Natural Language Interaction with an Expert System

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Overview

The LEX project

Communication with an expert system

Discourse Representation Theory

Representation of knowledge

Analysis of natural language

Generation of natural language

Drawing inferences

Conclusion

The LEX Project

A joint research project between the

- Research Unit for Natural Language Systems (U. Tübingen)
- Institute for Criminal Law, Computer Science in Law, and Philosophy of Law (U. Tübingen)
- Heidelberg Scientific Center (IBM Germany)

Duration

October 1984 — September 1987

Objectives

Research in

- Text understanding
- Text generation
- Dialog mechanisms
- Representation of knowledge
- Formalization of law
- Deductive techniques
- Expert system technology

Construction of prototypes

- Legal expert system on German traffic law
- Law tutor

A Consultation

Lawyer: case description

T ran off the road and hit a lamp post. A damage of 500 DM resulted. The accident happened at midnight in a residential area. It was not observed by anyone. T waited for 20 minutes. He left the scene of accident and he left his car behind.

Lawyer: query

Was the waiting time sufficient?

LEX

Was anyone present at the scene of accident?

Lawyer

No.

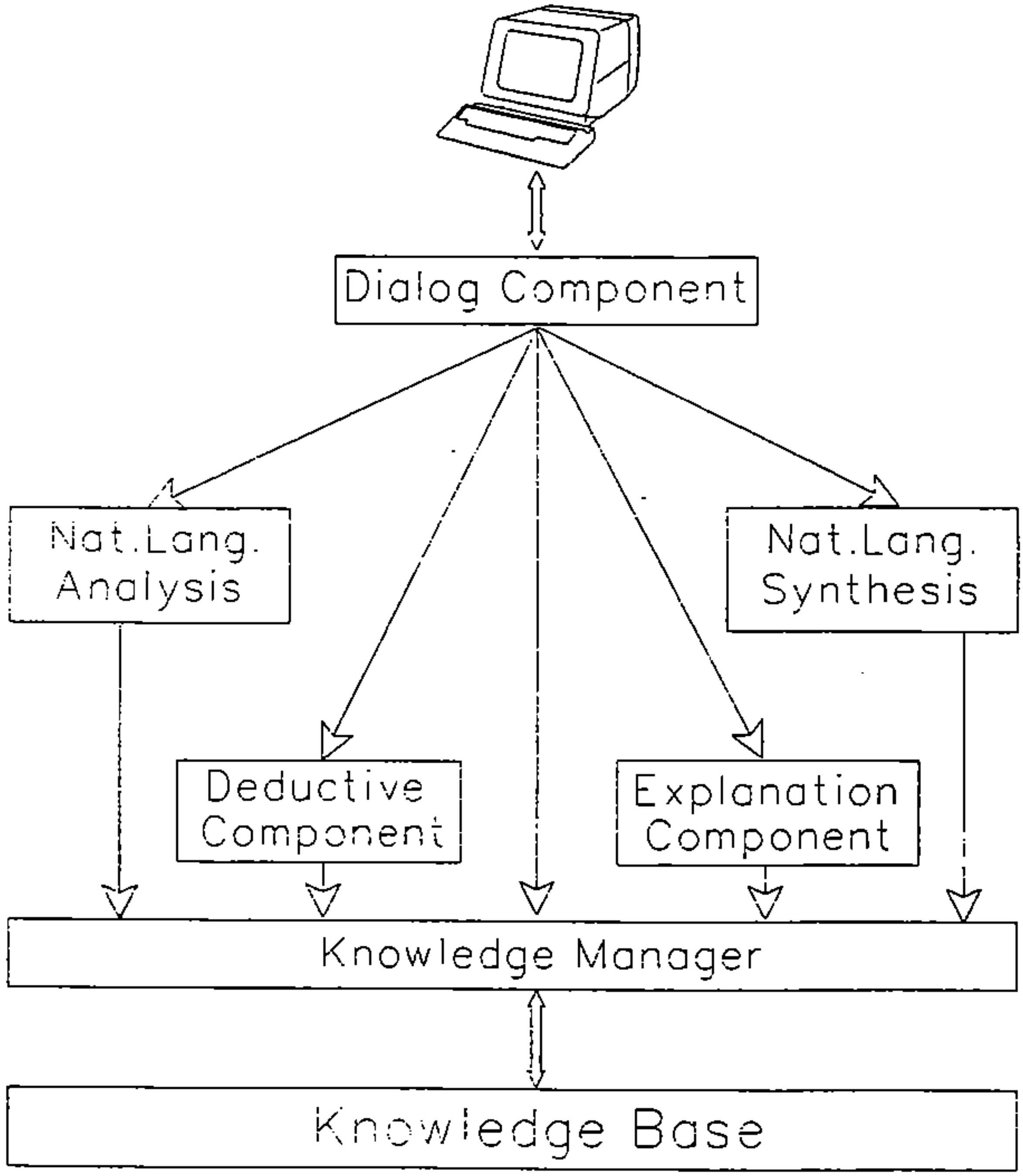
LEX

1. The damage is greater than 300 DM, therefore the damage is not small, therefore traffic density is considered.

2. Traffic density is high, therefore the minimal waiting period is 30 minutes.

3. The waiting period is smaller than the minimal waiting period, therefore the waiting period is not sufficient.

LEX System Structure



Communication with LEX

Treatment of cases

Input of a case description

Questions concerning the case

Knowledge acquisition

Rules and regulations

Legal definitions of terms

Common sense knowledge

Linguistic knowledge

Discourse Representation Theory

A theory integrating semantic and pragmatic aspects of natural language *discourse* in a single framework, in particular nominal and temporal reference

Basic notions

1. Discourse Representation Structures (DRSs): a DRS is a pair $<U,C>$ where U is a set of *reference markers* and C is a set of *conditions*

2. DRS construction algorithm: translates natural language into DRSs

Conditions

- atomic
  $p(u_1 \ldots u_n)$ where p is an n-place predicate
- complex
  - implicational   K1 → K2
  - disjunctive   K1 v K2
  - negative   ¬ K1
  - event condition   e: K3

