FUTURE CHALLENGES IN INTELLIGENT TUTORING SYSTEMS – A FRAMEWORK

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Intelligent Tutoring Systems (ITS) provide the benefits of one-on-one instruction in an automatic way and cost effectively, keeping in mind their multidisciplinary nature. The challenge remains on transporting to computers the expertise, skills and mode of action of the human tutor, overcoming space, time, socio-economical and environmental restrictions. ITS appear as a form of deployment of this issue and have been object of an increasing research. This paper aims to establish some characteristics, properties and functions that an ITS should provide, and the possible contributions that the different fields of research can make, proposing a multi-domain and multidisciplinary framework to address the research in this field. The framework incorporates a knowledge base where data and knowledge related to the problem are maintained and a model base related to student, teaching and environmental issues together with pedagogical perspectives.

Keywords Intelligent Tutoring Systems; Framework

1. Introduction

Since we've become teaching, providing knowledge to all that seek for it, with individualized support whenever it's needed (anytime, anywhere), when solicited, ideally even when that support isn't asked but the need for it is there, has been the ultimate goal search for everyone. In fact, there are studies [1] that show that one-on-one human tutoring is more effective than other modes of instruction . ITS are distributed systems capable to support on-line tutoring functionalities for the learning and evaluation in multi-disciplinary domains. They must be capable of accurately diagnose students' knowledge structures, skills, and styles; diagnose using principles, rather than pre-programmed responses; decide what to do next; adapt instruction accordingly; provide feedback. The advances in the development of the computer technologies has facilitated the use and design of ITS. The proliferation of ITS, has spawned many debates about their use and effectiveness: The Degree of Learner Control: How much learner control should be allowed by the systems? Individual vs. Collaborative Learning: Should learners interact with ITS individually or collaboratively? Situated Learning: Is learning situated, unique, and ongoing, or is it more symbolic, following from an information-processing model? Virtual Reality and Learning: Does virtual reality uniquely contribute to learning beyond computer aided instruction or multimedia?

Despite their advantages, ITS fail to prove their usefulness in wider academic environment, mainly because research is primarily driven by computer scientists, and doesn't address all the different issues from other fields [3]. The integration of this type of systems in an organization provokes obvious impacts at several levels, conditioning the success of its integration. Some aspects should also be considered like impartiality in evaluation, teachers' autonomy, time and resources administration and, accessibilities. They are seen as they are integrated and highly interrelated with the process of knowledge management (e.g., student models and profiles, knowledge base of each specific domain), dialoguing and argumentation (to facilitate tutor/student knowledge exchange) and experimentation by simulation (simulated evaluation to provide student's knowledge feedback and pedagogical experimentation). All these processes are continuously supported by technologies that accurately address issues related namely to ontology management, intelligent agents, data warehousing, data mining, case-based and rule based reasoning, adaptive interfaces and user modelling. In order to enumerate the possible contributions from the other fields and to propose a general architecture to model the future ITS, incorporating the actual challenges, it is presented a multi-model and multidisciplinary framework that:

- Defines the characteristics, properties and functions that of an ITS ;
- Identifies the contributions that the different fields of research can make;
- Addresses the research in this field;
- Defines a knowledge base where data and knowledge related to the problem are maintained and a model base related to student, teaching and environmental issues together with pedagogical perspectives;
- Enables an argumentative discourse-based tutoring participation of the actors.

This paper starts by an introduction, where the motivations for this work are briefly presented and then ITS relevant background issues are referred. Technologies useful to ITS development are the next subject of discussion, before presenting the proposed framework. It ends with some discussion and conclusions about the work.

2. Background issues and ITS projects

Sidney L. Presley built a machine in 1926 with multiple choice questions and answers that led to the notion of intelligent machines for teaching purposes. Since then, individual tutoring has been considered, by educational psychologists, the best learning method for people [1, 2]. It is well know that one-to-one learning environment is more effective than traditional classroom/lecture style environment because of the student/teacher ratio. ITS represent a potential solution to this problem, although current research is far from reaching this goal [4]. Carbonell [7], Sleedman [8] introduced the basic outline of requirements of an ITS. In [6, 11] student models are discussed as an important issue in developing ITS. In [10] ITS are classified as being computer-based, problem-solving monitors, coaches, laboratory instructors, and consultants. In [12] a review of the field in by Wenger demonstrated how much it had evolved in the five years since Sleeman and Brown's synopsis. Many systems wore developed since ITS research began, some of them being the foundations of many other systems being developed today. We can establish a pre 1990 era where ITSs developed are considered as "the Elders" in that they were seminal in forming the conceptual foundations for many intelligent tutors under development today, and a post 1990 era where ITS developed show some form of adaptive tutoring. Current trends in the ITS community show a marked interest in "evolving" ITS systems that are not constrained to any single instructional method, and that can be deployed in a distributed fashion. The Table 1 presents an historic perspective of the principal developments occurred on the both eras [2,9,15,16].

