SFB 378
Ressourcenadaptive
Kognitive Prozesse

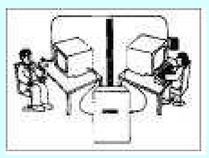
MI 3: DIALOG
Research Foci in Phase One

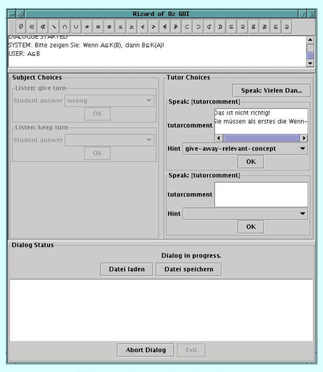
SPRACHE LOGIK

Project MI 3 — DIALOG — Pinkal, Siekmann, Benzmüller, Kruijff-Korbayová

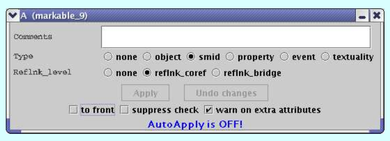
Experiment and Corpus

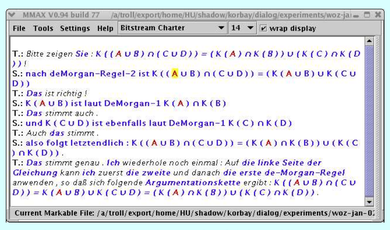
The subject window



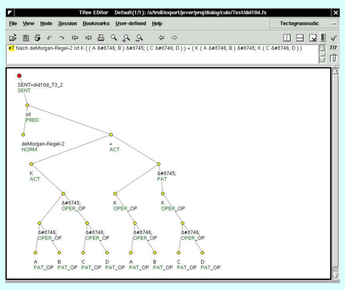


The wizard window





Annotation of symbol identifiers for coreference



Linguistic meaning of a sentence represented as a tectogrammatical dependency tree

Input Analysis

- Takes interleaved natural language and mathematical user input of varying degree of informality
- Transforms it to domain reasoner format via deep syntactic and semantic analysis
- Manages a variety of referential, structural, lexical, and domain-related ambiguities arising on the way

B contains $x \in A$

$\Downarrow$

B contains $\boxed{x \in A}$

$\Downarrow$

FORMULA contains FORMULA

$\Downarrow$

contain

FORMULA:B <ACT> FORMULA:$x \in A$ <PAT>

$\Downarrow$

(SUBFORMULA$_{PAT}$, embedding$_{ACT}$)

math parsing

$\Downarrow$

B contains $\boxed{x} \boxed{\in A}$

$\Downarrow$

CONST contains CONST 0_FORMULA

$\Downarrow$

contain

CONSTANT:B <ACT> CONSTANT:x <PAT>

0_FORMULA:$\in A$ <GENREL>

$\Downarrow$

CONTAINMENT(container$_{ACT}$, containee$_{PAT}$)

$\Downarrow$

$\in$(container$_{ACT}$,containee$_{PAT}$)

$\Downarrow$

Fact $\exists x$ **.** $(x \in B \wedge x \in A)$ **from** ■ **by** ■

math expression substitution

sentence parsing

lexical-semantic interpretation

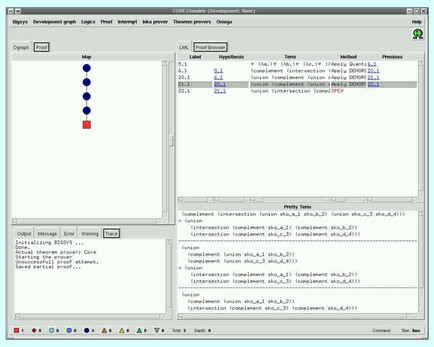
domain-specific interpretation

mapping to Proof Manager input

Proof Management

```
(input
  (label 1_1)
  (formula (= (complement (intersection (union a b) (union c d)))
              (union (complement (union a b)) (complement (union c d)))))
  (type ?)
  (direction ?)
  (justifications
   (just
    (reference DeMorgan)
    (formula ?)
    (substitution ?)
    (role ?))))
```

PM input (example)



