Content Adaptation for an Adaptive Hypermedia System

Marta Fernandes, Paulo Couto, Constantino Martins, Luiz Faria

GECAD – Knowledge Engineering and Decision Support Group
Institute of Engineering – Polytechnic of Porto
Porto, Portugal
mamaf@isep.ipp.pt

Abstract— **The aim of this paper is presenting the recommendation module of the Mathematics Collaborative Learning Platform (PCMAT). PCMAT is an Adaptive Educational Hypermedia System (AEHS), with a constructivist approach, which presents contents and activities adapted to the characteristics and learning style of students of mathematics in basic schools. The recommendation module is responsible for choosing different learning resources for the platform, based on the user's characteristics and performance. Since the main purpose of an adaptive system is to provide the user with content and interface adaptation, the recommendation module is integral to PCMAT's adaptation model.**

Keywords- adaptive educational hypermedia; user model; adaptation model; learning objects; recommendation module

I.   INTRODUCTION

E-learning has been gaining prominence in the past few years, but 2012 has seen some significant changes due to the rapid spread of massive online open courses (MOOCs).

MOOCs are free online courses aimed at large scale participation. They have existed for a few years [1], but after more than a hundred and sixty thousand students in over a hundred and ninety countries enrolled in Sebastian Thrun and Peter Norvig's "Introduction to Artificial Intelligence" in September 2011 [3], several free online learning platforms have launched that now offer courses on various subjects. Currently, Coursera, a social entrepreneurship company that partners with top US universities and was founded in January 2012, has had almost two million students enroll in its courses [2]. Udacity, founded by Sebastian Thrun and two colleagues after the success of "Introduction to Artificial Intelligence", has enrolled more than seven hundred and fifty thousand students [4]. And edX, a nonprofit start-up from Harvard University and the Massachusetts Institute of Technology, whose first courses started this fall, already has close to four hundred thousand students [2].

MOOCs are not massive in the number of students alone, there is also great diversity in the people enrolling. Students of these courses include both men and women from all over the world, with varying levels of education and ranging from preadolescents to senior citizens. As can be expected, these students do not all learn in the same way or with the same ease, yet MOOCs, as is the case with most e-learning, offer a one-size-fits-all solution.

Unlike traditional e-learning approaches, Adaptive Educational Hypermedia Systems adapt interface, content presentation, link navigation and so on, to the specific characteristics, needs and interests of different users. As these goals and characteristics change, so does the content presented by the system [5]. The aim of these systems is to help users achieve their learning goals, therefore characteristics such as previous knowledge and learning style are particularly important [5, 7].

AEHSs offer an educational experience that is tailored to each individual student and as e-learning continues to evolve and grow, they are a solution to a problem that is particularly noticeable in large-scale e-learning projects such as MOOCs: the absence of a teacher that will guide students and provide them with individual explanations, adapted to their specific abilities, knowledge and personality. A student who already possesses a doctorate will learn in a very different way than someone who is still in high school. AEHSs can adapt content presentation to suit each student's different level of knowledge and in that way improve their learning experience.

Adaptive Hypermedia Systems (AHSs), of which AEHSs are a subset, have been the subject of much research but more development, experimentation and implementation are necessary to conclude about the adequate features and effectiveness of these systems [5]. Some examples of Adaptive Educational Hypermedia Systems are AHA! [7], OntoAIMS [8] and WINDS [9].

In this paper, we introduce the adaptation model of the Mathematics Collaborative Learning Platform [10], and present an in-depth analysis of its recommendation module. PCMAT is an AEHS with a constructivist approach, which assesses the user's knowledge and presents contents and activities adapted to the characteristics and learning style of students of mathematics in basic schools. This adaptation is achieved by means of the recommendation module, which is responsible for choosing different learning resources for the platform. With the development of PCMAT, our main objective is to help drive AHS research forward, but we also hope to assist Portuguese students, who are still significantly below the OECD average in mathematics performance [11], improve their knowledge of the subject.

In SECTION II we make brief descriptions of the User Model and the Adaptation Model. In SECTION III we describe in more detail the platform's recommendation

module and in SECTION IV we take some conclusions and talk about future work.

