INTELLIGENT TUTORING SYSTEM FOR WEB-BASED EDUCATION

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ABSTRACT: Intelligent Tutoring System (ITS) is a branch of Artificial Intelligence (AI) that attempts to simulate a "human like" tutoring capabilities. The term "intelligent" refers to a system with the ability to know what to teach, when to teach and how to teach. Such a tutoring system can be effective because it can respond to the specific needs of student, guide slow learners, challenge rapid learners and monitor the progress of each student as well as establishing a training plan. ITS have the ability to understand, learn, and solve problems just like the human counterpart. To date education trend is geering towards Web-based education. However, Web-based education is still in the early development stage and most of the courses offered does not contain intelligent capability in the real sense. This paper discusses the state of the art of Web-based Intelligent Tutoring System and suggests ways to enhance the current Web-based ITSs.

Introduction

Over the last several years, computer technology has played an increasingly important role in the realm of education and training. Computer Assisted Instruction (CAI) has been around almost as long as computers themselves, but there has been much discontent with the current state of CAI. Educators and computer scientists realized the need for "intelligent" in these systems (Rickel,1989). The term "intelligent" refers to a system that have the ability to know what to teach, when to teach and how to teach.

Intelligent Tutoring Systems (ITS) emerged from Artificial Intelligence (AI) at the very time that AI was struggling to transcend the goal of mimicking human intelligence by creating machines that could "think" like humans. ITSs are computer-based instructional packages that used techniques discovered in Artificial Intelligence research to aid in teaching of some subject or skill. ITS are also refered to as Intelligent Computer Aided Instruction (ICAI) Systems because the integration of Artificial Intelligence techniques. ITS attempt to capture a method of teaching and learning exemplified by a one-to-one human tutoring interaction.

The increased influence and capability of the World Wide Web (WWW) has open new and innovative ways of learning and teaching. The WWW provides users with a uniform and convenient means of assessing the vast resources of the Internet. For educators, the WWW provides an exciting new opportunity for distance learning and teaching. Educational programs such as Web-based ITS can be accessed globally independent of time and geographic location using multi platform environment such as Unix, Macintosh and Microsoft Windows. Consequently, this could greatly enhance the effectiveness of the learning and teaching process.

What is An Intelligent Tutoring System?

ITS (also called Knowledge-based Tutors) is computer-based educational system that allow emulation of a human tutor. ITS used artificial intelligence techniques that can determine what to teach, how to teach and learn certain teaching relevant information about the student being taught. This requires the representation of a domain knowledge (called the *Domain Knowledge*), instructor's or teacher's knowledge (called *Pedagogy Module*) and the student learning state (called the *Student Model*). Through the interaction of these models, an ITS is able to make judgements about the student understanding and progress. Instructions can then be tailored by the *Pedagogy Module* to the student's requirements, automatically, without the intervention of a human instructor.

ITS is more intelligent than other conventional tutoring systems such as Computer Aided Instructions (CAI) and Computer Aided Learning (CAL) that are lacking "the flexibility and learner-centered orientation of ITS". ITS add "a dynamic and adaptive dimension to self-paced instruction". In addition to the model of the subject domain found in a conventional system, an ITS also includes pedagogical knowledge and a model of the student's knowledge level and undwerstanding. Figure 1 shows the difference between a conventional and an Intelligent Tutoring System.