Advantages

- Firm basis in logic, hence well-defined semantics and deductive theory

- Solves puzzling cases of contextual relations

- Novel approach to the treatment of tense

Representation of Knowledge

Adequacy conditions

1. Well-defined *syntax*

2. Well-defined *semantics*

    - clear relation to the structure of the domain of discourse
    - clear notion of expressive capacity

3. Well-defined *deductive theory*

    - correctness: nothing false can be derived
    - completeness: every truth is provable

Main problems

1. Formalization of the discourse domain

2. Making the formalization accessible to interaction in natural language

Kinds of Knowledge

Legal knowledge

A person who is involved in an accident and leaves before having waited for a reasonable time is liable to punishment.

Common sense knowledge

If someone leaves a place, he no longer is at that place.

Linguistic knowledge

If someone departs, he leaves

Legal Knowledge

Goals of formalization

Possibility to deal with juridical problems automatically, e.g.

- subsumption of a case under a law
- Search for "similar" cases
- Search for the circumstances under which a law applies

Sources of knowledge

- Laws, statutes, regulations
- Court decisions
- Commentaries
- Text books
- Previous attempts at formalization

Obligation

Basis

1. Description of the linguistic use of *obligation (Pflicht)* and related terms

2. Previous approaches to deontic logic, e.g. Von Wright, Åqvist, McCarty, Castañeda

3. Translation of modal operators into first order predicate logic (similar to Moore)

Formalization

- Introduction of a predicate *obligation*(p,u), where p is an obligation and u is the person obliged.

- Introduction of a predicate *fulfill*(u,p), such that *fulfill*(u,p) $= K$, where K is a DRS which describes an action by u.

- Thus the "paradoxes" known from the approaches based on modal logic can be avoided.

Common Sense Knowledge

- Case description contain information, which is not made explicit, since it is obvious.
- Hence, legal argumentation has to make use of common sense knowledge, but also needs to check for critical limitations of common sense arguments

An example

1. street(u) → seems-public(u)
2. [closed(u) v controlled-access(u)] → ¬ public(u)
3. [seems-public(u) & consistent(public(u))] → public(u)

Linguistic Knowledge

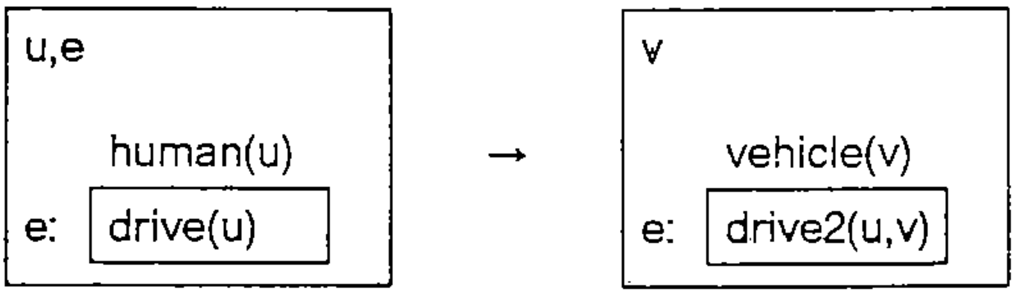
Concept hierarchy

Opel(u) → vehicle(u)
drive(u,v) → move(u,v)
alive(u) → living being(u)

