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Intelligent Tutoring System: An approach to the model of the student using multiple intelligences

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Abstract. An Intelligent Tutoring System (ITS) emulates human tutors to determine what to teach, when to teach and how to teach the students in an autonomous manner. The technique of Artificial Intelligence Reasoning Based in Cases is proposed, to be included into Student Modeling, thus achieving an efficient representation by means of modeling that incorporates the different abilities and intelligences (multiple intelligences proposed by Gardner) that students require for their learning, in our case study, Basic Algebra.

1 **Key Words**: Intelligent tutoring system, student model, case based system, multiple intelligences.

1 Introduction

The learning of Mathematics is one of the areas of utmost concern due to the low performance that students have demonstrated.

The main cause of the learning problems that have been identified is that the knowledge that should have been acquired in previous courses was actually never assimilated. [1].

The contents are not taught in depth and are oriented towards memorizing and repetitive exercise solving in order to mechanize the solving procedure, that is to say that previous learning is not used to build new knowledge [5].

The didactics of Mathematics has recently experienced a surge in research and development on teaching [3]. The inclusion of ICTs has acquired relevance through computational learning environments [8].

The development of tutoring systems has had a significant advance in the development of applications such as CAI (Computer Assisted Instruction), ICAI (Intelligent

adfa, p. 1, 2011.

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Computer Assisted Instruction) and ITS (Intelligent Teaching Systems) [7], [12]. Currently Virtual Learning Environments (VLE) are spaces where the right conditions are created so that the individual may seize new knowledge, new experiences and new elements that may suggest to him/her processes of analysis, reflection and appropriation of the same, according to Ávila [2].

1.1 Intelligent Tutoring Systems

The objective of ITSs is to imitate human tutors in their ability to determine —in an autonomous manner— what to teach, when to teach and how to teach in each case.

An ITS uses three types of knowledge: knowledge of the domain (topics of a particular subject), knowledge of strategies and teaching methods (e.g. the personal guidance or *coaching* method) and knowledge of the student (personal preferences and styles of learning). These three types of knowledge provide the system with the capacity to assist the student in his learning process.

Usually, an ITS should identify the strengths and weaknesses of a particular student in order to establish an instructional plan that will be consistent with the results. It should find all the relevant information on the learning process of that particular student (such as learning style) and apply the best teaching method according to his/her individual needs.

In order to support the learning process, the ITS proposes the implementing of Howard Gardner's (multiple intelligences) propositions where it has used his theories with good results in its applied tasks. Gardner considers all human beings to be different in learning capacities, without downplaying any particular one, but rather channeling them towards well defined objectives [9]. Due to the above, it is assumed that if the student counts with the necessary elements for his/her development within the ITS according to his/her specific needs, he/she will assimilate the structural knowledge from the expert by navigating the system in the way he/she considers to be fitting to his/her personal style of learning, the one that has to do with his/her preponderant intelligence.

1.2. Case Based Systems

Within the applications of Artificial Intelligence, we have that Case Based Reasoning (CBR) is a problem solving method based on remembering previous similar situations and reutilizing the knowledge and information about those situations [4].

Until now CBR has not been used to model the student within the ITSs, in spite of it being an AI technique that provides a cognitive model for the organization of memory, reasoning and human learning [16]. This approach provides a group of particular characteristics that can be used in the elaboration of ITSs such as [11]:

- Reasoning based on specific episodes. The students' cognitive state cannot be explained by experts such as generalized chains. It is therefore proposed that they be described by means of selected trait experiences.
- Knowledge maintenance does not require of expert intervention. The experience of new models can be evaluated and, if found convenient, it can be incorporated to the system by the very ITS user.

- Re-utilzation of previous solutions. In addition to methodology, student models that are frequently repeated may be used in the teaching-learning process.
- Derived solutions based on real cases. This allows the justification of decisions taken facing the user during his/her performance within the system.

The CBR works by trying to imitate human behavior as it solves problems found on the execution of a plan, based on similar cases that have been recorded and given optimal solutions.

