A Conceptual Framework for Internet based Intelligent Tutoring Systems

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Abstract

The Internet provides an infrastructure that supports unprecedented communication capabilities and collaboration opportunities. In the field of education, it supports collaboration between various domain experts and teachers in designing novel approaches to teaching and co-operation among teachers who can share instructional material. It offers a vast store of information that can be accessed in a structured manner or explored in an unstructured manner, providing opportunities for designing tutoring systems with diverse pedagogic strategies. The freedom and flexibility offered by the Internet can, however, turn into an extensive waste of time, effort and resources, if the nature of educational processes and the capabilities of educational technologies are not adequately considered while designing a tutoring system.

The development of Intelligent Tutoring Systems (ITSs) has suffered since its early days from the fact that the underlying software engineering methodology was not developed specifically for tutoring and did not possess all the desired attributes to facilitate intelligent tutoring. While an ITS inherits powerful functionality at the points of convergence between its objectives and the capabilities of the methodology employed, it also inherits a 'context gap' at the points of divergence between the purpose of the tasks performed within an ITS and the purpose of the methodology. The traditional ITS development was mainly based on the Expert Systems paradigm while the Hypertext paradigm is increasingly becoming popular with the ITS designers. In their pure form, ITS implementations of Expert Systems and Hypertext are respectively 'weak instructionist' and 'weak constructionist' systems, the weakness arising from the 'context gap'. This paper identifies, from an ITS design perspective, some of the negative attributes of both these paradigms and presents a framework that recognises the need to reduce the 'context gap' and suggests a combination of the favourable attributes of both the paradigms.

Background

The importance of the Internet has been widely recognised in the last few years. A number of learning systems have been developed on the Internet, most of them being Hypertext[1] based information retrieval systems. A few attempts have also been made to develop Intelligent Tutoring Systems (ITS) on the Internet but these systems differ from the traditional ITS's approach and are based on the Hypertext paradigm rather than the Expert Systems paradigm. The term Expert System was defined by Edward Feigenbaum (Harmon & King, 1985) as "*an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution*". Bielawski & Lewand, (1991) explained, "*Expert Systems are software programs that use knowledge and experience to simulate the performance of a human expert in a narrow field or domain. Hypertext or Hypermedia, in contrast, provides a vehicle for intuitive, non-linear access to information and program navigation that more realistically resembles intelligent behaviour.*"

The Expert System paradigm was developed ostensibly to capture human expertise and to replace a human expert and in practice provides assistance in problem analysis and evaluation, for example, in medical diagnosis or assessing credit worthiness for extending loans. The Hypertext paradigm was formulated to provide a user with a wide variety of information from distributed sources. Both these paradigms have their limitations with respect to the educational process since neither of them was originally developed to fulfil educational objectives. This paper presents a framework of an Internet based ITS that attempts to harness the benefits of both the paradigms while focusing on the process of the essential knowledge acquisition by most of the students. The structure of the framework is presented elsewhere (Patel & Kinshuk, 1997).

Inadequacy of the individual paradigms

Angelides & Gibson (1993) have provided a good critique of the Expert System paradigm. They mentioned two fundamental characteristics of Expert Systems that makes the paradigm less useful for tutoring systems. Firstly, the knowledge decomposition, representation and inferencing are exclusively hierarchical in the case of the Expert Systems. Secondly, as all the relationships are established through reasoning, the Expert Systems lack explicit information links while the Hypertext approach facilitates explicit hierarchical and non-hierarchical linking of the information.

Lesgold (1994) observed that there is always some limit to the level of expertise in an expert system, for example 'Sherlock II' does not know how to proceed if its assumption of only a single device failure at a time happens to be false. Besides these intrinsic limitations of the Expert System paradigm, further shortcomings arise from the context of its application to tutoring systems. Since it is designed to provide solutions to problems, it readily presents a solution rather than guide a student through active attempts at the various intermediate steps towards the solution. It instructs the intermediate steps as a narrative but is a 'weak instructionist' system as it requires a student to be motivated enough to learn by analysing the chain of reasoning presented by the system. An Expert System is time consuming to produce, limited in its expertise and inflexible whereas the Hypertext paradigm offers faster development, easy modifications and frequent updates.

