Designing Intelligent Tutoring Systems for Ill-Defined Domains

Applying learning research to ITSs

Kevin Ashley
University of Pittsburgh
Learning Research and Development Center

Defining "Ill-defined" problems

- Problem or domain is *ill-defined* when
  - essential concepts, relations, or features of it are un- or under-specified or intractable requiring a solver to frame or recharacterize the problem or the concepts as part of the solution process.
  - Since ill-defined domains lack a single strong domain theory uniquely specifying the essential concepts, relationships, and procedures for the domain and providing a means to validate problem solutions, a solver is required to structure or recharacterize the domain when working in it.

From Lynch, Ashley, Pinkwart, Aleven (revised, IJAIEd) "Concepts, Structures, and Goals: Redefining Ill-Definedness"

Characteristics of "ill-defined" problems

1. Involve open-textured concepts and competing domain principles which are subject to debate;
2. Lack widely accepted domain theories identifying all of the relevant concepts and functional relations;
3. Cannot be readily partitioned into independent subproblems;
4. Have prior cases that are inconsistent;
5. Involve the need to reason analogically with cases and examples;
6. Have a large or complex solution space which prohibits one from enumerating all possible characterizations or solutions;
7. Lack formal or well-accepted methods to verify solutions;
8. Lack clear criteria by which solutions are judged;
9. Are not considered to be "solved" when one solution is presented but may be readdressed by multiple, often distinct, solutions;
10. Involve disagreements among domain experts regarding the adequacy of the solutions; and
11. Require solvers to justify their solutions through argument.

ITS Development in Ill-Defined Domains

	ITS 2006	AIED 2007	ITS 2008
Medical diagnosis		√√	√
Legal reasoning	√	√√	√
Intercultural relations	√		√
Ethical reasoning	√		√
Language learning: vocabulary, grammar	√√	√	√
Programming: Object-oriented design; logic programming; Database design	√√√		√
Robot arm operation			√
Causal reasoning in public policy		√	
Psychology		√	
Inquiry learning in sciences	√√		

Methods for Assessment and Feedback in ITSs for Ill-Defined Domains

- Adaptive feedback on students':
  - discussion posts based on simplified model of good posts, to tutee directly and indirectly via peer moderator (Walker, Ogan, Aleven, Jones)
  - selected actions in student-modified versions of pre-analyzed ethics narrative (Hodhod, Kudenko)
- Compare student's:
  - solution to template of solutions-plus-variations (Moritz, Blank)
  - problem-states-visited with mined patterns of partial problem spaces (Fournier-Viger, Nkambou, Mephu Nguifo)
  - diagrammatic reconstructions of arguments in terms of feedback-related features to model, other students' diagrams (Lynch, Pinkwart, Ashley, Aleven)
- Objective tests geared to problem-solving process
  - specially designed multiple choice questions (Pino, Heilman, Eskenazi)
  - concepts labeled, defined, applied in written analyses (Goldin, Ashley)
- Support self-assessment
  - with expert decision map, visual representation of overall problem-solving process (Gauthier, Naismith, Lajoie, Wiseman)

