Generating Intelligent Teaching-Learning Systems using Concept Maps and Case-Based Reasoning

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Resumen—El empleo de métodos pedagógicos junto a las tecnologías de la información y las comunicaciones favorece la tarea de generar, transmitir y compartir el conocimiento. Tal es el caso de la fortaleza pedagógica de los Mapas Conceptuales, que constituyen una herramienta para la gestión del conocimiento, por la posibilidad que estos ofrecen de personalizar el aprendizaje, compartir conocimiento, y para aprender a aprender. Los Mapas Conceptuales facilitan la visualización de la información e organizan el conocimiento. Por otra parte, el Razonamiento Basado en Casos es una técnica de Inteligencia Artificial que cumple un importante rol en el proceso de recuperación de la información. En este trabajo se expone un nuevo enfoque que combina ambas técnicas para elaborar Sistemas de Enseñanza-Aprendizaje Inteligentes, utilizando un Sistema Basado en Casos como marco teórico para la representación del Modelo del Estudiante. El modelo propuesto se ha implementado en un sistema computacional nombrado HESEI, el cual ha sido aplicado exitosamente en la toma de decisiones en tareas de apoyo al proceso de enseñanza-aprendizaje, por personas no necesariamente expertas en el campo informático.

Palabras Claves— Inteligencia Artificial, Mapas Conceptuales, Modelo del Estudiante, Razonamiento Basado en Casos, Sistemas de Enseñanza-Aprendizaje Inteligentes.

Abstract—The use of pedagogical methods with the technologies of the information and communications produce a new quality that favors the task of generating, transmitting and sharing knowledge. Such is the case of the pedagogical effect that produces the use of the Concept Maps, which constitute a tool for the management of knowledge, an aid to personalize the learning process, to exchange knowledge, and to learn how to learn. Concept Mapping provides a framework for making this internal knowledge explicit in a visual form that can easily be examined and shared. However, it does not address how relevant Concept Maps can be retrieved or adapted to new problems. Case-Based Reasoning is playing an increasing role in knowledge retrieval and reuse for corporate memories, and its capabilities are appealing to augment the concept mapping process. In this paper the authors present a new approach to elaborate Intelligent Teaching-Learning Systems, where the techniques of Concept Maps and Artificial Intelligence are combined, using the Case-Based Reasoning as theoretical framework for the Student Model. The proposed model has been implemented in the computational system HESEI, which has been successfully applied in the teaching-learning process by laymen in the Computer Science field.

Key words—Artificial Intelligence, Case-Based Reasoning, Concept Maps, Intelligent Teaching-Learning Systems.

I. Introduction

To construct and to share knowledge, to learn significantly, and to learn how to learn, are ideas on which researchers have been pondering for a long time as well as the use of tools that would allow taking these aspirations into practice. To achieve this, different techniques and strategies have been used. Concept Maps provide a schematic summary of what is learned and they order it in a hierarchic range. The knowledge is organized and represented in all the levels of abstraction, the general knowledge goes to the upper part and the most specific one goes to the lower [1]. Over the last few years the Concept Maps have increasingly got a great popularity and its integration with the technologies of the information and the communications have become a very important element in the plans for the improvement of the teaching-learning process. The main application of the Concept Maps has had effect in the teaching-learning process, which is its basic intention, it is important to point out that the Concept Maps lead the attention of both students and professors on the restricted number of important ideas in which they must concentrate.

The Concept Maps are based on an instrument that combines the scientific rigidity with simplicity and flexibility, producing a general approval in the audience of students and professionals; this represents an important nexus between pedagogy and technology in a huge field of applications. Also, it constitutes an important aid for those who generate, transmit, store, and divulge information and knowledge and it comprises an important tool to obtain a highest practical value in the systems of the teaching-learning process [2].