3. The Framework

The development of an ITS is a complex task as individual students needs differ, and often students don't realize that they need help. Consequently, such a system must be capable of dynamically adapting and monitoring each student. The mere presentation of information does not qualify as instruction [13]. The development of learning systems involves many disciplines, as the psychology, the human-computer interface technologies, the knowledge representation, the databases, the system analysis and design [14]. This kind of systems is expected to perform the following tasks:

- Present to the students a content or a skill set they wish to learn, in a way that suits their particular personal, individual learning style and psychological features, delivering the right content to the right user in the right form at the right time;
- Advise the student, on how he should learn the content or skills and help him to work on a suitable study schedule;
- Co-work with the student in monitoring the learning schedule;
- The monitoring of students learning schedule integrated in the process of collaborative knowledge, namely because students must be aware from other's activities and the collaboration with other persons (students, instructors) must be regulated;
- Intelligent interactive analysis performed on what the students are doing and providing real time diagnostic help;

- Intelligent content schedule fitting the analysis performed on request, advising the student how his learning might improve.

Table 1 Some ITS Projects

ITS till 1990	ITS from 1990
SCHOLAR,1979; Carbonell, Collins et al.	OGF; Thepchai, S., et al.
WHY, 1975; Collins, Stevens et al.	MethodMan; Crampe Software Project Management.
SOPHIE, 1982; Brown, Burton et al.	ILEX; Cox, R., O'Donnell, M., Oberlander, J.
BUGGY, 1981; Suppes.	ISIS; Meyer, T., Miller, T., Steuck, K., Kretschmer, M.
LISP Tutor, 1984; Anderson et al.	PACT; Aleven, V., Koedinger, K. R., Cross, K.
MAIS, 1987; Tennyson, Park	

The need for pedagogical issues in ITS is focused, mainly, on the necessity to acquire knowledge about multiple pedagogical strategies separately from the domain expertise acquisition [5]. A modern ITS should incorporate several learning strategies. Each strategy has specific advantages and it appears to be useful to use adequately the strategy that will strengthen the acquisition process for a given learner. The selection of a strategy depends on several factors: the knowledge level of the learner; the domain; the motivation; the affective characteristics. Pedagogical actors are proposed, as agents to co-work with the learner, in order to facilitate the acquisition and modelling of knowledge, a problem which is still a crucial step in the design of ITS.

According to [19,6] several problems are associated with the current methodology of developing ITS:

- Each application is developed independently;
- Tutoring expertise is hard-coded into individual applications;
- There is little reuse of tutoring components, such as the student model, tutoring model, and user interface;
- There is a need for a standard language for representing knowledge, and a set of tools to manipulate the knowledge.

In [13] a framework for developing adaptive ITS is proposed, which permits personalized instruction to be delivered over the internet through the use of adaptive ITS. As stated, adaptation can be made based on content, or made based on sequence. It aims to give learners personalized instruction based on their preferred learning style, background knowledge and current understanding of the material. In [17] a conceptual framework is proposed for internet based ITS, with five important notions: the context of an ITS, recognizing the various contexts on an ITS, particularly the center role of a teacher as a design collaborator and as an developer; the expert system paradigm, providing a neat separation between knowledge and the processing of knowledge; the hypertext paradigm, building a larger tutoring system using intelligent tutoring applets; the object orientation, knowledge is viewed as a network of knowledge entities; human computer interaction, the system should maintain simple and instinctive interface. Progress ITS research has been impeded by the lack of modular system architectures, reusable components and sharable knowledge bases. Each new research or development effort typically starts from scratch, without a foundation on which to build [18]. The above considerations lead to a list of troublesome consequences:

High Development Costs - Researchers are forced to design their own system architecture, implement all the system components, develop knowledge representation strategies and reasoning mechanisms, and acquire and encode all relevant domain and instructional knowledge. While one or more of these tasks may indeed be focal research concerns, others are merely drudge tasks needed to erect enough infrastructures to allow work to precede on the core problem of interest.

Lack of Interoperability - A wealth of general-purpose software tools exists both in the marketplace (e.g., word processors, spreadsheets, drawing tools) and in research labs (e.g., planning systems, text generators), but these tools cannot be easily imported and used in ITS. Market forces are tending towards a modular, interoperable software designs, yet little has been done to enable ITS architectures to take advantage of these trends.

Restrictive Delivery Platform Requirements - Implemented ITS systems typically are large programs designed under assumptions of plentiful computing resources. They may require special-purpose hardware, and/or are implemented in languages that may limit delivery to certain types of platforms. As desktop computers become as interchangeable as toasters and kitchen whisks, ITS developers will need to respond with multiplatform architectures and tools.