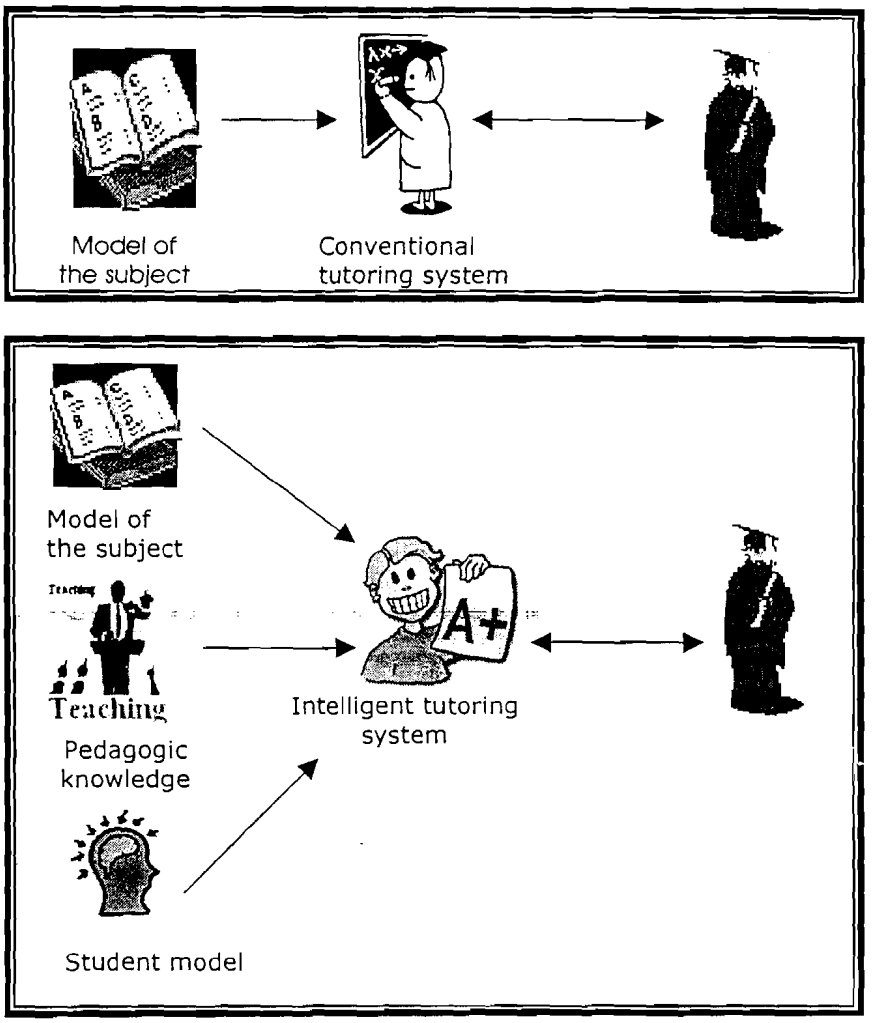


Figure 2: The conventional and intelligent tutoring system

The goal of ITS is to provide a learning experience for each student that approaches the standard of learning that he or she would receive in one-to-one tutoring from an expert teacher equipped with all necessary training aids. To achieve its goal, ITS monitors each student interactions, and builds a *Student Model* for each individual. This model comprises the student performance on training and remediation exercises; knowledge of all the information and remediation received; knowledge mastered, failed, unknown and misunderstood by the student as well as the student learning style. As an expert

teacher, who works on-to-one with a particular student would, an ITS develops a effective teaching style customised to each student.

The ideal ITS does not truly exist because of the limitations of computers and the over zealousness of the word "intelligent". Computers are not able to think like humans nor are they able to communicate or react like humans.

Despite the benefits of ITS, there are some resistance in organizations and educational institutes in implementing them because of high costs and training requirements.The cooperation between teachers and program designers is required so that the ITS could be used in the classroom and there would be an improvement on today's instruction tools.

Components of Intelligent Tutoring Systems

ITS may outwardly appear to be complex systems, but for the purposes of conceptualization and design, it is often easier to think about them as consisting of several interdependent components. There are four major components (Beck, 1996):

- Student model,
- Pedagogical module,
- Domain knowledge,
- Interface module.

