Agent-based algorithm dedicated to personalization of e-learning courses.

L. Rauch, K. Andrelczyk, J. Kusiak

Akademia Górniczo-Hutnicza, al. Mickiewicza 30, 50-059 Kraków, Poland
lrauch@agh.edu.pl, kusiak@agh.edu.pl

Abstract

The optimization of e-learning process, with respect to the diversified learner's abilities, plays an important role in the modern models of studies. Every learner is characterized by personal adeptness, skills, possessed knowledge, etc. Thus, each learner needs to receive different e-learning content, which optimizes the process of learning. Such optimization can be obtained in various ways, among which the personalization of e-learning courses is investigated. However, it requires the knowledge of the learner's progress tracking, passed exams, taken courses, etc. Gathering of that information can be assured due to the dynamic development of programming techniques, tools and most of popular e-learning platforms. It is possible not only to store such data, but also to perform the advanced processing of that information.

The main objective of the work was to design and implement the personalization algorithm inside the virtual learning environment, which would be able to create automatically individualized path of learning by combining various accessible courses. The proposed algorithm is based on the agent-system approach, which maps the set of agents onto the structure of available courses. Then, the communication between agents, weights of connections and the parameters determining learner's abilities allow the proper selection of courses and facilitate development of personalized learning path. The paper presents detailed description of created approach on the example of Moodle e-learning platform. The performed tests and obtained results are presented as well.

Keywords: e-learning, personalization, agent-based system, optimization

1. Introduction

1.1. Motivation

The functionality of available e-learning platforms has been growing very fast during last decade. This phenomenon was caused mainly by the development of Internet technologies and high interest in distance learning. The most popular platforms like Tutor (http://www.atutor.ca), Moodle (http://moodle.org), Claroline (http://www.claroline.net), OLAT (http://www.olat.org) or Sakai (http://sakaiproject.org) are equipped with hundreds of modules with specialized functionalities dedicated to users and courses management, schedules preparation, payments, etc. However, there is still a strong need of further development (Pahl, 2003), which is oriented on personalization of e-learning systems and content. The first issue (personalization of systems) is available in almost every e-learning platform, but the personalization of learning content is much more sophisticated issue (Sehring et al., 2005). It depends on many individual features e.g. motivation, cognitive aspects, intentions, emotions or learning history (Martinez, 2002). By consideration of these features for the purposes of learning process, learners obtain better possibility of efficient knowledge acquiring. Unfortunately, most of the reviewed e-learning systems suffer from the lack of

modules, which would be able to personalize learning content using any criterion. In fact, the concepts of personalization algorithms exist, however, they are not popularized in most commonly used e-learning platforms. Chosen representative approaches are described in the next subsection.

1.2. Literature Review

Recent publications in the domain of artificial intelligence applied in e-learning are dominated by a number of directions. Proposed approaches analyse mainly behavioural and cognitive models of learners. Then, they try to apply sophisticated algorithms able to support interactions with users inside e-learning platforms. The examples of such methodologies are proposed by Chen et al. (2005), and Mor, Minguillon (2004). Chen presented application of Item Response Theory, which is used to determine learners' abilities and course materials difficulties in reasoning process. Similar approach by Mor and Minguillon facilitates navigation through e-learning system using history of users interactions and behaviour. Although these two approaches are very interesting, the most popular and extensively investigated groups of methods can be enumerated as follows: adaptive hypermedia, semantic web usage, application of web services in distributed environment and agent systems.

Adaptive Hypermedia (AH) is the area of science, which has been developed for last ten years. One of the first papers describing the method, techniques and main idea of AH was published by Brusilovsky (1996). It presents the general definition of AH as a system of any kind, which is able to provide individualized interactions with the users. One of the areas, where such systems are used is a Distance Teaching and Learning (DTL) system, also sometimes called as Educational Hypermedia (EH). System gathers and analyses information about the users, their goals and knowledge, and then decides, which course to offer to a current user. The main disadvantage of such approach is the impossibility of splitting of available courses into smaller parts (subsections). Therefore, users always obtain whole course instead of necessary parts of required learning content. However, the next paper by Brusilovski (1998) presents new approach, which overcomes that problem and offers adaptable parts of content for different groups of users.