Giannotti & Ponta (1993) outlined the potential of hypermedia for learning as : (a) *learning as replication*, where hypermedia can provide text and graphic display of information, structural links for navigation and context links for expansion and reference, dynamic representation of information such as animations, sound, live video and other external media; (b) *learning by tautology*, where demonstrations can be designed to guide the learner through the learning process with the help of hypermedia; and (c) *learning by dynamic interactions*, where the computer is more active and information is not only provided by the courseware, but can be modified and generated by the learner.

The freedom and flexibility offered by the Hypertext based systems, however, frequently results in a user getting lost along a chain of links and the diversion of a user's focus away from the main goal to incidental links (Hammond, 1993). The success of a pure Hypertext based tutoring system depends on a learners' motivation and self-discipline. Though the Hypertext paradigm enables exploration of rich information and thus supports 'construction' of knowledge, it is a 'weak constructionist' system from the tutoring point of view as the soundness of the constructed knowledge cannot be assured by the tutoring system. Luck (1993) observed, *"Hypermedia learning environments are*

used cognitively in a wrong way if they are used as learning programmes." Hypertext paradigm lacks the logical inferencing mechanism necessary to validate student actions and requires amalgamation with the Expert System paradigm to procure these facilities.

Internet and learning - the existing research

The literature is full of instances where researchers have attempted to use the Internet for providing learning opportunities. Stanchev (1993) identified five attributes of the Internet, which benefit the learning process over the traditional methods, as (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 Internet, at least the first three are more readily available on the Internet. These attributes have enabled the development of concepts and systems such as those mentioned below:

Berns (1996) presented the concept of Global Tutoring as the use of information technology to provide individualised or group student instruction where the student and the tutor never meet, they only interact by electronic media.

Lemone (1996) described WebCourser, which assembles courses automatically, based on the profiles supplied by users, and Web ReCourse, which enables instructors and trainers to create automatically customised courses from pre-existing course elements, such as, HTML documents, graphic files, header files.

Nawarecki & Dobrowolski (1996) provided an intelligent distributed and decentralised (multi-agent) system. This system allows various students and teachers to interact with each other, while supporting intelligent learning through the use of autonomous agents.

Angelides & Gibson (1993) described PEDRO - a Hypertext-based intelligent tutoring system. 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.

The experiences recounted in the literature, however, caution that the development of tutoring systems on the Internet 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 useful learning material for the Internet, one still needs a team consisting of experienced people in the learning domain, in learning psychology and in computer science (Vanneste et. al.,1996).

ITS - the need for mass development applications

Yum & Crawford (1996) suggested that the survival of ITS concept depends the involvement of general user in the development cycle of ITS. They provide examples of operating systems, database and world wide web where success was mainly due to the provision for general users to develop their own material and integrate it into these applications. They ask whether the ITS development can be supported on a mass basis.

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. Most teachers do not have either time, resources or sufficient understanding of the hardware and software technologies to develop the ITSs on their own. They need a generic software structure that can be rapidly customised according to their individual needs. The proposed framework is an effort in this direction.

The proposed framework

The proposed framework is concerned with producing useful ITSs that are produced economically, implemented in the actual educational environment and used by a large number of students to justify the continuing research and development activities in this field. It is based on the following five notions.

