Large Spoken Language Dialogue Systems: Verbmobil & SmartKom

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http://verbmobil.dfki.de http://www.smartkom.org

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Overview

- Speech-to-speech translation: Verbmobil
- Multi-Modal Man-Machine Interaction: SmartKom
- Zooming in: Natural Language Generation

Content

- **Overview of Verbmobil**
- **A walk through the system**
  - Acoustic Processing
  - Dialog Translation
  - Selection and Speech Synthesis
- **Technical issues**
- **Human Factors and Experiences**

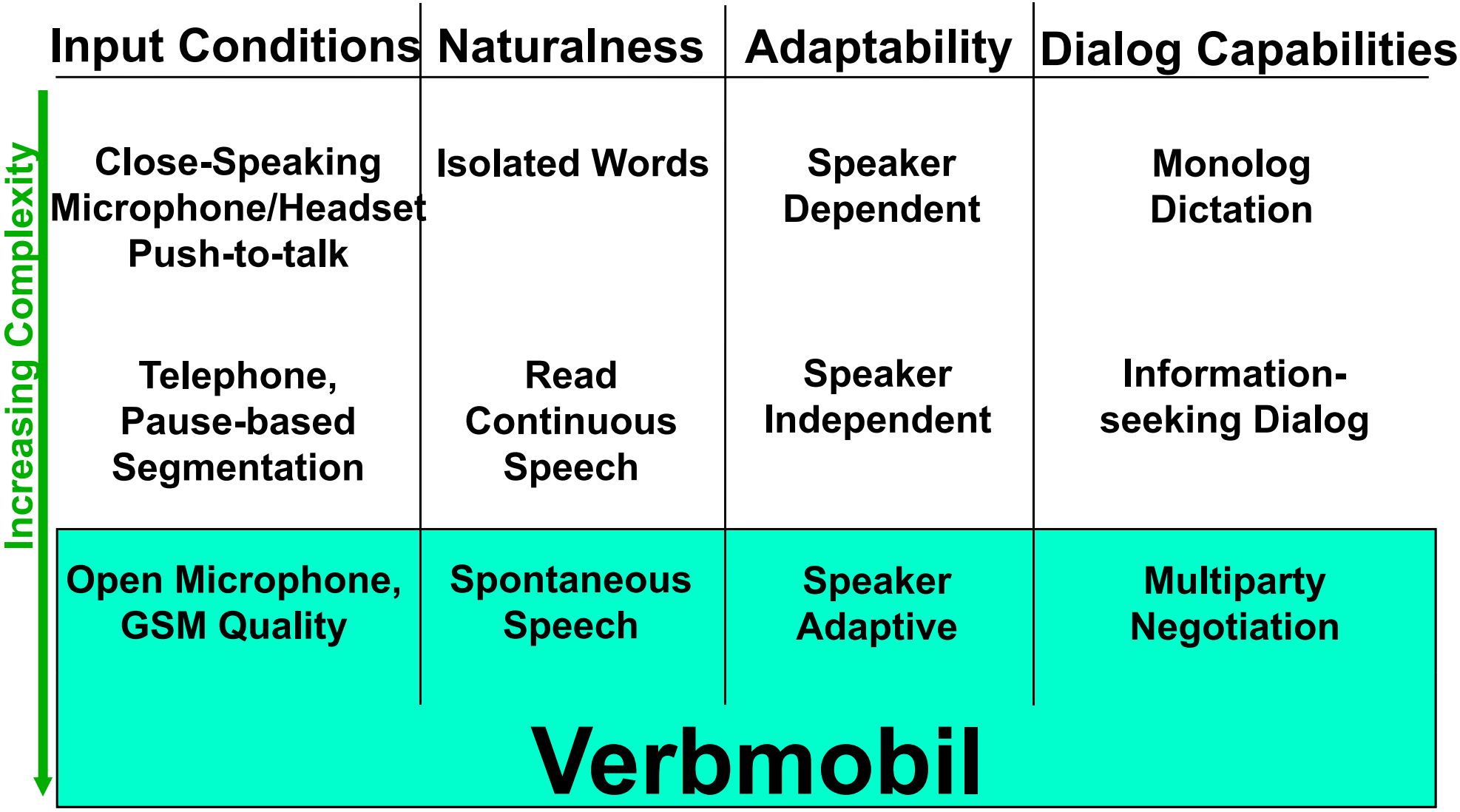
Overview of Verbmobil

Challenges, Partners, and General Approaches

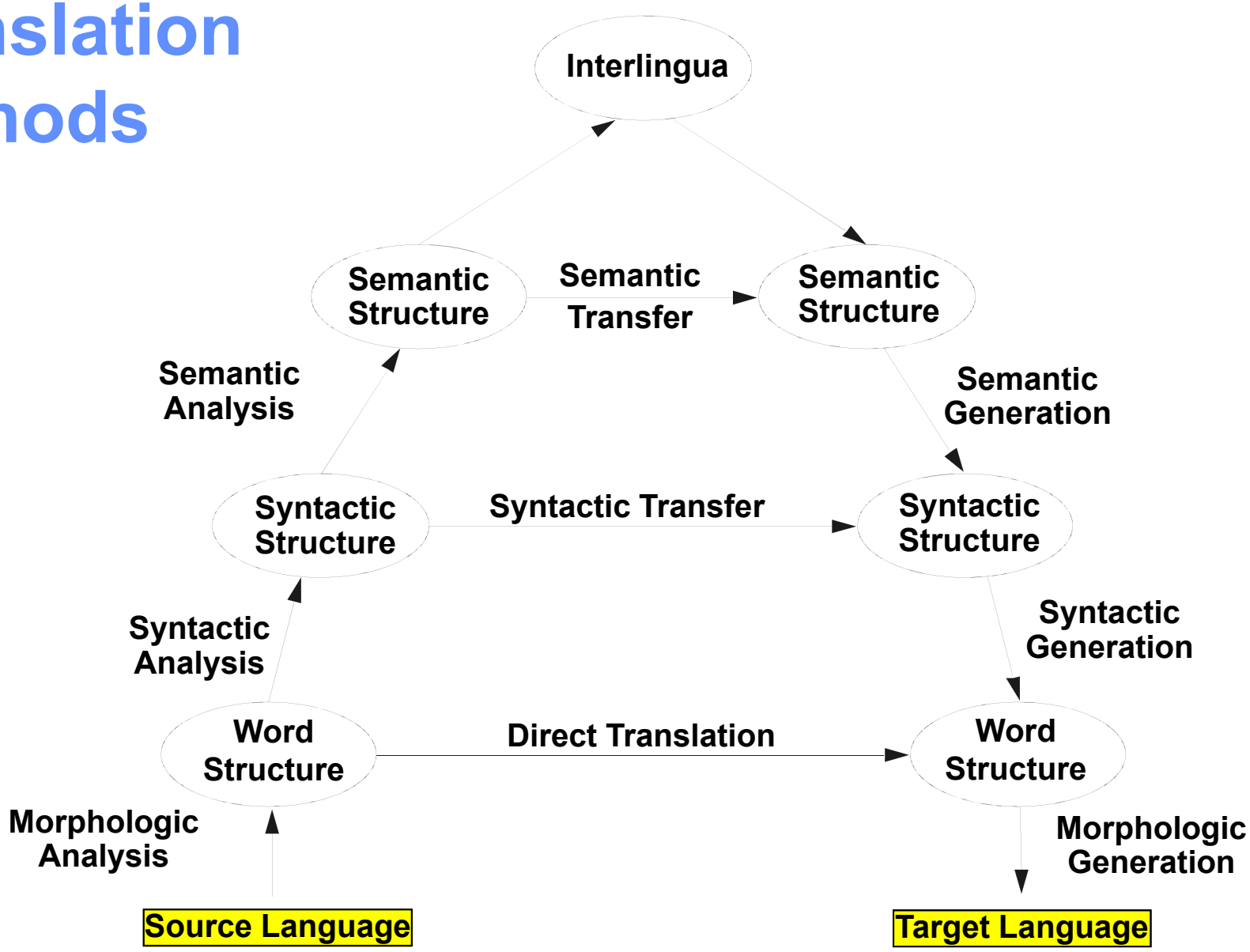
What is Verbmobil?

- Speech-to-speech translation system
- Robust processing of spontaneous dialogs
- Speaker independent (adaptive)
- Languages: English, German, Japanese
- Domains: Appointment scheduling, travel planning and hotel reservation, remote PC maintenance
- The system mediates between two humans, it does not play an active role
- There is no control of the ongoing dialog by the system

Challenges for Language Engineering

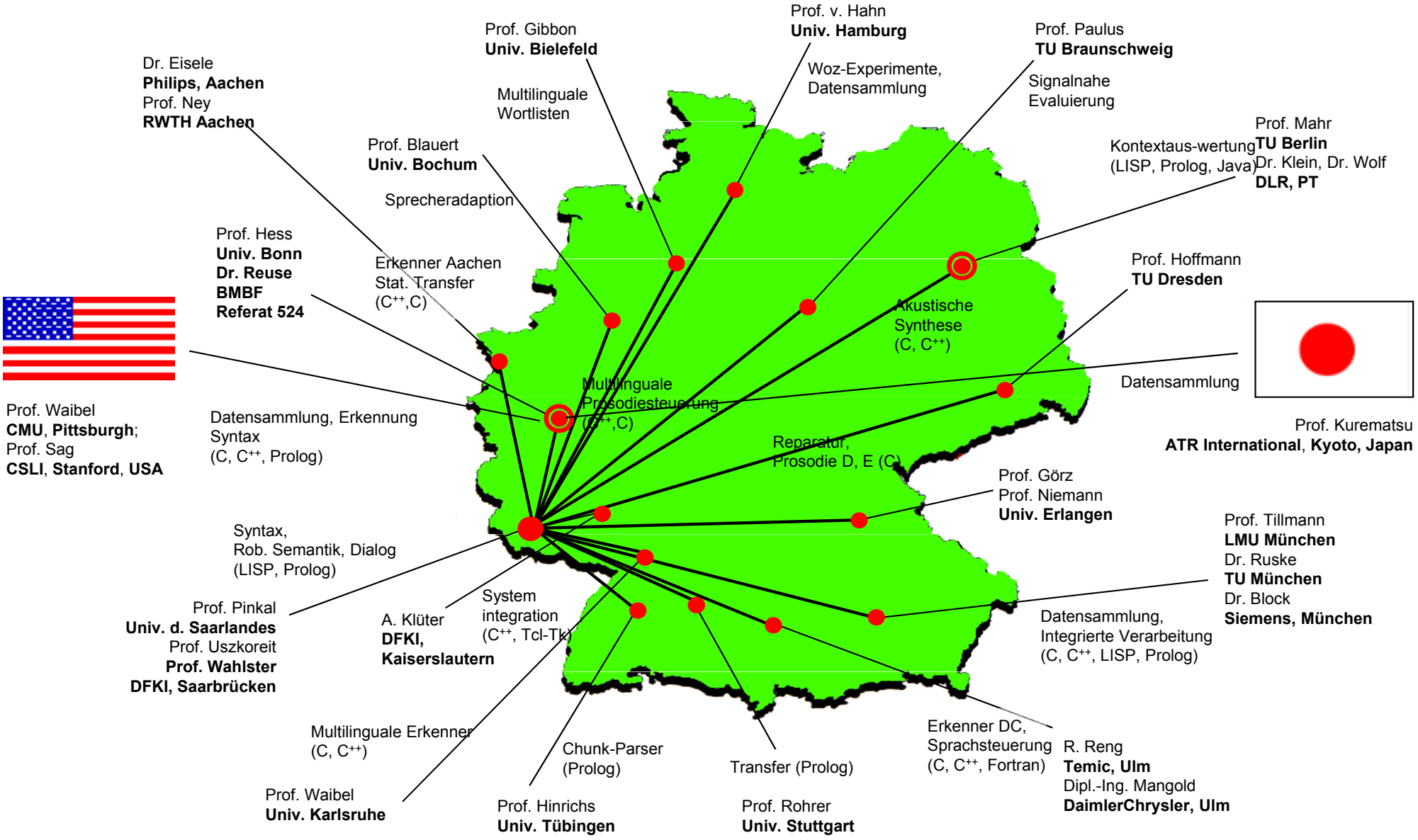


Classification of Machine Translation Methods



The Verbmobil Partners

The Verbmobil Partners



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Facts About the Project

- **23 participating institutions (in Verbmobil II), from Germany and the USA**
- **Over 900 full-time employees and students involved over the whole duration**
- **Funded by the German Ministry for Education and Science and the participating companies:**

BMBF-Funding Phase I, 1.01.93 – 31.12.96	62.7 Mio. DM	31.6 Mio €
BMBF-Funding Phase II, 1.01.97 - 30.9.2000	53.3 Mio. DM	27 Mio €
Industrial investment I+II	32.6 Mio. DM	16.5 Mio €
Related industrial R & D activities	ca. 20 Mio. DM	ca. 10 Mio €
Total	168.6 Mio. DM	85.1 Mio €

Verbmobil – The Book

There are over 600 refereed papers on the various aspects of and achievements in Verbmobil.

Wolfgang Wahlster (ed.):

"Verbmobil: Foundations of Speech-to-Speech Translation"

Springer-Verlag Berlin Heidelberg New York. 679 Pages

ISBN 3-540-67783-6

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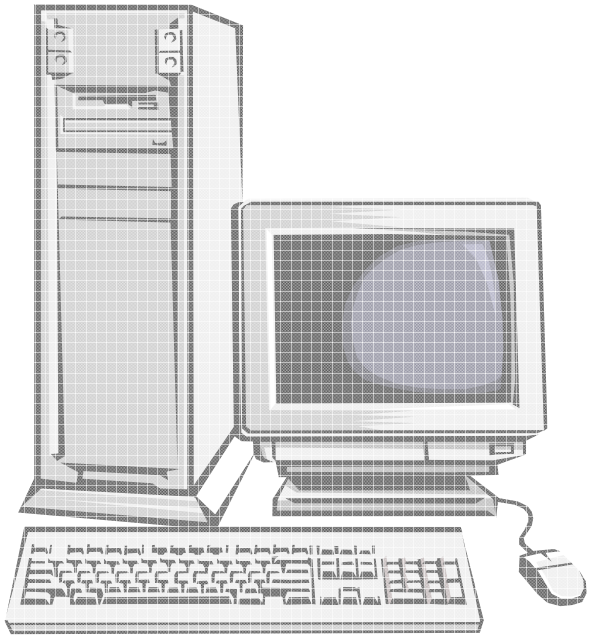
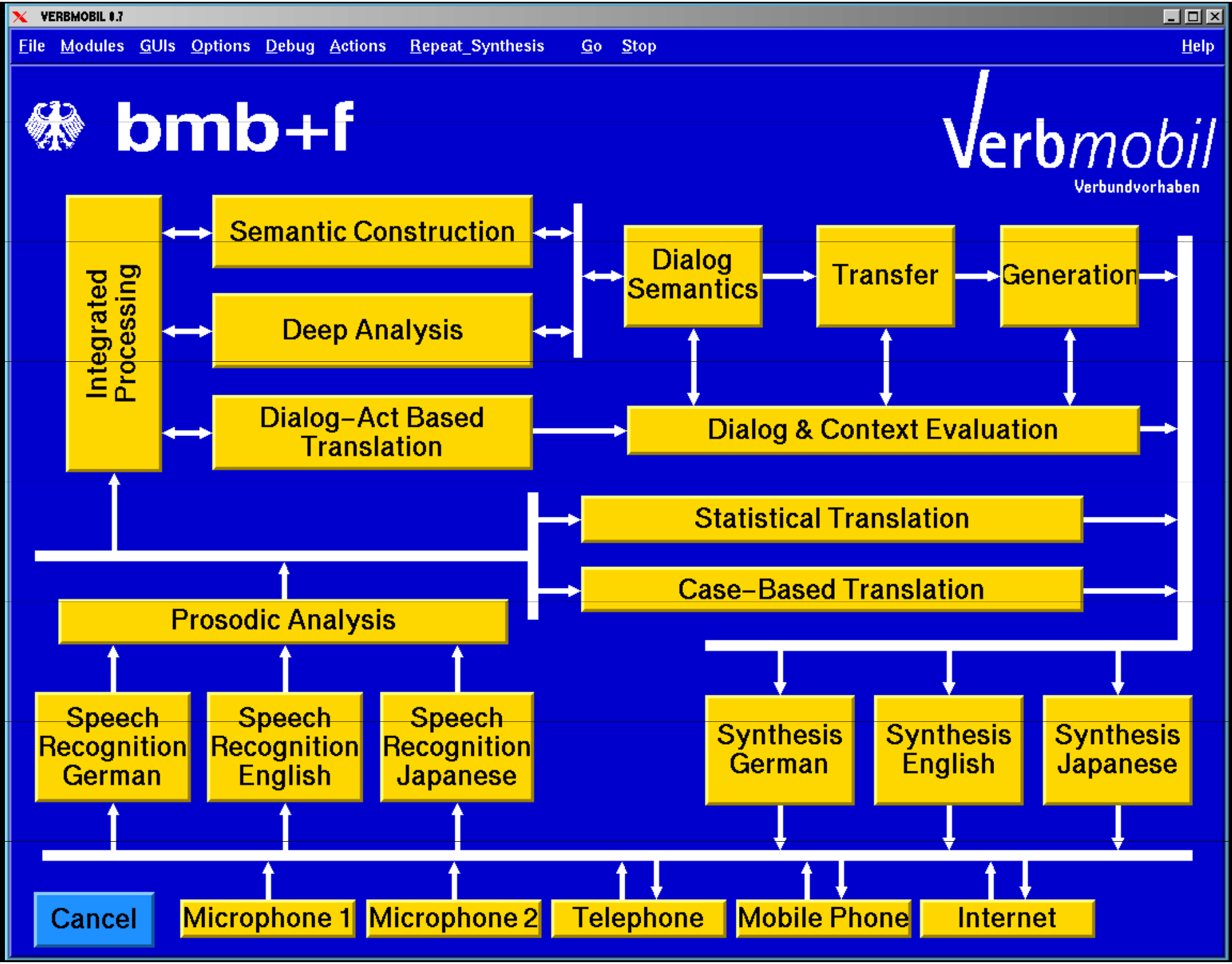
Typical Verbmobil Hardware



- SUN Ultra-Sparc 80
- 4 processors (450 MHz)
- 2 GB main memory
- 8 GB swap
- no special signal processing hardware
- Desklab Gradient A/D converter or Sun internal audio device
- close-speaking cordless microphones


VERBMOBIL 0.7
File Modules GUIs Options Debug Actions Repeat_Synthesis Go Stop Help
bmb+f
Verbmobil
Verbundvorhaben
Integrated Processing
Semantic Construction
Deep Analysis
Dialog–Act Based Translation
Dialog Semantics
Transfer
Generation
Dialog & Context Evaluation
Statistical Translation
Case–Based Translation
Prosodic Analysis
Speech Recognition German
Speech Recognition English
Speech Recognition Japanese
Synthesis German
Synthesis English
Synthesis Japanese
Cancel
Microphone 1
Microphone 2
Telephone
Mobile Phone
Internet

Walk Through the Verbmobil System

Detailed Module Presentation and Demonstration

Acoustic Processing

Recording, Synthesizing and Synchronization

- Task:

  Providing a uniform interface to varying audio hardware; synchronizing in- and output
- Input:

  Audio data and system states
- Method:

  Introducing audio modules; Finite State Machine for synchronizing
- Result:

  Audio Data and Synchronization
- Benefit:

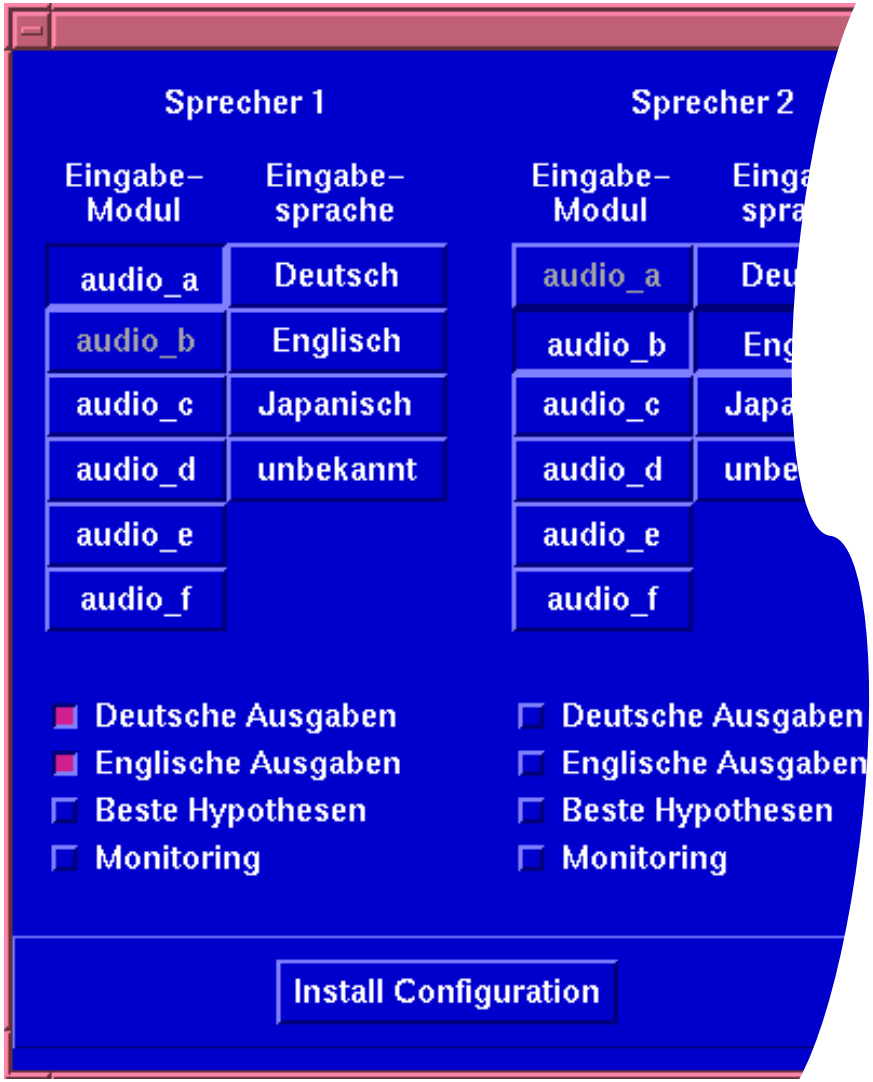
  Encapsulating audio hardware, “open microphone”, preventing out-of-sync or overlapping system output
- Responsible:

  DFKI, Kaiserslautern

Audio Configuration

- **Configuration of the systems I/O behavior**
  - How many speakers?
  - For every (possible) speaker:
    - Input device (channel identification, speaker adaption)
    - Output device(s) (translation output, destination for man/machine dialogs)
    - Source language (or „unknown“)
  - Desired system output categories

- **Audio channel configuration**
  - Uniform configuration of heterogeneous audio hardware



Recording Audio Data

- **Turn-based processing, barge-in available for voice commands**
- **Different audio quality:**
  - lab-quality close-speaking microphone (16kHz)
  - room microphone (16kHz)
  - telephone quality (8kHz)
  - GSM mobile (8kHz)

⇨ **Audio module concept**

  - provides a uniform interface of different hardware devices to the system
  - # of channels is only limited by hardware

- **Open Microphone Approach (essential for telephone translation service!)**
- **Input/output synchronization**
- **No cross-talk allowed**

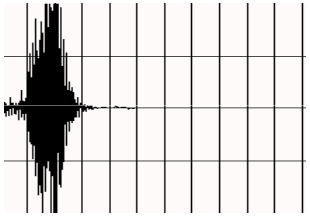
Open Microphone Approach

Microphone open

Microphone 1

Speech input

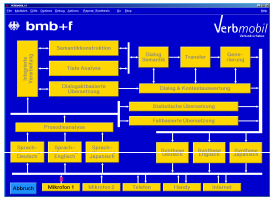
Pause detection



Microphone closed

Microphone 1

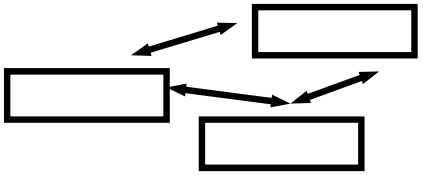
Translation



Speech output

Microphone 1

Synchronization



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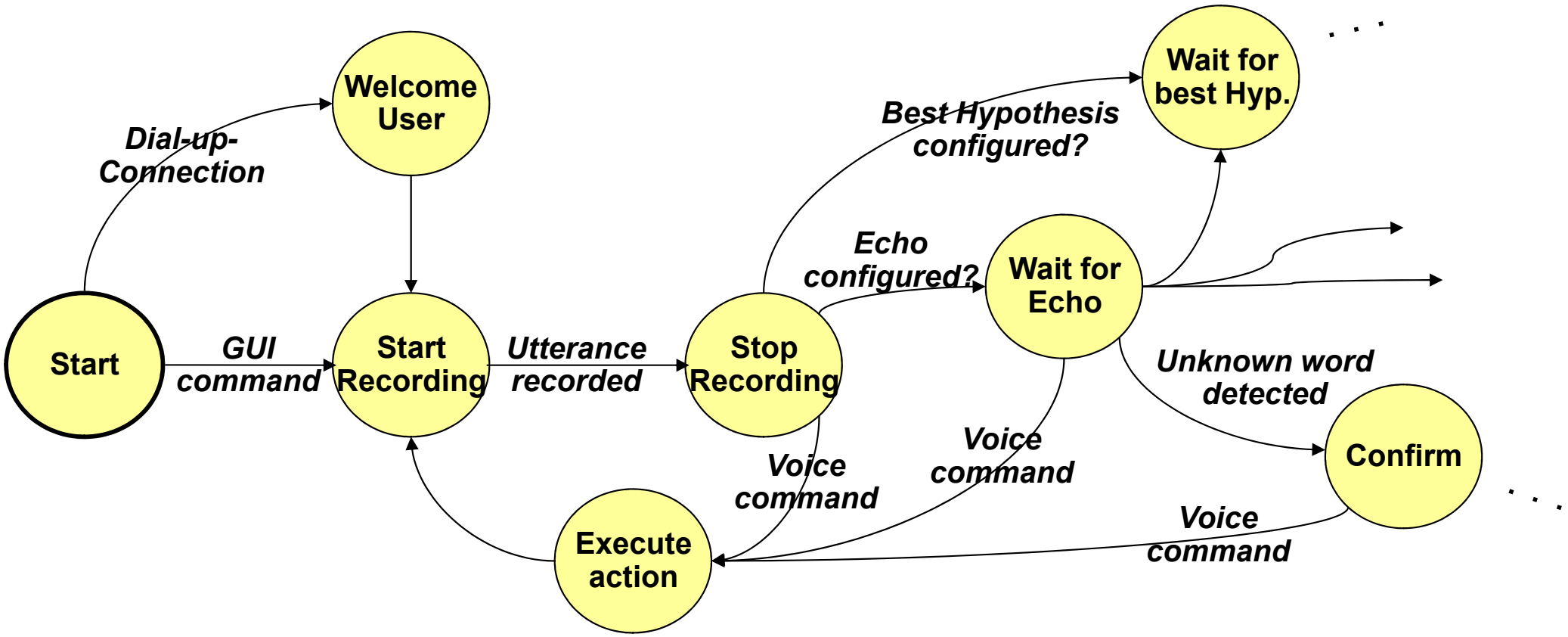
Synchronisation

- Synchronization controls the high-level System behavior
- Realized via Finite State Machine



Recognizing Speech

- Task:

  Analyzing continuous spontaneous speech signals
- Input:

  Audio data
- Method:

  HMMs, class based language models, etc.
- Result:

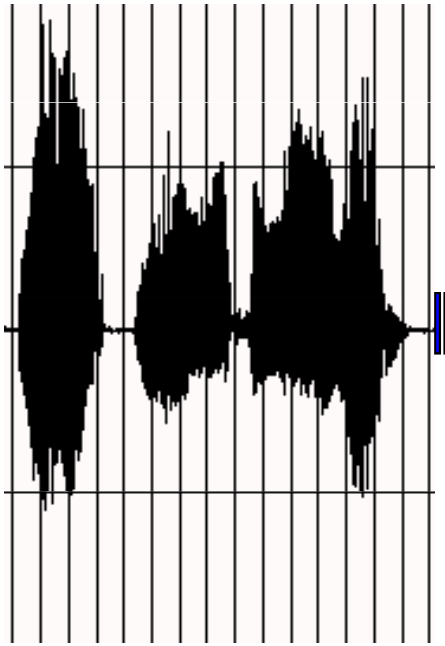
  Word Hypotheses Graphs (WHG) and speech commands
- Benefit:

  Compact representation of hypotheses of what has been said
- Responsible:

  DaimlerChrysler AG
  University of Karlsruhe
  RWTH Aachen
  Philips GmbH (Language Models)

General Speech Recognition Task

Audio Signal



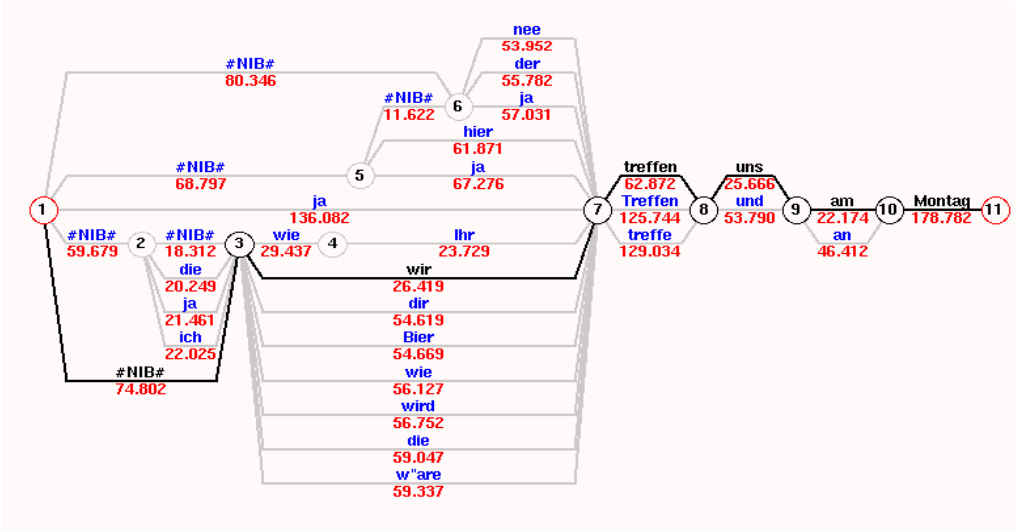
Recognizers

German

English

Japanese

Word Hypotheses Graph



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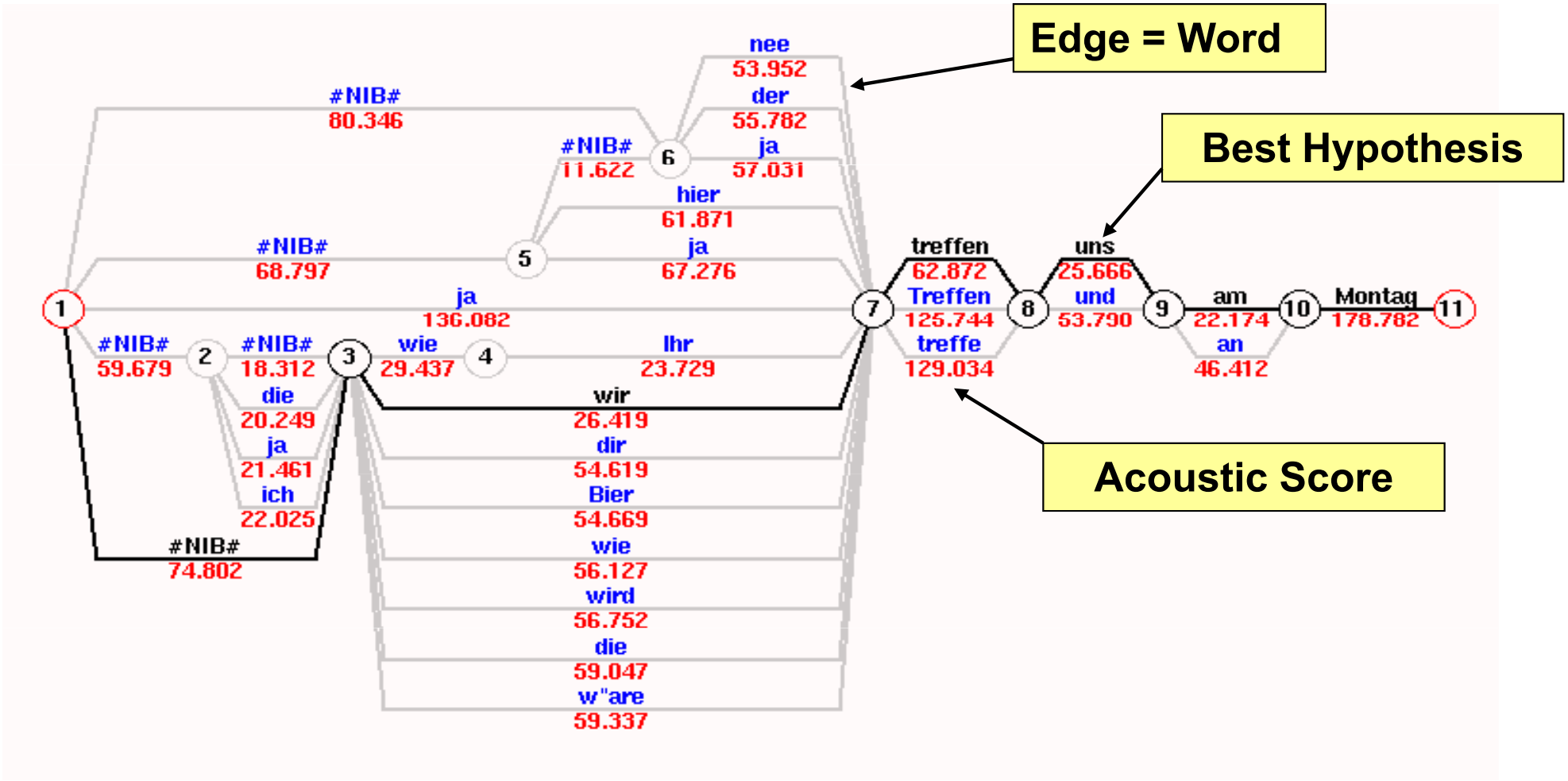
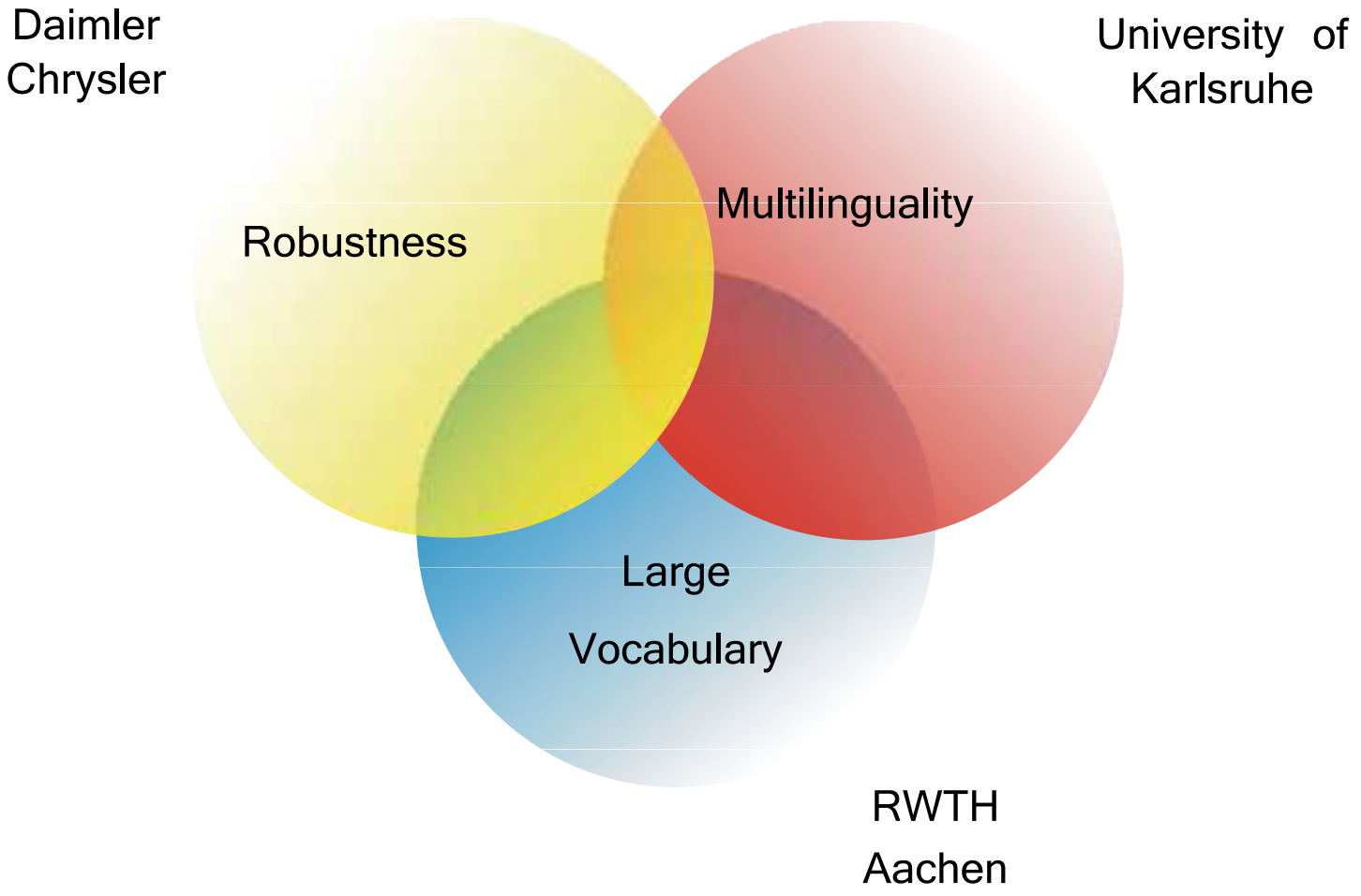
Word Hypotheses Graphs (WHGs)

WHGs realize the interface between acoustic and linguistic processing



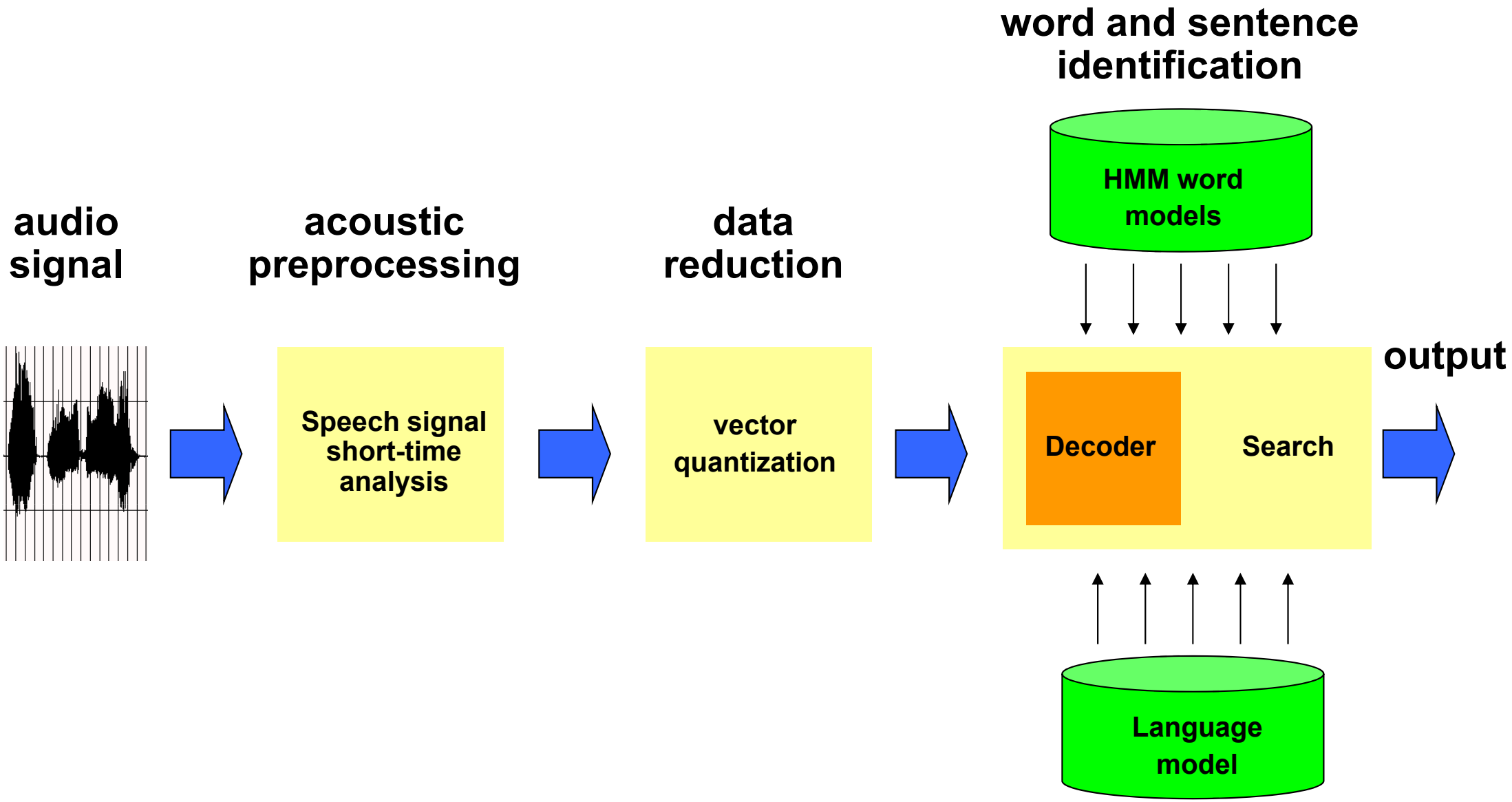
Focuses of Speech Recognition in Verbmobil



Nine Available Recognizer Modules

- **DaimlerChrysler**
  - German, 16 kHz, speaker adaptive, approx. 10000 words
  - German, 8 kHz, telephone/GSM quality, speaker adaptive, approx. 10000 words
  - English, 8 kHz, telephone/GSM quality, speaker adaptive, approx. 7000 words
- **University of Karlsruhe**
  - German, 16 kHz, speaker adaptive, approx. 10000 words
  - English, 16 kHz, speaker adaptive, approx. 7000 words
  - Japanese, 16 kHz, speaker adaptive, approx. 2600 words
  - Language Identification Component (German, English, Japanese)
- **RWTH Aachen**
  - German, 16 kHz, speaker adaptive, approx. 10000 words
  - German, 16 kHz, speaker dependent, approx. 30000 words