Other approaches to learning content personalization utilize semantic web technologies. Most of such methods use ontologies to standardize student model, monitoring progress, notes and passed exams (Gomes et. al, 2006; Gascuena et. al, 2006). Such model is used mainly to predict, which part of knowledge should be learnt by a student as a next one. More advanced approaches are developed as well (Henze et. al, 2004). Their functionality is extended in most cases with logical layer, which is implemented in dedicated TRIPLE language. Finally, the ontology-based systems and AH approaches can be combined together as one highly advanced platform (Conlan et al., 2003). Applications of such systems are very important especially in distributed environment, where learning content is divided onto the different platforms and spread throughout the network. The algorithm proposed by Dolog et. al (2004) uses both aforementioned technologies, i.e. Semantic Web and AH, and is based on web-services architecture. Dolog implemented the dedicated Personal Learning Assistant, which integrates personalization and other supported web services published by different e-learning platforms. Then, it provides personalized access to required learning resources in distributed e-learning environment.

Interesting improvement in personalization was proposed by Xu (2006), which created approach based on system of autonomous agents. The system was designed using three layers, responsible for creation of adaptive interface for online users, exchange of information between intelligent agents and gathering of data. Each agent in the middle layer is responsible for different issues i.e. users activity, learner profile, modelling and planning.

The communication of agents results in personalized behaviour of e-learning platform. On the other hand, Conlan (2002) proposed personalization algorithm based on Semantic Web technologies using Sharable Content Object Reference Model (SCORM) standard, which allows unified description of courses and facilitates exchange of information between distributed e-learning systems.

By combination of two approaches, i.e. agent-based and SCORM-based, new algorithm dedicated to learning content personalization was created and proposed in this paper. The main goal of the paper was to design and implement the approach, which is characterized by following features:

- effectiveness in teaching process as in Xu's agent-based approach,
- possibility of distributed data analysis,
- unification of data based on SCORM standards,
- processing of important users characteristics e.g. history of learning, time spent on different courses and learners' abilities.

The proposed module was implemented in the Moodle platform and SCORM standards. This fundamental technologies and software are described in section 2, which is followed by a detail description of proposed agent system and its implementation. Case study and the results are presented in section 4.

2. Available software and algorithms

2.1. SCORM – structures, parts of standards

SCORM is a set of standards and specifications for web-based e-learning software. SCORM was proposed in 2003 by Advanced Distributed Learning (ADL) initiative and is still developed by this organization as SCORM 2004 (3rd Edition). It defines communication between client and run-time environment, and specifies format of ZIP packages into which content may be packed. SCROM specification is divided into three basic parts (http://www.adlnet.gov/scorm/index.aspx):

1. Run-time Environment (RTE)
2. Sequencing and Navigation (SN)
3. Content Aggregation Model (CAM)

RTE describes how the content is processed by Learning Management System (LMS). Its aim is to ensure uniform behaviour of courses across different e-learning platforms. This part of standard defines the way of content presentation and methods of communication between content and LMS (e.g. elements used to transfer information about users' interactions). SN part describes methods and actions initialized by users or system. It allows to define conditions of access to individual parts of courses and sequences in which they are presented. The latter part, CAM, describes types of content used in e-learning courses and the means of its storage. It also defines format of meta-knowledge used to describe this content. CAM allows unifying the description, packaging and storage, which results in the ability of exchange knowledge between different e-learning platforms. According to SCORM standard, courses are stored in content packages containing content objects or set of content objects, as well as the knowledge about their organisation (Figure 1). Content of such packages is described by manifest stored in XML format, which facilitates its processing and modification.

