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Model to support synchronous and asynchronous in the learning process with an adaptive hypermedia system

Francisca Grimón, Marylin Giugni, Josep Monguet F., Joaquín Fernández, Luis León G.

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***Abstract*—** In blended learning environments, the Internet can be combined with other technologies. The aim of this research was to design, introduce and validate a model to support synchronous and asynchronous activities by managing content domains in an Adaptive Hypermedia System (AHS). The application is based on information recovery techniques, clustering algorithms and adaptation rules to adjust the user's model to contents and objects of study. This system was applied to blended learning in higher education. The research strategy used was the case study method. Empirical studies were carried out on courses at two universities to validate the model. The results of this research show that the model had a positive effect on the learning process. The students indicated that the synchronous and asynchronous scenario is a good option, as it involves a combination of work with the lecturer and the AHS. In addition, they gave positive ratings to the system and stated that the contents were adapted to each user profile.

***Keywords*—** Blended Learning, System Adaptive, Model, Clustering Algorithms.

I. Introduction

EDUCATION in a Blended Learning (BL) environment can combine the Internet, technologies, material resources and learning-teaching processes. Technologies can be used to create a learning space that is adapted to each individual and manages their education in a personalised way. This contributes to improving each student's learning process.

The model proposed in this study can resolve problems related to the following: 1) Physical presence. Students can be based anywhere in the world and follow a synchronous course with their lecturer; 2) Volume of contents and personalisation.

The proposed model allows information to be retrieved in a personalised way. This stops students from feeling confused by the large number and variety of information sources available for studying specific contents. Through the use of AHS, in the asynchronous part of the model contents are selected, systematised and presented in accordance with the student's profile. This encourages learning.

In the following sections, the model is presented, its application in three courses is described and the results are discussed.

Francisca Grimón. Faculty of Science and Technology, University of Carabobo, Valencia, Venezuela; phone +58 241 6004000 ext 375200; e-mail: fgrrimon@uc.edu.ve

Marylin Giugni O. Faculty of Science and Technology, University of Carabobo, Valencia, Venezuela; e-mail: mgiugni@uc.edu.ve.

Josep Monguet. Multimedia Applications Laboratory, Polytechnic University of Catalunya, Spain; e-mail: jm.monguet@upc.edu.

Joaquín Fernández. Multimedia Applications Laboratory, Polytechnic University of Catalunya, Spain; e-mail: jfernandez@upc.edu.

Luis León G. Faculty of Science and Technology, University of Carabobo, Valencia, Venezuela; e-mail: lleon@uc.edu.ve.

II. Design of the Model

The model was designed for the educational field. However, it is flexible, and could therefore be applied to other areas.

Fig. 1 shows the components of the model. BL focus was used to create two communication modes: synchronous and asynchronous. These modes facilitate team work in a multidisciplinary research environment. In the synchronous mode, two types of sessions were undertaken: Between the lecturer and the students, in order to analyse a course subject, and between the lecturer and the students, in order to evaluate knowledge of a course subject, with the corresponding feedback.

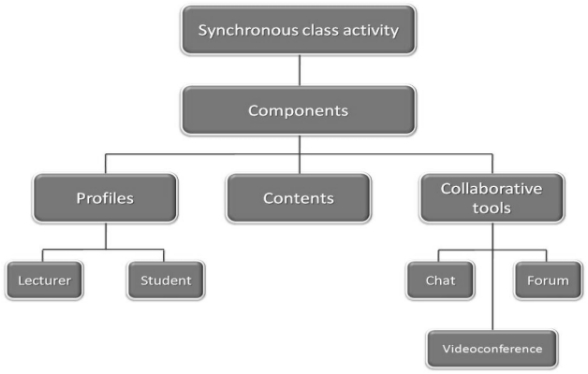


Fig. 1 Components of the model

In asynchronous mode, each student deepened their knowledge of the course subjects through the use of the AHS. The AHS provided them with contents that met the learning objectives and were adapted to their profile.

Fig. 2 shows the part of the model that corresponds to the synchronous mode.

