

# Learning Objects Recommendation in an Adaptive Educational Hypermedia System

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*Abstract:* - The aim of this paper is presenting the modules of the Adaptive Educational Hypermedia System PCMAT, responsible for the recommendation of learning objects. PCMAT is an online collaborative learning platform 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. The recommendation module and search and retrieval module choose the most adequate learning object, based on the user's characteristics and performance, and in this way contribute to the system's adaptability.

*Key-Words:* - Adaptive Educational Hypermedia, User Model, Adaptation Model, Learning Objects, Recommendation module, Search and Retrieval module

## 1 Introduction

Unlike conventional hypermedia systems, which use a one-size-fits-all approach, the main purpose of Adaptive Hypermedia Systems (AHS) is adapting interface, content presentation, link navigation and so on, to the specific characteristics, needs and interests of different users [6, 9]. As these goals and characteristics change, so does the content presented by the system. Brusilovsky [5] referred to AHS as the crossroads of hypermedia and user modeling.

Adaptive Educational Hypermedia Systems place the focus on helping users achieve their learning goals. For this purpose, characteristics such as the user's knowledge and learning style are particularly important [7, 9]. AHS commonly consist of three interdependent modules: user model, domain model and adaptation model [2, 11]. By relating the user model to the domain model the system can, through the adaptation model, adapt its content, navigation and interface to each user's specific needs.

E-learning is becoming increasingly more prominent and although AHS have been the subject of numerous research, more development, experimentation and implementation are necessary to conclude about the adequate features and effectiveness of these systems [21, 22]. Some examples of Adaptive Educational Hypermedia

Systems are AHA! [9], OntoAIMS [1] and WINDS [19].

The Mathematics Collaborative Learning Platform (PCMAT) [20] is an online collaborative learning platform 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. With the development of PCMAT our main objective is to help drive AHS research forward.

This project also serves the purpose of assisting Portuguese students improve their knowledge of mathematics. According to the OECD PISA 2009 study [26], Portugal is still significantly below the OECD average in mathematics performance. With this project we hope to develop an adaptive system that'll help improve these results by tailoring the way in which basic school mathematics is taught to each student's individual needs.

In this paper we introduce two of PCMAT's modules. The first is a recommendation module which takes as input certain student characteristics and outputs a set of requirements. The second is a search and retrieval module which searches for Learning Objects that fulfill the requirements indicated by the recommendation module.

## 2 Adaptation and Learning Objects

### 2.1 User Modeling

In AHS the User Model stores characteristics (given or inferred), such as the user's knowledge and preferences, and uses them to change several aspects of the system [5]. With Adaptive Educational Hypermedia Systems, because these systems are meant to help the users achieve their learning goals, the importance of the User Model, or Student Model, is even greater. For example, when the student reaches the objectives of the course, the system must be able to re-adapt to the newly acquired knowledge [5, 21, 22].

The Student Model includes Domain Dependent Data and Domain Independent Data. Domain Dependent Data refers to, among others, the knowledge the system assumes the user has on the domain, his learning objectives and a complete description of the navigation. The Domain Independent Data consists of personal information, demographic data, academic background, qualifications, learning style, cognitive capacities, etc. Some of these characteristics are relevant for a determined type of UM but not for others [4, 5, 22]. Therefore, for each AHS it will be necessary to define which are the characteristics and relevant parameters of the user to be kept [21].

One of the most important characteristics of PCMAT's Student Model is the user's learning style. Learning styles are representations of how a person learns. The learning process depends upon many different and personal factors [28] and isn't the same to all individuals. It was believed at first that each person had a single learning style, but recent studies have shown the majority of people are actually multimodal, meaning they have more than one learning style [13, 24]. The Learning Styles theory has been subject to criticism [3, 15, 29], but it's also supported by several studies [18, 25, 27]. There doesn't 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.

### 2.2 Adaptation Model

PCMAT's development is based on the constructivist learning theory. The user's previous knowledge is assessed and, with basis on that information, the system prepares a path into the subject. It also provides the student with content and activities adapted to his characteristics and performance, and is capable of making automatic feedback and support, through instructional methodologies and educational activities explored in a constructivist manner.

The adaptation [12] provided by the system is achieved by using the elements in the User Model to define a specific domain concept graph. This graph is adapted from the domain model and is used in response to the student's needs. Although the initial scheme is set by the teacher, the path of each student in the graph is determined by the interaction with the system using progressive assessment, the student's knowledge representation and the user's characteristics in the user model.