Selectional restrictions

```
nomsel(adequate,1,state,
    nom(all).
    for(all).nil).
nomsel(driver,1,role,
    nom(human).
    poss(vehicle).nil).
verb(drive,1,event,
    nom(dist,vehicle.human.nil).nil).
verb(drive,2,event,
    nom(dist,person.vehicle.nil).
    acc(dist,('physical object').nil).nil).
```

Meaning rules



Analysis of Natural Language

Narrative texts (case descriptions)

Normative texts (regulations, common sense knowledge, ...)

User questions

Lexical database

- Implemented under SQL/DS
- Contains morphological and syntactic information
- approx. 16,000 entries coded

Grammar

- Base: existing German USL grammar (Zoeppritz, 1984)
- Extensions: complement clauses, modal verbs and adverbials

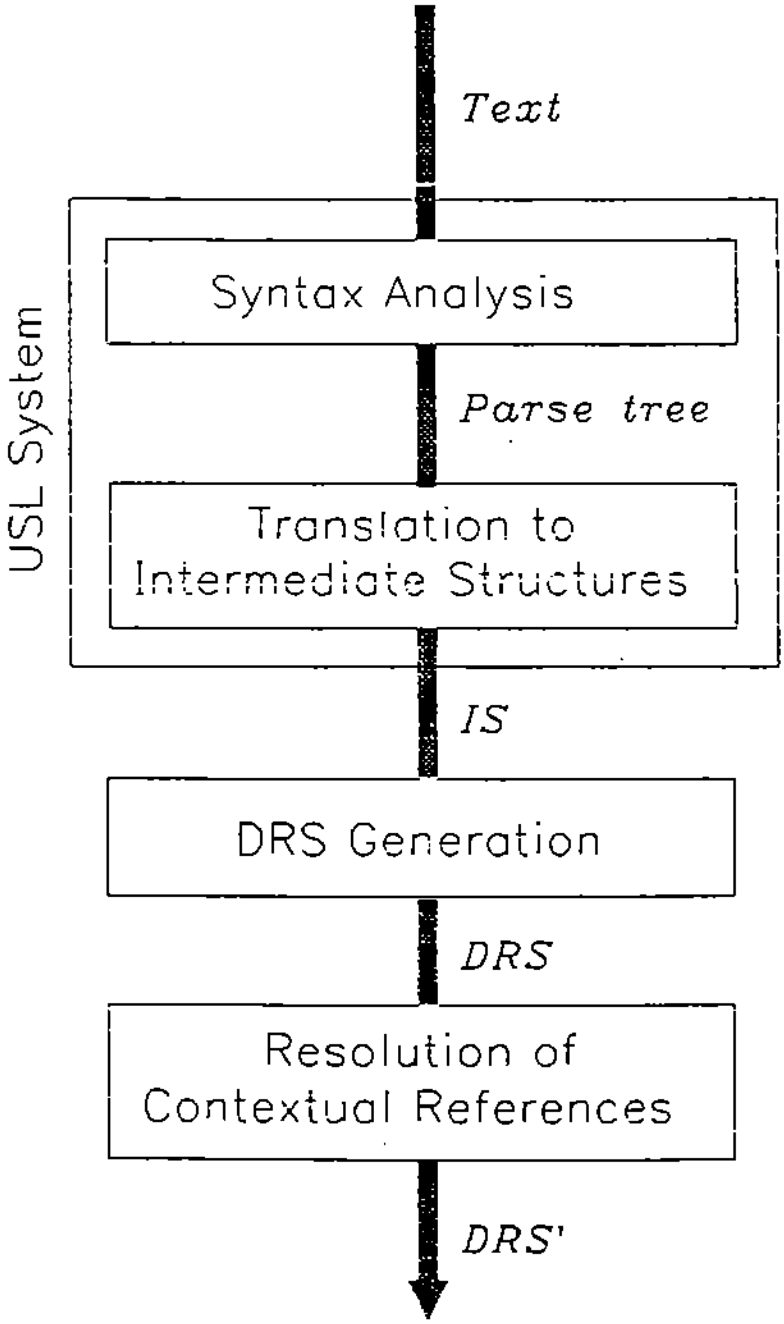
Generation of DRSs

- Generation of Intermediate Structures from parse tree (using USL interpretation routines)
- Prolog program to generate DRSs from Intermediate Structures (according to Guenthner/Lehmann, 1984)