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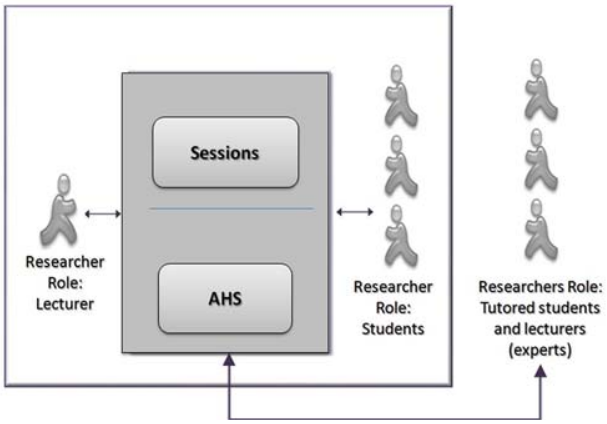


Fig. 2 Details of the model (synchronous part)

The class sessions are held in this mode, with interaction between the lecturer and the students, who are based in different countries. Collaborative tools, such as videoconferencing, chat and forums are used to carry out the class sessions. In this model, the contents are classified as follows: general (these contents meet the learning objectives and are the same for all the students) and specific (these contents meet the learning objectives and depend on the student's profile; they are specific for each student). In synchronous mode, general contents that meet the learning objectives are studied.

All AHS is a system that provides reading plans adapted to each user's profile. Its architecture (Fig. 3), part of the model that corresponds to the asynchronous mode, is based on a Contents Model, a User Model and an Adaptation Model. It uses an adaptation algorithm to adjust the user model in accordance with the users' evolution and to provide documents adapted to their interests.

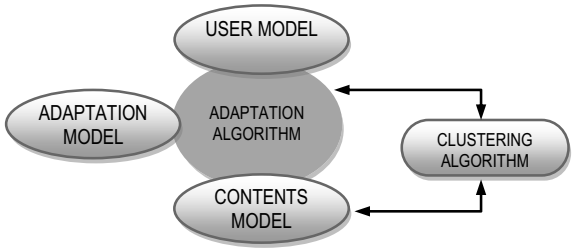


Fig. 3 System Components

Furthermore, it applies information recovery techniques and classification algorithms to divide the content domain into small groups with common characteristics so as to reduce the search space and render the adaptation process easier.

SHA initially stores students' static information, which is represented in their personal data and research areas. Then, upon an initial assessment, the application identifies the user's information needs relative to the subjects provided by the system; this information is used to place the student according to the initial knowledge level, which can be beginner, intermediate, advanced or expert. As students advance throughout their education process, statistical data is generated concerning evaluations and knowledge level acquired.

As far as contents are concerned, the system groups documents using the K-means clustering algorithm [1]. In this way, clusters consisting of documents that are similar to each other are obtained. This algorithm has been successfully used in other contents personalization [2].

The adaptation algorithm designed for this system considers different aspects including: the student's performance, knowledge level, number of times the students performs an evaluation, document location in each cluster, among others.

III. CLUSTERING ALGORITHM

Clustering algorithms have been used in the information recovery area, because they make it possible to identify typologies or groups where elements are very similar to each other and are very different from those in other groups [3]. K-means algorithm, proposed by [4] is a vicinity-based clustering method that is widely used because it is easy, fast and effective [5] [6].

First, an initial selection of k prototypes or centers, which are considered representative of each cluster, is carried out; then each one of the collection elements is assigned to the cluster with the closest prototype. The next step consists of calculating the center of each one of the resulting clusters. The collection documents are again assigned to the closest group. Prior steps are repeated until k centers remain in the same cluster [7] [4]

The previous steps are described in the following algorithm:

K-means Algorithm
Generate k centers with the first k documents
Assign n-k document to the closest centers
SumD=Sum of the (distances)^2 between docum/centers
repeat
Recalculate centers
Reassign documents to their closest centers
SumI = SumD
SumD = Sum (distances)^2 between docum/centers
until SumI - SumD < epsilon
end of algorithm

The Euclidean distance, i.e. the length of the straight line that joins two points in the Euclidean space, is used to assign each document to the closest cluster [8] [9].