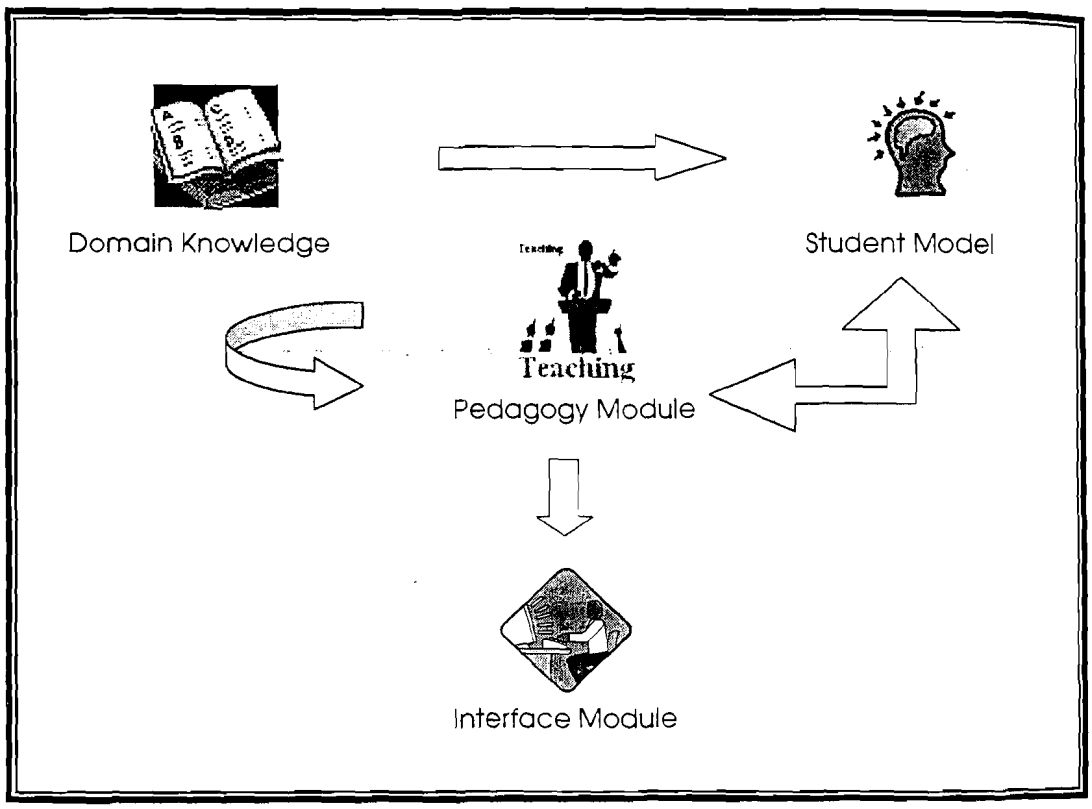
Figure 2 shows a view of the interaction between these components.

Student Model

The *Student Model* stores information that is specific to each individual learner. It contains information about the learner understanding of the knowledge domain by having a model of student's learning style and using diagnostic tools contained within the *Pedagogy Module* to extract learner's knowledge state about the subject domain. The *Student Model* is necessary in order to tailor instructions to a student's

idiosyncrasies and learning requirements. Without this knowledge, the *Pedagogical Module* of the tutor has no basis to make decisions, and is forced to treat all students equally.

Figure 2 : Interaction of Components in an ITS



Pedagogical Module

This module contains rules or other decision making tools that allow it to judge the student's understanding of the subject domain (as represented by the *Student Model*) and matches it with the actual knowledge structure (as represented by *Domain Knowledge*). The module uses information from student model to determine the domain knowledge aspects that should be presented to the learner and identify the needs for each student. The module provides a model of the teaching process and generates

correct forms of instruction to give to the *Interface Module.* . For example, information about when to review, when to present a new topic, and which topic to present is controlled by the pedagogical module.

Domain Knowledge

This component contains information about the subject knowledge domain; such as facts and concepts, and the processes needed to complete problems within the system. This module is the most important because without this module, there would be nothing to teach the student. Generally, it requires significant knowledge engineering to represent a domain so that other parts of the tutor can access it.

Interface Module

This module is responsible for processing the flow of communications between the ITS and the student. It presents the user with a uniform environment within which instructions, dialog and user driven learning is taking place. It handles the way of presenting the material to the student in the most effective way.

Benefits of Intelligent Tutoring Systems

ITS can make teaching and learning even more effective with the following features and benefits:

- Adaptively makes decisions on "how best to teach" each student based on knowledge of student in S*tudent Model,* knowledge of principles to be taught, and embedded teaching method.

- Automatically assesses each student's actions, so an ITS can provide a full record of student performance to:

- Aid instructor in helping student

- Provide a permanent record of student's learning performance
- Aids and documents achievement of job mastery in critical skills
- Enables the skills of a master instructor to be transferred to less experienced instructors via the default instructional methods that the master provides for a course of instruction in the software.
- An ITS can be guaranteed to stay with a student throughout the duration of a course and continue to learn about their individual students; human instructors may not.