Principal Recognizer Architecture



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The Speech Recognition Task

- **Some Highlights of the Verbmobil Recognizers:**
  - Speaker adaptive recognition:
    - Start speaker independent
    - Recognition results enhance during the dialog
  - Capable of dividing speech and noise input using garbage models
  - Segmentation of speech input allows incremental processing
  - Word class based language models and recognition allow flexible vocabulary extension
  - Online vocabulary extension through unknown word detection (names, towns, street names, …)
  - Integrated continuous und speech command recognition

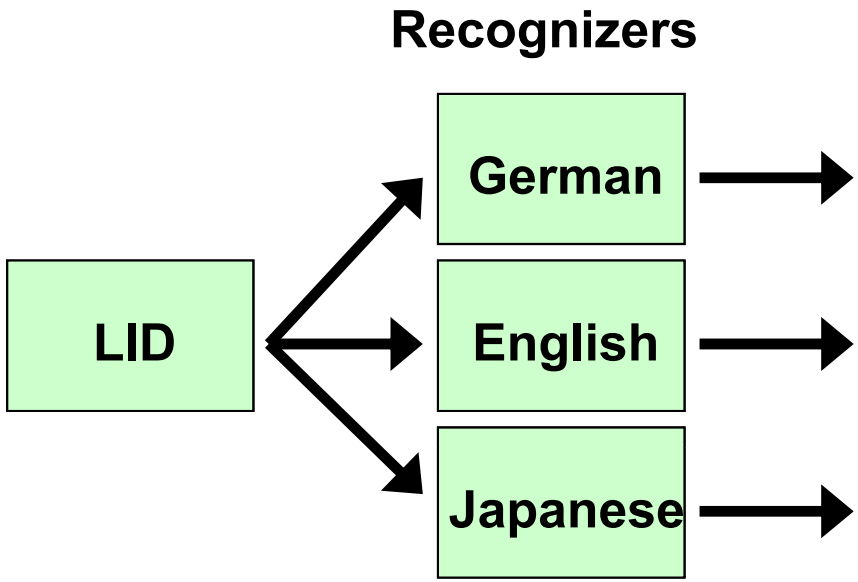
… and many more

Language Identification

- **Features**
  - ID on 3 seconds speech signal (maximum)
  - Real time factor 0.5
  - Speaker independent
  - Unknown audio channel
  - Using language model know-how

- **Flexible Architecture:**

  LID can be combined with any speech recognizer



Prosodic Processing

- Task:

  Recognizing prosodic phenomena (accents, sentence mood) and boundaries
- Input:

  WHG and speech signal
- Method:

  Neural networks and statistical classifiers
- Result:

  WHG annotated with accent and boundary information
- Benefit:

  Provides prosodic information needed for correct translation of spontaneous speech
- Responsible:

  Universität Erlangen-Nürnberg

Prosody in Speech Communication

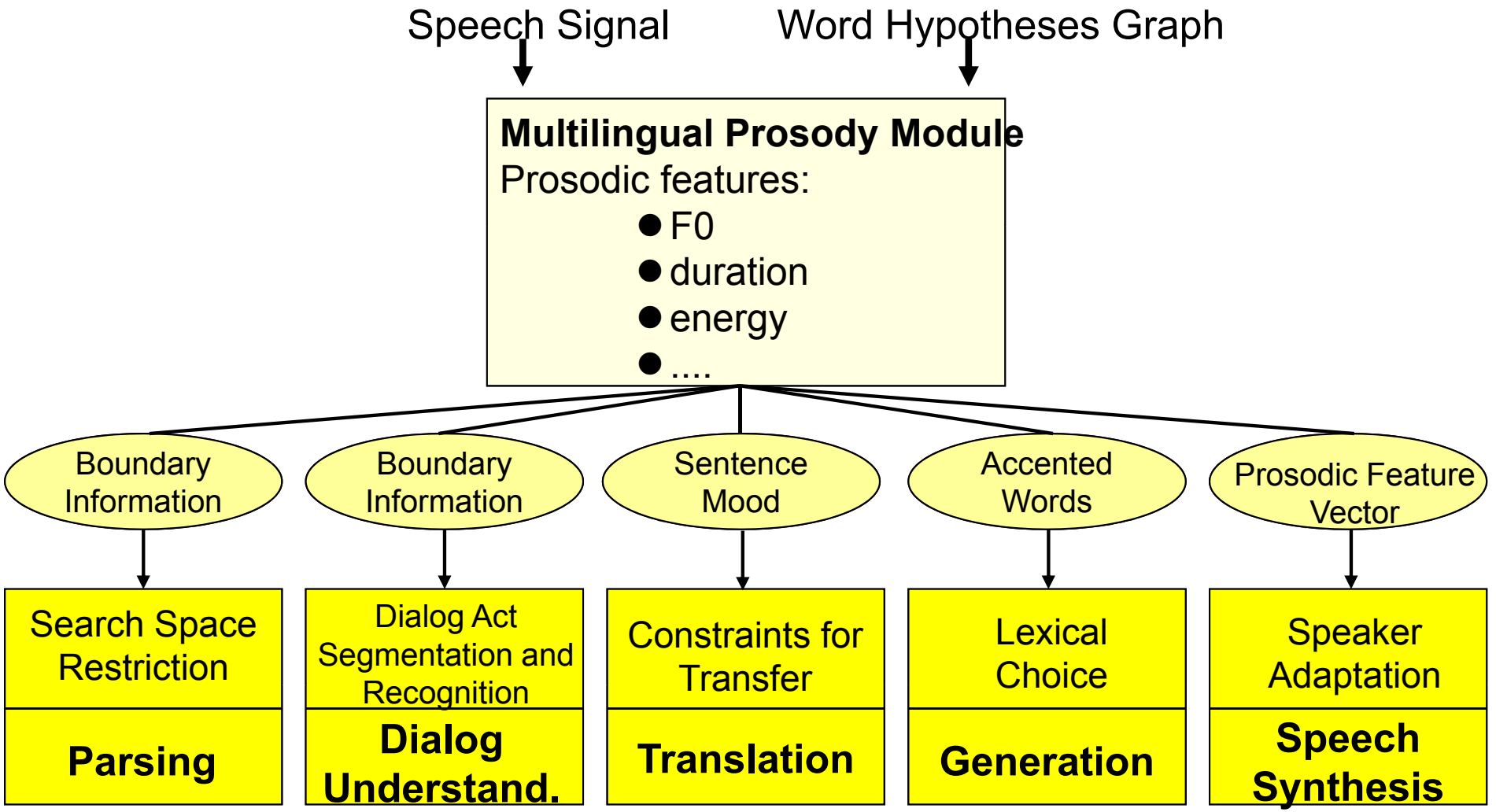
Prosody can help to disambiguate

- lexical and phrasal accent
- phrasing (chunks of speech)
- sentence mood
- emotion, attitude, foreign accent

Parameters represented by Features

- F0 (fundamental frequency)
- Energy
- Duration
- Speech tempo
- Pause

Prosody in Verbmobil



What Linguistic Analysis Really Needs

- **Syntactic Boundaries**
  He saw ? *the man* ? *with the telescope* **Prosody cannot help**

- **Dialog Act Boundaries**
  No, I have no time at all on Thursday. **D**
  But how about on Friday?
  Dialog acts are pragmatic units that chunk the input into units which can be processed alone.

- **Prosodic Syntactic Boundaries**
  Of course ? *not* ? *on Saturday*
  Syntactic boundaries that correlate to the acoustic-phonetic reality; help during analysis within one chunk/dialog act. Important in spontaneous speech with elliptical utterances.

Extraction of Prosodic Features

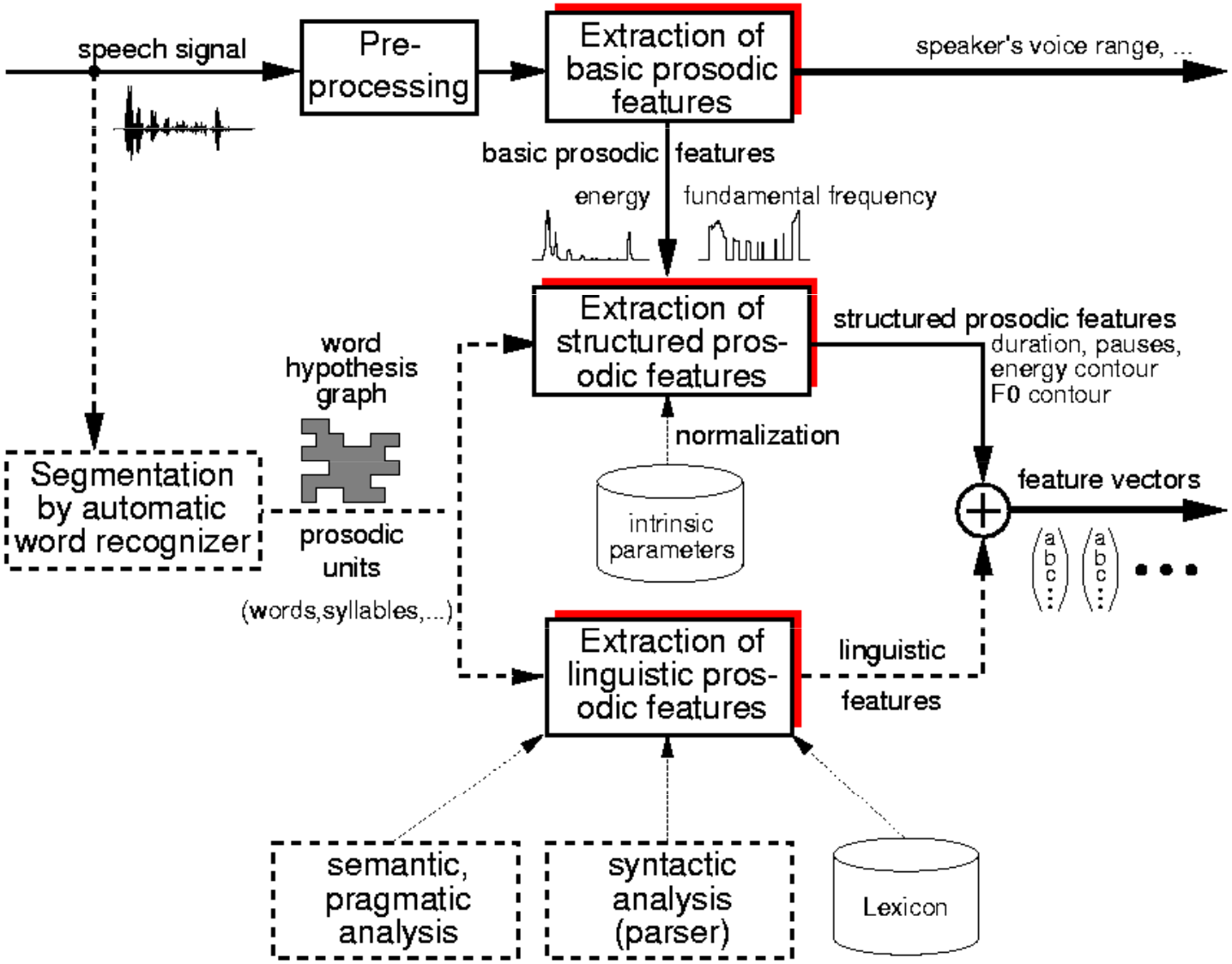
- computed for each word
- from basic prosodic features and segmental information
- over different time contexts
- modeling of FO:

  linear regression coefficient, regression error, mean, median, minimum, maximum, onset, offset and their temporal locations
- modeling of energy--contour

  mean, median, maximum, max-pos, regression coefficient, ...

  and phoneme intrinsic normalizations

Extraction of Prosodic Features



Prosodic Classification in Verbmobil

- five classes of boundaries: default, particles, phrases, clauses, sentences
- sentence mood: question vs. non-questions
- phrase accent: disambiguation of particles
- Computed by NN-classifiers and Language Models
- Language Models trained on a corpus annotated with syntactic prosodic boundaries and dialog act boundaries

An Example

I am calling about the trip to Hanover on the seventh and eighth of March

```
...
2       3       I       50.284023       34      46      (ID r3485) (PR (S 1.00 0.00 0.00 0.00 0.00)  (A 0.82 0.18)  (F 0.92 0
...
3       9       am      24.803406       47      52      (ID r3489) (PR (S 1.00 0.00 0.00 0.00 0.00)  (A 0.84 0.16)  (F 0.81 0
3       10      am      32.151409       47      54      (ID r3490) (PR (S 1.00 0.00 0.00 0.00 0.00)  (A 0.88 0.12)  (F 0.37 0
...
9       11      going   142.015503      53      91      (ID r3504) (PR (S 0.94 0.00 0.05 0.00 0.00)  (A 0.14 0.86)  (F 0.10 0
10      11      calling 131.019409      55      91      (ID r3505) (PR (S 0.39 0.01 0.32 0.27 0.01)  (A 0.07 0.93)  (F 0.13 0
11      12      about   125.144707      92      124     (ID r3506) (PR (S 1.00 0.00 0.00 0.00 0.00)  (A 0.22 0.78)  (F 0.92 0
12      13      the     40.895718       125     136     (ID r3507) (PR (S 1.00 0.00 0.00 0.00 0.00)  (A 0.90 0.10)  (F 1.00 0
12      13      that    42.615807       125     136     (ID r3508) (PR (S 0.80 0.00 0.07 0.00 0.12)  (A 0.84 0.16)  (F 1.00 0
13      14      trip    106.785835      137     167     (ID r3509) (PR (S 0.10 0.00 0.80 0.10 0.00)  (A 0.24 0.76)  (F 0.03 0
14      15      to      69.326729       168     188     (ID r3510) (PR (S 0.86 0.02 0.08 0.02 0.02)  (A 0.85 0.15)  (F 1.00 0
15      16      Hanover 245.755707      189     261     (ID r3511) (PR (S 0.02 0.14 0.43 0.01 0.40)  (A 0.01 0.99)  (F 0.04 0
...
16      18      and     69.891464       266     284     (ID r3514) (PR (S 0.57 0.08 0.11 0.23 0.02)  (A 0.87 0.13)  (F 0.95 0
17      18      on      75.358749       264     280     (ID r3515) (PR (S 0.92 0.03 0.01 0.03 0.00)  (A 0.87 0.13)  (F 0.62 0
18      19      the     37.180725       285     295     (ID r3516) (PR (S 1.00 0.00 0.00 0.00 0.00)  (A 0.94 0.06)  (F 0.98 0
19      20      seventh 184.631897      296     350     (ID r3517) (PR (S 0.06 0.10 0.31 0.00 0.53)  (A 0.07 0.93)  (F 0.11 0
20      21      and     44.750828       356     369     (ID r3518) (PR (S 0.99 0.00 0.01 0.00 0.00)  (A 0.85 0.15)  (F 0.15 0
21      22      the     42.576515       370     376     (ID r3520) (PR (S 1.00 0.00 0.00 0.00 0.00)  (A 0.95 0.05)  (F 1.00 0
22      23      eighth  134.293030      381     420     (ID r3521) (PR (S 0.00 0.00 0.99 0.00 0.01)  (A 0.24 0.76)  (F 0.38 0
23      24      of      62.543167       425     443     (ID r3522) (PR (S 1.00 0.00 0.00 0.00 0.00)  (A 0.74 0.26)  (F 1.00 0
24      25      March   204.886185      444     497     (ID r3523) (PR (S 0.02 0.63 0.03 0.02 0.30)  (A 0.04 0.96)  (F 0.03 0
```

Repair of Self-Corrections

- Task:

  Detecting and repairing self-corrections
- Input:

  WHGs
- Method:

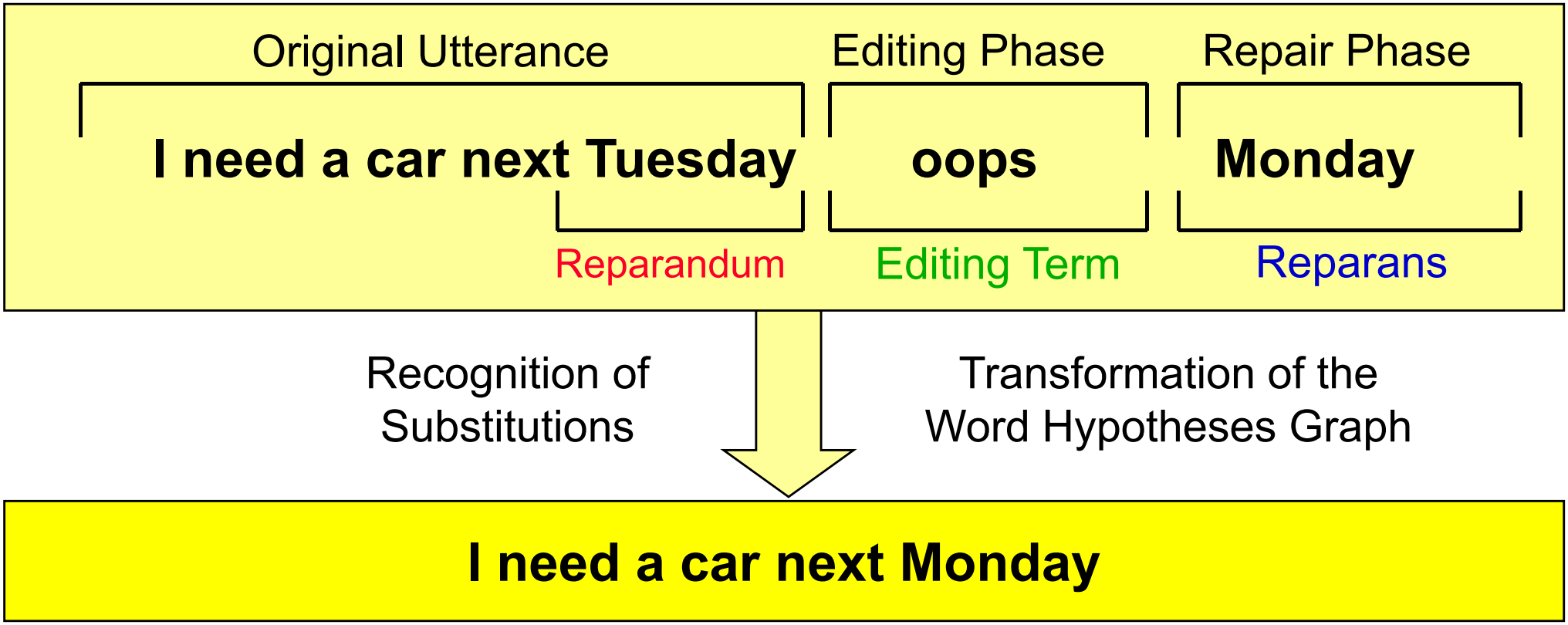
  Stochastic models
- Result:

  Enriched WHGs, including additional repaired hypotheses
- Benefit:

  Enabling Verbmobil to repair self-corrections of spontaneous speech input
- Responsible:

  Universität Erlangen-Nürnberg

The Understanding of Spontaneous Speech Repairs



Facts about Repairs in the Verbmobil Corpus

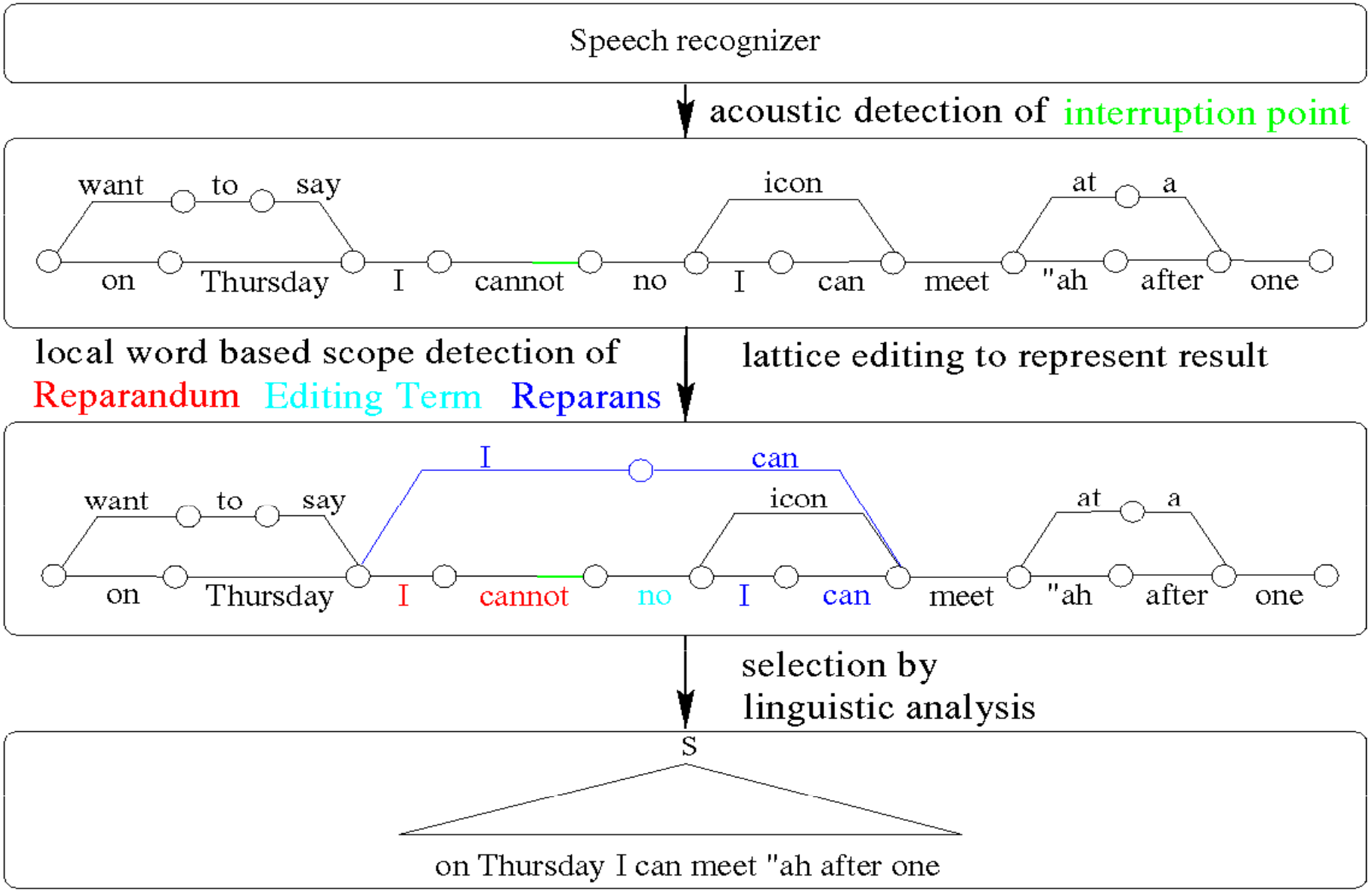
- 21% of all turns in the Verbmobil corpus (79 562 turns) contain at least one self correction
- The syntactic category is preserved in most cases

