Automatic Dialogue-Adaptive Feedback for Tutoring Proving

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Motivation

- Tutoring systems
  - natural language capabilities crucial [Moore ’93; Graesser et al. ’03]
  - Socratic teaching and hinting important for interactive learning [Chi et al. ’94; Rosé et al. ’01; Graesser et al. ’03]

$\Rightarrow$ *hints*:

- point to inference
- elicit, give-away information

- *Plato:* automatic production of hints for mathematical proving in tutoring dialogue system

Related Work

- Hume et al. [96] (CIRCSIM-Tutor): taxonomy of hints
- Person et al. [00] (AutoTutor): hints associated with curriculum scripts
- Matsuda and VanLehn [03]: hints adapting amateur's technique
- Hefferman et al. [00]: domain specific questions

$\Rightarrow$ hinting models limited in

- capturing underlying functions explicitly
- relating underlying function dynamically to domain knowledge

$\Rightarrow$ dialogue model often not separated from teaching model

Our Approach

- a Socratic teaching model for integration in a natural language dialogue system
- separate manipulation of cognitive and dialogue functions of hints

  $\Rightarrow$ natural language hints
- taxonomy of hints
- mathematical domain ontology
- specialised domain reasoner: ΩMEGA [Siekmann et al., 02]

Socratic Teaching Model

- tutor assists students learn based on their own knowledge
  - schema acquisition
  - cognitive load alleviation
  - motivation theory
  - empirical data (BEE corpus, Wizard-of-Oz experiments)
- Non-goal specific instructional teaching model [ATPs]

Taxonomy of Hints

- captures cognitive functions that underly hints
- separates these from dialogue move functions
  - four dimensions for four different functions

  $\Rightarrow$ hint categories are combinations of decision points on each dimension

Taxonomy Dimensions

- domain knowledge - instructional/anchoring points
- inferential role - performable vs. meta-reasoning
- elicitation status - elicit vs. provide
- problem referential perspective - concepts vs. general info

Domain Knowledge

- formal proof step as basis for hints [ΩMEGA system]
- DK determines the point for reference for the content of hints
- approach:
  - find expected proof step attempted based on student's contribution
  - compare student's contribution with the expected proof step

Domain Ontology

- in ΩMEGA: hierarchy of theories with definitions, lemmata, theorems, inference rules etc.
- Extension: relations between mathematical concepts, between concepts and inference rules, etc.
- Examples: *relevant concept*, *subordinate concept*, *inference rule*, *domain method*...[Schreiner '03]

Domain Ontology Use

- categorise domain contribution - generic qualitative evaluation
- track knowledge useful for tutoring - partial answers
  - anchoring points in use
  - anchoring points' instantiation

$\Rightarrow$ Basis for hint category choice and hint realisation relevance

Hinting Session Status

- collection of parameters that cover student modelling:
- representation of tutoring task - pedagogical knowledge
- only for current session, no inter-session modelling
- two parts:
  - *Global Hinting Session Status (GHSS)*
  - *Local Hinting Session Status (LHSS)*

GHSS

- captures the motivational level, e.g.:
  - number of domain contributions
  - number of bad answers
- used to:
  - decide if a hint should be produced
  - make choices in some of the hint dimensions

LHSS

- domain knowledge used by student
- domain contribution categories, other student contributions, number of wrong answers for the current step, strategies already used etc.
- pedagogically usable domain knowledge

Socratic Procedure

- Main task: tutoring proof
- Strategy for tutoring: non-goal specific instructional teaching model
- Substrategies realise teaching model - Socratic
  - subdialogue: diagnostics
  - subtasks: performable step, meta-reasoning, misconception, request assistance, etc.

Hint Determination

- Socratic procedure:
  - LHSS: use of domain knowledge, anchoring points, domain contribution category
  - GHSS: assess student performance

$\Rightarrow$ makes dimension decisions

$\Rightarrow$ gives progressively more informative hints when student performance is low

$\Rightarrow$ avoids certain types of feedback

$\Rightarrow$ tries to explicitely motivate the student

Hint Specification

- *hint specification*: instantiation of hint category
- hint realisation based on hint specification plus dialogue modelling issues

  $\Rightarrow$ human-oriented dialogue-sensitive realisation of hints possible

Hint Example

- hint category: *give-away-meta-reas-subord-concept*
- inference rule - universal quantifier elimination
  - domain knowledge: subordinate concept - variables to be used
  - inferential role: meta-reasoning
  - elicitation status: provide information
  - problem referential perspective: conceptual

$\Rightarrow$ possible realisation:

"In order for the expression to hold for all x, we need to prove it for an arbitrary but fixed constant a."

Conclusion

- schemata for implicit learning
- allow students to use their own reasoning without imposing a solution
- generate instructions to help student learn based on some heuristics - schema
- hint at anchoring points to support creating the schema
- specify anchoring points based on domain ontology
- allow for flexible natural language generation of hints
- implementation under way
- hint realisation needs separate research