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On-line Assessment of Expertise

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MARCH 1992

N00014-91-J-1532

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Cognitive science has developed a number of experimental paradigms that appear promising as tools for assessing expertise. However, they typically involve verbal report data and much labor by human analysts. This project will automate some of these paradigms and integrate them into a prototype system for assessment of an individual's progress in achieving expertise in a particular task domain. We have chosen college physics as the task domain. Not only is this task domain rich in conceptual as well as procedural knowledge, but many expert-novice experiments used physics as the task domain, so we can build in the results of these studies, which allows us to concentrate on automating their measurement and analysis.

From the students' point of view, the OLAE (On-line Assessment of Expertise) system is a workbench for studying examples and solving problems which occasionally interrupts to ask for an explanation of one's action. OLAE presents standard physics examples and problems, as well as qualitative physics problems, problem classification tasks, and other tasks. The student will attend lectures and read the prose parts of the textbook offline, but all the rest of the student's work will be done on OLAE.

From the assessors' point of view, OLAE provides three resources for making decisions. It contains a huge store of analyses and data on one or more students' performance. It provides facilities for further analyses of these data. It provides control over the collection of further data.

OLAE supports three levels of analysis: (1) The raw behavioral data can be saved so that it is always available for future analyses. (2) A computationally sufficient representation of the student's knowledge, such as a rule-based system, can be inferred. (3) Broad classifications, such as "understands Newton's second law" or "learns rapidly but forgets rapidly," can be defined and applied. Most of the classifications are based on the rules, which are in turn based on the student's performance.

The classifications are used both by the assessor to make decisions

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and by the system to control its assessment strategy. In general, the system will only collect and analyze data if the resulting analysis could affect classifications that the assessor considers important. However, the assessor can also indicate specific assessment policies for OLAE to follow. For instance, OLAE might always ask the subject to estimate the difficulty of a problem before solving it even though the data from that task currently have no bearing on classifications that the assessors has flagged as important.

The measures that we have selected for inclusion in OLAE are listed below.

1. OLAE collects a trace of the student's goals and actions during problem solving. These data are used to infer which rules the student uses reliably, unreliably or not at all. This kind of assessment is common in intelligent tutoring systems.
2. As students solve problems, they can refer to examples. OLAE records which example the student referred to, which lines were read and for how long. These data are used to infer, for instance, whether the student is lost and looking for a basic approach to the problem or whether she has a basic approach and is seeking advice on a specific detail. Chi, Bassok, Lewis, Reimann and Glaser (1989) have found that different ways of referring to the examples correlates with how well the students understood them.
3. The students' speed and accuracy during problem solving will be monitored. These form a crude index of expertise.
4. After the student has read a problem, OLAE may ask her to estimate how long it will take her to solve it as well as what features of the problem cause difficulty. Chi, Glaser and Rees (1982) found that expertise is correlated with accuracy in such estimates.
5. On some problems, the student will be asked to describe her basic approach to solving the problem instead of actually solving it. Typed descriptions will be analyzed for specific keywords that indicate knowledge of appropriate problem solving schemas. (The same analysis will be used for the "feature" given in estimating difficulty.) Chi, Glaser and Rees (1982) showed that ability to state a problem-specific basic approach is correlated with expertise.

6. The student will be asked to cluster problems according to their similarity, then describe each cluster with a list of short phrases. Chi, Feltovitch and Glaser (1981) showed that experts sort problems on the basis of their solution method, whereas novices use surface features to assess similarity.

7. As the student studies an example for the first time, OLAE will record the time spent examining each line and how often she looked backwards at lines preceding the current line. From these data, and perhaps some direct questions to the student, OLAE will assess whether the student is self-explaining the examples. Chi et. al (1989) and others have shown that self-explanation correlates with effective learning. VanLehn, Jones and Chi (in prep.) have shown that self-explanation data can be interpreted at the rule level.

8. As the student reads an example, OLAE may force the student to indicate after each line whether or not she understood the line. Chi et al. (1989) and others have shown that accuracy during example reading correlates with effective learning.

9. The student may be given qualitative physics problems, such as sketching the trajectory of a pendulum bob after the pendulum's string is cut, or labelling points along the trajectory of a cannonball with the forces and accelerations acting on it. Physics educators consider this an important measure of physics understanding even though it is not reliably correlated with assessments of formal, quantitative problem solving skill. Ploetzner, VanLehn and Chi (in prep.) first implemented a system to determine a student's qualitative rules on the basis of her answers to qualitative questions, then showed that the rule bases used to answer qualitative problems did not overlap much with those used for answering formal problems. Analyses in Chi and VanLehn (1991) suggest that success in formal quantitative problems may be attributed to the acquisition of "technical knowledge," such as vector decomposition, whereas solving qualitative problems often involve "conceptual knowledge" and "knowledge of principles." Thus, qualitative problems assess a different skill than the one taught, which is nonetheless important to assess.

As of the end of September, 1991, a user interface for studying

examples and solving problems has been implemented. It contains a "poor man's eyetracker" that allows OLAE to tell which lines of an example the student is looking at. All the examples and problems in the Chi et al. (1989) study have been entered, and a pilot subject has been run. Meanwhile, a analysis scheme based on belief nets has been sketched. Its computational feasibility is being explored by converting the knowledge base of an existing physics problem solver, Cascade, into its terms.

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