The field of the Intelligent Teaching-Learning Systems is characterized by the application of Artificial Intelligence techniques, to the development of the teaching-learning process assisted by computers. If the key feature of an Intelligent Teaching-Learning System is the aptitude to adapt itself to the student, the key component of the system is the Student Model, where the information associated to the student is stored. This information must be inferred by the system depending on the information available: previous data, response to questions, etc. This process of inference is identified as diagnosis, and is undoubtedly the most complicated process inside an Intelligent Teaching-Learning System, who uses the Artificial Intelligence techniques to represent knowledge, to shape the human reasoning, to emphasize the learning by means of the action, to combine experiences of resolution and discovery, to be able to solve problems by their own, to formulate diagnoses and to provide explanations. So, they count on a bank of instruction strategies which helps to decide what and how to inform to the student to get an effective direction.

Thus, Case-Based Reasoning is a technique of Artificial Intelligence that allows the use of previous experience in the solution of our problems. Cases are stored together with their respective solution, so when a new problem comes out, this information is used to solve it. So far, Intelligent Teaching-Learning Systems have demonstrated its effectiveness in diverse domains; however, to construct an Intelligent Teaching-Learning Systems implies a complex and intense work of knowledge engineering, which prevents an effective use of it. In order to eliminate these deficiencies there appears the idea to construct a tool to facilitate the construction of these kind of systems to all users (not necessarily expert in the Computer Science field), in particular to those instructors who are expert in others area of the knowledge.

The aim of this paper is to present a new approach to elaborate Intelligent Teaching-Learning Systems using a Concept Map, questionnaires able to catch the cognitive and affective state of the student (Student Model) and by using the paradigm of the Case-Based Reasoning. It will allow the students to navigate according to their knowledge and not in a free way as the Concept Maps are conceived. And it is the capacity to adapt dynamically to the development of the student's learning what makes this system intelligent. The proposed model was implemented in the computational system HESEI, which has been successfully applied in the teaching-learning process.

II. MOTIVATIONS FOR CONCEPT MAPS

Concept Maps provide a framework for capturing experts' internal knowledge and making it explicit in a visual, graphical form that can be easily examined and shared. Concept Maps constitute a tool of great profit for teachers, investigators of educational topics, psychologists, sociologists and students in general, as well as for other areas especially when it is necessary to manage with large volumes of information. They have become a very important element in the plans for the improvement of the Intelligent Teaching-Learning Systems and they have also extended its use to other areas of the human activity in which both management and the use of knowledge take up a preponderant place.

If to define a Concept Map is relatively simple, it is simpler to understand the meaning of the definition. The Concept Maps were defined by Novak, his creator, as a skill that represents a strategy of learning, a method to get the gist of a topic and a schematic resource to represent a set of conceptual meanings included in a set of propositions [2].

It is necessary to point out that there is not only one model of Concept Maps, several may exist. The important point is the relations that are established between the concepts through the linking words to form propositions that configure a real value on the studied object. For such a reason, in a concept there may appear diversity of real values. In fact, it turns very difficult to find two exactly equal Concept Maps, due to the individual character of knowledge.

The Concept Maps can be described under diverse perspectives: abstract, visualization, and conversation. Since significant learning is reached more easily when the new concepts or conceptual meanings are included under wider concepts, the most used Concept Maps are the hierarchic ones, the most general and inclusive concepts are placed in the upper part of the map, and the progressively more specific and less inclusive concepts, in the lower part. The subordinated relations among concepts may change in different fragments of learning, so in a Concept Map, any concept may rise up to the top position, and keep a significant propositional relation with other concepts of the map.

The use of Concepts Maps designed by the professor increases both learning and retention of scientific information. The students produce maps as learning tools. Considering that the Concept Maps constitute an explicit and clear representation of the concepts and propositions, they allow both teachers and students to exchange points of view on the validity of a specific propositional link and to recognize the missing connections in the concepts that suggest the need of a new learning. For this reason, this skill has complemented so favorably with the practice of distance learning which presupposes that students and teachers are not physically in the same place at the same time.