  (For example: Out of a sample of 266 verb replacements, 224 are again mapped to verbs)
- Repairs take place in a restricted context

  (in 98% the reparandum consists of less than 5 words)
- Repair sequences underlie certain regularities

Architecture of Repair Processing

"On Thursday I cannot no I can meet äh after one"



Scopus Detection

- **The editing term (ET) is given by the prosody**
- **Wanted: Beginning (RB) and end (RE) of the Repair**
- **Search the best replacement of a word order on the left hand side of ET through a word order on the right hand side of ET**

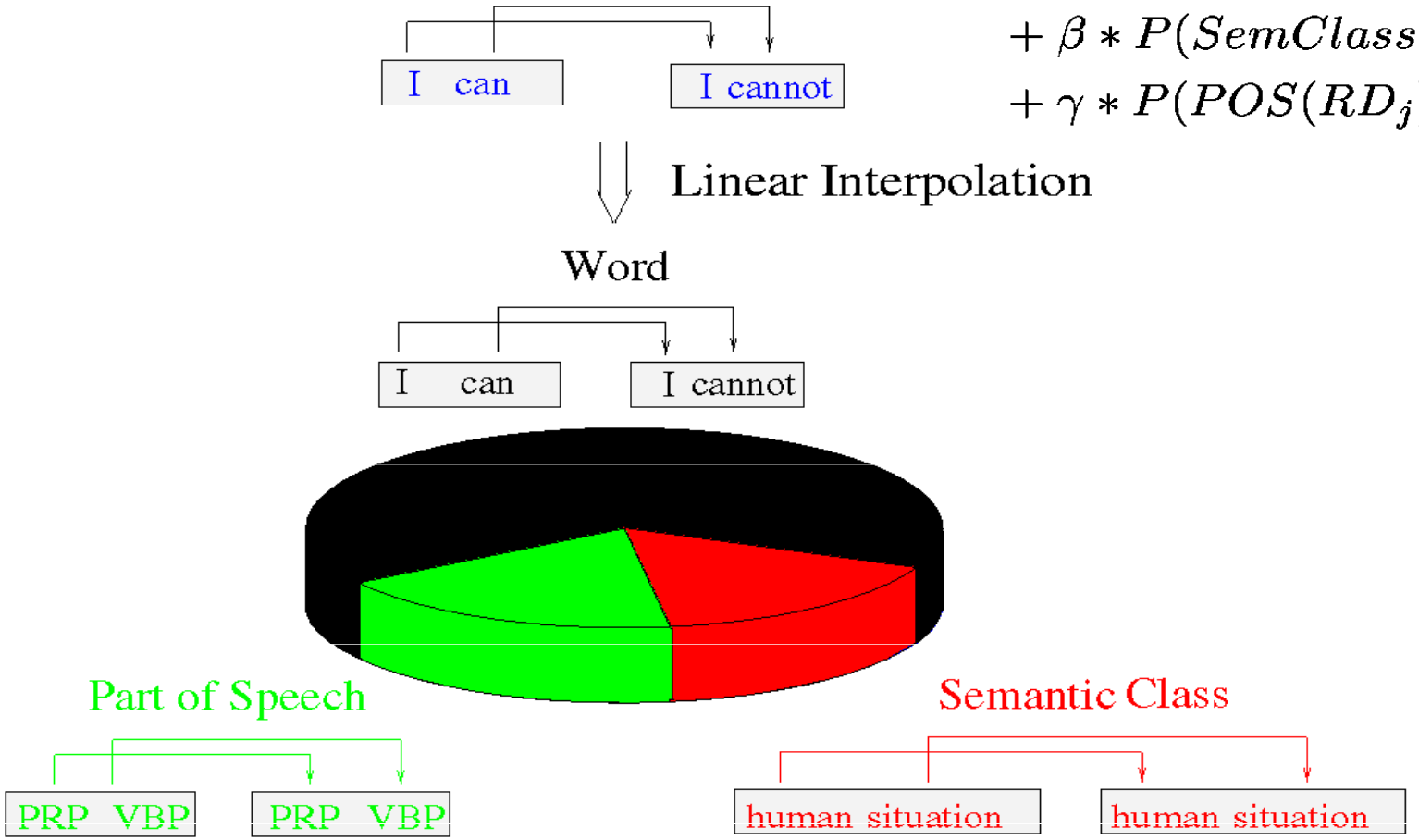
$\Rightarrow$ **rate the possible replacements**

search space is limited through looking at 4 words before and after ET

- ***Choose the best rated replacement over a certain threshold***

Repair Detection and Word Smoothing

$$P_r(RD_j|RS_{a_j}) =$$
$$\alpha * P(Word(RD_j)|Word(RS_{a_j}))$$
$$+ \beta * P(SemClass(RD_j)|SemClass(RS_{a_j}))$$
$$+ \gamma * P(POS(RD_j)|POS(RS_{a_j}))$$



Dialog Translation

Multiple Approaches

- **Mono-cultural approaches are dangerous**
  - humans vs. viruses 🡻 diversity
  - Microsoft vs. ILOVEYOU and copycats 🡻 alternative software solutions
- **Some sources of errors in a speech translation system**
  - external
    - spontaneous speech: not well formed, hesitations, repairs
    - bad acoustic conditions
    - human dialog behavior
  - internal
    - knowledge gaps in modules
    - software errors
    - probabilistic processing

❑ **Use multiple engines, varying approaches on various stages of processing**

Multiple Approaches in Verbmobil

- **Exclusive alternatives: three different 16 kHz German speech recognizers with various capabilities**
- **Competing approaches:**
  - three parsers: HPSG, Chunk, Statistical
  - five translation tracks: case-based, dialog-act based, statistical, substring-based, linguistic (deep) semantic translation
- **Needed: selection and combination of results from competing tracks**
  - parsers: combination of partial analyses in the semantic processing modules
  - translation: preselection module

Multiple Translation Tracks - Approaches and Advantages

- **Case-based:**
  - Approach: uses examples from the aligned bilingual Verbmobil corpus
  - Advantage: good translation if input matches example in corpus
- **Dialog-act based:**
  - Approach: extract core intention (dialog act) and content
  - Advantage: robust wrt. recognition errors
- **Statistical**
  - Approach: use statistical language and translation models
  - Advantage: guaranteed translation with high approximate correctness
- **Substring- based**
  - Approach: combines statistical word alignment with precomputation of translation ”chunks” and contextual clustering
  - Advantage: guaranteed translation with high approximate correctness
- **Linguistic (deep) semantic translation**
  - Approach: “classic” approach using semantic transfer
  - Advantage: high quality translation in case of success

Example Based Translation

- Task:

  Providing a translation based on translation templates and partial linguistic analysis
- Input:

  WHGs or best Hypothesis
- Method:

  Definite Clause Grammar (DCG), graph matching algorithms
- Result:

  Translation and a confidence value
- Benefit:

  Improving Verbmobils translation capabilities through an additional translation path
- Responsible:

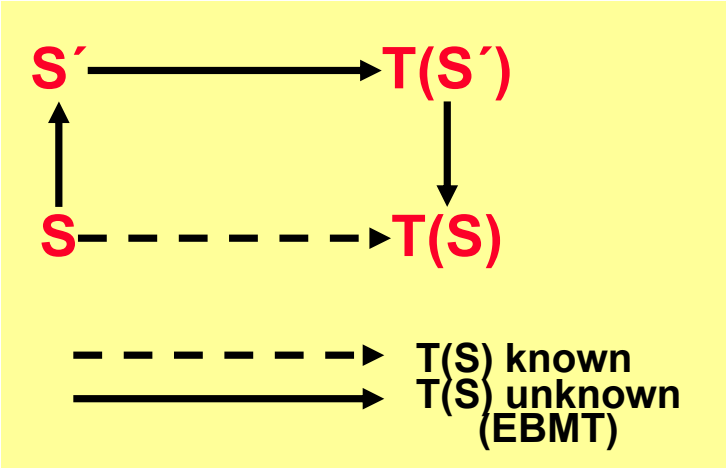
  DFKI, Kaiserslautern

The Case Based Approach

- **Training is based on Verbmobil‘s bilangual corpus**

```
E: I am on vacation, on the sixth and the seventh.
D: ich bin am sechsten und siebten verreist.
```

- **Principle: Look up an example in the example storage that matches the input sentence best, use it’s translation as output**



Generalization in Example Based Machine Translation (EBMT)

- **Handicap of this naive approach: inadequate coverage**

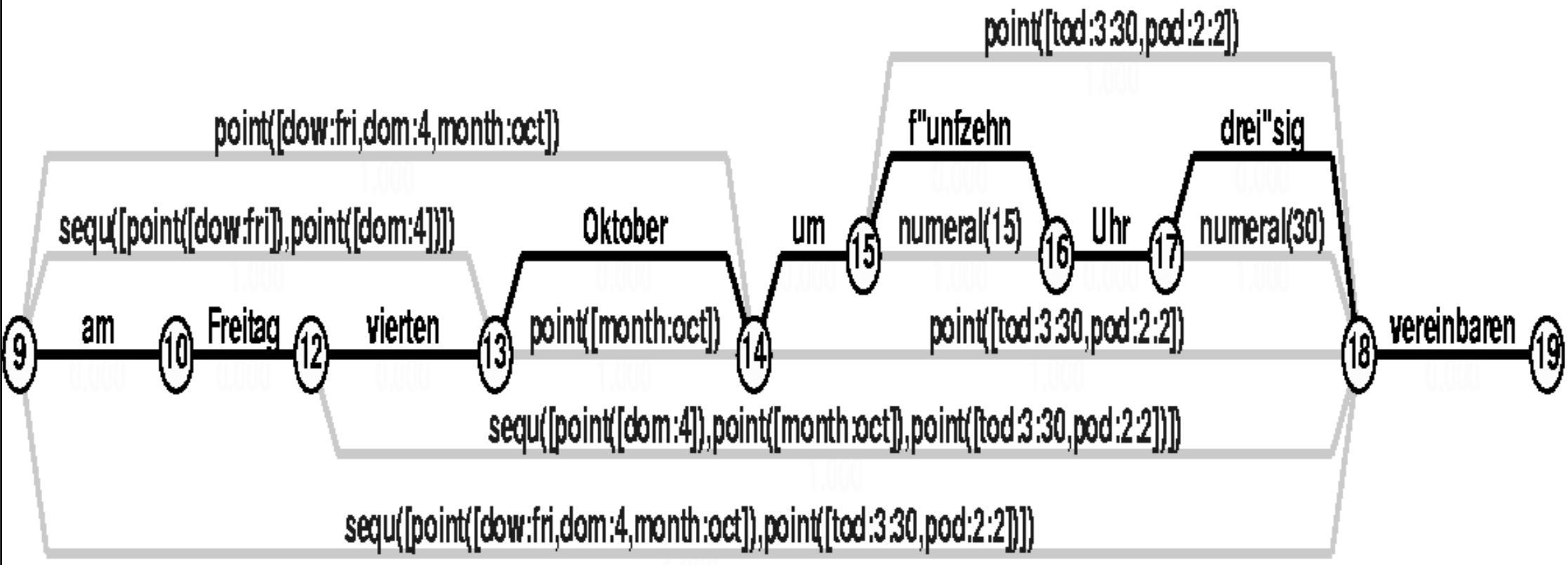
```
S :    I am not free on Friday.
S':    I am not free on Monday.
T(S'): am Montag habe ich keine Zeit.
```

- **Solution: partial generalization (analysis and generation)**

```
E: I am not free <Temp>.
D: <Temp> habe ich keine Zeit.
```

- **Automatic generalization approach:**
  - The grammar automatically generalizes the corpus (offline)
  - The runtime module generalizes incoming input (online)
  - Match generalized input sentence with generalized corpus example
  - Result: instantiated corpus translation

Generalization of WHGs



Example Based Translation – Some More Features

- **Generalization grammar for temporals, names, locations (region, town, country), institutions**
- **Fast and robust WHG search:**
  - WHG packing
  - Optimal alignment for fast corpus search
  - Search space pruning
  - Search space caching
  - Any time capable
- **Adequate confidence value for selection**

Dialog-Act Based Translation

- Task:

  Robustly provide a translation of core intentions and contents of the domain
- Input:

  Prosodically annotated best hypothesis (flat WHG)
- Method:

  Statistical dialog-act classifier and Finite State Transducers
- Result:

  Translation and a confidence value, additionally content descriptions for the dialog module
- Benefit:

  Robust translation and content extraction even when the recognition is erroneous
- Responsible:

  DFKI, Saarbrücken

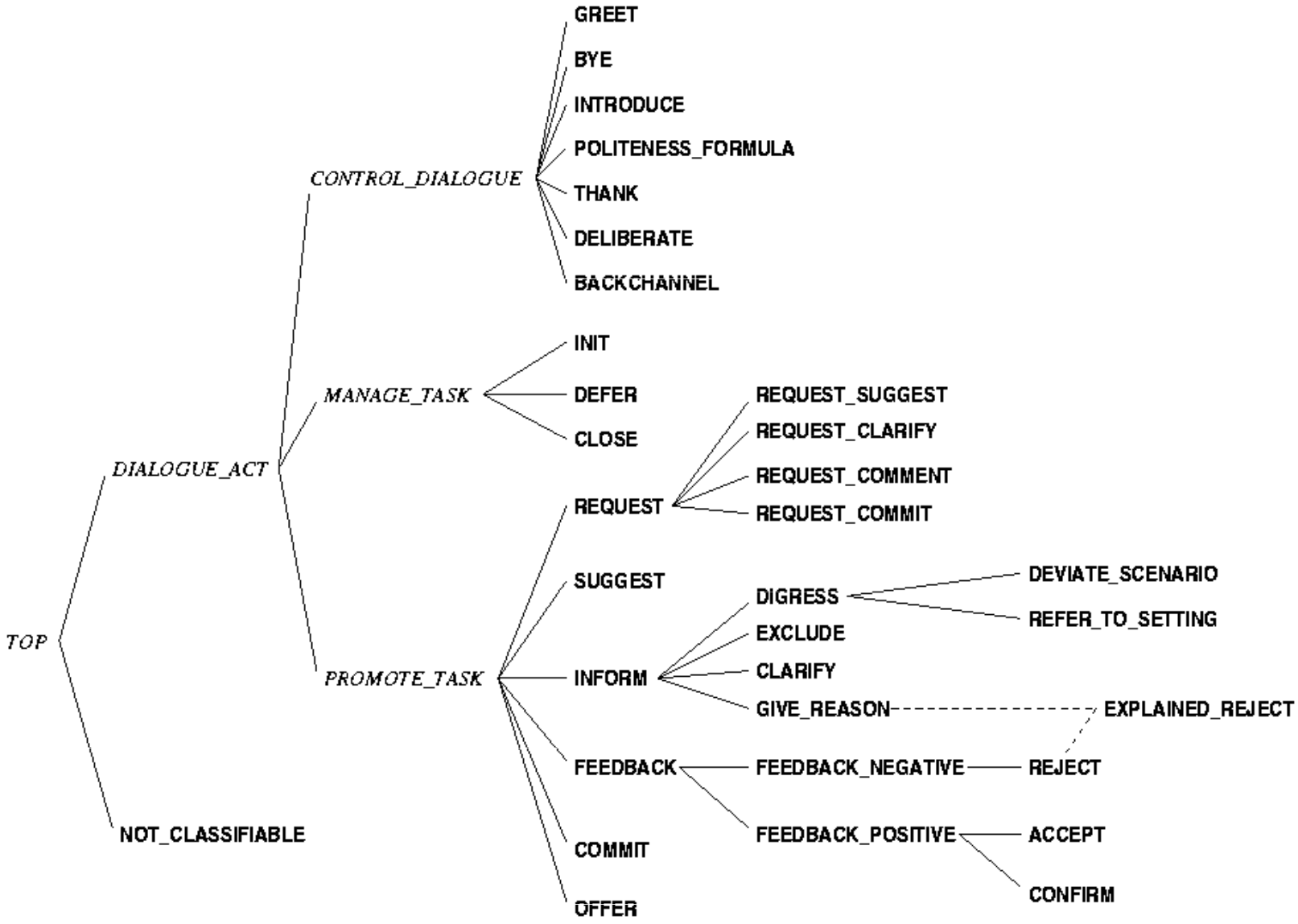
Dialog Acts

- Describe the core intention of an utterance
- 32 acts defined in a hierarchy, 19 used in processing
- 21 CD-ROMs with 1505 dialogs (German, English, Japanese) annotated with dialog acts for training and test purposes
- Computation uses bigram language models

$$D = \underset{D}{\operatorname{argmax}} P(w \mid D) \cdot P(D)$$

- Probabilities estimated from the annotated corpus
- Leave-One-Out test results for approx. 1000 German, English and Japanese dialogs: Recall 72.48 % (27185 of 37505), Precision 69.90 %

Dialog Acts - The Hierarchy



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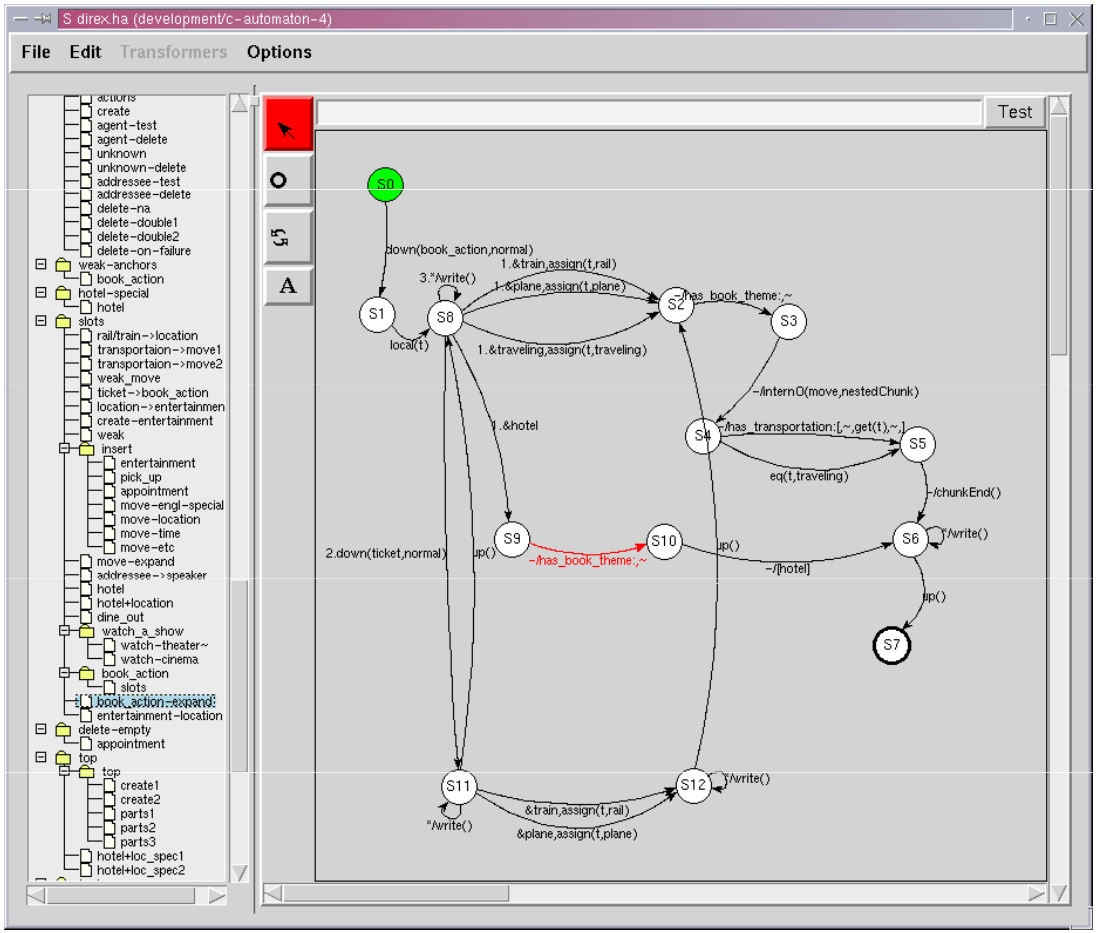
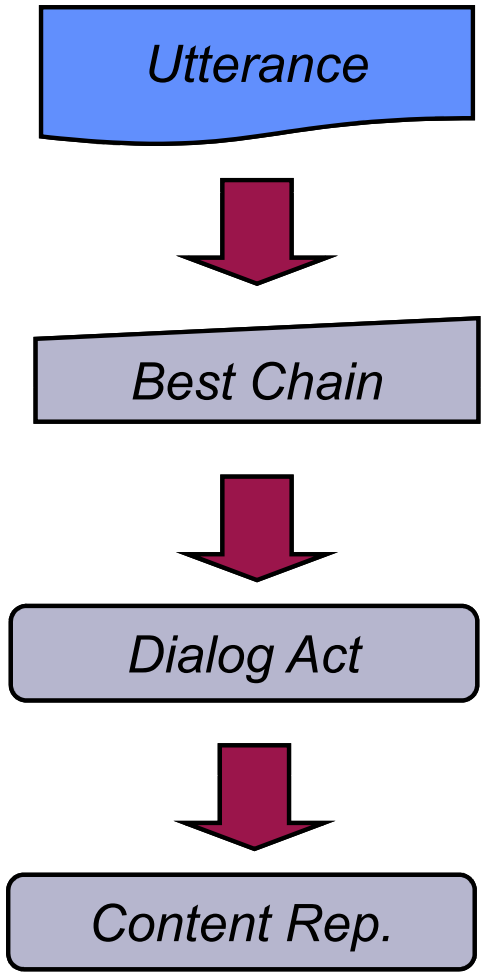
Representation of Information and Extraction

- **Semantic representation language, used also in the dialog and context modules**
- **Extraction using Finite State Transducers**
- **Semi-automatic creation exploiting semantic databases and lexica**
- **Comfortable development platform**



Processing Steps



good so we will leave Hamburg on the first

I would so we were to leave Hamburg on the first

INFORM

has_move:[move,has_source_location:[city,has_name =‘hamburg‘],
has_departure_time:[date,time=[dom:1]].