Before applying the classification algorithm, documents are processed through a clean-up phase, which consists of eliminating accents, images and other special characters. Then documents are numerically represented by using the vector space model [Salton, 91], which allows for representing each document by means of a weight vector. In order to calculate weights, AHS uses the TF-IDF (*Term Frequency Inverse Document Frequency*) scheme [10] [11] [12], which determines how significant a term is within a document.

The K-means algorithm is executed after this stage to obtain k clusters of documents ordered based on their distance to the

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center.

IV. ADAPTATION ALGORITHM

The adaptation algorithm was designed to support users in a learning process, by providing them with documents in accordance with each student's knowledge. This algorithm has a set of rules intended to determine when a user may go from one level to another. Furthermore, it is fed from a prior classification, performed by the K-means algorithm described in the previous section.

The algorithm starts when the user presents the diagnostic evaluation. The result of this evaluation is considered in the first adaptation function $f(adap_1)$ which is detailed in (1).

$$f\left(adap_1\right)_{i,j} = \left(\frac{DE_i}{D_{max}}\right) - \frac{Cd_j}{Cmax} \quad (1)$$

Here, *DE* represents document *i* Euclidean distance, i.e., the distance from the cluster center to the document. D_{max}, is the largest distance between the cluster center and a document within it. *Cd* is the grade obtained by student *j* in the diagnostic evaluation. C_{max} is the highest grade that a student can get, according to the grading scale defined by the teacher.

This first adaptation function determines the knowledge the student must acquired to attain the learning objectives of a specific topic.

The first factor in the equation represents the weight of the document in relation to the pieces of knowledge to be conveyed. The second element in the equation expresses the diagnostic evaluation/maximum grade ratio to obtain the desired knowledge. A positive result indicates that the document will provide the student with knowledge; a negative value means that the student already possesses the knowledge that this document could provide.

$f(adap_1)$ is used to generate the first reading plan, that is, the listing of documents recommended by the system. Then the student can perform a number *n* of evaluations and thereby update his/her profile.

Further reading plans consider the student's performance, so that the subsequent reading plan updates are governed by a second adaptation function, $f(adap_2)$, which considers: distance between the cluster center and a document, the student's knowledge level (1, beginner; 2, intermediate; 3, expert; 4, advanced), prior grade obtained by the student in a self-evaluation, and guessing parameter (guessing likelihood), considering studies developed by [13].

V. SYSTEM FUNCTIONS

AHS has 4 basic functions: contents classification, selection of documents, adaptation of the user's profile and presentation of the reading plan.

To classify contents, the clustering algorithm described in section 2 is used by creating document clusters that are very similar to each other. This previous clustering allows for structuring the information by classifying it according to its particularities and similarities, thereby streamlining personalization.

Once the documents that comprise the knowledge basis are classified, the system selects those that are more relevant for a specific user in a given moment, based on the user's profile. It is precisely in this case where the adaptation algorithm plays a key role in personalization because it looks for similarities or correspondence between the user model and contents.

This research work uses Euclidean distance as a similarity measure among documents in a cluster, which is fundamental to determine the pertinence degree of the document with relation to the topic where it is located.

The third function, which is related to the user's profile adaptation, refers to the profile feedback, which changes as the user interacts with the system and obtains information about his/her actions. The system adaptation and the user's evolution are reflected in the reading plan.

The parameters considered in this research for the adaptation of contents to the users' profiles are their interest in the subject under study and their performance in this subject. Although the system is capable of storing information related to their interaction and participation in the learning environment, this first research assesses the system effectiveness and the user's satisfaction vis-à-vis the proposed adaptation algorithm.

In summary, the system:

1. Stores the course taxonomy, which corresponds to the organization of knowledge areas and the key words that identify them.
2. Categorizes documents using K-means algorithm.
3. Produces the diagnostic evaluation according to the system configuration.
4. Gathers information about the student (personal data and preferences).
5. Determines the student's knowledge level based on the result obtained in the diagnostic evaluation. Steps 4 and 5 provide information to determine the learner‘s profile, classifying the learner as beginner, intermediate, advanced or expert.
6. Executes the adaptation algorithm to establish the relation between contents and user's profile.
7. Generates the reading plan.
8. Performs n self-evaluations for the student, according to the system configuration.
9. Updates the profile, relocating the student's knowledge level.