Concept Maps have particular characteristics that make them amenable to smart tools. These include:

1. Concept Maps have structure: By definition, more general concepts are presented at the top with more specific concepts at the bottom. Other structural information, e.g. the number of ingoing and outgoing links of a concept, may provide additional information regarding a concept's role in the map.
2. Concept Maps are based on propositions: every two concepts with their linking phrase forms a "unit of

meaning". This propositional structure distinguishes Concept Maps from other tools such as Mind Mapping and The Brain, and provides semantics to the relationships between concepts.
3. Concept Maps have a context: A Concept Maps is a representation of a person' understanding of a particular domain of knowledge. As such, all concepts and linking phrases are to be interpreted within that context.
4. Concepts and linking phrases are as short as possible, possibly single words.
5. Every two concepts joined by a linking phrase form a standalone proposition. That is, the proposition can be read independently of the map and still "make sense".
6. The structure is hierarchical and the root node of the map is a good representative of the topic of the map.

The students who analyze Concept Maps will have a wider basic knowledge; therefore, they will be more prepared to solve problems in comparison to those students who learn by memorizing. The Concept Maps have turned into a useful instrument for teacher training and for the student's understanding of diverse subjects. Concept Maps constitute an instrument that merges the scientific rigidity with the simplicity and flexibility. It represents an aid for those who generate, transmit, store and spread information and knowledge. They also constitute an important tool to achieve a practical value, especially in the Artificial Intelligence systems.

III. CASE-BASED SYSTEMS

In the traditional Case-Based Reasoning the solution of a problem is made taking the examples of cases stored in the case memory through the implementation of a function of distance or similarity, depending on the domain. The cases are composed by a set of attributes that describe the problem, among them the predictive features with the solution given to the problem described. The representation of the case is defined taking into account the nature of the problem, the important attributes, the problems to be processed, the proposed solution, etc. Also, it is necessary to define the mechanisms for the retrieval of cases. The most similar case will be the one closest to the current problem, depending on its attributes; it will be the case which evaluation of the target function or function of similarity takes the best value understanding as the closest value, the value of the target function that denotes minor difference between the current case and the evaluated case.

The functioning of the Case-Based Reasoning comprises related processes, so problems and their solutions can be used to derive solutions to new problems, these processes are: the retrieval of similar cases, the suitability to the proposed solution and the storage or incorporation of the new solution to the new case. The retrieval process consists of determining the most similar cases found in the case base in order to give solution to new cases: the practice to determine the value of similarity between two cases include a wide range that involves methods such as counting the number of similar predictive features and others that consider the importance of the predictive features within the function of similarity [7].

After obtaining the value of similarity between the cases stored in the case base and the new problem, those cases to be considered in the construction phase of the new solution are selected. The suitability is the process of modification of solutions that have already been retrieved in order to give solution to the new problems. The Case-Based Systems have a group of features [8], which can be used in the creation of Intelligent Teaching-Learning Systems such as the acquisition of knowledge, the flexibility in the representation of knowledge, the preservation of knowledge and the reuse of previous solutions.

IV. GENERAL ARCHITECTURE OF THE SYSTEM

The Intelligent Teaching-Learning Systems that are created by HESEI correspond with a Concept Map, with the particular feature that in some of its nodes there appears a questionnaire, capable to get the cognitive and affective state of the student and able to guide his navigation, creating this way an "Intelligent" Concept Map. Figure 1 shows the architecture of HESEI that includes Case-Based Reasoning, and an algorithm of Patterns Recognition to obtain the implementation of the Student Model with a previous selection of characteristics.

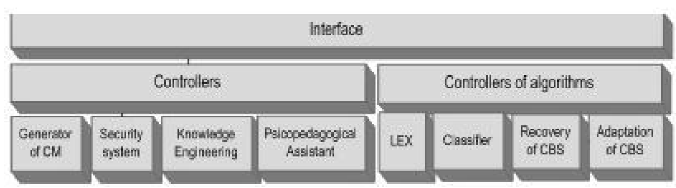


Figura 1. HESEI architecture.