Web-based Intelligent Tutoring Systems

Most previous ITSs have been developed and delivered as a stand-alone system rather than a web-based system. The rapid rise of the WWW has left many educational software developers turning over from developing stand-alone ITS to Web-based ITS because web-based system is more prevalent and attractive. However, porting an existing ITS into the web is not a trivial and a straightforward process due to the different in architecture between the two systems. Figure 3 show the architecture of a Web-based ITS that consist of the *Pedagogy Module, Domain Knowledge and the Student Model* on the server side. WWW clients however implement the *Interface Module*. Teaching knowledge dynamically generates HTML documents based on student current input and the student model. (Okazaki,1997)

Figure 3 Architecture of Web-based ITS

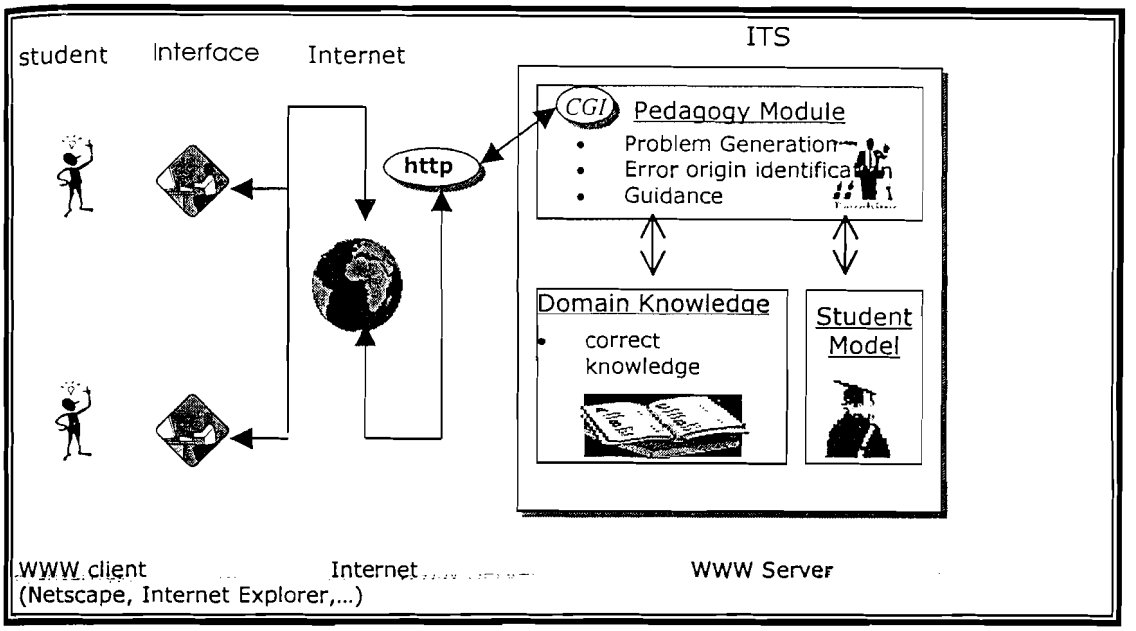


Table 1 shows the different between a stand-alone and web-based system in terms of distribution, delivery and development tools.

Stand-alone ITS	**Web-based ITS**
Distribution	
✓ Offline ✓ No bandwidth constraints ✓ One-to-one interaction ✓ Limited accessibility ✓ Self-study only	✓ Online ✓ Bandwidth constraints ✓ Many-to-many interaction ✓ Widely accessible ✓ Permits collaboration
Delivery	
✓ Through proprietary runtime software ✓ Platform-specific sometimes with license fees	✓ Through web browsers ✓ Cross-platform free
Development Tools	
✓ With standard programming languages or specialized authoring tools	✓ With generic web development tools

Table 1: Comparing Stand-alone and Web-based ITS

Once an ITS is implemented on the WWW it provides World Wide delivery and opens an effective and innovative way for web-based education. Stanchev (1993) identified five attributes of the WWW, which benefit the learning process over the traditional methods:

i. many-to-many communication
ii. place independence
iii. time independence
iv. multimedia-based communication and
v. computer mediated interaction.