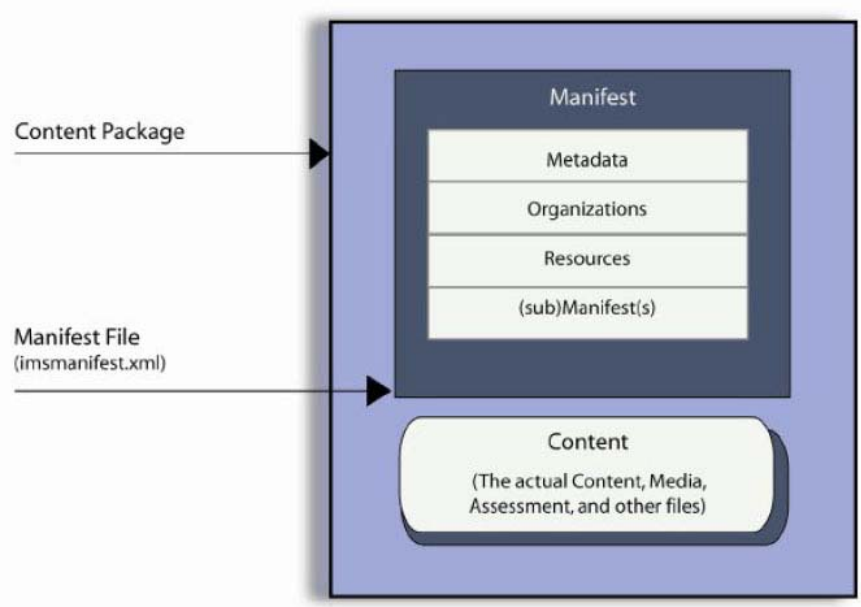

Figure 1. Conceptual diagram of content package (SCORM 2004 3rd Edition, Content Aggregation Model, www.adlnet.gov).

2.2. Moodle – codes and database

The system responsible for personalization of e-learning courses was implemented using Moodle Course Management System of the AGH University e-learning Platform. This e-learning platform was designed to support effective creation of on-line learning communities (http://moodle.org/). It contains tools for preparation and presentation of courses in many different formats, as well as for verification of acquired knowledge and communication between students and teachers. Adaptation of fully developed environment allows focusing on the concepts of personalisation without the need of implementation of basic functionality of e-learning platform. Moodle comes with full functionality of Content Management System, offers flexible user management and possesses additional tools for creation and management of on-line courses. This software package also includes support for courses in SCORM format, which was used to implement personalization system. Moodle was chosen mainly because of its growing popularity and the fact, that it is an open source code facilitating application of improvements and external modules' development. Widespread use of this platform assures easy access to knowledge that can be used in creation of personalized content. Faculties of AGH - University of Science and Technology use e-learning platform, which is based on Moodle software offering Authors possibility to test personalization system in real environment.

3. Developed recursive agent system

3.1. Structure of courses

The structure of personalized course can be represented as a graph (Figure 2). Its nodes represent particular SCO objects. Each of these objects is characterized by activation threshold parameter determining whether the object should be enclosed in personalized course or not. The higher the threshold value, the harder it will be for object to be enclosed.

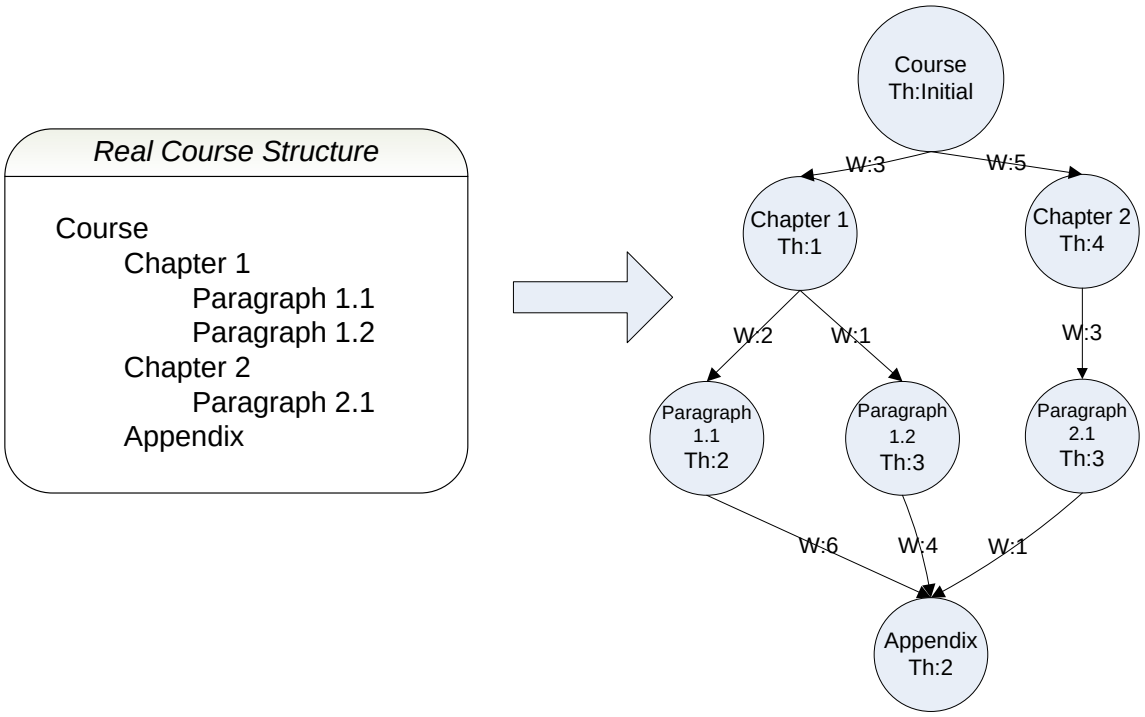

Figure 2. Example of graph representing SCO objects and connections between them (Th:n – threshold value equal to n, W:n – weight value equal to n).