Brief description of some components of HESEI:

Interface: It is provided with an editor that allows the teacher to introduce all the necessary information to prepare the Intelligent Teaching-Learning Systems. Through the Interface the system catches the cognitive and affective state of the student (Student Model). Also, through this component the students may be able to interact with the Intelligent Teaching-Learning System generated by HESEI using part of the information provided by the professor which best satisfies the students' need.

Knowledge Engineering and LEX: These components helps the teacher in the complex and intense work of knowledge engineering, using a Pattern Recognition algorithm to reduce the space of initial representation (features that shape the Student Model), calculating the typical testors (discriminates features) [11] which analyzes each questionnaire in order to facilitate the teacher the information of those questions that are worthless, they are eliminated by the teacher if they do not have a methodological value either. It was implemented the LEX algorithm for this task. A questionnaire is composed for n questions, and the teacher from the questionnaire conceives m categories (Student Model), in fact the experience has demonstrated that m is always very much minor than n.

Retrieval and CBS adapter: In this component a Case-Based System was implemented, it is composed by a case-base, the retrieval algorithm and case-adaptation algorithm. An algorithm is proposed for the retrieval of the most similar cases in which the function of similarity of the nearest Neighbors:

$$\beta\left(O_0, O_t\right) = \frac{\sum_{i=1}^{n} p_i \cdot \delta_i\left(O_0, O_t\right)}{\sum_{i=1}^{n} p_i}$$

is transformed into a new function of similarity that allows the handling of fuzzy values, as it shows (2).

$$\beta\left(O_0, O_t\right) = \frac{\sum_{i=1}^{n} p_i \cdot \delta_i^{'}\left(x_i\left(O_t\right), x_i\left(O_0\right)\right)}{\sum_{i=1}^{n} p_i} \quad (2),$$

where n is the number of predicting features, $\delta_i^{'}\left(x_i\left(O_t, x_i\left(O_0\right)\right)\right)$ is the similarity function transformed according to:

$\delta_i^{'}\left(x_i\left(O_t\right), x_i\left(O_0\right)\right) = \delta_i\left(x_i\left(O_t\right), x_i\left(O_0\right)\right)\left(1 - \left|\mu_i\left(O_0\right) - \mu_i\left(O_t\right)\right|\right)$ and

p_i is the weighting of the predicting feature x_i, calculated using the theory of the typical testors [11].

Psicopedagogical Assistant: In previous sections we have dealt with affective features and we considerer important going over it once more. The affective features are obtained through a psicopedagogical assistant in order to achieve a connection between affectivity and cognition. There has traditionally existed an absolute separation between the cognitive and affective aspects when studying their influence in the learning process. So, investigators would centre their studies in the cognitive aspects rather than in the affective ones or vice versa. At present, there exists an increasing interest in studying the two components simultaneously. The teaching-learning process is both cognitive and affective; in the development of the academic output it is necessary to take into account both the cognitive aspects and the affective ones. Learning is only possible if the chance to acquire the knowledge is given and the process is related to the capacities, knowledge, strategies, and the skills (cognitive component) of the student, but it is also necessary to have intention and the motivation to face this process (affective component). For this component the authors developed a system based on rules which team up with the learning process [5]. It allows to be acquainted with the mood of the student and check their motivation as well as their understanding on a specific subject. Thus the Intelligent Teaching-Learning Systems will be able to change the learning speed or, if necessary, to motivate and reorganize the study.

