relevance" describes the benefits of using the course. The scale "E-course cognitive rating" describes the course usability. The scale "E-course structure" is used to evaluate the structure of the content model used in the creation of the course. The scale "E-course content" helps to evaluate how much the content of the topic is suitable to the learner characteristics. The scale "E-course topic sequence" is evaluating the topic sequence variants offered in the system. Each scale was used in both the adaptive and non-adaptive course evaluation. The 5-point Likert scale was used to evaluate each statement in the survey. All statements have equal weight.

5.2 Results Evaluation

To identify the target audience from the respondents of whom the implemented methods in the LMPAELS have been applied to, a two-stage cluster analysis with automatic selection of number of clusters was used. As a result of cluster analysis, two groups of respondents were identified. The first group included 31 respondents (67.4%). The second group included 15 respondents (32.6%).

Both groups of respondents rated the adaptive course higher than the non-adaptive one, moreover, the first group rated the adaptive and non-adaptive course higher than the second group. Differences between the adaptive and non-adaptive course scales for respondents in the first group are small, which means that respondents from the first group do not see the difference between the adaptive and non-adaptive course.

Respondents in the second group rated the adaptive and non-adaptive course differently. Adaptive (A) course average arithmetic mean ($\bar{x}$) assessments are significantly higher than those of the non-adaptive (N) course. The scale "E-course relevance" (A $\bar{x}$=3.387, N $\bar{x}$=2.827) and the "E-course cognitive evaluation" (A

$\bar{x}$=3.412, N $\bar{x}$=2.903) have lower indicators of the assessments of the adaptive course than in the first group, while the scales "E-course structure" (A $\bar{x}$=3.876, N $\bar{x}$=3.267)," E-course content" (A $\bar{x}$=3.622, N $\bar{x}$=3.011), and "E-course topic sequence" (A $\bar{x}$=3.644, N $\bar{x}$=2.828) almost reach level of the first group. These differences in the adaptive and non-adaptive course evaluations indicate that the second group spots the differences between the adaptive and non-adaptive courses.

Kolmogorov-Smirnov test and Shapiro-Wilk test results show that the empirical distribution of both respondent groups corresponds to the normal distribution ($p>0.5$) with a reliability of 95%. By analysing scale measurements for each group of respondents with the T-test for related samples, it was concluded that for the first group differences in scales in pair assessments are not statistically significant ($0.143 \leq p \leq 0.903$, where p is the significance level value), but for the second group differences in scales for assessments are statistically significant ($0.001 \leq p \leq 0.007$).

The difference between the adaptive and non-adaptive course assessment scores for the second group is significantly higher than for the first group, and the differences in scale measurements are statistically significant. Therefore, the second group of respondents is a target audience. A more in-depth analysis of the respondents included in the second group was conducted. The second group (15 students in total) consists of 60% (9) of the first-year students and 40% (6) of the second-year students. Group composition by gender is 60% (9) men and 40% (6) women. 80% of respondents have general secondary education and 20% have vocational secondary education. 60% (9) of the second group have experience in using LMS. 53.33% (8) of respondents began to use Moodle for organizing the study process only during the last year. 46.67% (7) have Moodle experience that exceeds 1 year. By the level of IT competence, the higher percentage of students 73.33% (11) has an average level of skills. The percentage of the high and low level of IT competence in each category is 13.33% (2) of the respondents.

6 Conclusions and Future Work

Architecture of the LMPAELS proposed in the paper was successfully tested in an empirical study. Results of the study showed that Moodle, which was taken as the basis of the developed architecture of the system, was a correct choice because it provided many functions necessary for functionality of the LMPAELS system.

Methods used to provide adaptation improved the system's functionality and were also evaluated by the learners. A more detailed analysis of the approbation results is the subject of a new paper. The purpose of the data analysis in this paper was to identify those learners who perceive the differences between an adaptive and non-adaptive course. As a result, respondents whose differences in evaluations of both courses are statistically significant were identified. The developed system is particularly suitable for the respondent with the following characteristics: first study course female students with general secondary education, average level of IT competence, with LMS usage experience and Moodle usage experience less than a year. The described learner belongs to the "sensitive" learner category for the acquisition of programming courses.

Future research covers conducting an in-depth evaluation of the developed system by increasing the number of learners using different categories of respondents using courses in various fields including theoretical courses.

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