The system adapts to each user through changes in content presentation, in the structure of links and in the links annotation. 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 isn't appropriate yet.

### 2.3 Learning Objects

Being a learning platform, PCMAT requires a set of learning objects for the students to interact with. It was then decided that the learning objects supporting the operation of PCMAT would reside in a repository, and that this would be searchable and the objects retrieved accordingly.

To make this possible, a single metadata record, consisting of a XML document, is associated to each learning object (LO). This metadata record is produced by means of the PCMAT Metadata Authoring Tool, a web application developed specifically for PCMAT that allows teachers and content developers to manage on-line the metadata associated to each learning object [8].

The PCMAT Metadata Authoring Tool presents the metadata creator with nine different forms, each corresponding to a category of the IEEE Learning Object Metadata (LOM), a multi-part standard, currently consisting of a conceptual data schema

[16] and its XML schema binding [17]. This standard defines a structured set of 76 elements, covering a wide variety of characteristics found to be relevant to define a learning object, grouped in the following categories:

**general** – information that describes the LO as a whole, as, for example, an identifier, the title, a description, a set of keywords;

**life cycle** – information pertaining to the development of the LO;

**meta-metadata** – information concerning the actual metadata document and not the described LO;

**technical** – information regarding technical requirements and technical characteristics of the LO;

**educational** – information about the LO's educational and pedagogic aspects;

**rights** – information on the LO's intellectual property rights and conditions of use;

**relation** – information that defines the relationship of the described LO with other LOs;

**annotation** – space for storing comments on the LO's usage; and

**classification** – description of the LO in accordance with different classification systems.

According to IEEE LOM, every element within a category, and every category, is optional (actually, in accordance with this standard, a "LOM instance that contains no value for any of the LOM data elements is a conforming instance" [17]), but because such a degree of freedom in filling the metadata record would deny the possibility to search for a specific LO, the PCMAT Metadata Authoring Tool makes it mandatory the filling of some elements, as the keyword element in the general category, or the elements concerning the identification of the creator and the identification of the LO.

Filling as correctly as possible the metadata forms is of the utmost importance to guarantee that the Adaptation Model exhibits the most suitable learning objects adapted to the student's characteristics and performance. Still, a problem persists: how to ensure that the Adaptation Model always retrieves the most adequate LO in accordance with the learning style of the student, and the concept(s) to be learned? Our answer to this question was the development of two modules, a recommendation module and a search and retrieval module.

## 3 Module Development

### 3.1 Recommendation module

In order to choose the most appropriate type of learning object for a given student in a given section of his learning path, it's first necessary to map the relationship between certain student characteristics and specific parameters of a learning object. To accomplish that task, PCMAT has a recommendation module that takes as input data from the User Model and uses Fuzzy Logic to output a set of parameters the learning object is required to comply with. These parameters are based on elements of the IEEE LOM's general and educational categories.

The input data includes Domain Dependent Data, such as the knowledge the system assumes the student has on the domain, and Domain Independent Data, namely the student's learning style and learning rate. These characteristics are mapped into the following parameters [14]:

**difficulty** - indicates the level of ease associated with the use of 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**

In our understanding, both the knowledge level and learning rate should have an influence on the choice of the difficulty level of a learning object. The influence of the student's knowledge level is obvious, but the learning rate should also be taken into account since a student that learns at a faster rate should be able to understand the contents of a learning object with a high degree of difficulty more easily than a student that learns at a slower rate. The choice of resource type must be constrained by the student's learning style. For example, if a student's learning style is visual then the learning object

should be of an appropriate type, such as a diagram or a figure. The learning rate must be considered as well 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. Semantic density can refer to the ratio of spoken or written words and the total number of words or the total length of the learning object [14]. Considering that definition, both the student's knowledge and learning rate must be regarded when determining the semantic density of a learning object. 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.

The recommendation module uses Fuzzy Logic to perform the mapping between parameters. With the exception of the learning style, the input data is represented in the form of numeric values. The system fuzzifies these values and uses the specified Fuzzy rules to determine the parameter values the learning object must be in accordance with. An example of the Fuzzy rules used is: if learning\_rate is slow and knowledge\_level is low then difficulty is very\_easy.

### 3.2 Search and retrieval module

Having translated the platform LO requirements to values of IEEE LOM, the recommendation module could easily perform a search over the full set of XML documents that constitute the repository of metadata records. However, depending on the number of XML files in the repository, this could be a time consuming and rather inefficient process. Thus, the need for a more efficient mechanism.