2 Multiple Intelligences

Developmental psychologist Howard Gardner [9] propounds the theory of multiple intelligences, where he holds that human intelligence has eight differentiated dimensions, to each of which corresponds a different symbolic system and manner of representation: i.e. musical, bodily-kinesthetic, linguistic, logical- mathematical, spatial, interpersonal, intrapersonal and naturalistic.

Gardner holds that educational practice is basically centered on the mathematical and linguistic intelligences. However, due to the multiple character of human intelligence, the perspective ought to be widened in order to take into account the diverse abilities of the individuals. In this manner, projects that admit alternative ways of symbolic expression should be proposed to the students, in order to create group projects that invite the students to work with the language of the media as well as with those symbolic systems with which they feel the greatest affinity.

2.1 Types of Intelligence and their Characteristics

Our model is based on the following considerations according to Gardner [8] and Rivière [18]:

1) We don't all have the same interests and capacities.
2) We don't all learn the same way.
3) Nowadays no one can learn all there is to learn.

Howard Gardner has identified eight different types of intelligences [8]:

- *Logical-mathematical* intelligence uses logical thinking to understand cause and effect, connections, relations between actions, objects and ideas
- *Linguistic* intelligence is the ability to think in words and use language to express and understand complex meanings.
- *Visual-spatial* intelligence is the ability to think and perceive the world in the form of a three dimensional mental model.
- *Auditory-musical* intelligence is the ability to think in terms of sounds, rhythms and melodies.
- *Bodily-kinesthetic* intelligence is the ability to use body movements as a means of self-expression.
- *Intrapersonal* intelligence is the ability to understand oneself.

- *Interpersonal* intelligence is relating and understanding other persons, harmonizing and recognizing the differences among persons and appreciating their perspectives, while being sensitive to their personal motives and intentions.
- *Naturalistic* intelligence is the understanding of the natural world including plants, animals and the scientific observation of nature.

3 Intelligent Tutoring Systems

In order to integrate new technologies and produce a new tool which allows us to adapt to a dynamic environment, which in turn is the cognitive state of the student, we propose to develop an ITS with reactive characteristics [11], [13].

The main components of an ITS are shown in Figure 1, the detailed description of which follows.

The *Student Model* is integrated by the data base, which represents the cognitive state of the student, and its environment, which we intend to change.

The *Expert Module* is the place where the expert knowledge is accumulated.

The *Tutoring Module* is in charge of determining the pedagogical and instructional strategies of the system.

The *Interface* may be considered as a simulation environment in the sense that it is the place where the inputs and outputs of the system take place. Its basic responsibility is the communication between the system and the student, though, since it is the output means of the ITS actions, it also has the didactic responsibility [13], [14] and [23].

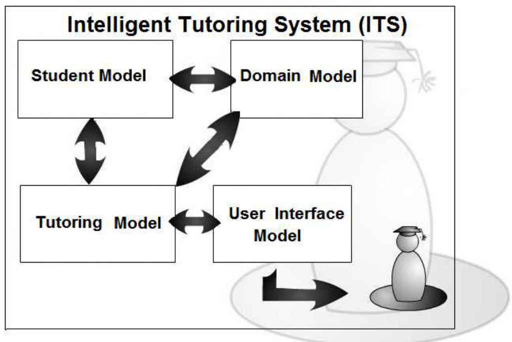

Figure 1. Components of an Intelligent Tutoring System.

ITSs approaches the learning process as co-operation between tutor and student. The tutor, based on the student's perception, decides at every moment which is the right strategy. These strategies are decided based on parameters such as mistakes made, learning style, acquired knowledge and so on.

All of the above, in order to decide what to explain, at which level of detail and when and how to interrupt the student. Research on ITSs has focused on different aspects, from the inspection of each of its constituent modules, to the elaboration of generic architectures as well as automatic learning and the construction of teaching system aide design.

