A Dialogue Based Tutoring System for Basic Electricity and Electronics

Carolyn Penstein Rosé
LRDC, Univ. of Pittsburgh
Pittsburgh, PA 15260, USA
rosecp@pitt.edu

Barbara Di Eugenio
LRDC, Univ. of Pittsburgh
Pittsburgh, PA 15260, USA
dieugeni@cs.pitt.edu

Johanna D. Moore
HCRC, Univ. of Edinburgh
Edinburgh EH8 9LW, UK
jmoore@cogsci.ed.ac.uk

Abstract

The Computational Model of Tutorial Dialogue project addresses the question of how to build natural language interfaces for a tutoring systems. We focus on the problems of dialogue management and robust language understanding. Our approach is to study human tutorial dialogues to uncover correlations between successful tutoring strategies and the way they are carried out in human-human conversation and then to implement them in our computational model. Similarly, our analysis of student responses in our corpus provides the motivation for our approach to robust language understanding.

The question of how best to build natural language interfaces for tutoring systems is one that is only beginning to be addressed. Previous work on analysis of tutoring strategies leaves open a number of questions that must be addressed in order to implement effective tutoring strategies in a computational model. Although [1] describes a wealth of features of tutoring dialogues, it does not correlate them with learning gains, thus cannot pinpoint which subset of features is the most effective one. [3] provides a helpful characterization of pervasive dialogue patterns, however each step of the proposed *5-step dialogue frame* can be realized in a variety of ways, and the question of which way is most effective or appropriate is not addressed. While [7] explores the correlation between specific conversational features and learning gain, the features tested and demonstrated to correlate with learning gain do not by themselves constitute complete strategies as they could be implemented in a computational model. In our work, we apply a similar approach to [7] in order to compare relative effectiveness of alternative tutoring strategies. We base the tutoring strategies employed by our prototype dialogue-based system on preliminary findings from a study with 37 undergraduate students interacting with a non-dialogue based version of our system.

A major focus of our work has been on effective natural language understanding for dialogue based tutoring systems. Previous approaches to robust parsing have taken two main directions. The first direction focuses on shallow parsing and information extraction techniques [4] where the goal is to do the most limited analysis that makes it possible to extract specific types of information from a corpus. These techniques have already been demonstrated to be useful for short answer processing in CIRCSIM tutor [2]. The second approach is robust full sentence interpretation [6] where the goal is to do as complete an analysis as possible, relaxing constraints as necessary. In our system we make use of the LCFLEX [6] parser, which is easily adjusted to be flexible along multiple degrees of freedom by setting global parameters. In its highest flexibility settings, LCFLEX can perform like a shallow parser, extracting partial analyses when no complete analysis can be constructed. However, its efficient and robust algorithm has the ability to construct as complete an analysis as possible. Thus, it makes it possible to explore the possibility of processing longer, more involved language input in a tutoring system[1].

The context of our work is a web-based course on basic electricity and electronics (BE&E) originally developed with the VIVIDS authoring tool [5] at the Navy Personnel Research and Development Center in San Diego, CA. The original curriculum consisted of four lessons and four labs covering basic concepts of current, voltage, resistance, and power. We added two advanced labs exploring some mathematical computations and problem solving.

Our prototype dialogue based system currently covers only the portion of the curriculum focusing on measuring DC voltage. The concept of voltage and the procedure for measuring voltage are described in the lesson. In order to keep the students engaged while reading the lesson, we integrated the lab and lesson so that the students apply the new knowledge while they are reading about it. After the student reads about

[1] The LCFLEX parser is available for research purposes. Interested parties should contact the first author.

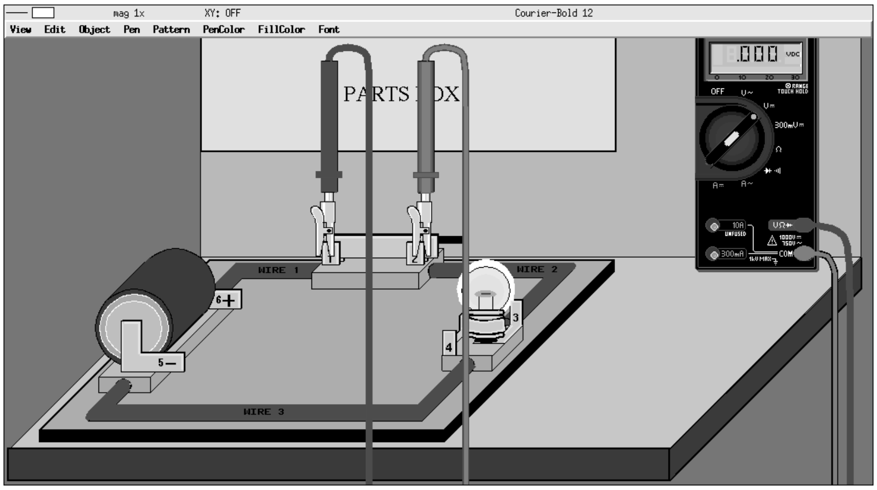

Figure 1: **Simulation Window**

each step in the lesson, he is required to carry out that step in the lab. The procedure is performed within a simulation window, displayed in Figure 1. The student must first set the multimeter (displayed on the right) to the correct mode for measuring DC voltage. The student must then attach the multimeter's red and black leads to the circuit (displayed on the left) in such a way that they can get a non-zero voltage reading. Finally, the student observes the voltage reading on the multimeter. Note that in Figure 1 the multimeter leads are attached incorrectly.

If a student makes a mistake while working through a step in a lab, the system attempts to correct the student's understanding and then asks the student to try the step again. It does not allow the student to proceed with the next step until he has performed the current step correctly. To force the student to learn how to generalize his knowledge, he is asked to find three distinct places in the circuit to measure voltage, whereas only two examples are given in the lesson. For each mistake a student can make in the lab, the system provides the student with feedback indicating that such a mistake has been made. In its Socratic style dialogues with the students, the system directs the students with focused questions and provides theoretical explanations to address specific student mistakes and to instruct them how to apply their knowledge more generally. A sample dialogue addressing the problem of no difference in voltage potential can be found in Figure 2. As in our corpus, at each step the tutor first gives the student feedback. The tutor then prompts the student with a question in order to engage the student in the knowledge construction process.

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This research is supported by the Office of Naval Research, Cognitive and Neural Sciences Division (Grants N00014-91-J-1694 and N00014-93-I-0812) And the National Science Foundation (Grant IRI-94-57637).

System: You cannot get a non-zero voltage reading across the portion of the circuit where you have hooked up the leads. Can you tell me which two types of components you can get a non-zero voltage reading across?
Student: I don't know. Batteries and light bulbs?
System: You correctly identified instances of sources and loads, and sources and loads are the two types of components across which you can get a non-zero voltage reading. Can you tell me why it is possible to get a non-zero voltage reading across these two types of components?
Student: Is it something like differences in the charges over the place where you measure?
System: Very good. You can get a non-zero voltage reading wherever there is a difference in charge. A difference in charge is present wherever energy is converted from one form to another. For example, in a battery, chemical energy is converted from electrical energy to light and heat. Using this information, would you predict that you could get a non-zero voltage reading across a wire or a closed switch?
Student: I don't think so.
System: Right! There is no difference in charge across a wire or a switch because no electricity is converted to a different form. It simply flows through. Therefore you don't get a non-zero voltage reading. Remember, you can only get a non-zero voltage reading across a source or a load.

Figure 2: **Interaction with System**