ADVANCES IN TECHNOLOGY-BASED EDUCATION: TOWARDS A KNOWLEDGE BASED SOCIETY

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INTELLIGENT TUTORING SYSTEMS - PAST, PRESENT AND FUTURE

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Abstract

Academic organizations are changing. Students require systematically for more effective means to support their daily activities. Managers are concerned with providing special structures and mechanisms, disposing to students the necessary means to evolve themselves in specific knowledge domains. Some of them consider implementing special computational systems integrating educational abilities in order to help teachers, specifying what to teach, applying different kinds of pedagogical strategies, and defining the way to teach, and students, establishing better studying plans and lessons support. In this article we will present a study about Intelligent Tutoring Systems and their influence in a learning environment, discussing their fundamental characteristics, applications, and social impact. Additionally, we complement this study, extending the functionalities of a conventional Intelligent Tutoring System through its transformation in a teaching oriented multi-agent system.

1 Introduction

Many of the efforts done today go towards the promotion of self-learning activities inside teaching environments. Schools' managers are concerned with providing special structures and mechanisms, disposing to students the means to evolve themselves in specific knowledge domains. This is not a simple task. The difficulties that we face trying to get attention from students are enormous. There is no consensus about the best way to attenuate or even eliminate such difficulties. However, some people believe that a lot of obstacles can be overcome with learning model and strategies adaptation, combined with proper computational tools that was especially designed and implemented for learning environments. Due to this belief, a lot of software products have appeared during the last few years to help teachers and students in their day-by-day activities. One of the most significant tools for learning environments are the *Intelligent Tutoring Systems* (ITS). These computational systems integrate educational abilities that help teachers specifying what to teach, applying different kinds of pedagogical strategies, and defining the way to teach. All these aspects are used to manage the design and implementation of an ITS. In any learning environment, students have different styles and forms for knowledge acquisition. Thus, it is important that an ITS will be able to provide different kinds of individual learning. During a learning session, an ITS must adapt itself, reconfiguring services towards the best interests and styles of the students. In its basic structure, a conventional ITS integrates different teaching and learning models that were acquired from humans' knowledge and experience. Through the combination of agent-based computing techniques and others imported from social sciences – psychology, cognition, social education, etc. – we can develop very appealing computational models providing the basis for effective development of sophisticated learning systems. They should have the capacity to understand, learn, solve problems, or identify student's capacities and difficulties, in order to be able to establish a training and study plan. Additionally, it should also be capable to identify the relevant types of information involved with each student's learning process, as his study method or learning style, applying the best available teaching resources individually to each student. Consequently, the learning process can be adapted to the specific needs of each student. The application context of these tools can be seen as organized in two separated slopes: the attendance in all phases of the knowledge communication process, and the support to the preparation and accomplishment of exams. Traditionally, the methods used in evaluation tests were based on "static" approaches where evaluators analyze the collected information and give classifications. Nowadays, it is expected that a so called "intelligent" evaluation system has specific tools that allow student's self-evaluation, based on his competence degree, in the results of the evaluation tests, and in his learning profile grounded on a set of parameters previously defined. The main difference between the traditional evaluation methods and the "intelligent" ones, consists, basically, in the capacity that these last ones have to adapt, process by process, to the knowledge and learning needs of a student, confronting him in each one of the phases with new problems, evaluation topics, or explaining solutions.

2 The Evolution of Intelligent Tutoring Systems

In 1926 Sidney L. Pressey built a machine with multiple choice questions and answers that led to the notion of intelligent machines for teaching purposes. The *modus operandi* of such machine was characterized by delivered questions and the immediate feedback to the user. Since then, individual tutoring has been considered by Educational Psychologists the best learning method for most people. Some time later, Skinner influenced the *Programmed Instruction* (PI), basing his theory on the idea that the learning process is a function of the change