1. *The Contexts of an ITS*: Providing the foundation to the proposed framework, this notion recognises the various contexts of an ITS, particularly the central role of a teacher as a design collaborator and as an implementor, the capabilities and limitations of the educational technology employed, the nature of discipline and the constituents of knowledge. For example, Patel & Kinshuk (1996a) identified that it is easier to learn from mistakes when the learning is action oriented and requires less abstraction - making the operational type of knowledge more suitable for an interactive computer based tutoring system.
2. *The Expert System paradigm*: Tutoring involves more than presenting information and requires validation of student actions, with dynamic feedback while learning to prevent possibilities of 'practised' misconceptions and delayed feedback for periodic assessment for student knowledge. The Expert System paradigm provides a neat separation of knowledge and the processing of that knowledge, increasing the reusability of such processes.
3. *The Hypertext paradigm*: The flexibility offered by the 'link' mechanism of the Hypertext enables a teacher to link appropriate intelligent tutoring applets to build a larger tutoring system. It allows the build up of an inventory of applets that can be copied and altered incrementally to create more applets and linked by various teachers in various tutoring systems. The traditional multi-media browsing facility can still be implemented in the accompanying explanatory narrative.
4. *Object orientation*: Knowledge is viewed as a network of knowledge entities. The tutoring applets are designed around these knowledge entities, creating a good match between the structuring of knowledge and the Object Oriented Programming paradigm employed by languages such as 'Java'.
5. *Human Computer Interaction considerations*: The student should not have to work through a rigid path to a solution and need not perform superfluous tasks. The system should maintain simple and instinctive interface, calling upon a 'zoomed' finer grained interface for the learning of details e.g. constituents of a formula.

The basis of the proposed framework and a possible implementation

The conception of the framework followed the development of four diverse Intelligent Tutoring Tools (ITTs) under the Byzantium project - a consortium of six universities. The ITTs are *mixed-initiative* systems with an *overlay* type of student model. The structure and functionality of ITTs are discussed in Patel & Kinshuk (1996b). These ITTs are being introduced into the mainstream teaching across a number of institutions and are well received (Kinshuk, 1996).

The development of the ITTs provided necessary information to formulate the methodology to construct a *general purpose tutoring system builder*. The builder, with the help of an interactive dialogue with a subject teacher, will produce an Intelligent Tutoring Applet (ITA) for any numeric discipline (Patel & Kinshuk, 1996c) for implementing it on the Internet. The ITAs created by different teachers build up to a large inventory of accessible knowledge that can be linked in various configurations of

single or multiple ITAs to create Intelligent Tutoring Systems (ITSs). Figure 1 shows a schema of such Internet based ITS and its links with various ITAs. The possibility of linking various ITAs in a configurable teacher designed ITS allows the extension of the framework to more complex applications, however, the methodology can only be firmed up after prototypes are built and tested on the Internet.