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Generation

- **Generation templates (>140), depending on dialog act, topic, content**
- **Translated in Finite State Transducers**
- **Examples:**

suggest scheduling $has_date
    g:ich w"urde $* vorschlagen &loc_mode_dat
    e:how about $*

suggest entertainment or($has_location,$has_theme)
    g:wir k"onnten $* gehen &loc_mode_acc
    e:we could go $*

request_suggest
    g:was schlagen Sie vor
    e:what do you suggest
    j:itsu ga yoroshii deshou ka

- **Result for our example:** *also wir fahren ab Hamburg am ersten*

Statistical Translation

- Task:

  Provide approximative correct translations
- Input:

  Prosodically annotated best hypothesis (flat WHG)
- Method:

  Use statistical language and translation models
- Result:

  Translation and a confidence value
- Benefit:

  Approximative correct translation for spontaneous speech
- Responsible:

  RWTH Aachen

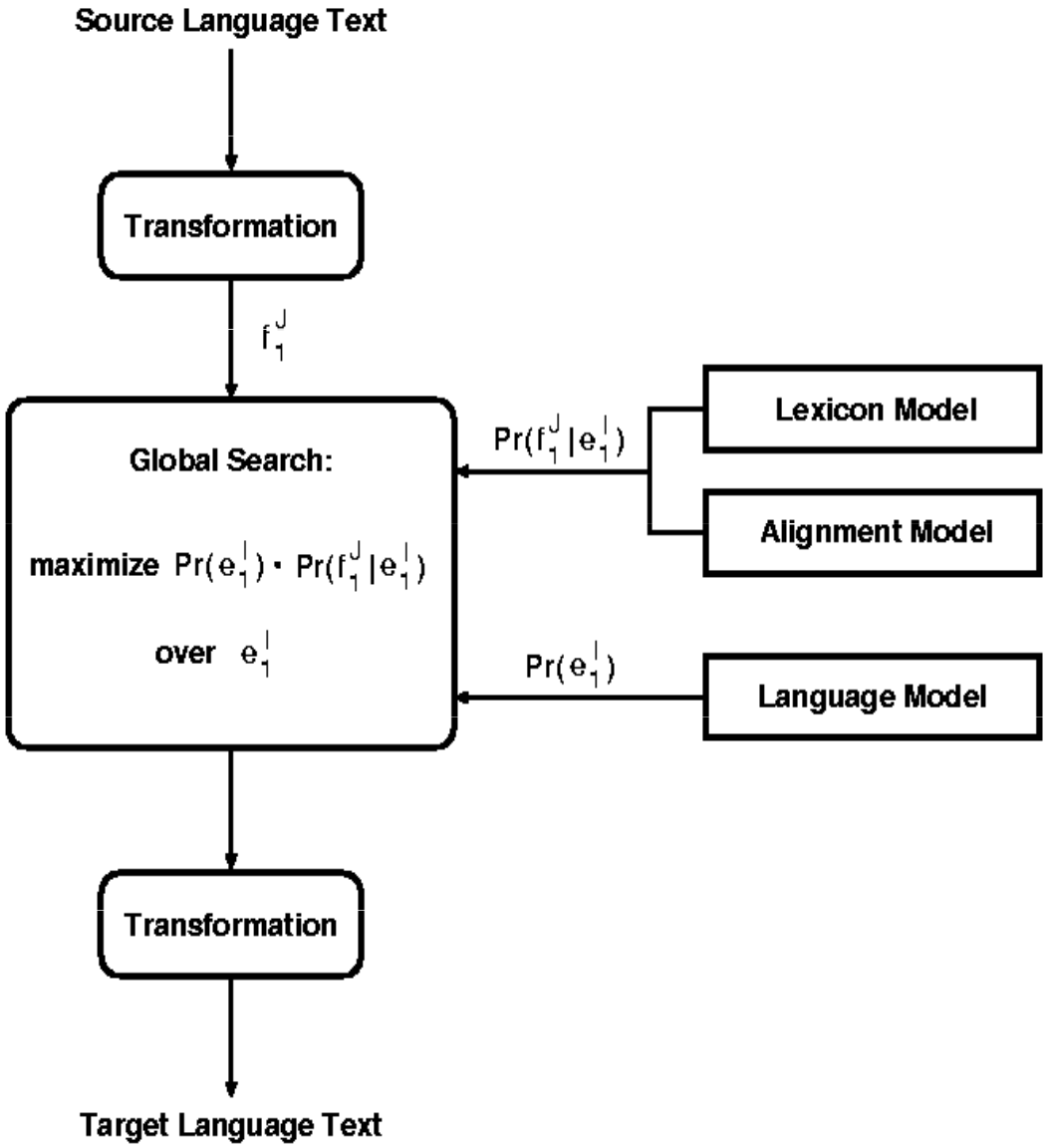
The Statistical Translation Model

- **Task: translate the source string *f* in the most probable target string *e*:**

$$\hat{e}_1^I = \arg\max_{e_1^I} \{p(e_1^I|f_1^J)\}$$

$$= \arg\max_{e_1^I} \{p(e_1^I) \cdot p(f_1^J|e_1^I)\}$$

- **Bayes' rule needs language model of the target language, and lexicon and alignment models**
- **Learned from aligned corpus**

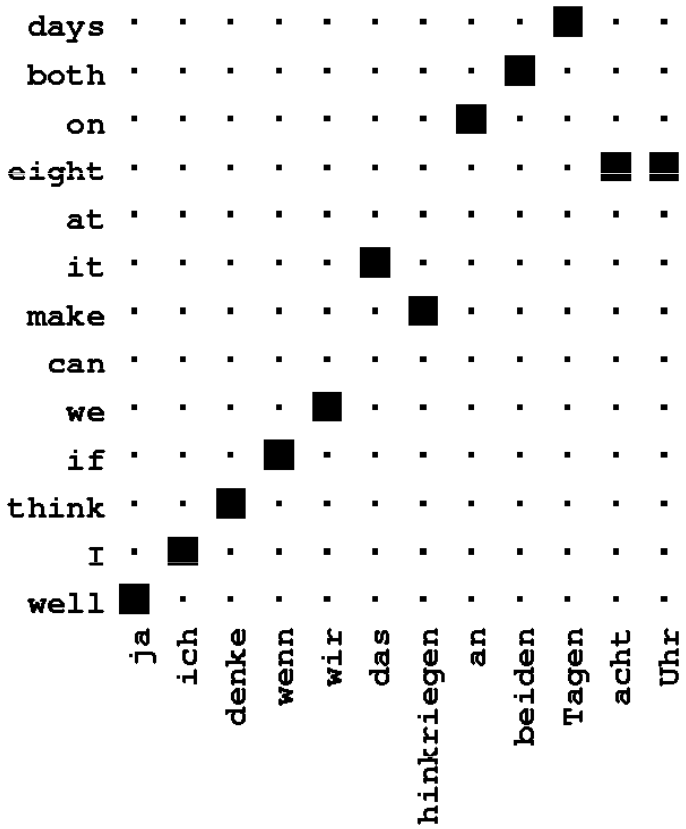


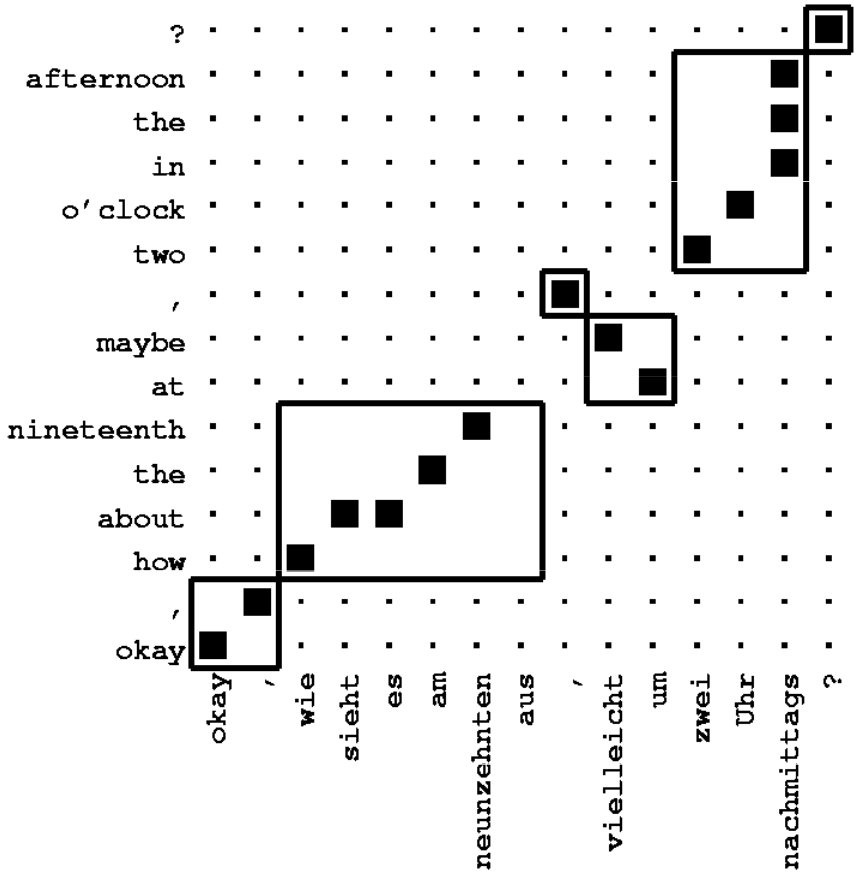
Alignment Templates

- **Find corresponding words in source and target language sentences**
- **Difficult for language pairs with different word order**
- **Solution: alignment templates**
  - based on word classes (sparse data problem: approx. 40% of the words in the training corpus are singletons)
  - first step: statistically learn alignment of words for each translation direction
  - second step: combine the alignments of both directions
  - third step: statistically learn alignment of “phrases”, i.e. word sequences

Alignment

Word-to-Word vs. Alignment Templates





Deep Translation

- Task:

  Provide high quality translations
- Input:

  Prosodically annotated WHG and contextual information
- Method:

  Use syntactic and semantic approaches to analysis, transfer, and generation
- Result:

  Translation containing content information, suited for high quality speech synthesis
- Benefit:

  Delivers the highest quality, but is sensitive to recognition errors and spontaneous speech phenomena
- Responsible:

  Siemens AG, DFKI Saarbrücken, Universität Tübingen, Universität des Saarlandes, Universität Stuttgart, TU Berlin, CSLI Stanford

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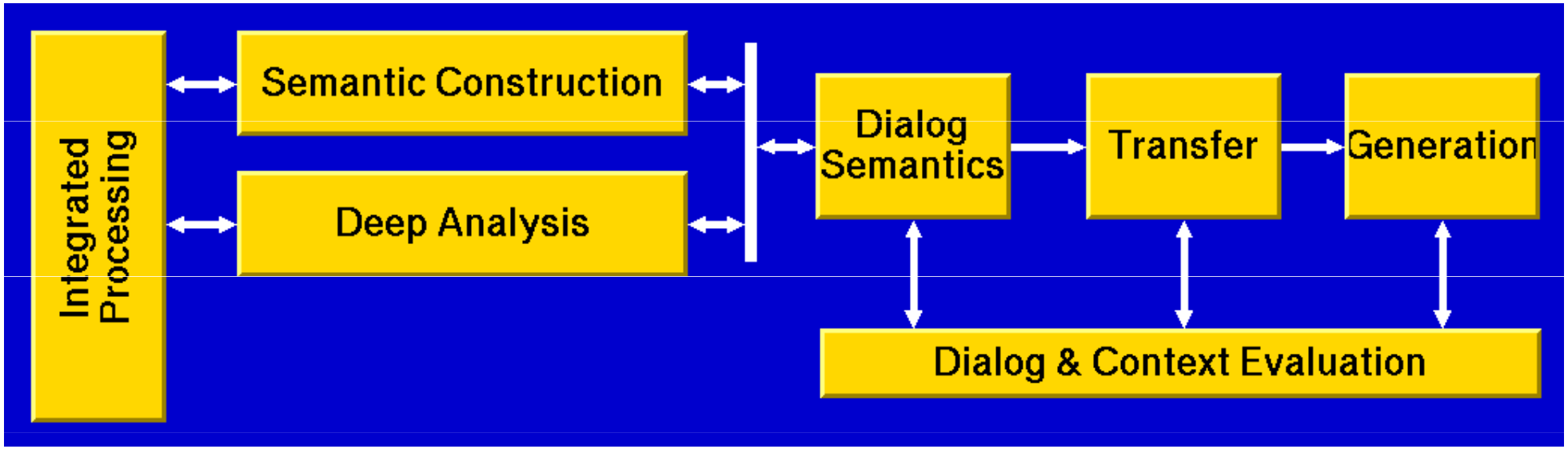
Modules Involved



- Integrated processing comprises
  - search through the WHG
  - statistic parser
  - chunk parser
- Semantic Construction provides VITs from statistic and chunk parser output
- Deep Analysis: HPSG Parser
- Dialog Semantics:combination of parsing results, and semantic resolution
- Transfer: VIT to VIT transfer
- Generation: TAG generation from VITs
- Dialog+Context: provides contextual information

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The Multi-Parser Approach

- **Verbmobil uses three different syntactic parsers:**
  an HPSG parser, a chunk parser, and a probabilistic LR parser.

- **Every parser implements another level of parsing accuracy, depth of syntactic analysis, and robustness of the analyzing process.**

  - Chunk parser: Most robust but least accurate analysis
  - HPSG parser: Most accurate by least robust analysis
  - Probabilistic parser: Level of accuracy and robustness between HPSG and chunk parser

Integrated Processing

- **Gets WHGs for the English, German, or Japanese speech input and dispatches WHG information to the three parsers**
- **Provides an A* search algorithm that allows any connected parser to find the best scored path using**
  - acoustic score of the speech recognizer
  - Verbmobil trigram language model
- **Parsers analyze the same utterance simultaneously**

VIT: Verbmobil Interface Term

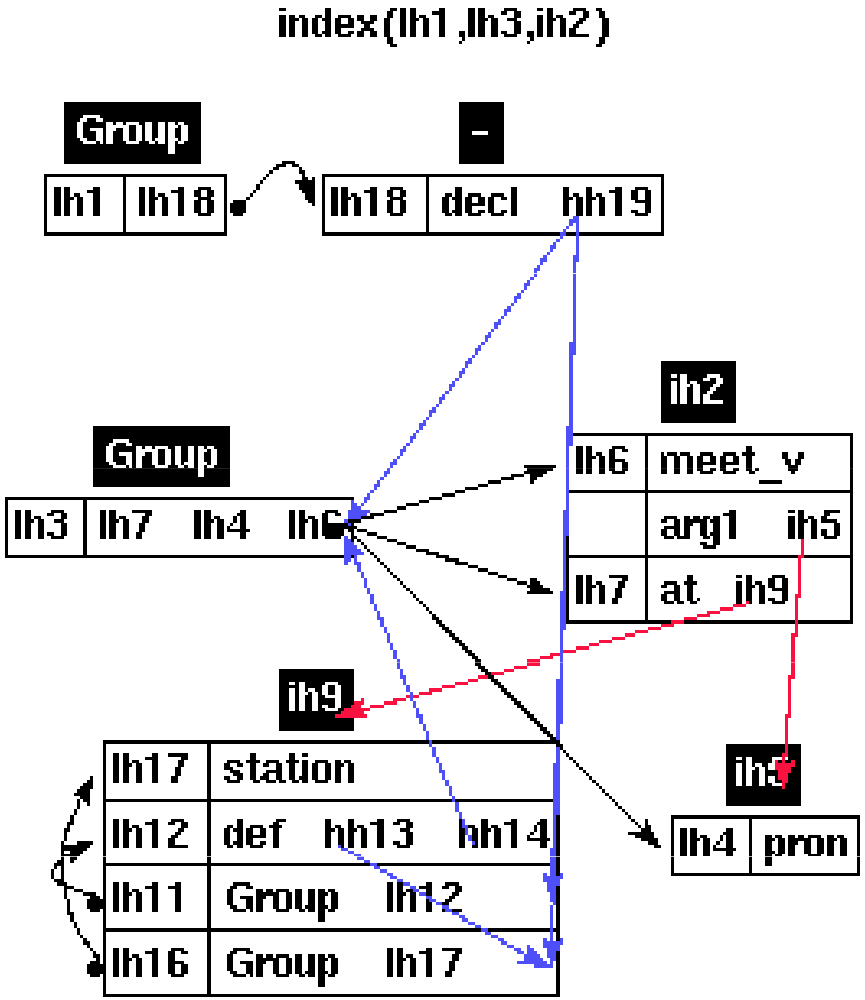
- Common syntactic-semantic interface
- Contains all linguistic information relevant for translation
- Record-like data structure: variable-free lists of non-recursive terms
- ``Flat'' set representations: semantic, scopal, sortal, morpho-syntactic, prosodic, and discourse information
- Labels relate different kinds of information
- Abstract Data Type implements construction, access, update, check, print, etc. facilities

VIT: Verbmobil Interface Term

```
vit(vitID(sid(...),                                  %Segment ID
    []),                                             %WHG-String
    index(l250,l234,i72),                            %Index
    [start_v(l248,i72),                              %Conditions
     arg1(l248,i72,i75),
     nop(l240,h85),
     quest(l249,h84),
     time(l238,i73),
     abstr_vacation(l247,i75),
     pron(l242,i74),
     poss(l244,i75,i74),
     temp_loc(l239,i72,i73),
     def(l245,i75,h87,h86),
     whq(l235,i73,h83,h82)],
    [in_g(l235,l237), ...                            %Constraints
     leq(l234,h85), ...],
    [s_class(l240,mp), ...],                         %Sorts
    [ana_ante(i74,[i75,i69,i67,i66]),                %Discourse
     prontype(i74,third,std), ...],
    [gend(i75,masc), num(i75,sg)],                   %Syntax
    [ta_mood(i72,ind), ...],                         %Tense and Aspect
    [...])                                           %Prosody
```

When do your vacations begin?

VIT: Verbmobil Interface Term



We meet at the station.