of behavior. Changes in behavior are the result of individual reactions (answers) to events (stimulus) that happen (in a particular environment). An answer produces an action just as to utter a word or to solve a mathematics problem. When a specific stimulus-answer pattern is verified, the individual is conditioned to answer in the same way the next times that same incentive happens. This definition is quite approximated to the classic definition of the Pavlov's behaviorism. The contribution of the Skinner's theory is based on the idea that an individual can emit an answer without an external incentive [1]. PI was the pioneering method that conditioned the emergence of *Computer Assistance Instruction* (CAI) used in some types of "learning" machines instead of computers. But, due to its architecture based on frames, it conditioned the first attempts to supply adaptive instruction. Although, it was used in several teaching fields with success, namely in training situations and knowledge recovering. The low fidelity of its teaching environment and its low adaptation capacity, limited by its static screens ramification, contributed to the immersion of some well-known difficulties. An imperative and mono-directional communication style (from the computer to the student), a fixed and lineal path followed by the student, and an individuality restricted by the amount of time invested in the learning process, reinforce the criticism to the rigidity of these systems based in the action/reaction concept. Despite allowing the computer works as a tutor, unhappily the experience showed that this type of isolated software did not produce the expected success, once the majority of the programs was not on-line, not supplying any communication characteristic. In other words, the social aspects were not considered.

The ITS area combine the CAI philosophy with *Artificial Intelligence* (AI). These systems should act as intelligent tutors that are capable of knowing their students and to teach them in a personalized way. They should be capable of communication with the student, evaluating his acting, and then inferring on the appropriate teaching method to apply. It should be make possible that the teaching process can be adapted to the specific needs of each student. Originally known by ICAI (Intelligent CAI) systems, they were for a long time mentioned in the literature as synonyms of ITS. This association, much questioned by several researchers, ended to be abandoned. Ever since, there have been many studies presented in this area, some of the former [2], where it was defended that the main idea of an ITS, is in first place, to model the knowledge in a specific respective domain (domain model), of the student (student model) and of the pedagogic strategies (tutor model), and secondly the creation of a powerful interface. Other studies [3], more recent, alert for the modeling of ITS according to the organization of an architecture based in agents. With agents' uniformity and modularity and with the standardization of the interaction protocols, the level of scalability and inter-operational can be reached, what cannot be gotten so easily with the use of other techniques. The multi-agents architectures allow the constant growth and the heterogeneity of the software environment. Any way, it seems to be consensual that any ITS possesses a basic organization, with some very well defined functional components, that can be observed in most of the cases. This organization integrates four distinct modules, namely:

- **Domain**, where is stored all the information that tutors need during a teaching process.
- **Student**, which maintains the information about the students in all their teaching stages, keeping as well a log concerning the actions executed by students in a particular knowledge domain.
- **Tutor**, this is the pedagogical module; it provides the necessary methodologies for learning processes; it owns the knowledge about teaching strategies and techniques and the way how to select them according student's abilities.
- **Interface**, which supports the interaction between the tutor and the student.

ITS usually are distributed systems capable to support on-line tutoring functionalities for the learning and evaluation in multi-disciplinary domains. An ideal ITS could be that capable of supplying real-time instruction and evaluation, in all knowledge domains, at any student type, available and accessible 24 hours a day, every place. Teachers and students could interact with the system, without the inherent embarrassments of to which they belong. The integration of this type of systems in organizations, particularly in teaching institutions, provokes some obviously impacts at several levels, conditioning the success of its integration. Other aspects must also be considered, in particular:

- **Democratic aspects in a classroom**. Is a democratic teacher the one who distributes his time and attention equally to each student, or is he democratic if that distribution considers proportionally the specific needs, capacities and abilities of each one of them? With an ITS, this issues can be perfectly diluted, once the system will be available whenever the student wants or needs, depending strongly on the student determination.
- **Accessibilities.** Which will be the best way of working with a student, who has special teaching needs, like visual, moving, or any type of deficiency? It is known that the necessary time to teach a blind to operate in the Web is widely superior than the time usually attributed to a medium student. It is now possible to attenuate some contradictory education politics for the integration of those citizens, in the so called normal teaching institutions. If a student has special needs, and if he needs more time and support than a medium student, how can he, with the same type of resources, reach the same goals that the other students? In the actual scenario, these issues will always be limited to the institution itself, its internal politics, and, naturally, their own financial and implementation capacities.