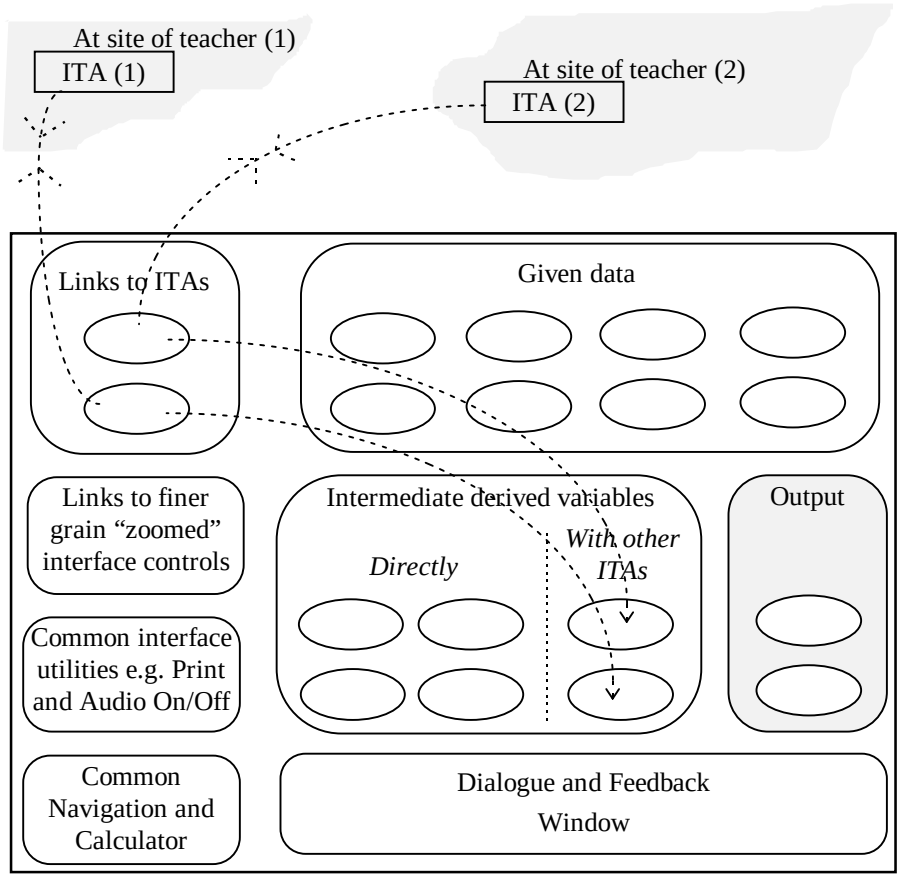

Figure 1. Intelligent Tutoring System on Internet and its linking with various ITAs

A review of the proposed implementation

The proposed implementation utilises Hypertext's hierarchical and non-hierarchical information linking abilities, while using the inferencing mechanism from the Expert System paradigm. The knowledge base of the proposed ITS is distributed over a number of ITAs. Though within an ITA, the knowledge structure is hierarchical, the linking of knowledge across ITAs provides a non-hierarchical structure. An index of the ITAs and ITSs can be maintained to enable faster searches for locating ITAs suitable to the ITS being designed. The explicit information links employed for connecting appropriate ITAs is many times necessary and desirable as this allows the customisation of the knowledge base.

The structure of the proposed implementation of an ITS is quite flexible. Once an ITS is created, it may be copied and modified to create another ITS. The knowledge management is also customisable in the same way. Thus the process of ITS development becomes easier and faster. The inferencing mechanism in the ITSs uses

Expert System paradigm, though the process has been broken into small components (smaller inference engines of various ITAs) for the sake of efficiency and flexibility.

Conclusion

Despite expensive resources and years of research, most of the Intelligent Tutoring Systems have not been developed to a standard where they can be utilised in practical academic environment. This paper identifies two important causes. First, the underlying methodologies used for developing an ITS were not designed from an educational viewpoint and hence do not possess all the attributes necessary to fulfil educational objectives. Second, the development of ITSs seems to have been removed from the actual needs of the teachers and students. The developments, in main, appear to be driven by the latest available technology or the intellectual challenges taken up by the researchers rather than the considerations of the typical amount of time spent on acquisition of operational knowledge and skills by introductory students, the typical sizes of student cohorts pursuing various disciplines, the resources available to a typical student in these diverse disciplines and the phenomenal amount of time spent by teachers in assessing the student work.

The Internet offers a vast amount of multi-form and multi-sensory information but the Hypertext based browsing facilities do not provide, in themselves, any mechanism for the proper structuring of the tutoring process. These structures have to be provided by a human teacher and enforced through assessments. Such assessments can only extend a delayed feedback. A purely Hypertext based tutoring system, therefore, depends on student motivation for the initial as well as remedial process of learning. Nevertheless, Hypertext is a powerful facility and combined with the traditional Expert System paradigm, object orientation and HCI considerations, as suggested by the proposed frame work, it can provide an extensible ITS on the Internet.

Notes

1. Though 'Hypermedia' may be a more suitable term after embodiment of graphics, audio, video, and animations, the term 'Hypertext' is used to conform with the initially used terminology for the paradigm. 'Hypermedia' is used when quoting or paraphrasing authors.

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