In the case of educational resources, the contribution of ITSs refers to learning techniques that support the problem solving process and, thus are able to diagnose the student's mistakes. In the specific case study we refer to basic algebra. This dominion was determined based on the analysis of the diagnostic tests given to university students, where conflict areas of students from different semesters and studies that integrate the Unit were detected. We must take into account that the student should seize his knowledge and should do so in a step by step manner, and thus begin with the conflicting areas, increasing the complexity and based on his/her cognitive maturity. This is a corrective aspect due to academic history deficiencies. The *diagnosis of mistakes* allows us to know —based on the mistakes the student makes— whether he/she has understood, thus, to design remedial strategies. Learning techniques allow us to implement the most appropriate learning styles as well as instructional strategies and tactics. In this context, ITS are considered virtual environments, where AI techniques can be applied to its different modules in order to simulate the one-on-one teaching-learning process, so that it emulates human behavior during the interactive process [13], [14] and [23].

4 Methodology for the Development of the Intelligent Tutoring System (ITS)

The methodological aspect of this work started with a *first phase* of qualitative and quantitative study derived from a mathematics diagnostic test given to students of different areas, i.e. International Commerce, Education for Health and Intelligent Systems Engineering. The exam was given to 600 college students of the *Universidad Autónoma del Estado de México – Unidad Académica Profesional Nezahualcóyotl*.

The test included Basic Arithmetic, Algebra, Analytic Geometry and Trigonometry topics. The evaluation showed a series of deficiencies mainly due to a cognitive lack of maturity in the knowledge of basic Algebra. From the above, the ITS will be made up of questions about these topics, starting with Arithmetic, following with Basic Algebra, Analytic Geometry and finally Trigonometry. The order goes from the simple to the more complex.

The relations between the fundamental components of a Case Based System and an Intelligent Learning System are described in the architecture of the final ITS in Figure 2. For this, the definition given by Gutiérrez [11] —which states that all the Case Based System is basically conformed by the Knowledge or Case Base, the Case Recovery Module and the Solution Adaptation Module— is followed. The proposition that the three main components of all ITSs, i.e. contents knowledge, knowledge of the student and knowledge of the learning methodologies and strategies, thus generating the final architecture of the system, is taken from Sánchez.

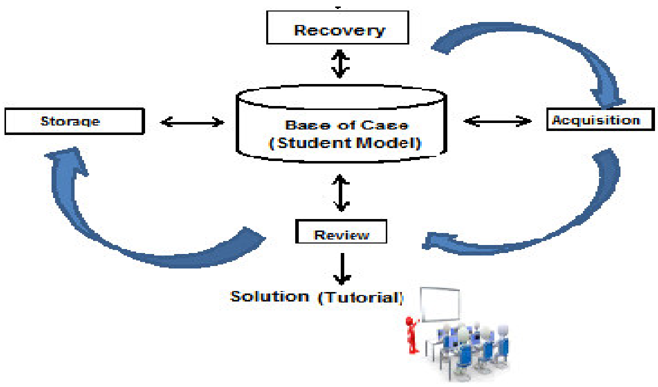

Figure 2. ITS Architecture.

The phases for the development of the ITS are specified in the following steps.

1. Design of the knowledge graph, is conformed by the different Micro-worlds of knowledge or topics that will constitute the ITS, taking as its reference the areas of knowledge on which the diagnostic test was structured (Arithmetic, Elementary Algebra, Analytic Geometry and Basic Trigonometry). See Figure 3.
2. Design of the cognitive model that allows the citing of the user characteristics according to Gardner's proposal (multiple intelligences). In our case study, in order to detect the type of intelligence that allows the adapting of the system to the student, only four of the eight propositions in his theory were considered, to be applied at the time of the study, since they are the most representative i.e. logical-mathematical, auditory-musical, verbal or linguistic, and visual. From here on the system will be denoted by the initials MALVI.
3. The case based teaching/learning model proposed is structured by means of a series of questions or reactives —each of which is, in turn, pondered by means of a weighted system— in order to determine to what type of intelligence it belongs predominantly, i.e. logical-mathematical, auditory-musical, verbal or linguistic, and visual, where each of these pure types may include aspects of any of the other three types, which in turn may be used within the system. The classifying, according to their relative weight, was done by the expert in Pedagogy. In those instances in which the questions or reactives were oriented in their majority towards a single type of intelligence, they were adjusted so that that same reactive could be adapted to the remaining types of intelligences in the project. This part of the modeling was backed by an expert in the Mathematics Area.
4. In agreement with the above analysis, different scenarios were designed (presented interfaces) where, according to the different weight that each question presented, it was oriented towards that particular type of intelligence. In some cases changes were made in order to adapt the reactives to the four types of intelligence to be used in our system, with the support of our mathematician ex-

