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Towards Less Intelligent Tutoring Systems

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Abstract

Intelligent tutoring systems are becoming increasingly popular teaching tools within the business domain. These systems carefully diagnose the behaviour of the learner in order to gain insight into the learner's knowledge state to tailor the instruction according to the needs of the individual learner. Although the artificial intelligence research within the field of diagnosis has progressed significantly, diagnostic processes are still far from perfect and doubts have emerged whether perfection can ever be achieved.

This paper, therefore, explores suggestions that have been made on how to achieve effective teaching without detailed student models. It then proposes to merge these suggestions with the valuable ideas that have emerged from the research in the field of intelligent tutoring systems in order to develop effective teaching tools.

Still, the development of these hybrid systems raises further questions about the concrete implementation of some of the ideas raised. This paper concludes by addressing some of these problems as a point of departure for further research towards "less intelligent tutoring systems".

Intelligent Tutoring Systems

Recent years have seen an increased awareness of the potential of intelligent tutoring systems to support learning in both industrial and academic environments. Intelligent tutoring systems use ideas from the field of artificial intelligence in order to create a teaching environment that provides individualised tutoring (Kaplan and Rock 1995). They adapt the teaching process to the learner by exploring and understanding the learner's special needs and interests, and by responding to these as a human teacher does. In order to provide this adaptability to the student an intelligent tutoring system makes use of three knowledge models, i.e. the domain model, the tutoring model and the student model (Winkels 1992).

The *domain model* includes an explicit representation of the knowledge about the topic, which the intelligent tutoring system intends to teach. The domain model provides the 'expert knowledge' against which the behaviour of the user can be compared. An intelligent tutoring system is also equipped with teaching expertise which is contained in the *tutoring model*. This teaching expertise is represented in the form of different teaching strategies, such as successive refinement and analogue reasoning. A teaching strategy determines the style of material delivery that is employed in order to lead the student through the tutorial. The choice for a particular teaching strategy within a specific teaching situation might depend on factors such as the topic being taught and the preference of the student for a particular strategy. Finally, an intelligent tutoring system has the ability to perform diagnosis of the learner's current knowledge about the subject area being taught. This is achieved by collecting feedback from the student during the course of interaction and by analysing this feedback against a wide range of predefined student behaviours. This information about the student is stored in the *student model* and is used as a basis for both giving corrective feedback on any student errors that might occur and advancing the student to the next topic to be learned.

The Problems of Student Modelling

However, there are a number of problems which have been associated with the development of these conventional intelligent tutoring systems.

Most intelligent tutoring systems were developed based on the assumption that within a problem solving context learners' thinking processes can be modelled, traced and corrected using computers (Derry and Lajoie 1993). This concern for student modelling approaches was a major focus of intelligent tutoring system research in the 1980s. As a result many systems have been built using the model-tracing method. However, it is argued that research on complete and precise student models has hardly shown any progress and serious doubts exist whether such progress can be expected in the near future or if it is at all possible (Bierman et al 1992). Furthermore, the diagnostic processes developed have remained very domain specific. The systems developed, for example, largely fall into procedural domains such as geometry and programming.

Further criticism has been raised addressing the fact that student modelling has remained an exclusively cognitive analysis. However, effective tutoring also needs to account for issues such as the student's motivation, attention, and preference for a particular teaching strategy (Lepper et al. 1993).

An Alternative Approach: Giving More Control to the Student

The doubt that it is feasible to construct student models that can provide a basis for ideal adaptation to the individual in respect to both the learner's current knowledge state and his preference or need for a particular teaching strategy has led some researchers to divert from the conventional teaching style which is dependent on good student modelling towards the teaching style of guided discovery learning. Within this teaching style the tutor attempts to reduce intervention as the teaching process commences, and the student is encouraged to control and reflect upon his own performance. Typical areas which lend themselves to the implementation of student control in intelligent tutoring systems include the sequencing of the material that has to be learned, and the selection of the teaching strategy used (Laurillard 1991).

Student control over the sequencing of the topics may be supported through the implementation of facilities, such as an index of the content to be learned, a map that displays the links between different topics, the option to escape to the index or map at any time, the option to jump forward or back a chosen amount, and the option to retrace a chosen route through the learning material.

In order to allow the student control over the teaching strategy used a system may provide the user with a choice of appropriate teaching strategies prior to commencing with the teaching process.

It is argued that in such an environment effective learning is achieved through allowing the learner to practice conscious reflective surveillance of thought. At the same time student control keeps the student involved and motivated, so that the student is likely to concentrate over a longer period of time.