Contextual linking

Based on Guenthner/Lehmann (1983)

The DRS Construction Algorithm



Syntax Analysis in LEX

Formalism used

- General phrase structure grammar with three kinds of features (binary, case, integer)
- Logical and comparison operations on features
- Specification of routines to apply during syntax analysis
- Specification of interpretation routines

Description Strategy

- Verb complements are picked up one by one, first going right from the verb, then to the left.
- Noun complements (attributive adjectives, appositions, relative clauses, genitive and prepositional attributes are picked up one by one, starting at the governing noun.
- Which complements can be picked up is controlled by a feature which expresses valency.
- „Transformations" are performed as operations on Intermediate Structures

Linguistic coverage

- Declarative, interrogative, and imperative sentences
- Relative clauses, complement clauses
- Modal and auxiliary verbs
- Nouns and complex noun phrases
- Adjectives
- Pronouns
- Coordination

The LEX Parser

Basis

M. Kay (1967): "Experiments with a Powerful Parser"

Implementation in the REL System (Thompson et al. 1969)

Extensions - especially concerning the treatment of features (Bertrand and Daudenarde, 1981)

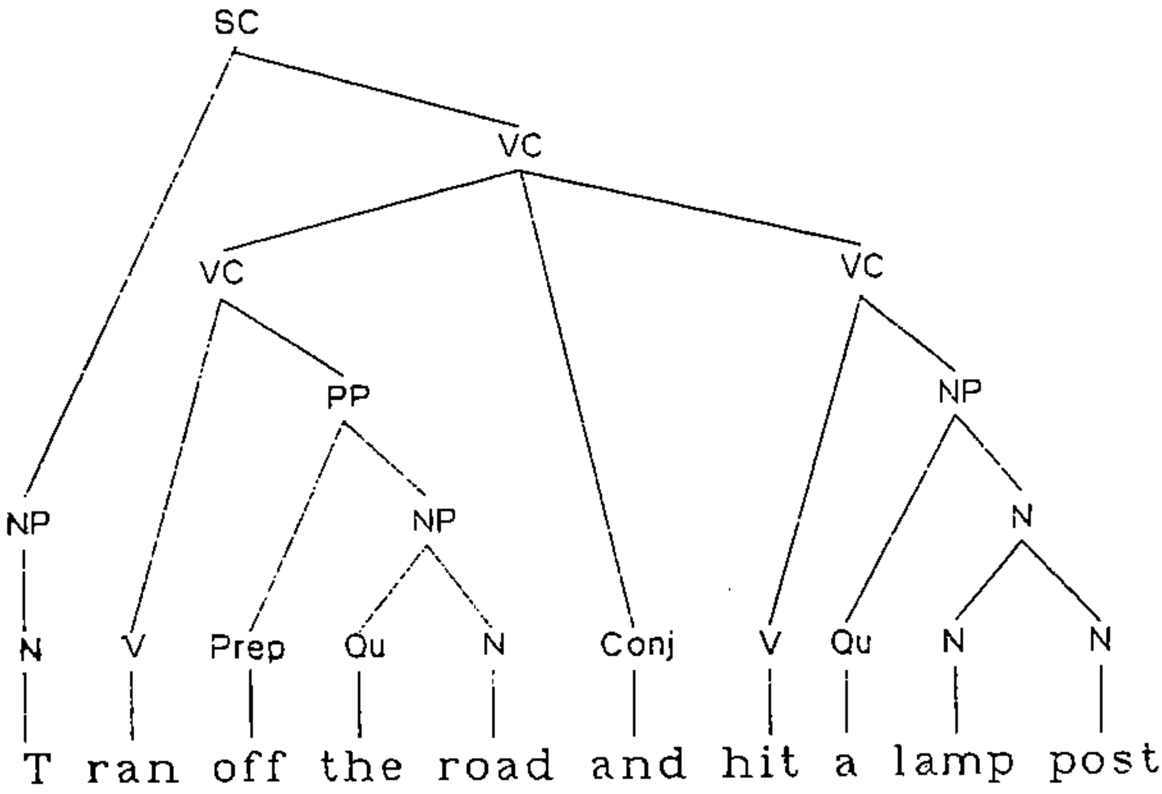
Approach

- Bottom-up
- Right-to-left
- Single Pass

All possible analyses are generated in parallel

Implementation in PL/I under VM

A Parse Tree



SC
VC
VC
VC
PP
NP
NP
NP
N
N V Prep Qu N Conj V Qu N N
T ran off the road and hit a lamp post