Though these attributes may not be unique to the WWW, at least the first three are more readily available on the WWW. From the evaluation on the effectiveness of ITS it has shown that ITS has significantly improve the quality of student learning process (McArthur, 1993)

Current Research on Web-based Intelligent Tutoring Systems

The literature is full of instances where researchers have attempted to use the WWW for providing learning opportunities. This section provide a briefly review on some current research and development of Web-based ITS for different types of knowledge domain within the last five years.

Specht et. Al (1997) described Adaptive Statistic Tutor (**AST**), an adaptive courseware on the WWW. AST is based on conceptual model of the domain of intoductory statistics and uses the programmable WWW-server CL-HTTP to generate individualized courseware.

Angelides & Gibson (1993) described **PEDRO** - a Hypertext-based ITS. PEDRO - The Spanish Tutor is designed to assist intermediate level students with their learning of Spanish grammar, by testing their knowledge of regular and irregular verbs. The program is based on HyperCards, which are chosen and presented to the student according to the user's earlier performance.

Rainer et. Al. (1997) described **CyberProf** an interactive, web-based teaching system developed at University Of Illinois. Using CyberProf, lecturers can create on-line lecture notes that include equations, animations and graphics; write on-line interactive homework problems; communicate with student using CyberProf web-based conferencing system; survery students in order to receive feedback on course material; and record student grades in CyberProf on-line gradebook.

Kiyoshi et. al., (1995) described **CALAT,** a Web-based ITS that have a web server consisting of a tutoring system called CAIRNEY which has been developed as stand-alone ITS with easy-to-use authoring system. CALAT utilized user identification mechanism that provides an individual adaptation capability.

Brusilovsky et. al., (1996) developed **ELM-ART** (ELM Adaptive Remote Tutor), a Web-based ITS to support learning programming in LISP. ELM-ART can be considered as an on-line intelligent textbook with an integrated problem solving environment (called I^3 textbook, or intelligent interactive integrated textbook). It provides all the course materials (presentations of new concepts, test, examples, and problems) in hypermedia form.

Ritter (1997) developed **PAT**, a model-tracing Algebra Tutor being used in several middle, high school and college classes in USA and deployed on the World-Wide Web. The PAT tutor contains an expert system capable of solving the problems that are posed to students. As students take steps to complete the problem (for example, by filling in cells in the spreadsheet), the tutor considers whether or not those steps are consistent with a direct solution to the problem. If so, the tutor remains silent, and the student proceeds. If the student's action is not recognized as being on some solution path, the tutor checks to see if the step is consistent with a common misconception (or "bug"). In such cases, the tutor is able to provide instruction tailored to that bug.

Okazaki et. al., (1997) described **WITS,** a Web-based ITS for guiding differential calculations at high school in Japan. The basic structure of the WITS follows a standard ITS. All modules of the WITS are constructed on a WWW server except interface, that is implemented with a WWW client. The individualized tutoring mechanism is accomplished by combination of CGI (Common Gateway Interface) and FOF (Fill-Out Form) facilities of the WWW and user modeling technique on ITS technology.

Warendorf (1997) described **ADIS** an The Animated Data Structure Intelligent Tutoring System (ADIS) is an intelligent tutoring system developed as a teaching aid for a course on Data Structures to enhance students' understanding of data structures such as linked-lists, stacks, queues, trees and graphs. ADIS has the capability to display data structures graphically on the computer screen as well as allowing graphical manipulation of the data structure created. There is a tutorial mode incorporating exercises, where students can learn basic algorithms (insertion, deletion etc.) of data structures visually.

Fritz (1998) is developing **DiscMath** a Web-based ITS . One of the component called Web-based Proof Tutor provides exercise and guidance for students learning a variety of proof techniques: logical equvalances, logical implications, direct proof, indirect proof, and mathematical induction..