Complementing Student Control with System Intervention

Leaving the control over the tutoring process to the student leaves the student with a certain freedom of learning. There are, of course, certain dangers associated with this freedom. The student may, for example, acquire and apply incorrect knowledge, i.e. make an error, or he may fail to acquire all the knowledge he is supposed to learn. Furthermore, his choice of tutoring strategy may not necessarily be the best choice (Moyse 1992).

However, intelligent tutoring systems possess the knowledge resources which could provide constructive system intervention to regulate the teaching process in such situations. They may make use of the student model which traces the knowledge the student has acquired and may intervene when corrective feedback or guidance is required. Furthermore, the student model may record the success rate of teaching strategies that

have previously been selected by the student and use this information to suggest a suitable teaching strategy if the choice of the student fails to be successful.

Future Research

The previous section has argued that guided discovery learning should go hand-in-hand with constructive system intervention based on student modelling. Through the application of artificial intelligence computers can and should serve part of a cognitive mentoring function without taking over complete control. However, there are problems associated with the intervention of the system for the purpose of error correction and teaching strategy recommendation as outlined in the section above. Although an exhaustive discussion of these problems goes beyond the scope of this paper they are raised below as a point of departure for further research.

The Timing of System Intervention

Although the student model of an intelligent tutoring system may be able to provide corrective feedback on student errors the question remains when exactly the system should interfere, i.e. whether the corrective action should be triggered as soon as an error has been detected or whether the system should accumulate occurring errors over a certain period and then carry out all necessary remedial tutoring collectively at a designated point within the tutoring process.

Immediate remediation has the advantage that it is easier for the student to analyse the mental state that led to the error and therefore make appropriate corrections. Furthermore, immediate remediation can give immediate feedback before the student has to commit himself to an incorrect solution thereby avoiding the frustration that might build up whilst he struggles unsuccessfully in an error state. However, particularly in less structured domains, such as business management, a possible danger is that the student might form a local solution according to the focused remediation given, without viewing or rethinking the solution within the more global context of the overall task.

Delayed remediation on the other hand has the advantage that the error becomes visible to the student. If, however, delayed remediation is chosen as the sole approach there are two inherent dangers. The student might anticipate the remediation and await its arrival without putting maximum effort into the task. The second danger arises from the experience that judgement biases are generally hard to remove. Once the student has committed himself to a solution he might be reluctant to accept its inappropriateness when - at a later stage - remediation takes place.

System Strategy Selection

It was further proposed that the intelligent tutoring system suggests a suitable teaching strategy if the choice of the learner fails to be successful. Although the intelligent tutoring system might use the success rate with particular teaching strategies recorded in the student model to support its choice, there are a number of additional factors that need to be considered.

For instance, whether a particular teaching strategy is applicable within a certain teaching situation might be restricted by the degree of structure of the subject area in which the error occurs. Teaching strategies span the scope of subject areas from structured to unstructured (Silverman 1992). A strategy such as successive refinement, for example, tends to be suitable for more structured problems where a detailed diagnostic result might be available providing the details required to provide step-by-step refinement. A strategies such as analogue reasoning, on the other hand, is more frequently applicable within less structured domains.

A further common discriminating factor which might be considered when selecting a teaching strategy at a stage where the creation of a full blown cognitive model has not yet been achieved, is the differentiation between student advancement stages.

Yet, the issue of the system selecting an appropriate strategy remains a delicate one and much further research is required to arrive at a commonly agreed selection mechanism.

Conclusion

An intelligent tutoring system is a teaching tool that uses information about the learner stored in its student model to adapt its instructions to the needs of the individual. However, the creation and maintenance of student models rely on the ability of the intelligent tutoring system to perform detailed diagnosis and is far from being perfect.

The doubt that it is possible to construct perfect student models has led researchers to pursue alternative teaching styles such as guided discovery learning in which the student is given more control over his teaching process. Apart from the advantage that guided discovery learning can reduce tutor intervention that has to rely on detailed student models, increased student control over the tutoring process is beneficial for effective tutoring. By controlling his learning process the student can construct his own conception of the knowledge to be learned.

Whilst work on both, student modelling and teaching styles that allow for greater student control over the teaching process, has contributed to the research in the field of instructional technology there is a strong belief that the future lies in merging the findings of these two areas (Derry and Lajoie 1993). Such a merge might not only lead to the reconciliation of the theoretical differences between the two areas, but more importantly, they might complement each other thereby opening up opportunities for "less intelligent tutoring systems".

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