Adding a Cognitive Model of Human Tutors To an Intelligent Tutoring Systems

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ABSTRACT

I propose that a more effective intelligent tutoring system (ITS) for the domain of algebra symbolization can be made by building a cognitive model of human tutors and incorporating that model into an ITS. First I describe the domain and the argument for a tutorial model. Secondly, I review the research that went into the student model. Finally I describe the experiment I will be conducting that will look at two different scaffolding strategies as well and compare this new ITS to a pervious benchmarked ITS.

Keywords

Intelligent Tutoring Systems implementation, Model Tracing, algebra, tutoring, Socratic dialogue.

INTRODUCTION

Model Tracing tutors built by Anderson et.al. that are driven be a *student model* have proven they can be effective educational systems [1 4]. These system are effective even though their tutoring method is very different from what human tutors do. One important observation is that human tutors ask more questions while model tracing tutors give more hints. Can we improve on model tracing tutors by building a model of the tutor and combining that with a student model?

The Domain: Symbolization

I am building an ITS for algebra *symbolization.* Symbolization is the act of translating a problem situation into the language of formal algebra notation. Symbolization is ubiquitous: from using a spreadsheet to programming a computer. Symbolization is usually introduced to students by starting with simple word problems like the following:

> Ann is in a rowboat and starts out 800 yards from the dock. She rows towards the dock for "m" minutes but then stops to rest. Her rowing speed was 40 yards per minute. Write an expression for her current distance from the dock.

Problem 1. The answer is "800-40*m"

Socratic Dialogue for Symbolization

Researchers at Carnegie Mellon University have already built a Model Tracing ITS, called Cognitive Tutor Algebra (CAT), that attempts to teach all of high school algebra including symbolization [4]. Currently the cognitive student model in CAT treats symbolization as a single atomic skill. But even though its output is a single expression, symbolization appears to require a composite set of skills. I have done research, described below, which shows symbolization actually involves at lest three processes including comprehending the story, building up a representation of the quantitative structure and finally outputting the correct symbols [3]. Therefore I call symbolization a compound skill, in that it is not a single skill but the result of a chain of reasoning. Since a student might have trouble anywhere along that chain of reasoning, current ITSs that produce a single hint are unlikely to be effective. One response of ITS designers to a compound skill has been to change the interface to force the student to state his intermediate results, much as Corbett & Anderson [1] redesigned their LISP tutor to have students reify their sub-goals before they write their program. One worry is that students will be confused by the extra interface components, impeding learning and transfer. Another concern is that the task becomes too easy when broken into parts.

My approach is inspired by preliminary protocol analyses that suggest that one major difference between human tutors and ITSs is that humans tend to ask more questions and the ITSs tend to tell more information. Lepper [6]also reports that 80-90% of tutorial utterances were in the form of questions. I believe that we might build a better ITS if it can dialogue more like a human. What changes does this imply for building ITSs? I argue that traditional model tracing tutors do not provide the necessary flexibility. I argue that what is needed is a cognitive model of human tutoring

Completed Research: The Cognitive Student Model

I have conducted empirical studies [2 3] that have led to the construction of a cognitive student model of symbolizing. I collected data from 80 subjects who symbolized word problems that were carefully constructed to determine what factors most affected the difficulty of symbolizing. This research also determined the relative difficulty of these factors. I currently have an student model that is able to account for the major trends in the data. This model of symbolization predicts how people decompose this task and has led to a suggested improvement of the scaffolding in the current ITS. This model is capable of diagnosing a student's input and figuring out what sorts of misconceptions the student is expected to have.

PROPOSED MODELING OF THE TUTOR

I have collected protocols of experienced humans tutoring students and compared them to the Algebra Cognitive Tutor. I found that human tutors give hints in the form of questions while the compute tutor gives hints in the form of statements. I suspect a significant benefit of using questions, is that the tutor can help the student by breaking down the problem into sub-problems. Therefore, my ITS ALT is able to have a question-and-answer dialogue with a student. ALT helps a student construct their own knowledge rather then just telling them information. From my protocols, I have selected two strategies for scaffolding algebra word problems. The first strategy I call *Inductive Support Scaffolding* which tries to help the student induce the correct expression by asking the student a simplified problem that replaces the variable with a concrete number as shown below. The following is an example of the *Inductive Support Scaffolding* as ALT presents it:

Tutor: Ann is in a rowboat and starts out 800 yards from the dock. She rows towards the dock for "m" minutes but then stops to rest. Her rowing speed was 40 yards per minute. Write an expression for her current distance from the dock.
Student: 800*m
Tutor: No. Let me ask you an easier question. Suppose the number of minutes she had been rowing was "3" instead of "m". What would be the distance to the dock?
Student: 680
Tutor: Correct. Can you show the math for how you got that?
Student: 800-40*3
Tutor: Good. Now, lets go back to the original question of when the number of minutes she had been rowing was "m" instead of "3". What would be the distance to the dock?
Student 800-40*m
Tutor: Good.

A second strategy I call *Decomposition and Substitution Scaffolding*. Here is an example:

Tutor: Ann is in a rowboat and starts out 800 yards from the dock. She rows towards the dock for "m" minutes but then stops to rest. Her rowing speed was 40 yards per minute. Write an expression for her current distance from the dock.
Student: 800*m
Tutor: No. Let me ask you an easier question. What is the distance Anne rowed in "m" minutes?
Student: 40*m
Tutor: Correct. Now suppose the distance rowed in "m" minutes was "X" instead of "40*m". What would the distance to the dock be?
Student: 800-X
Tutor: Good. Now, tell us the distance to the dock without using the variable "X". Substitute the value of "X" into the expression of "800-X" you just wrote.
Student 800-40*m
Tutor: Good.

I desire to see which of these scaffolding methods is better and also compare them to the benchmarked Cognitive Algebra Tutor. I hypothesize that Inductive Support will be most effective for students when they are learning simple symbolization problems, such as one operator problems where connecting back to concrete instances will help. By the time the students is asked to do problems that have many operators (e.g. 2-3 operators), I expect *Decomposition and Substitution* to be more effective.

Tutorial Reasoning

I have built a cognitive model that is able to reason about what high level strategy to select, as well as lower level reasoning about which questions to ask. The tutorial model keeps track of any questions the tutor plans to ask in the future. The tutor model accepts as input a diagnosis of what sub-goals were or were not correctly achieved and what types of errors were made In addition, the tutor model will take as input the context of the dialogue, the state of the tutor's estimate of the student's knowledge, and the success and use of the various tutorial strategies. Ideally, the tutor model should also attempt to reason about 1) what is the best way to word a response, 2) when to provide declarative instructions, 3) the motivational state of the student and 4) the next best problem to try.

Empirically answerable questions

This project will allow us to determine which scaffolding strategy is a more effective one, and under what circumstances. This project will also help us to understand what architectural enhancements are useful to allow an ITS to carry on a more human-like dialogues.

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