V. EXAMPLE OF AN INTELLIGENT TEACHING-LEARNING SYSTEM IMPLEMENTED WITH HESEI TO LEARN THE GRAPH THEORY

The graph theory is a subject of Discrete Mathematics and due to its importance it is also present in other subjects related to the Computer Science. Some difficulties when learning this subject have lead the authors to the design and implement an Intelligent Teaching-Learning Systems able to deal with the subject as well as to link it to others such as Data Structures and Compilers; as a general example, the authors present a simple part of the Intelligent Teaching-Learning Systems [12]. Figure 2 shows the Concept Map to learn the basic terminology [13], [14], [15], the way the map is conceived enables the student to navigate freely by any node interacting with all the materials related to this topic, and in Example 1 we show one of the questions of the questionnaire to transform it into an Intelligent Teaching-Learning Systems with Concept Map features.

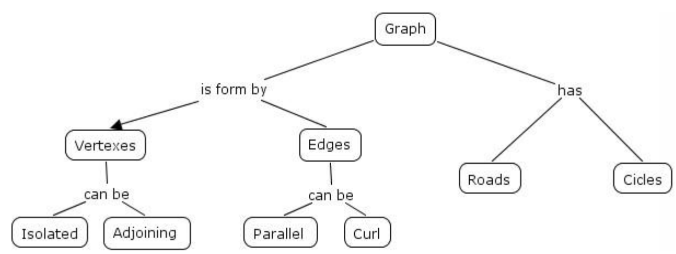
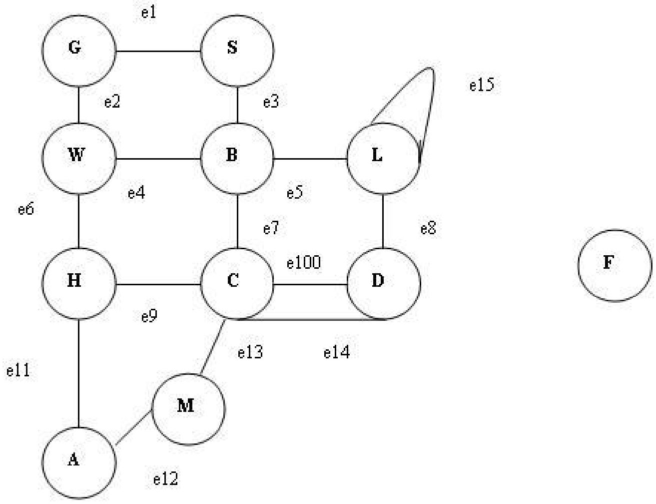


Figura 2. Basic terminology.

In the example, the professor makes the questionnaire in the root node of the Concept Map, where the Student Model is constructed. So, by using the Case-Based Reasoning paradigm, the branch where the students must navigate in accordance with his learning should be inferred.

Example of a questionnaire:

Given the following graph. Match column A and B.



Column A	Column B
a). G, L, D	__ are parallel edges.
b). e1	__ are isolated vertexes.
c). e1, e7, e8	__ are vertexes.
d). M y C	__ are bows.
e). e10, e14	__ incident edges in G and S.
f). ce15	__are edges.
g). F	__ are adjacent vertexes.
h). e2, e3	

Figure 3 shows a stage of the Intelligent Teaching-Learning Systems after the student answers the questionnaire, where it is plain to see that the student has not overcome the knowledge on the left branch, so he can not navigate by the right branch. In the left branch the student has already overcome the knowledge related to the concept of vertexes, so he can have free access to further information. However, he must study the topic of Edges, because there is a poor knowledge in this area.

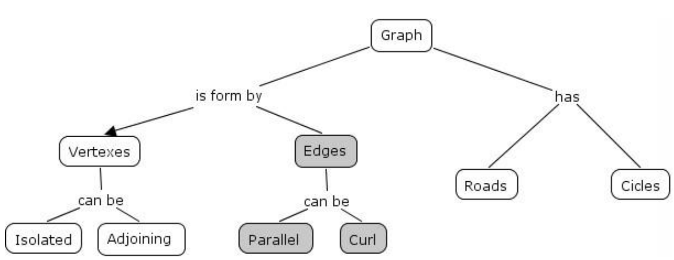


Figura 3. Resultant Concept Maps (Intelligent Teaching-Learning System).