Technological Enhancements of Web-based Intelligent Tutoring System

This section provides some technological enhancements and improvements that can be integrated into Web-based ITS. Although some Web-based ITS have integrated some of these technologies, the technological advancements are still in the early development stage. Hopefully, by integrating the technologies, all web-based systems are able to be more effective, useful and intelligent.

a. Curriculum Sequencing

The goal of the *curriculum sequencing* technology (also referred to as instructional planning technology) is to provide the student with the most suitable individually

planned sequence of knowledge units to learn and sequence of learning tasks (examples, questions, problems, etc.) to work with. In other words, it helps the student to find an "optimal path" through the learning material. Curriculum sequencing was implemented in different forms in the following ITS: ELM-ART (Brusilovsky et.al., 1996), CALAT (Nakabayashi et al., 1995), and InterBook (Eklund & Brusilovsky, 1999).

b. Intelligent Analysis Of Student Solutions

Intelligent analysis of student solutions deals with students' final answers to educational problems (which can range from a simple question to a complex programming problem) no matter how these answers were obtained. Unlike non-intelligent checkers which can tell not more than whether the solution is correct, intelligent analyzers can tell what exactly is wrong or incomplete and which rnissing or incorrect knowledge may be responsible for the error. Intelligent analyzers can provide the student with extensive error feedback and update the student model. Currently, there are at least two ITS on the Web which implement intelligent analysis of student solutions on WWW adaptively (i.e., students with different student models may get different feedback): ELM-ART (Brusilovsky et al., 1996) and WITS (Okazaki et.al., 1997).

c. Interactive Problem Solving Support

The goal of *interactive problem solving support* is to provide the student with intelligent help on each step of problem solving - from giving a hint to executing the next step for the student. The systems which implement this technology can watch the actions of the student, understand them, and use this understanding to provide help and to update the student model. However, only two systems demonstrate that Interactive problem solving support technology can work on the WWW; PAT-Online (Ritter, 1997) and ADIS (Warendorf & Tan, 1997).

d. Example-Based Problem Solving

In an *example-based problem solving* context, students solve new problems using as help examples from their earlier problem. In this context, an ITS helps students by suggesting them the most relevant *cases* (examples explained to them or problems solved by them earlier). The only system which uses this technology on WWW is ELM-ART (Brusilovsky et al., 1996).

e. Adaptive Presentation Technology

The goal of *the adaptive presentation technology* is to adapt the content of a hypermedia page to the user's goals, knowledge and other information stored in the user model. In a system with adaptive presentation, the pages are not static, but adaptively generated or assembled from pieces for each user. For example, with several adaptive presentation techniques, expert users receive more detailed and deep information, while novices receive more additional explanation. Adaptive presentation is very important in WWW context where the same "page" has to suit to very different students. Only two Web-based ITS implement full-fledged adaptive presentation: C-Book (Kay & Kummerfeld, 1994) and De Bra's adaptive course on Hypertext (Calvi & De Bra, 1997). Both these systems apply the conditional text technique.

Yum & Crawford (1996) suggested that the survival of ITS concepts and technology depends the involvement of general user in the development cycle of ITS. They provide examples of operating systems, database and WWW where success was mainly due to the provision for general users to develop their own material and integrate it into these applications. However, there is no mention of any existing ITS in the literature, which allows the teaching community to contribute towards the development of an ITS without starting the design process from scratch (Kinshuk & Patel, 1997). Most teachers do not have either time, resources or sufficient understanding of the hardware and software technologies to develop the ITSs on their own. Therefore, another important

technology enhancement is the development of a generic Web-based ITS authoring tool for the teaching community to rapidly customised intelligent educational courseware according to their individual needs.

Conclusion

Web-based education is currently a hot research and development area. Benefits of web-based education are clear: classroom and platform independence. An application installed and supported in one location can be used by thousands of learners globally. While the evidence is still limited but very positive, Web-based ITSs have the potential to create a revolution in effective, low-cost education and training. However, one must realize that the WWW is just a tool that can be harnessed for web-based education. The effectiveness of the system using it depends on the quality of the underlying material and the pedagogical framework used in the development of the systems

The experiences recounted in the literature, however, caution that the development of tutoring systems on the WWW involves more than acquiring good web-publishing tools and the lessons learned during the evolution of CAL and ITS need to be recalled and applied. To develop an effective and useful tutoring system for the WWW, one still needs a team comprising of experienced people in the learning domain, in educational psychology and in computer science (Vanneste et. al.,1996).

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