Our choice fell upon using a balanced k-d tree to store the pointers to all the metadata records in the repository and upon the k-nearest neighbours (KNN) algorithm to locate the k records containing the values closer to the ones required by the recommendation module.

#### 3.2.1 PCMAT's k-d tree

PCMAT's k-d tree is a five dimensions tree based on the possible values of the selected five elements from IEEE LOM educational category:

**interactivity type** – according to IEEE LOM, possible values are: active, mixed and expositive. These were quantified with the values 0, 1 and 2, respectively;

**learning resource type** – according to IEEE LOM, possible values are: exercise, simulation, questionnaire, diagram, figure, graph, slide, table, narrative text, exam, experiment, problem statement, self-assessment, and lecture. In an attempt to quantify these values it was noticed that it was possible to classify each value according to the type of interaction that it implies. Consequently, we grouped the learning resource type values as active (exam, exercise, experiment, problem statement, questionnaire, self-assessment, simulation), textual (lecture, narrative text, table) or visual (diagram, figure, graph, slide) and assigned the values 0, 1 and 2, respectively. However, because a single LO may be described as a combination of any of these values, to each possible combination was assigned a numeric value, as follows: active and textual = 3; active and visual = 4; textual and visual = 5; active and textual and visual = 6;

**interactivity level** – according to IEEE LOM, possible values are: very low, low, medium, high, and very high. These were quantified with the values 0, 1, 2, 3, and 4, respectively;

**semantic density** – according to IEEE LOM, the possible values are the same as for the interactivity level, and as such they were quantified accordingly;

**difficulty** – according to IEEE LOM, possible values are: very easy, easy, medium, difficult and very difficult. These were also quantified with the values 0, 1, 2, 3, and 4, respectively.

Having determined the set of values for each dimension it was possible to build a balanced k-d tree with all the possible nodes resulting from the combination of the values of each dimension. Once the k-d tree was built, it was feasible for the PCMAT Metadata Authoring Tool, when saving a metadata record, to calculate its node coordinates and allocate a pointer to the relevant node in the k-d tree.

#### 3.2.3 Search and retrieval mechanism

When this mechanism receives the request from the recommendation module it calculates the coordinates of the respective k-d tree node, in accordance with the values recommended for each

of the five elements of the IEEE LOM educational category, and locates its k nearest neighbours.

Subsequently, it retrieves the metadata records associated to the node and its k nearest neighbours and, by descending order regarding their proximity, looks within each metadata record for the keyword element values. If the metadata record does not contain all the mandatory keywords then it is discarded and the mechanism looks into the next metadata for the same keywords. If the metadata record contains all the mandatory keywords, then the mechanism verifies if the metadata record does not contain any other keywords aside the optional ones. This constraint ensures that the student will not be shown a LO that requires him to know anything more than what is strictly necessary to learn the new concept. Only a LO whose metadata record contains all the mandatory keywords and solely all the optional keywords or a sub-set of these, will be selected.

Once the LO is selected as an option it is verified if it has already been shown to that particular student. If it has, then the mechanism discards this LO and returns to the descending ordered list, picks up the next metadata record and checks it for the keywords constraint. This cycle goes on until a suitable LO that has not yet been shown to the student is selected and sent to the PCMAT platform.

## 4 Conclusion

The PCMAT platform is being developed in an attempt to contribute to the progress of AHS, in particular AEHS. As e-learning systems grow in prominence, the need for adaptive systems becomes more apparent and with PCMAT we intend to demonstrate the usefulness of these systems, as well as perform more experimentation on User Modeling.

Thus far, PCMAT has allowed the definition of new strategies for the implementation of an AEHS to support and improve Mathematics in the context of basic schools. This project has also contributed to the definition of a student model describing the 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 [23].

In this paper we have presented two of PCMAT's modules, a recommendation module and a search and retrieval module. Together, these modules are

responsible for choosing the most adequate 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.

The PCMAT platform has already undergone some preliminary tests, with good results. In the coming weeks a new testing phase, with a larger sample size, will begin. We hope to obtain additional results that will allow us to conclude about the adequate features and true effectiveness of the PCMAT system.

## 5 Acknowledgments

The authors would like to acknowledge FCT, FEDER, POCTI, POSI, POCI and POSC for their support to GECAD unit, and the project PCMAT (PTDS/CED/ 108339/2008).

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