VI. VALIDATION OF THE RESULTS

The validation process of the tool had two stages, on the one hand to validate the tool as far as facilities that it provides to construct new Intelligent Teaching-Learning Systems to all users (not necessarily expert in the computer science field) and to validate the possibilities of use and success of the new generated systems, in which it influences the efficiency of the algorithm and the teacher's experticity together his methodological work. The analysis of the efficiency of the intelligent system to learn the graph theory is made having in consideration the results obtained in the solution of new problems, using the proposed model and the criteria of the expert.

The authors used a Crossed Validation method in order to carry out this process, this general method consists of dividing the base of joint cases in n of equal size and carrying out the algorithm of learning n times, in each one of which the training set (learning sample) are all, except one of the n subgroups where it is evaluated (control sample). The results for n=6 are shown in figure 4:

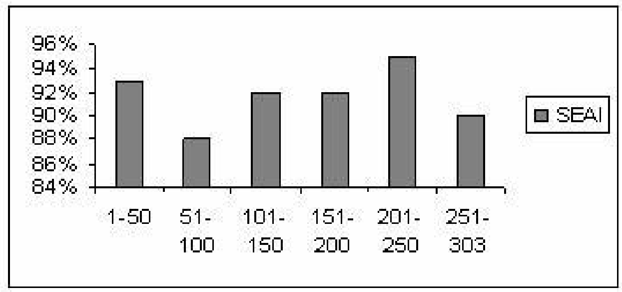


Figura 4. Results of the efficiency in the valuation of the student model.

We considered that the obtained results are good, considering that we are working with fuzzy classes where a student can belong to one or another model with certain degree of property.

Figure 5 shows a window of the HESEI interface with an Intelligent Teaching-Learning Systems generated for the subject of Binary Heaps in the course of Data Structures. We are elaborating some courses in different subjects.

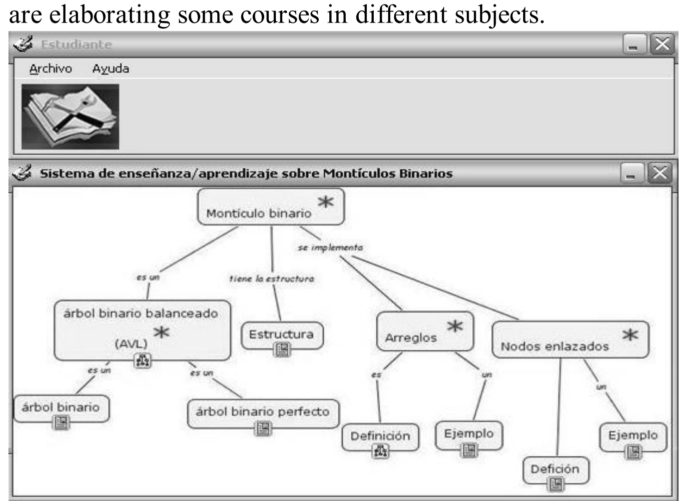


Figura 5. HESEI Interface

VII. CONCLUSIONS

Concept mapping is useful for knowledge management as a vehicle for externalizing "internal" expert knowledge, to allow that knowledge to be examined, refined, and reused. Case-Based Reasoning is useful for knowledge management in providing an easy to understand knowledge representation records of specific reasoning episodes and methods for accessing relevant information and building up a corporate memory of experiences. The synergy of the two technologies provides a promising approach for addressing corporate "knowledge loss" by supporting the capture and reuse of expert design experiences, helping to manage and maintain an important component of organizational knowledge assets.

With this work we propose a new Student Model that could be considered in the construction of Intelligent Teaching-Learning Systems, where are combined the facilities of the Concept Maps for the organization of the knowledge and the potentiality of the Case-Based Reasoning like inference tool. The proposed ideas were implemented in the computational system HESEI, which has been applied successful in the elaboration of Intelligent Teaching-Learning Systems by users that there are not necessarily expert in the Computer Science field.

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