HPSG Processing

- Task:

  Thorough syntactic analysis

- Input:

  Word chains from integrated processing

- Method:

  Apply HPSG analysis

- Result:

  Source language VITs

- Benefit:

  Delivers the highest quality, but is sensitive to recognition errors and spontaneous speech phenomena

- Responsible:

  DFKI Saarbrücken, CSLI Stanford

Head Driven Phrase Structure Grammar

- Well known advanced grammar theory in linguistics
- Based on the concept of a *sign* as integrated information structure for all types of linguistic information
- Inherently multilingual by distinguishing universal principles from language specific aspects
- Typed feature structures with inheritance
- Small number of rules, due to general principles
- Independent of specific processing strategies, usable for analysis and generation

HPSG Basic Principles

- *Lexicalism*: Words carry all the important information about what they can be combined with, thus allowing to deal with regular and idiosyncratic properties in a uniform way
- *Heads*: Phrases contain a head which determines their combinatory potential, e.g. verbs as heads determine what complements must be present, and what modifiers they can combine with
- *Principles*: Few language independent general projection principles stating, e.g., how to combine a head with complements and modifiers
- *Unification*: Monotonically combines constraints from different sources

HPSG Parsing in Verbmobil

- **active chart parser allowing bidirectional and island parsing on word hypotheses graphs or strings**
- **fast processing by**
  - eliminating disjunctions, enabling fast conjunctive unification
  - precompiling type unifiability, avoiding runtime computations
  - quick checks on mostly relevant features, avoiding full unification
  - quick checks on possibly discontinuous constituents, e.g. separable verb prefixes in German, reducing the chart size
  - precompiling rule filters on possible rule sequences
  - scoring rule applications
- **anytime behavior**
- **robust: best partial analyses even for ungrammatical input**

Statistical Parser

- Task:

  Robust probabilistic parsing

- Input:

  n-best hypotheses

- Method:

  LR-Parser trained on Verbmobil´s tree-bank

- Result:

  Syntactic tree representation of the input sentence

- Benefit:

  Increasing robustness in Verbmobil´s multi-engine parser strategy

- Responsible:

  Siemens AG

Statistical Parser – Approach

- (Non-probabilistic) LR-parsing worked quite well for parsing speech in Verbmobil's first phase.
- LR-parsing is well known to be able to parse huge amounts of input very efficiently.
- Probabilistic chart parsing of spontaneous speech input had some problems i.e. the combinatorical explosion of edges in the chart on a word graph

$\Rightarrow$ try probabilistic LR-Parser

Statistical Parser – Training and Transformations

- **Training process: derivation of an LR table and the estimation of unknown probabilistic parameters from the Verbmobil tree bank**
  - Find the set of all context free rules (G) contained in the tree bank.
  - Construct an LR table from G using well known standard
  - Problems: sparse data, different annotation styles
    ⇒ **eliminate rules that do occur less than N times**
- **Transformations:**
  - Needed after parsing to correct errors of the probabilistic context free parser
  - Rules are learned automatically from the training corpus

Chunk Parser

- Task:

  Robust and efficient partial parsing, even on ill-formed input
- Input:

  N-best hypotheses
- Method:

  Cascaded Finite State Transducers
- Result:

  Syntactic tree representation of the input sentence
- Benefit:

  Increasing robustness in Verbmobils multi-engine parser strategy
- Responsible:

  Universität Tübingen

Parsing Based on *Chunks*

1st Step: Chunk Parsing using Cascaded Finite State Transducers

"Chunks are non-recursive cores of 'major' phrases, i.e. NP, VP, PP, …"

2nd Step:

Building a syntactic tree out of the parsing results

Benefit: **Robust and efficient parsing**

But: **Partial parsing: Often no spanning analysis**

Example for Chunks

“Ich habe bei meinem letzten Besuch in Hannover so eine nette Kneipe entdeckt”

Chunks:

- **[NX Ich] [VX habe] [PX bei [NX meinem letzten Besuch]] in [NX Hannover] [PX so [NX eine nette Kneipe]] [VX entdeckt].**

where

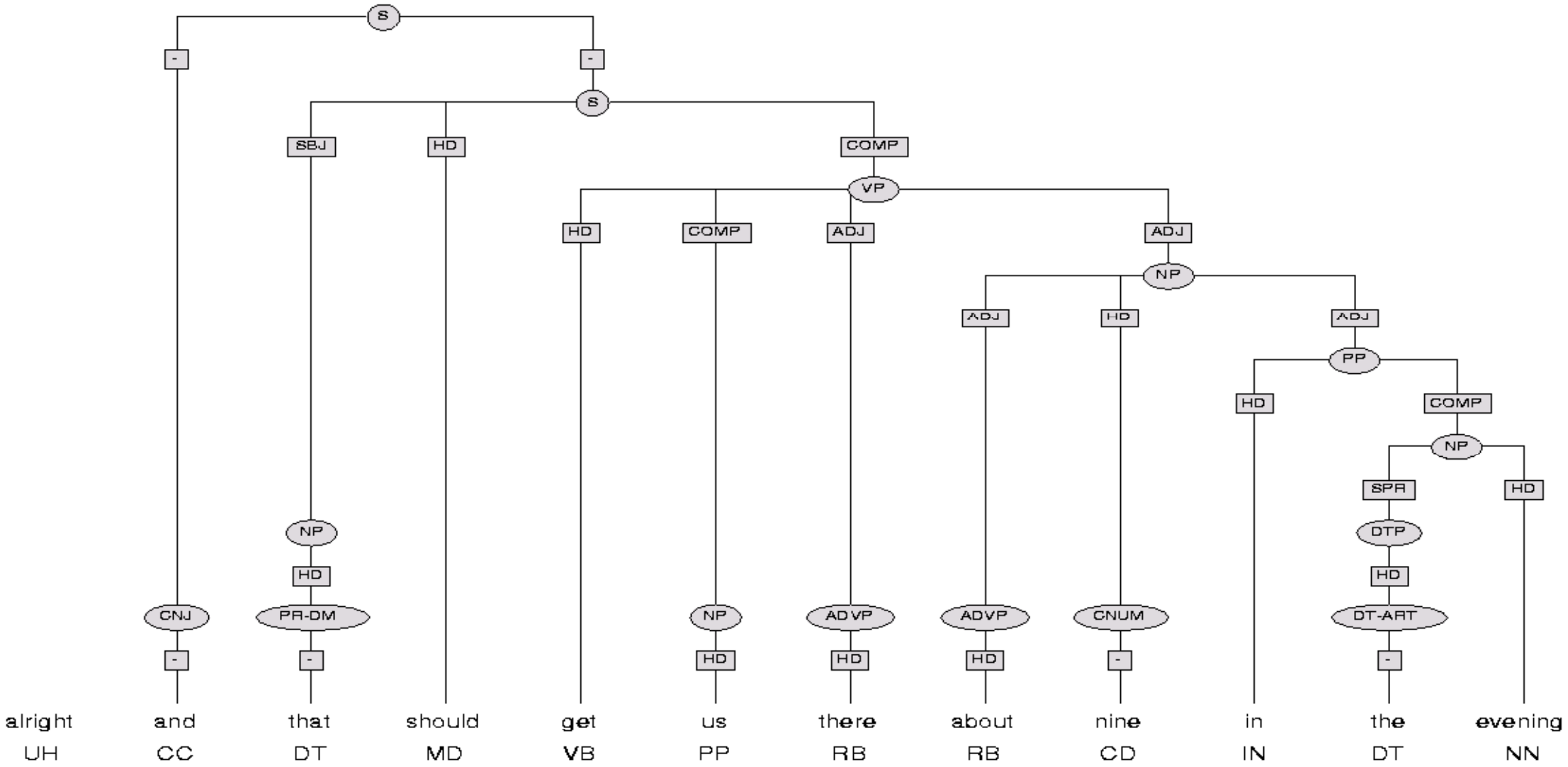
- **[NX]: Extends from the beginning to the head of a NP**
- **[VX]: Includes all modals, auxiliary verbs and medial adverbs, but ends at the head verb or predicate adjective**
- **[PX]: Extends to the end of an [NX]**

Tree-Building Tasks

- Determine the chunk position inside the syntactic tree
- Complete the internal chunk structure
- Determine functional categories and topological fields
- Rearrange chunks to obtain a complete syntactic tree

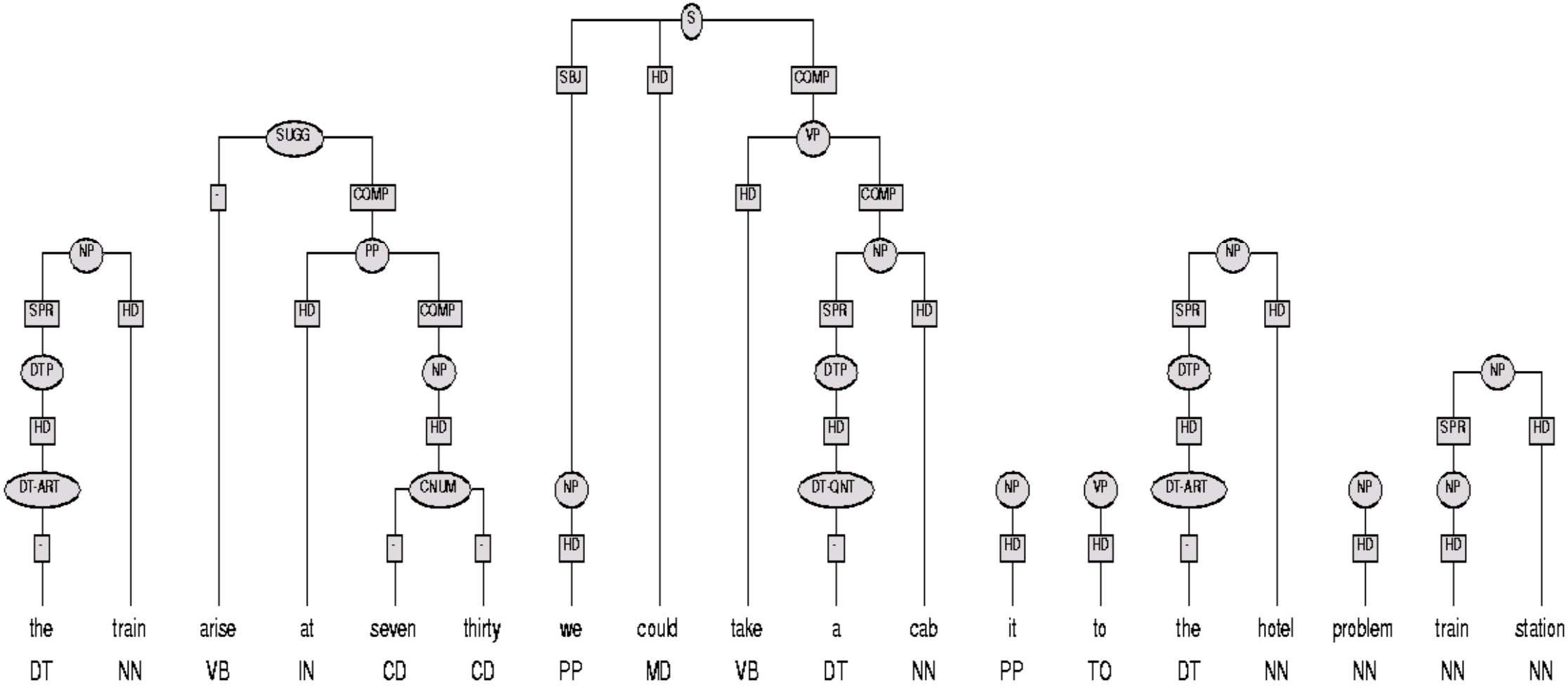
The Result is a Syntactic Tree

"Alright, and that should get us there about nine in the evening."



... but analysis is not always spanning

"The train arise at seven thirty. We could take a cab it to the hotel problem train station."



Semantic Construction

- Task:

  Convert and extend syntax trees to VITs
- Input:

  Syntax tree from statistical and chunk parsers
- Method:

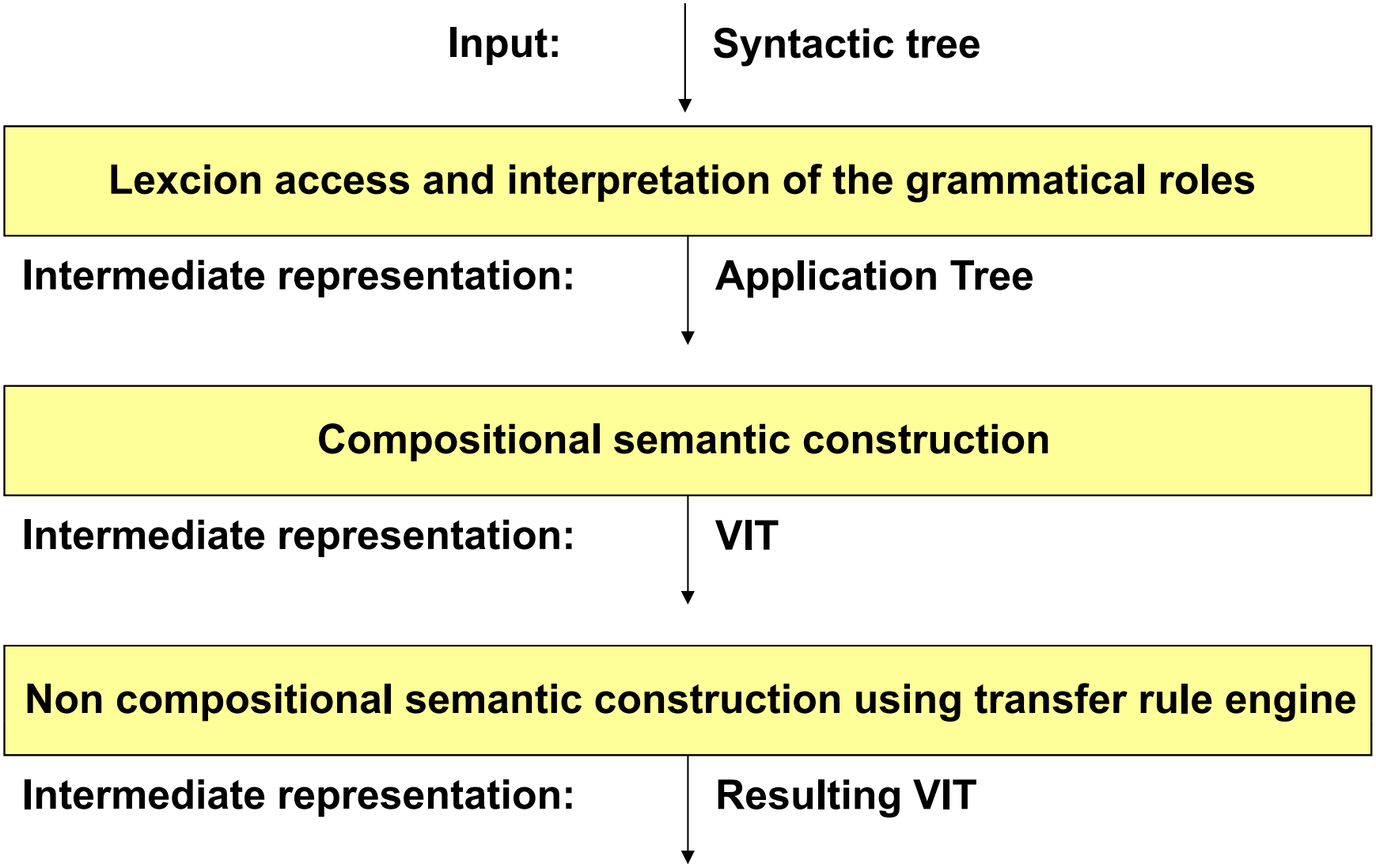
  Compositional construction using semantic lexicon
- Result:

  VITs
- Benefit:

  Providing results of shallow parser to the deep analysis track
- Responsible:

  Universität Stuttgart (IMS)

Schematic Processing



Dialog Semantics

- Task:

  Combining results from various parsers, reinterpret and correct VITs, and resolve non-local ambiguities
- Input:

  VITs from different parsers
- Method:

  VIT models and rule based approaches
- Result:

  VIT ready for transfer
- Benefit:

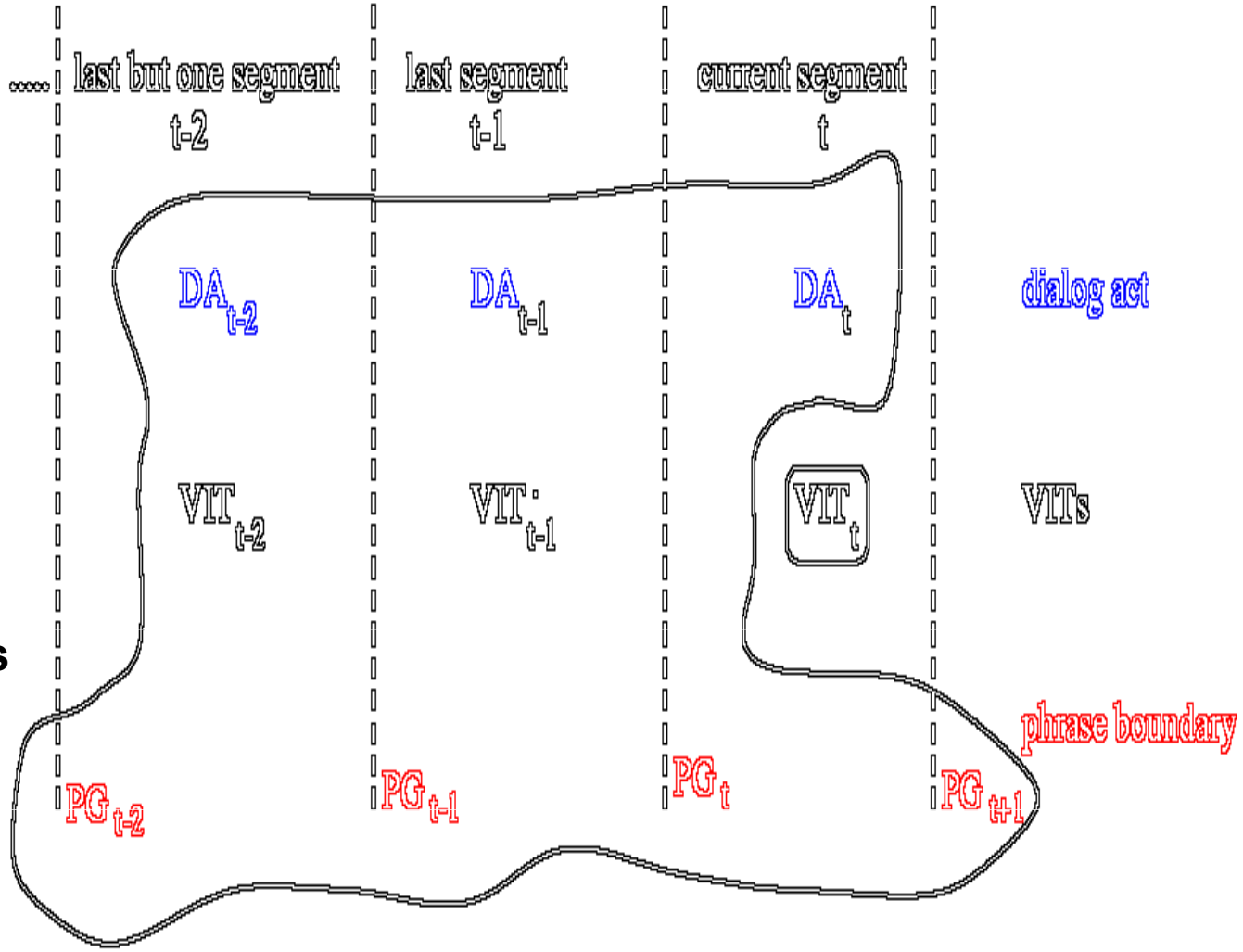
  Enhances robustness of deep analysis and provides vital information for transfer
- Responsible:
  Universität des Saarlandes, Saarbrücken

Combining Analyses from Various Parsers

- **Parsers deliver VITs for segments of a turn**
- **May be spanning analyses or just partial fragments**
- **Combination necessary, both analyses of one parsers, but also analyses from various parsers**
- **Combination criteria**
  - HPSG is better than statistical parsers is better than chunk parser
  - Integrated results are better than fragments
  - Longer results are better than short ones

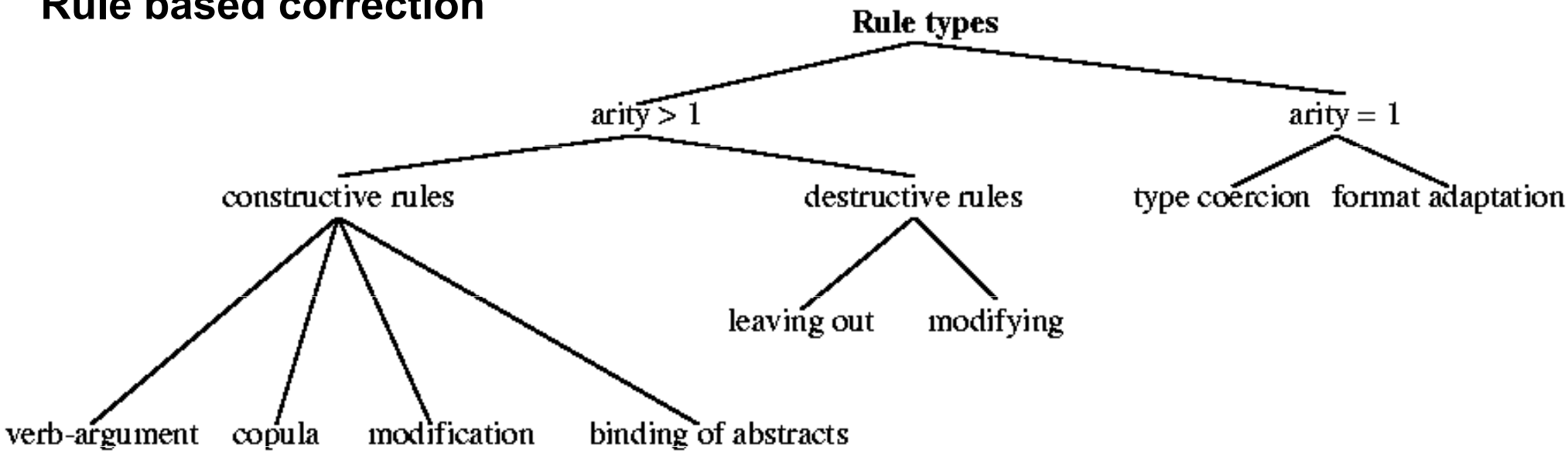
Stochastic Choice of Spanning Results

- Parser internal scores not normalized ⇒ external scoring necessary
- Statistical model based on VIT content and dialog act (Tetragram language models)
- Search through Vit Hypotheses Graph VHG comparable to search through WHG