Steps 6 to 8 are repeated until the user completes the study or the tutor considers that the learner's knowledge level is suitable. The main functions of the system are shown in Fig. 4, which includes the models comprising the system.

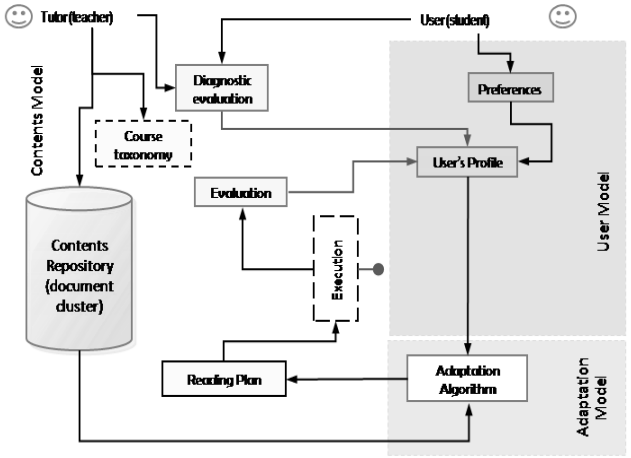


Fig 4 Functions of the system

The user model employed, as well as the adaptation and clustering algorithms, assume the student's knowledge as a subset of the knowledge administered by the system, and the goal of personalized reading plans is to extend this subset.

VI. METHOD

The case study method was used, as it enables recent events to be examined in a real-life context [14].

The sample sizes and the instruments used in the empirical studies are shown in Table 1.

TABLE 1
EMPIRICAL STUDIES

Study	Participants	Instruments
Multimedia Doctoral Programme (Course 1)	16	Questionnaire 1 Type B Evaluation
Degree in Computing (Course 2)	26	Questionnaire 2 Interview 1 Type B Evaluation
Multimedia Doctoral Programme (Course 3)	07	Questionnaire 2 Interview 1 Interview 2 Type B Evaluation

The course participants were based in different countries: the USA, Spain, Portugal and Venezuela.

A. Description of the empirical studies

The following activities were carried out in each of the studies: Firstly, the students used the synchronous mode. They had sessions with the lecturer in which they found out about the subject under study, through the lecturer's explanations. The interaction between students and the lecturer was carried out via chat and videoconferencing. In a subsequent session, the students were evaluated using a tool that enabled them to be assessed in real time. [15]

Subsequently, the students in asynchronous mode studied the subject in greater depth via the use of the AHS. Each student received a reading plan from the system, in accordance with his/her profile. This plan contained the contents that would enable the students to deepen their knowledge of the subject and to meet the learning objectives. When they used the AHS, the students had to carry out two types of evaluations: Evaluation A and Evaluation B. In addition, the students completed a questionnaire that contained a mix of open and closed questions.

B. Data Analysis

The content analysis method was used to analyse the data, as it reveals the meaning of a message. This method consists in classifying and/or coding the different elements of a message, in order to create categories [16]. The stages of the content analysis [17] in this research were as follows:

1. Define the research objectives.
2. Build a corpus: gather together the material that will be used in the analysis.
3. Divide the corpus into units of analysis, according to the research objectives.
4. Group the units into categories.
5. Deal with the data quantitatively and qualitatively.

VII. RESULTS

The study revealed the students' opinions of the proposed model. The results indicate that the model had a positive effect on the learning process. The students gave a good rating to the AHS and stated that the contents were adapted to the profile of each user. Results of the different tests contribute to research into content personalisation in BL environments.

Table 2 shows the results of the three courses, about the effect of AHS and the model in the learning process.

TABLE 2
INFLUENCE ON LEARNING

Will the students consider that the AHS has a positive effect on their learning process?	100% (yes)
How will the model influence the learning process of each individual?	100% (positively)

With respect to the most suitable scenario for the learning process, the following question was asked:

Which of these scenarios is most appropriate for the learning process?

- Only the lecturer, either face-to-face or synchronously.
- Synchronous and asynchronous (lecturer and AHS)
- Asynchronous (only AHS)

Students in the different studies were 100% in favour of a combined synchronous and asynchronous scenario, which involves a mix of a lecturer and the AHS. The justification that students gave for selecting this scenario is shown in Table 3.