Graph's edges represent connections between objects. Weights assigned to these edges define dependencies between objects. Higher weight means that information inside an object depends on information in another one. On the other hand, low weight means that information inside object is almost irrelevant to the others. Such connection allows deciding automatically if learner needs to acquire the knowledge in the course or paragraph before going to the next step of education.

3.2. Agent system (Main algorithm)

The main goal of the presented agent-based algorithm (Figure 3) is to select elements of courses from database, which are crucial and indispensable for further student's education. The selection is based mainly on the history of education and the result is in form of new personalized courses.

The basic unit of created agent system represents one SCO object and the whole system is organized in form of recurrent structure. Such architecture allows agents to have set of links to other agents, which makes them able to represent the courses according to SCORM standards. Every agent in this system includes content of represented object and meta-knowledge, which describes it. Connections between agents correspond to connections between SCO objects and courses. Meta-knowledge includes information about access to given course's elements such as date of last access by particular students, time spend on this element and grades obtained in the tests verifying the learnt content. Each agent is characterized by activation threshold and weights of connections with other agents. Values of those properties are equal to corresponding values in related course elements.

In the first step of algorithm, the initial agents (courses elements) are marked as active. Then, these agents send signals to connected agents with the calculated strength value. The

sum of all signals, which reach agent, is compared to the activation threshold due to the following rules:

- If the value of sum is higher than the threshold, the agent is marked as active.
- If the sum is lower than the threshold, the agent is marked as inactive.
- If the sum is equal to the threshold, the state of agent remains unchanged.

If the system of agents has changed in current iteration then all signals are recalculated recursively one more time. This process is repeated until no further changes in the state of agents occur. At the end of the selection, elements represented by active agents are returned as part of the personalized course.