pert. If a student with a mainly visual intelligence was identified, (s)he was presented with reactives oriented mainly towards a visual–spacial interface (supported by images and graphs). If a logical-mathematical student was identified, (s)he was presented with the normal scenarios (without adding any other component to the interface). In the case of the mainly linguistically oriented student, scenarios were designed so that the question or reactive was presented to him/her on screen and, additionally in an oral manner, by means of a recording which indicated what the question to be answered consisted in, Lastly, for the auditory-musical scenarios —depending on the degree of complexity of the proposed system, from beginning to advanced— Vivaldi's Four Seasons would be added within the interface, According to the expert in Pedagogy: Spring, the first season, for the first micro-world (Arithmetic, simple degree of complexity); Summer, the second season, for the second micro-world (basic Algebra); for the third micro-world (Analytical Geometry) the third season, Autumn; and for the fourth micro-world (Trigonometry) of a high degree of complexity, the fouth season, Winter, which consists of a soft melody, which is, in turn, considered adequate for the high degree of concentration needed to resolve the questions of this micro-world.

5. Design of the teaching-learning process from two perspectives: 1) the type of intelligence related to the type of knowledge, and 2) the type of intelligence detected in the user.

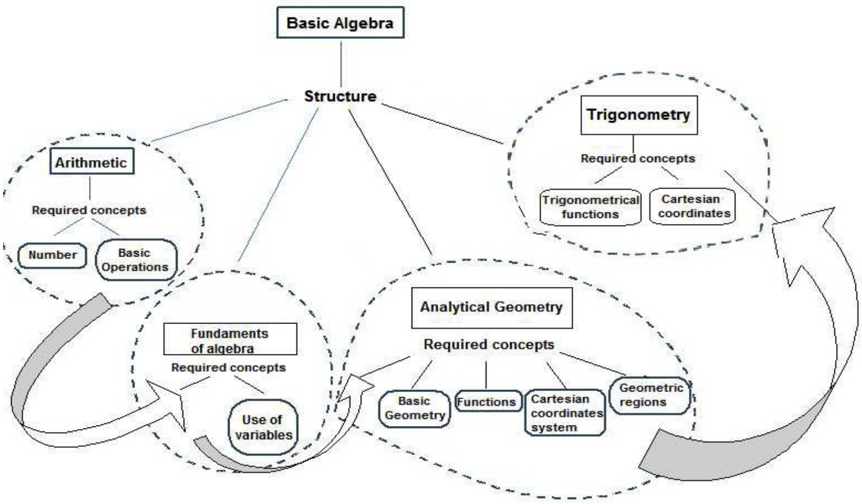

Figure 3. Graph of the Basic Algebra Knowledge ITS.

6. Adapting of the reactive inference motor that would be integrated to the teaching-learning process along the different scenarios.
7. Design of the interface that would integrate the techniques for the diagnosis, and instructional tactics and techniques.

5 Conclusions

In this work we propose a new model that may be able to take into account the Intelligent Tutorial Systems, which will be implemented in a Computational System (MALV I), thus intending to prove the previously stated hypothesis.

The proposed model maintains the fundamental components of all the Case Based System, the basis of knowledge or data base, where the cases describe models of students, and the teaching methodologies to be followed in order to achieve its personalization.

The case retrieval module and the solution adaptation module execute the diagnostics, which is —without any doubt— one of the most important processes within any ITS, since its quality will depends on the capacity of the system to adapt to the student.

The system is about to be finished and soon its performance will be tested in the student community of the *Unidad Académica Profesional – Nezahualcóyotl*, so that the results thus obtained may be shared.

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