II. ADAPTATION

A. User Modelling

AHSs change several aspects of the system based on the user's characteristics, such as goals and preferences. These characteristics, which can be provided by the user or inferred by the system, are stored in the User Model [12]. In the case of AEHSs, the User Model, or Student Model, also stores the user's knowledge. The purpose of AEHSs is helping users achieve their learning goals. When one goal is reached, the system re-adapts to the newly acquired knowledge [12, 13, 14]. This means that the Student Model is of particular importance for AEHSs because the information it contains about the user's knowledge is crucial for a properly adapted learning experience.

The Student Model includes Domain Dependent Data and Domain Independent Data. The first consists of the user's subject knowledge, learning goals and a complete description of the user's navigation through the course. Domain Independent Data consists of personal information, demographic data, academic background, qualifications, learning style, cognitive capacities, etc. Depending on the system being developed, some of these features are relevant for the User Model and some are not [12, 14, 15]. Determining which of the user's characteristics should be used is an important step in the creation of an AHS [13].

PCMAT's Student Model stores several characteristics, but the most relevant one is the user's learning style. Learning differs from individual to individual and depends on many unique and personal factors [16]. Learning styles attempt to be representations of how an individual learns. It is now known most people are multimodal, meaning they have more than one learning style [17, 18], as opposed to having only one learning style as was previously believed. The Learning Styles theory has been subject to criticism [19, 20, 21], but it is also supported by several studies [22, 23, 24]. There does not seem to be, however, any evidence suggesting the use of learning styles is detrimental. Moreover, it is the personal opinion of the mathematics teachers working on this project that learning styles might indeed be useful and facilitate the user's learning process. One of the objectives of this project is assessing the usefulness of learning styles as a feature of the User Model of Adaptive Educational Hypermedia Systems.

B. Adaptation Model

The development of PCMAT takes into account the constructivist learning theory. The system sets up a path into the subject, using the information obtained from assessing the user's previous knowledge. It adapts content and activities to the user's characteristics and performance, and is capable of automatic feedback and support, through pedagogical strategies and educational activities explored in a constructivist manner.

PCMAT uses the features contained in the User Model to create a specific domain concept graph, adapted from the domain model, and uses it to provide adaptation that will respond to the student's needs. The initial scheme is set by the teacher, but the path each student takes in the graph is determined by the interaction with the system using progressive assessment, the student's knowledge and the user's characteristics in the user model. Adaptation occurs through changes in content presentation, in the structure of links and in the links annotation [29].

Changes to content presentation are achieved by showing or omitting each of the multiple fragments a course page is composed of. These fragments consist of different learning objects such as exercises, figures and narrative text, among others. Changes in the structure of links and the links' annotation serve the purpose of guiding the student through the course, towards the most relevant information and away from knowledge that is not appropriate yet [5].

III. RECOMMENDATION MODULE

Choosing the most appropriate learning object for a student, for a given section of his learning path, implies defining the relationship between specific student characteristics and the parameters of a learning object. The recommendation module takes as input data from the User Model and uses a Fuzzy Logic system to output a set of parameters the learning object must comply with. These parameters are based on elements of the IEEE LOM's general and educational categories [27].

The system takes as input both domain dependent data, such as the student's subject knowledge, and domain independent data, namely the student's learning style and learning rate. The Fuzzy Logic engine then maps these characteristics into the following parameters [25]:

difficulty - indicates the level of ease associated with the learning resource.

resource type - indicates the potential educational use(s) or type(s) of content associated with the learning resource.

semantic density - indicates the degree of concision or brevity of expression in a resource.

interactivity level - indicates the degree to which the learning resource is able to respond to the actions and input of the user.

interactivity type - indicates whether the resource requires action on the part of the user.

The relationships established between User Model characteristics and Learning Object parameters are the following:

knowledge + learning rate -> difficulty
learning style + learning rate -> resource type
knowledge + learning rate -> semantic density
learning style -> interactivity level
learning style -> interactivity type

Both knowledge level and learning rate contribute to the choice of a learning object's difficulty level because, in our view, a student that learns at a faster pace should more easily be able to understand the contents of a more difficult learning object than a student that learns at a slower pace.