- **Time and resources administration.** It is possible to improve the students and teachers availability. On one hand, students can access the system whenever they want, managing its availability in a more autonomous way. On the other hand, it is equally advantageous for the teachers to have the possibility to update the contents and pedagogical techniques, collecting the results of each student's evaluation, or student group.
- **Teachers' autonomy.** How will the teacher's autonomy become with the emergence of the active study centers? In these, student makes use of his self-learning capacity, being the teacher's work just like a simple consultant. In a functionalism perspective, the teacher could see his work reduced to a mere employee, teaching contents that he didn't elaborate or executing methodologies that he didn't select, without the possibility of creating or managing some type of intellectual property. Another vision, much more realistic, is the one of an active professional that, besides the normal attendance of the teaching process and the student's learning, be endowed with critical capacity, capable of suggesting new examples and approaches for a same exercise or topic, and to assure the noble function of maintenance of contents, techniques and methodologies that guarantee the constant updating of the tutorial system.
- **Impartiality in the evaluation**. Traditionally, the students' evaluation is, usually, a subjective task, being strongly dependable from the teacher in charge. Tasks like elaborating an exam, selecting questions in a specific context, the degree of difficulty intended, and so one, to be well accomplished, they are usually slow and of difficult specification, not considering in the great majority of the cases any type of social aspect. The individualization of the evaluation doesn't exist, except in oral exams or in very punctual and specific cases. Usually, the best alternative to elaborate an evaluation process is to possess a wide collection of questions, with the definition of the respective degree of difficulty, and through a random process allow that the students, or even the system itself, to be capable of selecting a group of subjects with the adjusted complexity at the study level that is intended, so defining the structure of the exam. Using this type of methods, the evaluation becomes impartial and the results become more solid and correct. Allowing simultaneous access, these tools tolerate that several students accomplish different evaluation types at the same time, in several thematic areas, based on their specific needs of study.

3 ITS and Agents

The most recent advances in intelligent learning environments conduced to the use of architectures based on agent societies. Many of the principles and characteristics of multiagent systems shown their suitable potential to the development of education systems, due to the fact that the nature of the teaching/learning issue is better solved in a cooperative fashion way. Additionally, multiagent systems technology deals very well with criticize applications, involving systems where issues like distance, cooperation between different entities, and integration of different software components are crucial.

Agents (or communities of agents) can be a real solution in the implementation of specific learning environments, if agents have the ability to work together in an autonomous and concurrently manner, complementing expertise and knowledge in order to solve together the problems posted by students. Their autonomy must be ensured. Usually, agents do not require human supervision, at least directly, which ensure flexible and efficient real world systems. When an agent-based system is well designed and implemented it is possible to avoid a central coordination entity, guarantying that no communication bottlenecks occur.

Agents also dispose new characteristics to educational systems. They bring the ability to react automatically to student requests, credibility, permanent availability, and a natural way to approach multidisciplinary domains. An agent-based system implementation is modular by nature. Each agent constitutes a unique module, independent from any other. They maintenance do not affect directly the performance of other agents. The integration of new agents is also very simple: a new educational model is materialized in the system as a new agent.

It is not difficult to found in the literature, or in web sites, several studies, taxonomies and systems concerning ITS. Covering a large variety of topics, ITS has been developed in several applications areas, such as diagnosis of infections in medicine, error detection in electronic circuits, information science, mathematics, or geography, just to name a few. More recently, other research and development efforts have been done, particularly, on the integration of agent-based technology in ITS environments, doing as well comparative studies supplying analysis elements that allow the identification of patterns used in the development of such systems. In our study, in order to demonstrate the integration of agent-based technology in ITS, we selected some of them, namely:

- The LeCS project (Learning from Case Studies) is a distance teaching intelligent system, which according to [5], possesses an architecture based in a federal system of agents. The communication is not established directly among the agents, but through a special entity, a Facilitator, that waits for the information on each agent in the system, and is responsible for the rotation of those messages. The Facilitator works as a typical

broker. The system considers two different kind of units: a server and a groups of clients. The server system stores the teaching sessions, which are associated with groups of students that work cooperatively. The client systems are executed in the student's workstation, allowing that several students may participate in a same session. LeCS supports collaborative learning through World Wide Web platforms, using CBS (Case Based Reasoning) strategies in their teaching sessions.