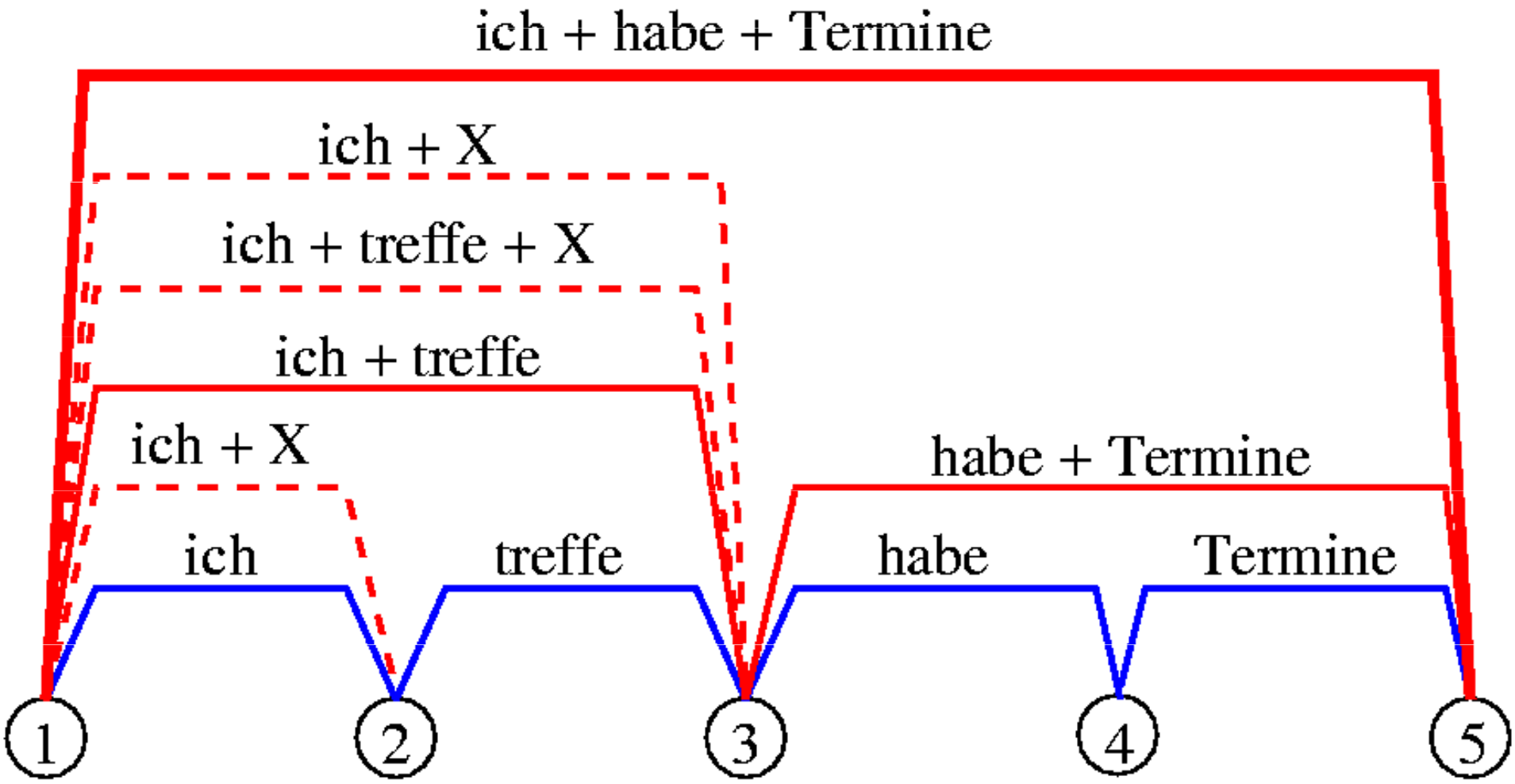


Robust Semantic Processing

- **Partial results don't necessarily fit together**
  - phenomena of spontaneous speech
  - recognition errors
  - parsing errors
- **Rule based correction**



Bridging Mechanism for False Starts



Resolving Non-Local Ambiguities

- **Based on prosody and dialog act information**
- **Ambiguities processed:**
  - Verb disambiguation:
    Wir gehen in's Theater (We go to the theater)
    Montag geht bei mir nicht (Monday does not suit me)
  - Sentence mood
    Wir gehen in's Theater **!** **vs.** *Wir gehen in's Theater***?**
  - **Adverb disambiguation**
    Wir gehen eher in's Theater (We go to the theater earlier)
    Montag geht bei mir eher nicht (Monday does not really suit me)
  - **Anaphora and ellipsis resolution**
  - **Japanese: Definiteness, topic phrases, zero anaphora**

Semantic Based Transfer

- Task:

  Transfer VITs from the source to the target language
- Input:

  VITs
- Method:

  Rule based transfer
- Result:

  VITs for generation
- Benefit:

  Translate VITs inside the deep translation path
- Responsible:

  Universität Stuttgart (IMS)

The Transfer Approach: Rule Based Transfer

- VITs are mapped onto VITs: Transfer is a VIT rewriting system
- Rule based, context conditions restrict application
- Transfer rules remove matching source language expressions from the VIT
- Efficient implementation
- Examples:
  - Simple Rules: `adelig(L,I) -> noble(L,I)`
  - Simple Templates: `@mod(adelig, noble, L, I)`
  - Selectional restrictions:

```
#sort_check(I,human) -> true
@mod(gross,tall,_,I)
#sort_check(I,location) -> true
@mod(gross,large,_,I)
```

Advanced Features of Transfer

- **Structural changes:**
  - Adjective to PP: tagsüber -> during the day
  - Insertion: übernachte -> spend the night
  - …
- **Disambiguation:**

type of ambiguity	kinds of knowledge needed for disambiguation	modules that contribute to the resolution
lexical	syntactic, semantic, contrastive, domain, prosodic	parsers, semantic construction, discourse semantics, transfer, context
structural	syntactic, semantic, domain	parsers, semantic construction, transfer
anaphora and ellipsis	syntactic, semantic, domain	discourse semantics, context
semantic focus and operator scope	prosodic, syntactic, semantic, contrastive, domain	discourse semantics transfer

Performance of Transfer

- Rules are compiled and packed
- 18088 rules German ⇔ English
- 4694 rules German ⇔ Japanese
- Mean runtime per sentence: 80 msec (Sun Ultra II, 300 MHz)

Context Evaluation

- Task:

  Resolving ambiguities in the dialog context during semantic transfer
- Input:

  Requests from transfer
- Method:

  Using world knowledge and rules
- Result:

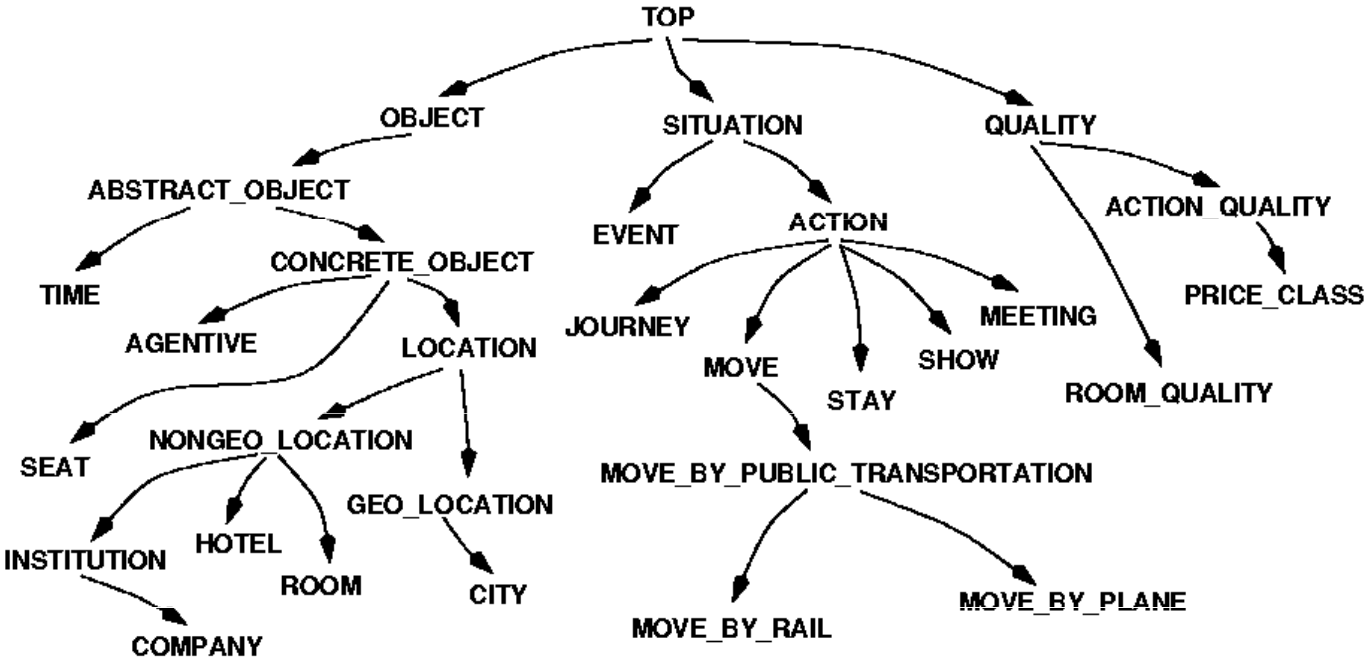
  disambiguated transfer requests
- Benefit:

  Higher quality of transfer results
- Responsible:

  Technical University (TU) Berlin

Context Evaluation - Tasks and Methods

- Supports semantic transfers and processes VITs
- Gets information from dialog module from shallow tracks
- Extends disambiguation of the dialog semantic module and uses ontological information



Using World Knowledge for Transfer

Example: Platz ➔ room / table / seat

1. Nehmen wir dieses Hotel, ja. ➔ Let us take this hotel.
   Ich reserviere einen **Platz**. ➔ I will reserve a **room**.

2. Machen wir das Abendessen dort. ➔ Let us have dinner there.
   Ich reserviere einen **Platz**. ➔ I will reserve a **table**.

3. Gehen wir ins Theater. ➔ Let us go to the theater.
   Ich möchte **Plätze** reservieren. ➔ I would like to reserve **seats**.

Dialog Processing

- Task:

  Provides dialog context for all tracks and computes main information for dialog summaries
- Input:

  Data from a lot of modules
- Method:

  Frame-like topic structuring and rules
- Result:

  context information and dialog summaries and minutes
- Benefit:

  Verbmobil knows what happens throughout the dialog and can present it
- Responsible:
  DFKI, Saarbrücken

Dialog Processing

- **Dialog Memory:**
  - Stores information from each track
  - Only dialog act based and semantic transfer provide abstract representations:

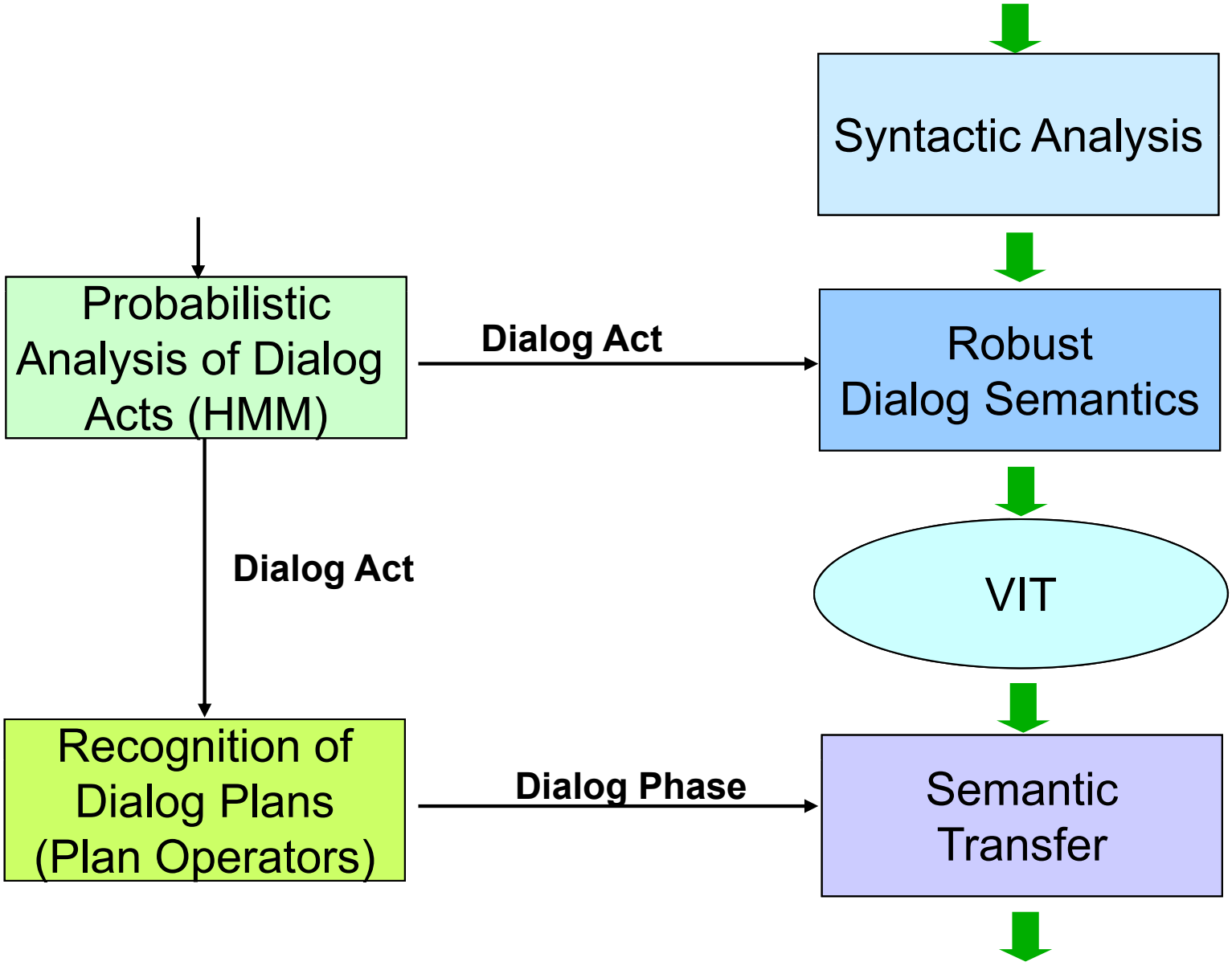
    Discourse Representation Language DRL:

    I would so we were to leave Hamburg on the first

    ```
    [INFORM,has_move:[move,has_source_location:[city,has_name='hamburg’,
                                    has_departure_time:[date,time='day:1’
    ```

- **Discourse Interpretation:**
  - Groups information into topics
  - Completes information
  - Keeps tracks of negotiation structure

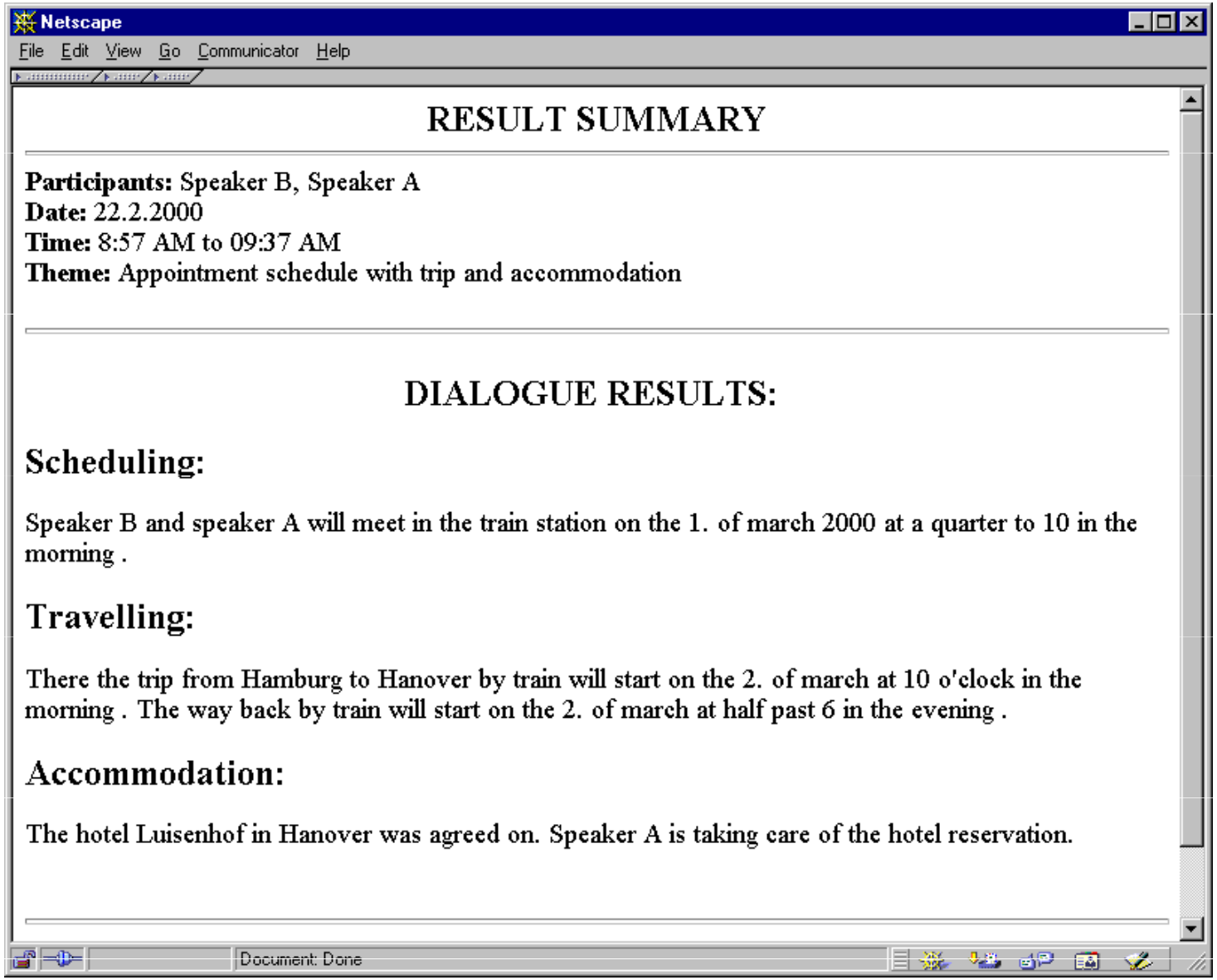
Dialog Information in Semantic Transfer



Collaboration for a New Functionality: Result Summaries

- **Provide the users with a summary of the topics that were agreed**
- **Two benefits**
  - have a piece of information to use in calendars etc.
  - control the translation
- **Approach: exploit already existing modules for**
  - content extraction
  - dialog interpretation
  - planning the summary
  - generation
  - transfer

Result Summary



Generation

- Task:

  Robustly generate the output of the semantic transfer in German, English, or Japanese
- Input:

  VITs from transfer
- Method:

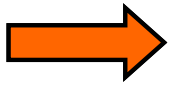
  Constraint system for micro-planning, TAG grammar (reusing HPSG grammars) for syntactic realization
- Result:

  Strings, enriched with content-to-speech (CTS) information to support synthesis
- Benefit:

  Output from the semantic transfer track
- Responsible:
  DFKI, Saarbrücken

Architecture

VIT (Verbmobil Interface Term)



Robustness Preprocessing	***•Repairing structural problems •Heuristics for generation gap***

Microplanning Module	*•Selecting planning rules •Lexical choice constraints*
Syntactic Realization Module	*•Selecting LTAG trees •Tree combination*
Surface Realization Module	*•Inflection •Synthesis Annotation*

Annotated String

Preprocessing for Robustness

Why *pre*-pocessing:

- **Check and repair inconsistencies as early as possible**
- **Keep robustness and standard modules separate**
- **Alternative: relax constraints**

Preprocessing for robustness means:

- **Executing a set of solution submodules in sequence**
- **For each problem found, the preprocessor lowers a *confidence value* for the generation output which measures the reliability of our result**

How much robustness?

- **PRO:**

  In a dialog system, a poor translation might still be *better than none* at all,

- **CON:**

  one of the shallow modules can be selected when deep processing fails,

  so respect the *inherent limitations of robustness*.