The PM employs OMEGA-CORE

```
"((KEY 1_1) ->
   ((Evaluation
     (exgStepNegr
      (LABEL 1_1)
      (FORMULA (=(complement(intersection(union(A B) union(C D)))
                        union(complement(union(A B)) complement(union(C D))))))
      (TYPE INFERENCE)
      (DIRECTION FORWARD)
      (JUSTIFICATIONS (
       (REFERENCE DEMORGAN-2)
       (FORMULA MIL)
       (SUBSTITUTION ((X union(A B) Y union(C D))))
       (ROLE MIL))))
     (StepCat CORRECT)))
    (ProofCompleted FALSE)
    (completeProofs (
     (Proof (
      (FORMULAS (=(complement(union(C D))
                        intersection(complement(C) complement(D)))))
      (DIRECTION FORWARD)
      (FORMULAS (=(complement(union(A B))
                        intersection(complement(A) complement(B)))))
      (DIRECTION FORWARD)))
     (Proof ((
      (FORMULAS =(union(complement(union(A B)) complement(union(C D)))
                   union(intersection(complement(A) complement(B))
                         intersection(complement(C) complement(D)))))
      (DIRECTION BACKWARD)
       (JUSTIFICATIONS
        (DEMORGAN-2
         . =(complement(intersection(union(A B) union(C D)))
            union(complement(union(A B)) complement(union(C D)))))))
      ((FORMULAS
        =(union(complement(union(A B))
                intersection(complement(C) complement(D)))
          union(intersection(complement(A) complement(B))
                intersection(complement(C) complement(D)))))
       (DIRECTION BACKWARD)
       (JUSTIFICATIONS
        (DEMORGAN-1
         . =(complement(union(C D))
            intersection(complement(C) complement(D))))))
      ((FORMULAS
        =(union(intersection(complement(A) complement(B))
                intersection(complement(C) complement(D)))
          union(intersection(complement(A) complement(B))
                intersection(complement(C) complement(D)))))
       (DIRECTION BACKWARD)
       (JUSTIFICATIONS
        (DEMORGAN-1
         . =(complement(union(A B))
            intersection(complement(A) complement(B))))))))))"
```

PM output (example)

Direct Support for Assertion-level Reasoning

- The assertion application module constructs and represents proofs at assertion-level: "by applying the DeMorgan rule, we can prove $\overline{(A \cup B) \cap (C \cup D)} = (\overline{A} \cap \overline{B}) \cup (\overline{C} \cap \overline{D})$ by showing that $\overline{(A \cup B)} \cup \overline{(C \cup D)} = (\overline{A} \cap \overline{B}) \cup (\overline{C} \cap \overline{D})$."
- Large mathematical databases incur expensive search for applicable assertions. Proposed solutions: agent-based architecture.

Resolution of Underspecified Knowledge

- Reconstruct user proof at assertion-level and match it with a 'golden' proof of the main problem.
- A problem is to adapt the symbols used by the user to those of the system.

First Approach to Proof Step Evaluation

- Evaluation of a user proof step along the three dimensions: soundness, relevance and granularity.
- Current approach for granularity and relevance: relate assertion-level user proof to a 'golden' proof of the main problem.
- Challenge: recognize user's intention (reasoning direction, strategy, etc.).

Tutoring

Flexible natural language dialog allows the realization of different tutoring strategies. In particular, we looked into

Didactic method where the tutor provides (didactic) explanations and asks questions directing the student towards already explained information.

Socratic method is characterized by eliciting information from the student through a directed line of reasoning, thus encouraging active learning.

Algorithm Simulating Socratic Tutoring Strategy

- Allows students to build their own schemas, and to reflect on the tutoring feedback.
- Employs as input the current proof step, proof status, task related dialogue status, and characterization of the student input.
- Hinting session status specifies pedagogically relevant information (domain dependent and independent).
- Content specification of hint categories is based on enhanced mathematical ontology and dialogue purposes.

Multi-dimensional Hint Taxonomy

- Proof step information: domain relation/objects, inference rule, substitution
- Performable step vs. meta-reasoning: info in proof step vs. its explanation
- Active vs. passive: info elicited vs. info given away
- Conceptual vs. pragmatic: different ways of referring to same info

Hint categories constitute different combinations of the dimensions.

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