Intermediate Structures

Use

- Canonical representation of syntactic information
- Recovery of implicit syntactic information

Types of nodes:

rel, arg, nomstr, verbstr, coord, dimnum, arstruc

Generation

Intermediate Structures are generated by a total of 75 interpretation routines, e.g.

PRNAME, NOMEN, NPDEF, NPINDEF, PREP, VERB, NOM, ACC, POB, TWO, QUEST

DRS Generation from Intermediate Structures

Processing of a VERBSTR

- Test whether the verb "to be" occurs, then recog.·ze the predicate
- Process verb arguments
  - Processing of a NOMSTR
  - Processing of verb and clause coordination
  - Processing of the verb condition
  - Processing of Tense
  - Processing of verb negation

Resolution of Contextual References

The principle of contextual linking

If a contextually bound element is introduced into a discourse, it must be linked to an appropriate antecedent, where such an antecedent exists.

Problems

1. How to find out what are contextually bound elements (difficult especially for those not explicit in the discourse).

2. How to find out what are **appropriate** antecedents.

Use

Contextual linking establishes additional facts which generally cannot be derived otherwise.

Types of Contextually Bound Elements

Pronouns	Constraints: morphological: gender and number syntactic: disjoint reference configurational: accessibility semantic: compatibility pragmatic: e.g. focus (simulated by preference rules)
Definite NPs	Constraints as for pronouns, exception: morphological constraints
Ellipsis	Approach: recover of missing element and then proceed as for pronouns or definite NPs
Temporal relations	Realized by tense, temporal adverbials and conjunctions, often indirectly through spatial and causal relations
Spatial relations	Realized by adverbials of place and spatial conjunctions
Causal relations	Realized by causal adverbials and conjunctions. Can often be indirectly derived from the nature of the processes described.
Logical relations	Realized by conditionals and causal adverbials and conjunctions.

Ellipsis

T ran off the road and hit a lamp post. A damage of 500 DM *resulted*

```
n, u1, u2, u3, u4, u5, e1, e2, e3, e4

     T(u1)
     road(u2)
e1: [run(u1,u2)]
     e1 < n
     lamp post(u3)
e2: [hit(u1,u3)]
     e2 < n
     u5 = 500 DM
     damage(u4,u5)
e3: [result(u3,e4)]
     e3 < n
```

Replace e4 by e2

- selection restriction: effect results from event
- events are e1, e2, and e3
- exclude e3 on syntactic grounds
- preference rule: take the latest one that fits

Definite Noun Phrases

The accident happened at midnight in a residential area.

```
n, u1, u2, u3, u4, u5, u6
e1, e2, e3, e4, e5, e6, t1

     T(u1)
     road(u2)
e1:  [run(u1,u2)]
     e1 < n
     lamp post(u3)
e2:  [hit(u1,u3)]
     e2 < n
     u5 = 500 DM
     damage(u4,u5)
e3:  [result(u3,e4)]
     e3 < n
     accident(e5)
e6:  [happen(e5)]
     midnight(t1)
     residential(u6)
     area(u6)
     lp(e5,u6)
     e6 < n
```

Replace e5 by e2

- generalization: accidents are events
- events are e1, e2, e3
- exclude e3 on semantic grounds
- preference rule: take the latest one that fits

Pronouns

It was not observed by anyone.

```
n, u1, u2, u3, u4, u5, u6
e1, e2, e3, e4, e5, e6, t1

      ...
      e2 < n
      u5 = 500 DM
      damage(u4,u5)
e3:   result(u3,e4)
      e3 < n
      accident(e5)
e6:   happen(e5)
      midnight(t1)
      residential(u6)
      area(u6)
      lp(e5,u6)
      e6 < n
      u7, e7, e8

  ¬   e7:  observe(u7,e8)
           e7 < n
```

Replace e8 by e5 (= e2)

- no morphologically acceptable candidate within the sentence
- only candidate in the preceding sentence: e5

Temporal Connections

Compare

1. *T ran off the road and hit a lamp post.*
2. *T hit a lamp post and ran off the road*

But

T ran off the road and U hit a lamp post.