- The **LANCA** project [6], where the authors try to expose the reason to use intelligent agents in ITS, presenting the main characteristics that they must have especially for teaching systems, as well as their functions in distributed environments. They also propose an architecture for the teaching environment, with the specification of the different roles for the agents. The combination of the several agents - cognitive or not -, with the learning strategies available for each student, provides an interesting distributed learning environment.
- The **Baghera** project [7] was developed with the aim of developing a theoretical and methodological basis to guide the conception and modeling of learning environments. The Baguera platform was conceived based on the idea that the education function of the system is in the organized interactions among the components: agents and humans, and not merely in the functionality of one of its parts. The system was developed using JatLite, where each agent was extended with an interaction module that supports the agent's communication protocols. System agents have the ability to communicate with other agents, reasoning and make decisions. The communication is based on the theory exposed in [8], which proposes a set of primitives for communicative acts such as inform, ask-to-do, answer, propose, etc. Users can have access to the learning environment through any browser that supports JAVA Applets.
- The **Explanation Agent** [9] has as main objective to supply answers or explanations about contents with larger quality, identifying problems that can happen during the explanation process or resolution of problems. The Explanation Agent has two specific objectives: to discover the source of the student bad understanding through the student's model, and to help the designer of the course to adapt his explanations in agreement with such observations. The theory of conceptual maps is used to structure the explanation in a formal representation. This representation is used by Explanation Agent to do their deductions on concepts badly understood by the student.
- The **Vygotsky Theory**, it is a work that describes a proposal for a framework to support the use of Information Technology in education scenarios. Is based on the partner-cultural theory of Vygotsky and it is projected as a multi-agent society to support remote teaching activities. The objective is to propose an environment to privilege the collaboration as form of social interaction through the use of languages, symbols and signs [10]. The underlying pedagogic model is based on collaborative learning that is reached basically through social interaction. The interactions can be of several types, considering criteria such as longevity, number of participants, reciprocity, hierarchies and even some other criteria based on behaviors: personality, motivation, emotional state, etc.
- The **Siesta System** [11] is a typical multi-agent system that was conceived in order to be installed in a private intranet domain, providing on-line facilities for student evaluation and tutoring in multi-disciplinary domains. Through the use of a conventional web browser, students have the possibility to access and consult remotely distinct repositories of evaluation and tutoring packages through conventional Internet browsers.

Teaching environments based on agents still rare today. This could be justified by the difficulty that we have in modelling and implementing such learning environments due to the variety of a large set of distinct components involved with and due to the complexity of the tasks that cooperative processes consider. Nevertheless, any application that is designed and developed today for a specific educational system provably will consider disparate and distributed sources, involving the expertise and knowledge of many people and requiring cooperative abilities to support joint work among teachers (and students) located in different geographic sites. We can not avoid that. As we can realize this is a common scenario in teaching environments. Thus, based on the basic agent-based systems characteristics and functionalities, we can easily point out that they will be the basis for tomorrows' ITS.

4 Conclusions

During many years, the teaching process worried more about the contents, than with the form of transmitting them. More and more the social aspects have been waking up the attention of the teaching agents. But the great challenge of this kind of teaching, that should be capable to supply individualized instruction, is that it shouldn't be centered in the technical aspects, as the design, development and implementation, but in its capacity to treating each student on his own way, paying attention to the social, ethnic and cultural factors, and, more important, attending to the restrictions imposed by the micro-society regulation of the teaching environment where the student is inserted.

However, and as far as the technical aspects are concerned, it is important to improve the efficiency and the performance, in a way to obtain more robust and efficient systems, as well as the improvement of the applications that ensure the communication aspects in a way that allows for the implementation of more friendly and versatile interfaces. Another aspect to take in account in the design, development of ITS, is its modularity and consequent reusability considering the emergence of new platforms. With a development in layers, it is possible to maintain the key characteristics of the architecture layer, developing new independent interfaces for mobile devices, set-top-boxes, Web-PDAs, etc.

The integration of agents inside ITS environments open the doors to receive the ability to deal with multidisciplinary sessions where several artificial tutors work together assisting students doing things. Thus students can select the tutor that they want or appealing to the combination of their expertise and knowledge. Agent cooperation in ITS environments offers a large diversity of applications for tutoring systems. Today, we can find already agent-based ITS in distinct application areas, advising and monitoring students, supporting navigation in instructional Web sites, or as tools for authoring tutorial dialogue knowledge. In the ITS arena, agents are and will be a very appellative technology every time we need to deal with complex problems involving multidisciplinary aspects and strong modular approaches.

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