Towards a More Presentation-Oriented Approach in Intelligent Tutoring System Blackboard Architectures

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Abstract

Blackboard architectures for Intelligent Tutoring Systems (ITSs) tend to focus on control structures for selecting knowledge sources. Current research has begun to explore the psychology of how knowledge should be presented, rather than simply on the mechanics of what knowledge to present. Specifically, experiments have shown than presenting the same knowledge using different formats can produce quantifiable differences in the effectiveness of an ITS session. This paper introduces a variation on a "standard" ITS blackboard, emphasizing presentation method as well as content selection.

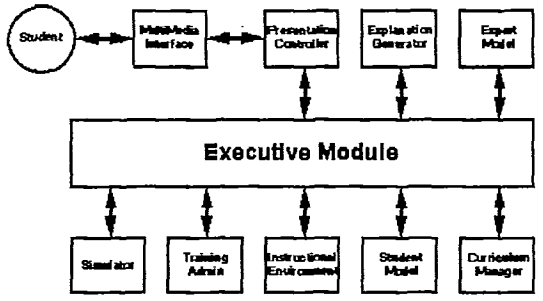

Figure 1: A Generic ITS

Motivation for ITS

Value of ITS in General

Computers in education are here to stay. The literature from as far back as 14 years ago refers to the significant impact of computer-aided instruction (CAI) on the educational landscape. (O'Shea 83) As the presence of CAI becomes ever more commonplace in the learning environment, it is natural to expect that the state of the art in CAI will advance accordingly. Unfortunately, CAI software in general has failed to keep up with the high expectations fostered by the microcomputer revolution of the 1980s. (Ely 88) Reliance on oversimplified teaching models and emphasis on teaching basic skills and rote drills has somewhat cooled the enthusiasm of educators who want software that teaches problem-solving and higher order thinking.

This is the breach into which the artificial intelligence community has stepped. Artificial Intelligence in Education (AI-ED) is a prospering field, with annual conferences bringing in dozens of papers and thousands of participants. (Brna 93) Numerous examples exist in the literature, detailing and eventually refining the architectures into the form we see in a "standard" ITS today.

In nearly every example of an ITS in the literature one encounters the same basic building blocks. The system is controlled via some sort of executive module, that interfaces with various semi-independent assistant modules each of which is an expert system in its own right in the area of concern. Figure 1 shows an example of such a system, with representative modules dealing with various aspects of the tutoring session. (Warren 93) It is important to note that while the student interacts with the ITS via some sort of interface module, that interface in turn interacts through a presentation controller. This presentation controller comprises the focus of this discussion.

Value of Presentation-Oriented ITS

A search of the literature reveals that, to date, the bulk of research into ITS technology has fallen into two categories: philosophical discussions and implementation issues. Little effort has been expended in the large area in between. (Mizo 96) In particular, two critical areas are in dire need of attention: the psychological aspects of effective instruction (Reichgelt 94) and evaluating the success (or failure) of an ITS in teaching. (Mark 91)

When viewed at the highest level of abstraction, the key issue of a tutoring session becomes, "what did the student experience?" Numerous methodologies exist in the literature for acquiring knowledge; codifying that information into knowledge bases; and crafting systems that can decide what information is best to present, and when. I contend, however, that *how* the knowledge is presented is just as important as the content of the knowledge itself–to the extent that presenting the same information using different methods can have a measurable impact on the effectiveness of the presentation. Examples of preliminary research in this area in the literature tend to support this contention. (Mark 91; Woods 96; Mark 96)

A Typical ITS Blackboard

One popular architecture for ITS applications is the so-called "blackboard." Knowledge is stored in different knowledge sources (KSs), with each KS functioning as an "expert" in some aspect of the knowledge domain. A global structure–the blackboard–holds the current state of the evolving solution, while each KS has the potential to "write on" the blackboard if a scheduler function deems that KS has useful information to provide. The overall system is event-driven, wherein a problem event triggers the scheduler to decide which KSs are applicable, and to place the advent of their inputs onto an agenda structure. This agenda structure consists of individual tasks to be solved, as well as a record (the Knowledge Source Activation Record, KSAR) of which KS is to be enabled when a given task comes up on the agenda for resolution.