Two Approaches to ITSs for Ill-defined Problems

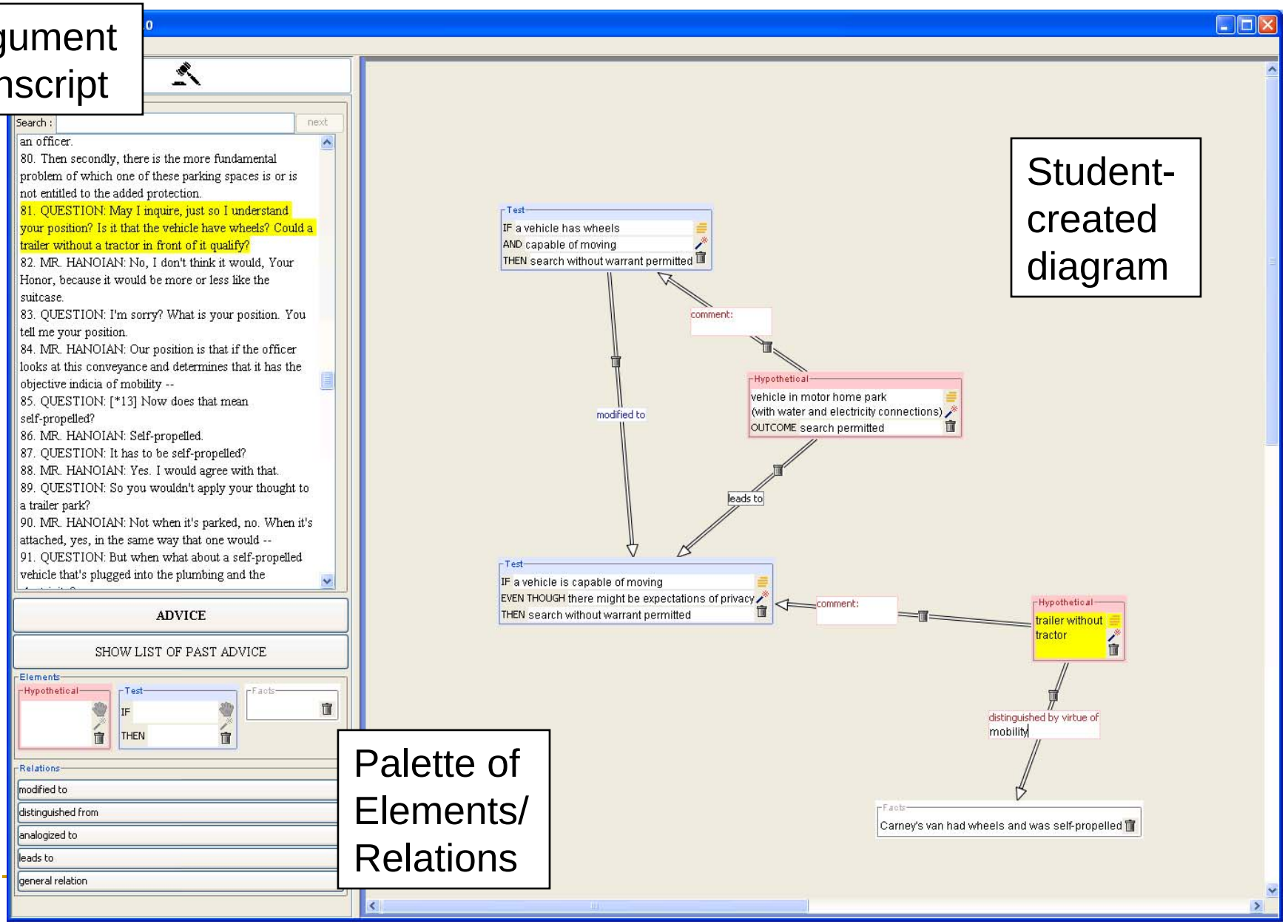
1. Diagrammatic argument reconstruction with LARGO*

- Students reconstruct hypothetical reasoning in SCOTUS oral arguments
- They make argument diagrams:
  - Diagram elements based on a model of hypothetical reasoning
  - Nodes: Proposed tests, hypotheticals, current facts
  - Links: Relations such as: modified to, distinguished from, analogized to, leads to
- LARGO provides feedback
  - Feedback based on "argument patterns", text mark-up, and collaborative filtering
  - Detects:
    - important parts of argument text not diagrammed
    - mistaken linkages
    - opportunities for reflection
- Outputs advice prompting students to:
  - Remediate apparently weak parts of diagrams.
  - Reflect on significance of relations among tests, hypotheticals, and responses.

*** Pinkwart, N., Lynch, C., Ashley, K. and Aleven, V. (2008) Reevaluating LARGO in the Classroom: Are Diagrams Better than Text for Teaching Argumentation Skills? In Proc. ITS-08, 90-100.**

LARGO Approach

Argument transcript



Student-created diagram

Palette of Elements/ Relations

Two Approaches to ITSs for Ill-defined Problems

2. Peer-review-based student model*

- Modify existing peer review system to solicit reviewer feedback in a structured way on the conceptual issues in the assignment
  - Not just generic review criteria such as “style”, “flow”, and “logic”
- Structured feedback on issues invites student reviewers to compare their knowledge of issues with authors’.
- Computational student model combines the information about issue understanding and generates instructor’s report.

*** Learning in Peer Reviewers: A Student Model for Ill-Defined Problem-Solving**
Ilya M. Goldin (PhD proposal defended)

Conclusions

- Solving ill-defined problems is a major focus of education, cognitive and learning science, but until recently, not addressed by ITS research.
- Recent interest/progress in designing ITSs for teaching ill-defined problems.
- Research issues remain:
  - How to provide feedback in absence of one right answer?
  - How to assess learning objectively?
  - How to enable ITS to “understand” students’ solutions/arguments?
  - How to motivate students to engage ITS resources productively?