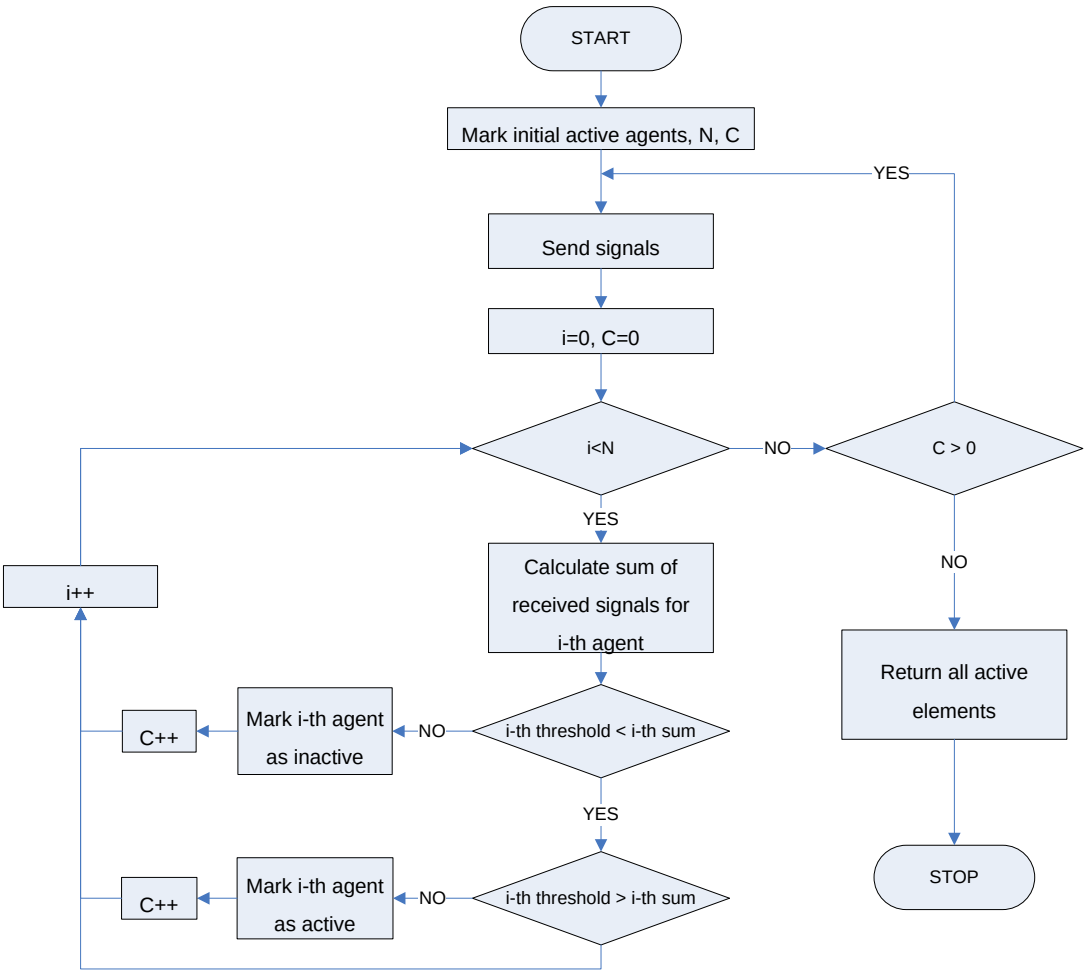

Figure 3. Scheme of algorithm dedicated to selection of SCO objects represented by agents, where N is a number of all agents, C is a variable denoting change in system of agents.

Personalized courses are created by concatenation of returned elements into new courses, which are stored in platform's database. The new courses are equipped with parameter used to determine the final recipient. Individual SCO objects (elements of new courses) are stored in database with the information about their original parent course. These records are removed if new personalized courses of the same owner are created.

3.3. Implementation in Moodle

Implementation of described software inside Moodle required creation of new functional modules focused on initial preparation of course structure and on personalization based on

history of learner's education. First part of this functionality was implemented and applied in the process of import of new content packages. After selection of package, user is redirected to special form, which allows him to set weights of connections between elements. This task requires knowledge about structure of imported course and relations between its elements, therefore it has to be performed by teacher or administrator.

The personalization of learning content was implemented in form of agent-based algorithm (section 3.2) as additional function of module responsible for SCORM content presentation. Required parameters of agents and connections between them are loaded directly from database. Agent system selects required elements and proposes new personalized courses. Entire process of personalization is performed without any interactions with users.

4. Obtained results – Case Study

As an example, the proposed approach of personalization was implemented to the **Optimization methods** course. Two chapters of that course describing simplex and golden ratio methods were selected. Each chapter contains description of algorithm and set of definitions related with corresponding method.

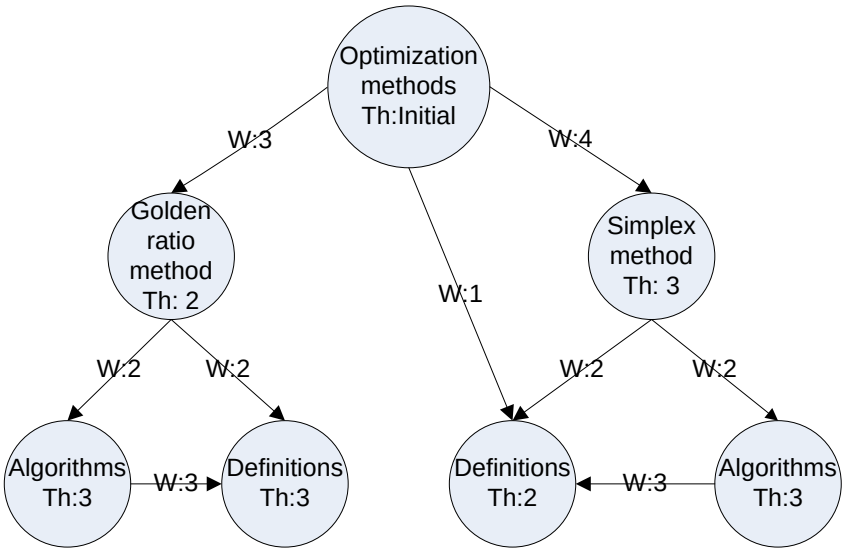

Figure 4. Structure of agent system based on the course of Optimization Methods.

Connections between elements suggest that:

- to accomplish this course user should acquire knowledge from both chapters,
- understanding of each chapter requires knowledge of associated algorithms and definitions,
- understanding of each algorithm requires knowledge of associated definitions,
- understanding of main part of course requires knowledge of definitions associated with simplex method.