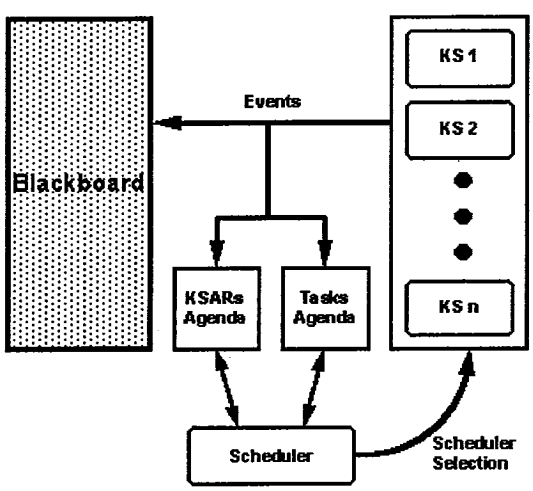

Figure 2: **Standard Blackboard ITS**

A useful analogy is to consider the problem event of an orbiting space shuttle about to encounter a particle of debris. KSs could be members of a panel brought to bear on the problem, each with a unique perspective. A pilot might want to offer maneuvers to avoid the debris, whereas a propulsion expert might want to discuss fuel reserves, a materials expert would be concerned with an analysis of how much damage the shuttle would sustain in the impact, and a physiologist might be offering details on the effect of the ensuing decompression on an unprotected crew. Clearly, such a potentially chaotic atmosphere would require a panel chairperson armed not only with knowledge of which KS is most appropriate at the time, but also with the power to enforce input only from selected KSs according to an established agenda.

Blackboards are useful in ITS applications for a variety of reasons. The blackboard itself provides a good abstraction of the synthesis between a student's learning behavior *vis-a-vis* the material in the lesson–clearly a good candidate for representation by a steadily-evolving knowledge structure. If one were to view the KSs as teachers, each with a particular area of expertise, the agenda as the curriculum, and the scheduler as the dean of the college, one can begin to see how neatly this architecture maps to the real world.

A Presentation-Oriented ITS Blackboard

I propose altering the "standard" blackboard ITS architecture to include a new set of information: presentation methods (PMs). This set of methods can be viewed as a "filter" between the KSs and the blackboard, moderating how a given KS can present its input. The scheduler then must take on another role: not only mapping KSs to each step in the tutoring session, but also mapping both the KS and the task to the proper *method* by which to "write to the blackboard."

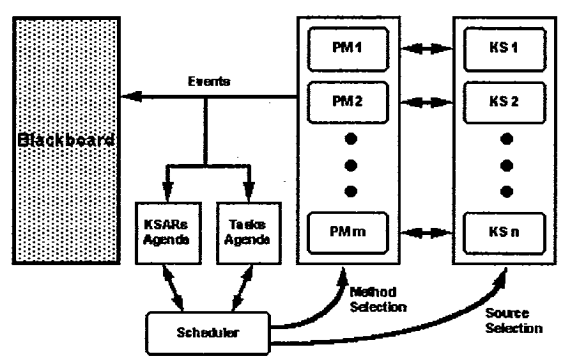

Figure 3: **Presentation-Oriented Blackboard ITS**

In figure 3 I use the blackboard structure to repre-

sent the selected information being presented via the selected PM–the "solution" as it currently exists within the context of the blackboard's problem: teaching a required lesson. For example, suppose the current lesson involves teaching a given student to understand the Pythagorean theorum. Previous experience with this student leads the ITS initially to avoid an analytical approach such as presenting the theorum as a formula. Instead, the concepts are presented graphically beginning with an illustration of the classic 3-4-5 triangle. A narrative describes the salient portions of the diagram; the student is then invited to select triangles with properly-labeled lengths from groups of distractors whose lengths do not form correct ratios. Once the student correctly identifies Pythagorean triangles within an acceptable rate of success, the ITS might then elect to complete the lesson with a more analytical approach, such as presenting the actual formula along with calculation exercises.

The addition of PMs to the blackboard architecture adds another layer of complexity to the knowledge base, and the scheduler function. In a given design containing n KSs, a layer of m PMs has the potential of increasing the taskload of the scheduler to $n * m$. In this light, an obvious bounding method will be to pare the size of m to the bare minimum commensurate with achieving the system's learning objectives. Research into applying this architecture will require field testing of competing (and possibly overlapping) presentation strategies, as well as re-evaluating knowledge partitioning strategies to include grouping by some hierarchy of preferred presentation methods for mapping into a PM structure.

Conclusion

On an abstract level, an ITS exists for one purpose: to provide a student with a quality computer-based learning experience. While great strides have been made in the AI community with regard to teaching theory and system design, a great deal of work remains to be done in the area of the psychology of how an ITS and a student actually interact. I assert that one method of addressing this issue is by giving *how* information is presented as much emphasis as is given to selecting the information itself. I propose a modified blackboard ITS architecture that can make use of this emphasis through making selection of an appropriate PM a necessary condition for the information in a given KS to be presented. Areas of future research include identifying a method for quantifying presentation methods and defining a mapping scheme to relate KSs to an appropriate PM.

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