Approach

Classification of verbs into **state** and **event** verbs

Consideration of aspect

Problems

- Often the whole verb phrase contributes to the classification, but not all factors involved seem to be known yet.
- Aspect is not explicit in German.
- The interaction with spatial and causal links is poorly understood.
- Frame adverbials

Spatial Connections

Compare again

1. *T ran off the road and hit a lamp post.*
2. *T hit a lamp post and ran off the road*

Why is the lamp post not on the road in the first sentence, but on the road in the second?

Approach

Classify verb arguments of movement verbs according to their respective involvement in the moving event.

Problems

- Complexity of spatial relations
- Interaction with temporal and causal links
- Frame adverbials

Generation of Sentences

- as answers to user questions
- as questions posed by the system

Why text generation?

prestored text has several shortcomings:

- the user cannot refer to entities *(persons, objects and events)* mentioned in prestored text

- the system cannot refer to entities introduced previously in the dialog in a natural way

- if user questions are too complex to be translated into single predicates text patterns for predicates are inadequate

Descriptions of Entities

Answers to wh-questions posed by the user involve descriptions of the entities satisfying them.

Questions posed by the system to the user also involve descriptions of entities.

Guidelines for the Construction of Descriptions

Grice's conversational maximes

- *maxime of manner*
  descriptions should be unique, i.e. the dialog partner should be able to uniquely identify the entity described

- *maxime of quantity*
  descriptions should not contain more information than is necessary for a unique description

- *maxime of relevance*
  descriptions should be relevant, i.e tautologies are inappropriate as answers to questions

Influencing Factors

- *Mutual Knowledge*

  - shared knowledge about the entities that have already been introduced in the discourse

  - shared background knowledge

  For persons and objects the user knows the definite article is used and only facts the user knows about them are in a description

  For persons and objects the user does not know the indefinite article is used

- ***conventions in the use of properties to describe objects and persons***

  preference of certain properties

- ***the current focus of attention***

  The entity currently in focus can be referred to by a pronoun

  From the facts known about entities use the ones that relate it to the entity currently in focus

Generation of Answers

- ***Generation of descriptions for the entities that have been determined***

  selection of ***atomic and event conditions*** to describe the reference markers that have been substituted for those introduced for the interrogative pronouns in the user's question

  - assumption: ***user and system share the knowledge gathered during the dialog***

  - simple descriptions involving ***names***, ***common nouns***, ***qualifying adjectives*** and ***verbs***

- ***Generation of intermediate structures (ISs) from the conditions selected***

  - noun phrases for persons and objects

  - noun phrases or that-clauses for events

- ***Generation of the IS representing the answer***

  - imbedding of the ISs generated for the descriptions of entities into the one of the user's question

- ***Generation of the answer text from the IS***

Generation of Questions

- *Selection of conditions to describe the reference markers that are known*

- *Generation of an IS for the question*
  - generation of interrogative pronouns for the reference markers to be determined
  - insertion of an auxiliary verb ('to be' or 'to have') if the predicate requested is a noun or an adjective

- *Generation of the question text from the IS*

Drawing Inferences

Deduction

- proof search procedure for DRSs based on tableau calculus
- receives the user's question as a goal
- formalization of the systematic search for counter examples
- In the case where no rules or information from the case description are applicable, **secondary knowledge** (i.e. knowledge which is only used if consistet with already established facts) can be activated.
- If a predicate is classified as **askable**, a question is posed to the user. These requests are restricted to questions
  - on whether a given predicate holds for a tuple of reference markers
  - to determine unknown reference markers that are arguments of a given predicate

Imbedding of secondary processes

Can be applied for consistency checking, i.e. to establish that the negation of a goal cannot be proven.

Conclusions

Knowledge representation

1. Important aspects of legal knowledge have been modeled.
2. Interaction between legal and common sense knowledge has been investigated and described.
3. Investigations of ways to organize and to discover concept hierarchies and selection restrictions have been conducted.

Analysis of natural language discourse

1. Discourse Representation Theory has been proven to be a fruitful approach to extended discourse.
2. Rules governing processes of contextual reference have been described and implemented.
3. Representation of space and time in discourse have been investigated.

Generation of questions and answers

A procedure for the discourse dependent description of entities has been developed taking into account the notion of **mutual knowledge** and conversational maximes.

Inference techniques

1. A proof search procedure based on tableau calculus has been developed.
2. A mechanism to check consistency was developed and used to deal with common sense knowledge.