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TABLE 3.
BLENDED LEARNING

Professor	*AHS*
Has experience in the subject area.	Enables the subject to be studied in more depth.
Should introduce the subject.	Enables students to go into the subject in more depth.
Clarifies doubts about the subject.	Complements the subject.
Motivates students.	Enables knowledge of the subject to be strengthened.

In general, the students who were surveyed in these studies considered that the lecturer and the AHS were complementary. This combination of lecturer and AHS can be used for lifelong training. It is a strategy that fits in well with e-learning.

A. Users' Satisfaction Degree

Students, with their information needs, are the main information source in this experiment. In this case, the Technological Acceptance Method (TAM) developed by [18] has been used. This method measures the quality of information systems and is used to forecast acceptance and the use of new technologies.

The perceived easiness of use is employed as a measure of quality in studies on the success of Information Systems [19] and is specifically considered a component of the quality of websites [20]. According to [21], TAM is the theoretical system most applied to assess ICTs acceptance within the scope of information systems in corporate and educational environments.

This research has been based on TAM model with a view to analyzing AHS acceptance as a reading personalization system; tables 4, 5 and 6 show the results of the surveyed sample.

At the end of the experiment, the three questions on perceived usefulness (see Table 4) show that 87.5% of respondents considered that their productivity was increased. This fact reflects a positive perception about the usefulness of the whole system.

With respect to the results obtained for easiness of use of the tool, when data in columns "High degree of agreement" and "Agreement" are summed, it can be observed that the entire sample considers that both learning as well as using the tool was easy.

TABLE 4
USEFULNESS PERCEIVED BY USERS OF THE TOOL

Construct: Usefulness	High degree of agreement (%)	Agreement (%)	Not decided (%)	Little agreement (%)	Total disagreement (%)
It allowed me to perform my tasks more quickly	62.5	25.0	12.5	0	0
I increased my productivity	62.5	25.0	12.5	0	0
I believe this tool is relevant for my research	87.5	0	12.5	0	0

TABLE 5
EASINESS OF USE PERCEIVED BY THE USERS OF THE TOOL

Construct: Easiness of use	High degree of agreement (%)	Agreement (%)	Not decided (%)	Little agreement (%)	Total disagreement (%)
It was easy for me to learn how to use the system	100.0	0	0	0	0
I find it easy to use the system	87.5	12.5	0	0	0

It can be observed that data is in agreement with [22], [23] and [24], who point out that the easiness of use in an information system must positively influence its perception of usefulness.

TABLE 6
INTENTION OF USE PERCEIVED BY THE USERS OF THE TOOL

Construct: Intention of use	High degree of agreement (%)	Agreement (%)	Not decided (%)	Little agreement (%)	Total disagreement (%)
I would use this system every time I have to research a particular topic	87,5	0	12,5	0	0
I would use this system every time I need to be prepared for an evaluation	75	25	0	0	0

The results presented in Table 6 reveal that more than 93.75% of the sample has a positive attitude (global positive or negative attitude toward the possibility that a behavior may take place) toward the intention of use of the tool.

VIII. Conclusion

This paper proposes a model that combines synchronous and asynchronous mode. In asynchronous mode working with a AHS. According to [25][26], adaptive hypermedia are an alternative to the "one-size-fits-all" traditional approach. They make it possible to adapt contents to each user's needs. This study presents an approximation and a first attempt implement the proposed model and the results suggest that the AHS had a good effect in the learning- teaching process. Offers contents that are in accordance with the students' needs and reduce their cognitive load. In the future, this system may provide a better tool to follow up and monitor students

This system not only helps students recommending documents tailored to their needs and by working groups, but also helps the teacher by providing a tool to monitor student progress, which may suggest reading plans remediation if necessary.

The integration of data mining techniques with AHS was effective, which has led to a system that can be used in different research domains.

The result of this research work benefits the community of application developers in the area of information recovery in adaptive hypermedia systems, who desire to put this experience into practice.

This research must be further developed with other groups of students in order to be able to make comparisons among the different experiments. Other elements within the adaptation function may also be included.

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