The resource type depends on the learning style for obvious reasons. If the student tends toward the visual learning style, a diagram will be a more appropriate learning

object than a block of text. The learning rate is also taken into account because certain resource types, such as exercises, might at some point in the course be appropriate for faster learning students, whereas slower learning students might need more learning time before being presented with a learning object of that type. The semantic density of a learning object can be determined in two different ways. It might refer to the ratio between the number of written or spoken words and the total number of words, or it may be determined by the total length of the learning object [25]. We take into consideration the student's knowledge level and learning rate when determining the appropriate semantic density of a learning object because not only will it be easier for a more knowledgeable student to understand a learning object of greater semantic density, but a student who learns faster is one who understands content more rapidly and therefore should be able to deal with greater semantic density more easily. As for the interactivity level and interactivity type of a learning object, we have chosen to only factor in the student's learning style because we believe neither knowledge nor learning rate must influence the interactivity of a learning object. A student's learning style, on the other hand, should be taken into consideration because a highly interactive object seems more appropriate to a student with a kinesthetic learning style, than to a student with an auditory learning style.

The mapping between student characteristics and learning object parameters is performed using Fuzzy Logic. The recommendation module takes the numeric values, which represent the input data and, after fuzzifying them, uses the specified Fuzzy rules to determine the output parameters the learning object must be in accordance with. An example of a Fuzzy rule is: if learning_rate is slow and knowledge_level is low then difficulty is very_easy.

These parameters, as well as a set of context-dependent keywords, are then used by PCMAT's search and retrieval module to retrieve a list of compliant learning objects.

After obtaining the list, the recommendation module verifies in the Student Model if the object at the top of the list has already been presented to the student. If there is a record of that object in the Student Model, the system checks the following objects until it cannot find a match. If all the learning objects in the list have already been shown to the student, the recommendation module asks the search and retrieval module for more learning objects that comply with the parameters specified. It then checks the Student Model again until it finds an object in the list that has not been shown to the student yet. If, after asking the search and retrieval module for learning objects a given number of times, no such object can be found, the system searches the Student Model for the learning object with the oldest timestamp. Once the system finds a learning object that can be presented to the student, be it a brand new one or one retrieved from the Student Model, that object is processed for inclusion in one of the fragments that make up the course's pages.

The courses pages are created using XHTML, which means that the recommendation module must process the learning object so that it will extend the Web page seamlessly. Learning objects can be of many different types, such as images, videos, text documents, and so on. Integrating these different types of objects in a seamless manner is achieved by using JQuery to determine some of the object's parameters (height and width, for example) and adjust the fragment's own parameters accordingly.

IV. CONCLUSION

The PCMAT platform is being developed in an attempt to contribute to the progress of AHSs, in particular AEHSs. As e-learning systems become more commonplace and grow in prominence, the usefulness of adaptive systems becomes more apparent. Our work on PCMAT intends to show the advantages of such systems, as well as perform more experimentation on User Modeling.

This project is still a work-in-progress, but has already helped define new strategies for the implementation of an AEHS to support and improve mathematics in the context of basic schools. It has also contributed to the definition of a student model describing the personal information, knowledge, preferences, and learning style of the user, the definition of a process and tools needed to produce learning objects aligned with the IEEE LOM standard, and the implementation of a set of adaptive and dynamic pedagogical strategies [26].

In this paper, we have presented PCMAT's recommendation module. This module is responsible for defining the parameters of a learning object, based on the user's characteristics and performance. The proper choice of learning objects is crucial to the system's adaptability and the individualization of the learning process.

PCMAT has already undergone some preliminary tests in two basic schools and achieved good results. After the testing phase, students from both the experimental and control groups had to answer a written test set up by their teachers. The results show the average student scores, from both schools, in the experimental group was higher than the average student scores in the control group, 59,1% (σ = 19,7) against 44,2% (σ = 21,8). The differences observed are statistically significant (p=0,010). Students from the experimental groups also performed better in the knowledge acquisition of individual concepts. The two groups were statistically compared using a two sided, independent samples t test with a 0.05 (5%) critical level of significance [28].

These results are very positive, and a strong indicator that PCMAT's architecture is viable and appropriate for AEHSs used in the context of basic schools. They also allow us to conclude that AEHSs, by adapting to the different needs and characteristics of a student, contribute indeed to the effectiveness and efficiency of the learning process. In addition, students perceived this tool as being relevant to their learning experience, and as a self-operating application to be integrated in a more global learning strategy that also includes tutoring (direct contact with the teacher) and peer learning. The teachers that participated in this experiment agreed with these definitions of the platform as well.

PCMAT will enter a new testing phase in the coming months, with a larger sample size. We hope to confirm the results previously obtained in order to conclude about the adequate features and true effectiveness of the PCMAT system. We will continue working on the system in order to improve its adaptability. Our current and future work also focuses on a Natural Language Processing module, which is capable of analyzing and assessing the answers given by students to open-ended questions.

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