Processing of this course by created agent system starts by selection of main element (**Optimization methods**) as active. This element is connected with three other elements i.e. **Golden ratio method**, **Simplex method** and **Definitions** (from simplex chapter). Depending on weights assigned to those connections, next elements are selected as active. In this example only weights associated with **Simplex** and **Golden ratio** methods are high enough to activate corresponding elements. At this moment all elements are connected with active elements and receive signals. **Definitions** element from **Simplex method** chapter receives now signals from two sources i.e. **Simplex method** and **Optimization methods**. Because

sum of these elements is higher than its activation threshold, this element is marked as active. Signals reaching the remaining elements are not sufficient enough to activate them, and no further changes occur in the state of system. In result, personalized course consists of following elements: **Optimization methods** + **Simplex method** + **Golden ratio method** + **Definitions** (from simplex chapter).

5. Summary

The paper presents new approach to personalization of learning content implemented to the Moodle platform (AGH Univeristy e-learning Platform). The proposed algorithm is based on the agent system. Every agent represents a single SCO object of the available courses in platform's database. The algorithm works using connections between agents to exchange information about learner's progress and history of education. Such architecture allows creating new courses constructed from various SCO elements, which are indispensable in learner's further education. Thus, each student obtains new learning content, which is personalized to its needs and abilities, and improves efficiency of learning process.

Created software is prepared to be used in distributed environment of e-learning platforms, however it requires implementation of web services, which would publish the courses from different platforms on the Internet. Therefore, the agent-based approach will be developed in future.

Acknowledgment
Financial support provided by Polish Ministry of Science and Higher Education, no. 11.11.110.575, is acknowledged

6. References

Brusilovsky P. (1996), Methods and techniques of adaptive hypermedia, User Modelling and User Adapted Interaction, vol. 6, no. 2-3, pp. 87-129.

Brusilovsky P., Eklund J., Schwarz E. (1998), Web-based education for all: a tool for development adaptive courseware, Computer Networks and ISDN Systems, vol. 30, no. 1-7, pp. 291-300.

Chen C., Lee H., Chen Y. (2005), Personalized e-learning system using Item Response Theory, Computers & Education, vol. 44, pp. 237-255.

Cheung B., Hui L., Zang J., Yiu S.M. (2003), SmartTutor: An intelligent tutoring system in web-based adult education, The Jounral of Systems and Software, vol. 68, pp. 11-25.

Conlan O., Lewis D., Higel S., O'Sullivan D., Wade V. (2003), Applying adaptive hypermedia techniques to semantic web service composition, Proc. International Workshop on Adaptive Hypermedia and Adaptive Web-based Systems, Budapest, Hungary.

Conlan O., Dagger D., Wade V. (2002), Towards a Standards-based Approach to e-learning Personalization using Reusable Learning Objects, Proceedings of E-Learn 2002 World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education.

Dolog P., Henze N., Nejdl W., Sintek M. (2004), Personalization in Distributed e-learning Environments, Proceedings of the Thirteenth World Wide Web Conference, New York City.

Gascuena J.M. (2006), Fernandez-Caballero A., Gonzales P., Domain Ontology for Personalized E-Learning in Educational Systems, Sixth IEEE International Conference on Advanced Learning Technologies, pp. 456-458.

Gomes P., Antunes B., Rodrigues L., Santos A., Barbeira J., Carvalho R. (2006), Using Ontologies for eLearning Personalization, 3rd E-learning Conference – Computer Science Education, Coimbra, Portugal.

Henze N., Dolog P., Nejdl W. (2004), Reasoning and Ontologies for Personalized E-Learning in the Semantic Web, Educational Technology & Society, vol. 7, no. 4, pp. 82-97.

Martinez M. (2002), What is personalized learning?, The E-learning Developers' Journal, pp. 1-7.

Mor E., Minguillon J. (2004), E-learning Personalization based on Itineraries and Long-term Navigational Behavior, Proceedings of the Thirteenth World Wide Web Conference, New York City, vol. 2, pp., 264-265.

Pahl C. (2003), Managing evolution and change in web-based teaching and learning environments, Computers and Education, vol. 40, pp. 99-114.

Sehring H.W., Bossung S., Schmidt J.W. (2005), Active Learning By Personalization - Lessons Learnt from Research in Conceptual Content Management, Proceedings of the 1st International Conference on Web Information Systems and Technologies, pp. 496-503.

Xu D., Wang H. (2006), Intelligent agent supported personalization for virtual learning environments, Decision Support Systems, vol. 43, pp. 825-843.