Difficulty of Sharing Materials and Benchmarking - Current ITS designs employ idiosyncratic knowledge representation formalisms, architectures, internal data and control flow schemes. As a result it can be exceedingly difficult to ascertain the strengths and weaknesses of individual tutoring approaches, to identify and reuse functional units across domains, and to share instructional materials and tutoring strategies.

High Maintenance Costs - ITS today, especially laboratory prototypes, are designed and built as complex, integrated AI applications, with little attention paid to problems of evolutionary development or maintenance. Consequently, as design flaws are uncovered or new functional requirements identified, large portions of the system often need to be thrown out and re-implemented from scratch.

To address these problems, the research should be focused on issues like reusability, share ability and interoperability of ITS components, the goal should be redirected to the reduction of the work it takes to build a system and make it viable. A framework is proposed to mitigate the above concerns and to emphasize the new directions and contributions that should be considered to construct a new generation of ITS [Fig. 1]. In this view, the future ITS are knowledge based systems, incorporating or addressing one or more of the following efforts and characteristics:

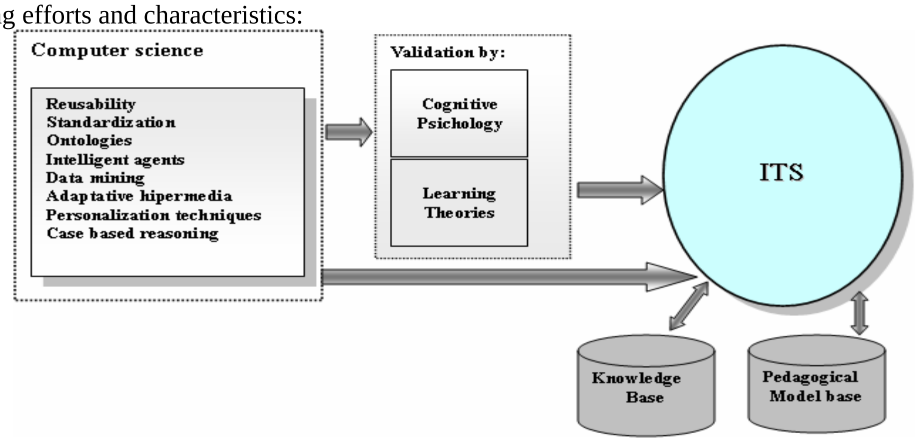

Fig 1 The proposed framework

Reusable Components - Descriptions of reusable components suitable for ITS use (e.g., user modelling tools, planners, KR systems) which the author(s) are willing to make available to the community;

Standardization Efforts - Experiences with and assessments of the role of existing software architectures and standardization efforts for interoperability of ITS;

Shared Vocabularies - Work on developing shared vocabularies of parameters describing student characteristics and tactical control of tutoring (e.g., problem selection, explanation generation, feedback tactics);

Ontologies - Structured ontologies or upper models that define and organize pedagogically relevant attributes of knowledge for classes of domains, enabling the writing and sharing of instructional strategies in terms of these attributes;

ITS Shells - ITS shells, especially those with modular design and well-defined intercommunication strategies, or those which address any of the items above;

Distributed and Agent-Based Architectures - Architectures and protocols involving collaborating processes or shared knowledge bases which address issues of modularity and reusability. These include autonomous agent and client/server methodologies, WEB-based architectures, and integrating commercial packages within ITS substrates.

Personalization techniques (**web mining**) - techniques have been implemented and tested such as User profiling, content management and web site publishing, but one of the powerful techniques is the Web Mining. Applying statistical methods and data mining processes to web log files its possible to find interesting patterns that identify the student's behaviour on the system;

Case based reasoning - to store students interactions and feedback with the ITS, in order to maintain past memory experiences and then derive new paths of teaching;

Adaptive hypermedia - to deliver and present contents to the student, in a chosen platform in such a way that firmly address the students needs and according to his profile and past interactions, and not in a pre determined way.

The participation of psychology and educational sciences, is another inevitable requisite if we intend to develop efficient and effective ITS. This may be achieved by an interaction with computer science, namely the validation of tutoring strategies to be followed by the tutoring module of the ITS, and the right choice of the way to present contents to the student, according to the pedagogical model adopted

4. Conclusions

In this paper some of the actual limiting problems and future challenges of the ITS were depicted. Based on an historical perspective, some important advances and mythic systems were identified. The main contribution of this work is resumed in a proposed framework. This resulted from an exhaustive study in order to identify the principal efforts and characteristics that should be addressed by the next generation of ITS: Reusable Components, Standardization Efforts, Shared Vocabularies, Ontologies, ITS Shells, Distributed and Agent-Based Architectures, Personalization techniques (web mining), Case based reasoning, Adaptive hypermedia. The final conclusion of the work is related with the crucial role that sciences like the psychology and educational play in this field.

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