  ⇒ Generation knows its limits and sometimes decides not to produce a string

- **Selection module: uses training corpus and confidence values to select from the different translation paths**

Microplanning: Create Syntactic Building Blocks

Method: Mapping of dependency structures

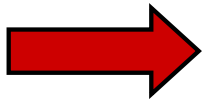
Example: Time Expressions

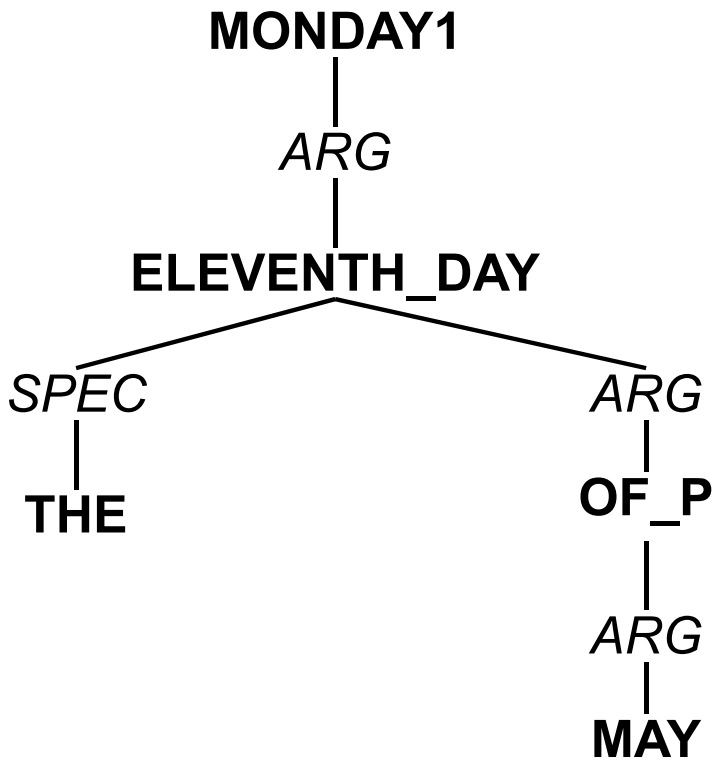
DEF (L,I,G,H)

DOWF (L1,I,mo)

ORD (L2,I,11)

MOFY (L3,I,may)





Semantical dependency: VIT

Syntactical dependency: TAG

Multilingual Generation for Translation in Speech-to-Speech Dialogues and its Realization in Verbmobil

Tilman Becker . Anne Kilger . Peter Poller . Patrice Lopez

DFKI GmbH

Stuhlsatzenhausweg 3

66123 Saarbrücken

Tilman.Becker@dfki.de

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VM-GECO:
VerbMobil's GEneration COmponents

- Multilingual Generation: German, English, Japanese
- Language-independent kernel algorithms
- Language-specific knowlegde sources
- Extended "standard" pipeline architecture:
  - Microplanning
  - Syntactic Realization
  - Surface Realization

Annotated String

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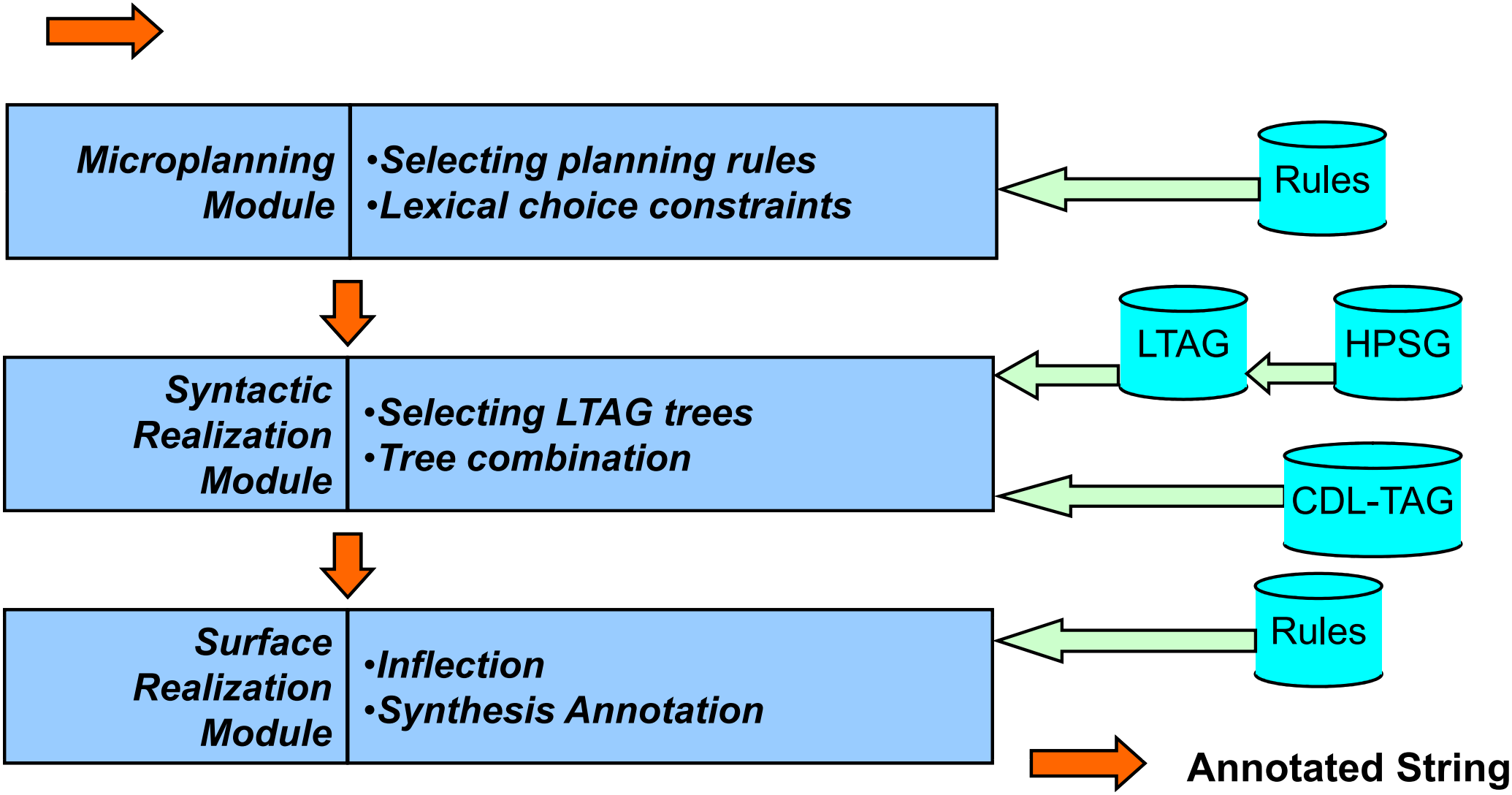
Standard Architecture

VIT (Verbmobil Interface Term)



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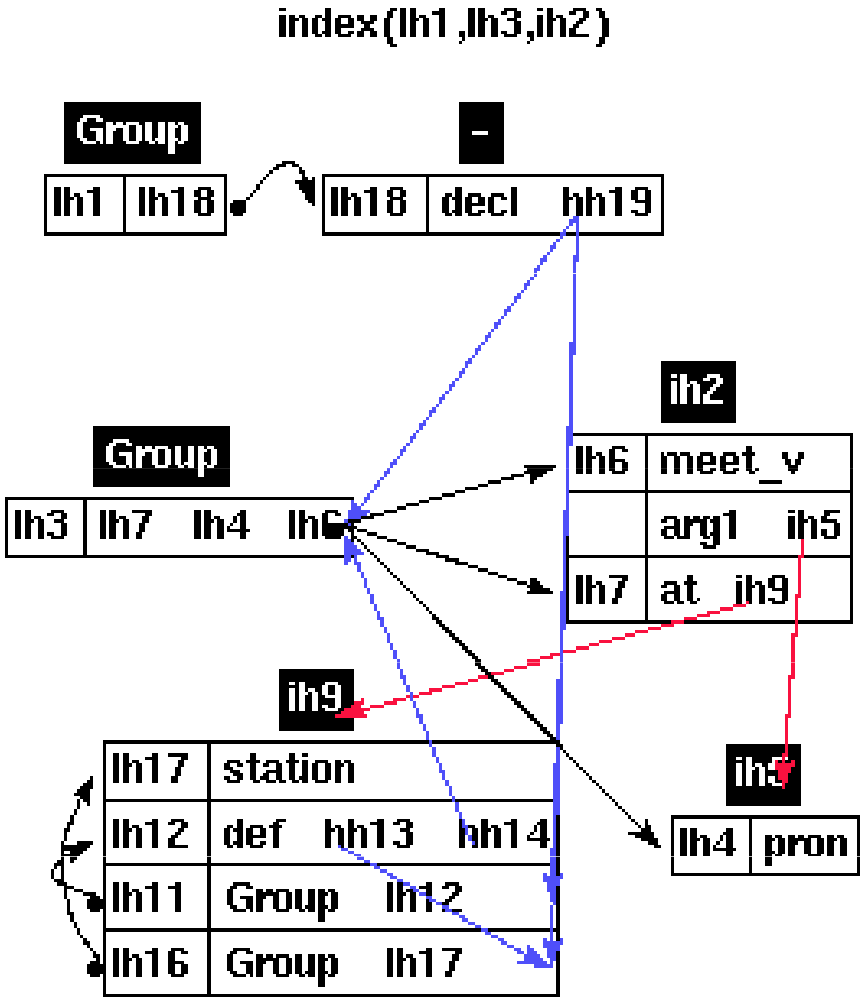
VIT: Verbmobil Interface Term

```
vit(vitID(sid(...),                                  %Segment ID
    []),                                             %WHG-String
    index(l250,l234,i72),                            %Index
    [start_v(l248,i72),                              %Conditions
     arg1(l248,i72,i75),
     nop(l240,h85),
     quest(l249,h84),
     time(l238,i73),
     abstr_vacation(l247,i75),
     pron(l242,i74),
     poss(l244,i75,i74),
     temp_loc(l239,i72,i73),
     def(l245,i75,h87,h86),
     whq(l235,i73,h83,h82)],
    [in_g(l235,l237), ...                            %Constraints
     leq(l234,h85), ...],
    [s_class(l240,mp), ...],                         %Sorts
    [ana_ante(i74,[i75,i69,i67,i66]),                %Discourse
     prontype(i74,third,std), ...],
    [gend(i75,masc), num(i75,sg)],                   %Syntax
    [ta_mood(i72,ind), ...],                         %Tense and Aspect
    [...])                                           %Prosody
```

When do your vacations begin?

VIT: Verbmobil Interface Term



We meet at the station.

Microplanning: deriving a sentence plan

- Microplanning tasks:
- determine type of utterance
- determine syntactic structure
- execute word choice

- Microplanning rules map parts of VIT input to partial dependency structures

- Implemented as constraint solving problem
- Approx. 7,200 microplanning rules (German)

Microplanning: deriving a sentence plan

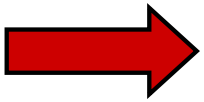
- **An example:** *"the eleventh of May"*

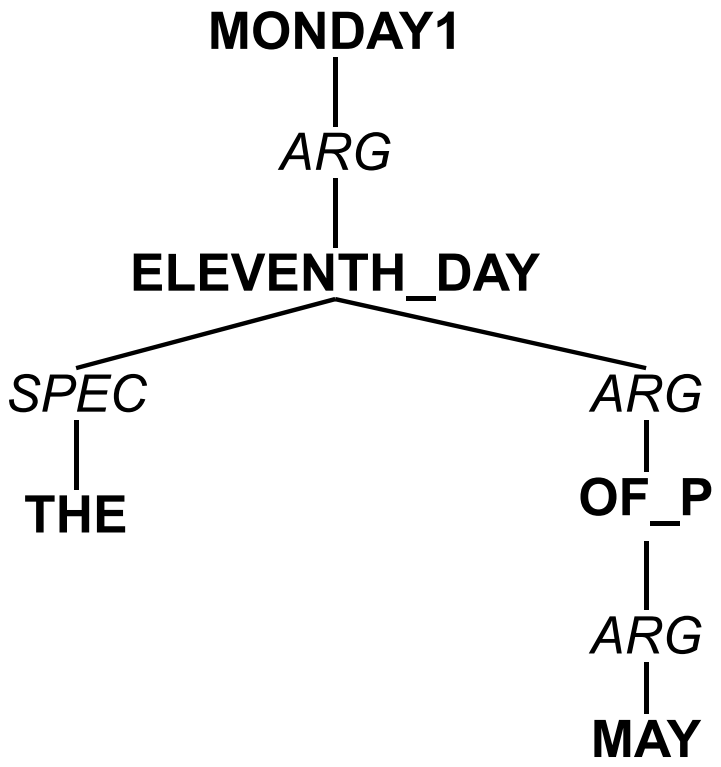
DEF (L,I,G,H)

DOWF (L1,I,mo)

ORD (L2,I,11)

MOFY (L3,I,may)





Semantic dependency: VIT

Syntactic dependency: TAG

Syntactic Realization

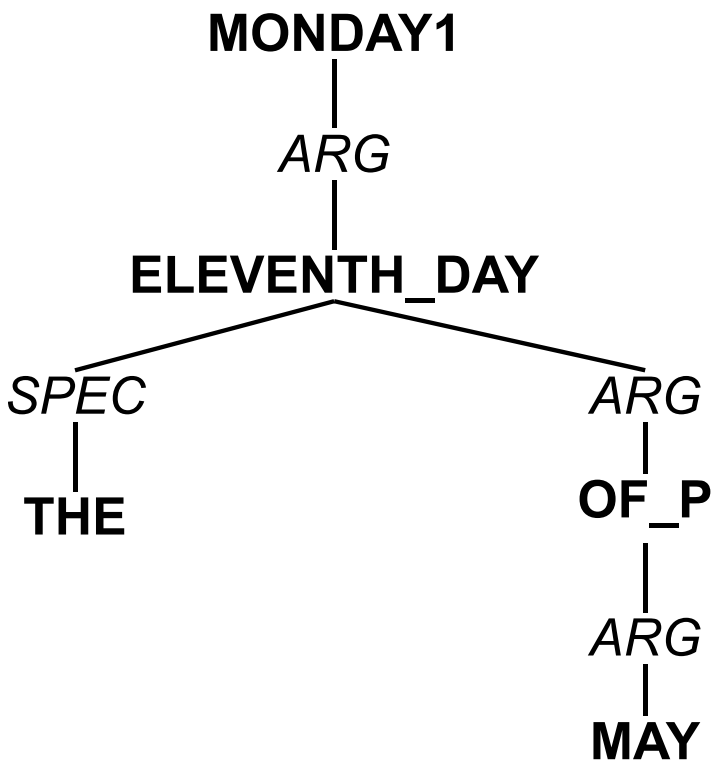
- **Tasks of syntactic realization:**
- **selecting lexicalized (TAG) trees**
- **constructing a phrase structure tree**
- **provide all information for surface realization:**
  - inflection and annotation for CTS (content to speech) synthesis

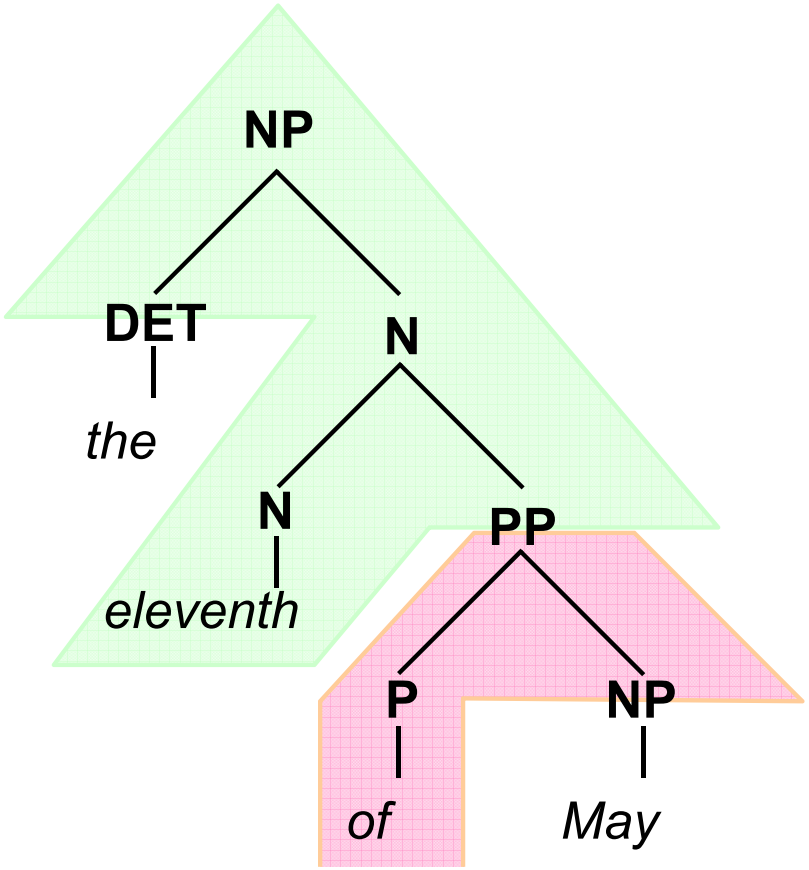
- **Based on FB-LTAG:**

  Feature-Based Lexicalized Tree Adjoining Grammars
- **Compiled from HPSG grammars**

Syntactic Realization:

- **An example:** *"the eleventh of May"*





Syntactic dependency:

TAG derivation tree

Syntactic phrase structure:

TAG derived tree

HPSG to TAG Compilation

- **HPSG: context-free rules (schemas)**
- **TAG: extended local lexical structures (trees)**

- **Off-line compilation computes all projections from lexical types**
- **Generates approx. 2,300 TAG trees from 250 lexical types**
  - Reuse existing Resources:
    - Spontaneous speech, syntactic/lexical coverage of Verbmobil domain
  - Speed vs. space
  - TAG captures dependencies
  - HPSG include syntax-semantics interface, vast body of linguistic work

Problems for generation

- **Technical problems**
  - should be eliminated
  - hard to eliminate in a large-scale system
  - better to be robust
- **Task-inherent problems**
  - Spontaneous speech input
  - Insufficiencies in the analysis and translation
  - Generation gap:
    mismatch between semantic input and coverage of the grammar

→ **Robust generator necessary**

Problems for generation (2)

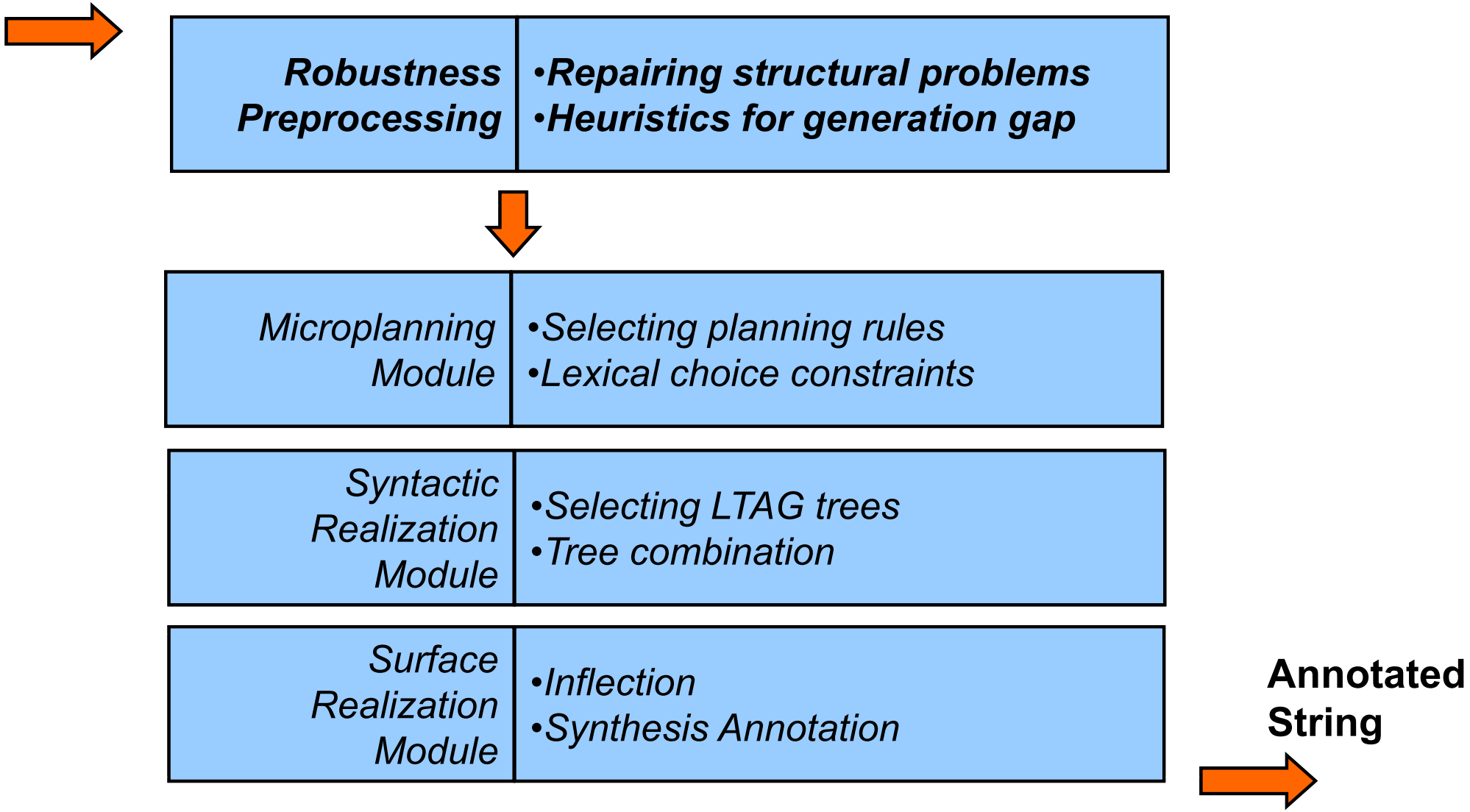
(Task-inherent) problems manifest themselves as fault

wrt. the interface language definition

- **Problems with the *structure* of the semantic representation:**
  - unconnected subgraphs
  - multiple predicates referring to the same object
  - omission of obligatory arguments
- **Problems with the *content* of the semantic representation:**
  - contradicting information
  - missing information (e.g. agreement information)

Extended Architecture

VIT (Verbmobil Interface Term)



Extended Architecture (2)

Why *pre*-pocessing:

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  In a dialogue system,

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  so respect the *inherent limitations of robustness*.

- **Selection module: uses training corpus and confidence values to select from the different translation paths**

Content-to-Speech (CTS) Output

- **Output annotated with information like speech act, syntactic grouping, word classes, prominence, ...**
- **Enhances synthesis quality**
- **Example:**

{SpeechAct:begin}{SpeechActType: Inform}{Language:English}{Utterance:begin} {SentenceType:Aussagesatz}{WordClass:N}Verbmobil{WordClass:AUX}is {WordClass: DET-ART} a{Prominence:2} {WordClass:ADJ}speaker_independent{WordClass:N} system{BorderProminence:5} {WordClass:CONJ-SYN}that {Prominence:15}{WordClass:V}offers {Prominence:4}{WordClass:N}translation_assistance{BorderProminence:2} {WordClass:PREP-SYN}in {Prominence:4}{WordClass:N}dialog {WordClass:N}situations {Utterance:end}

Minutes and Summaries

- Dialog module keeps track of the dialog:

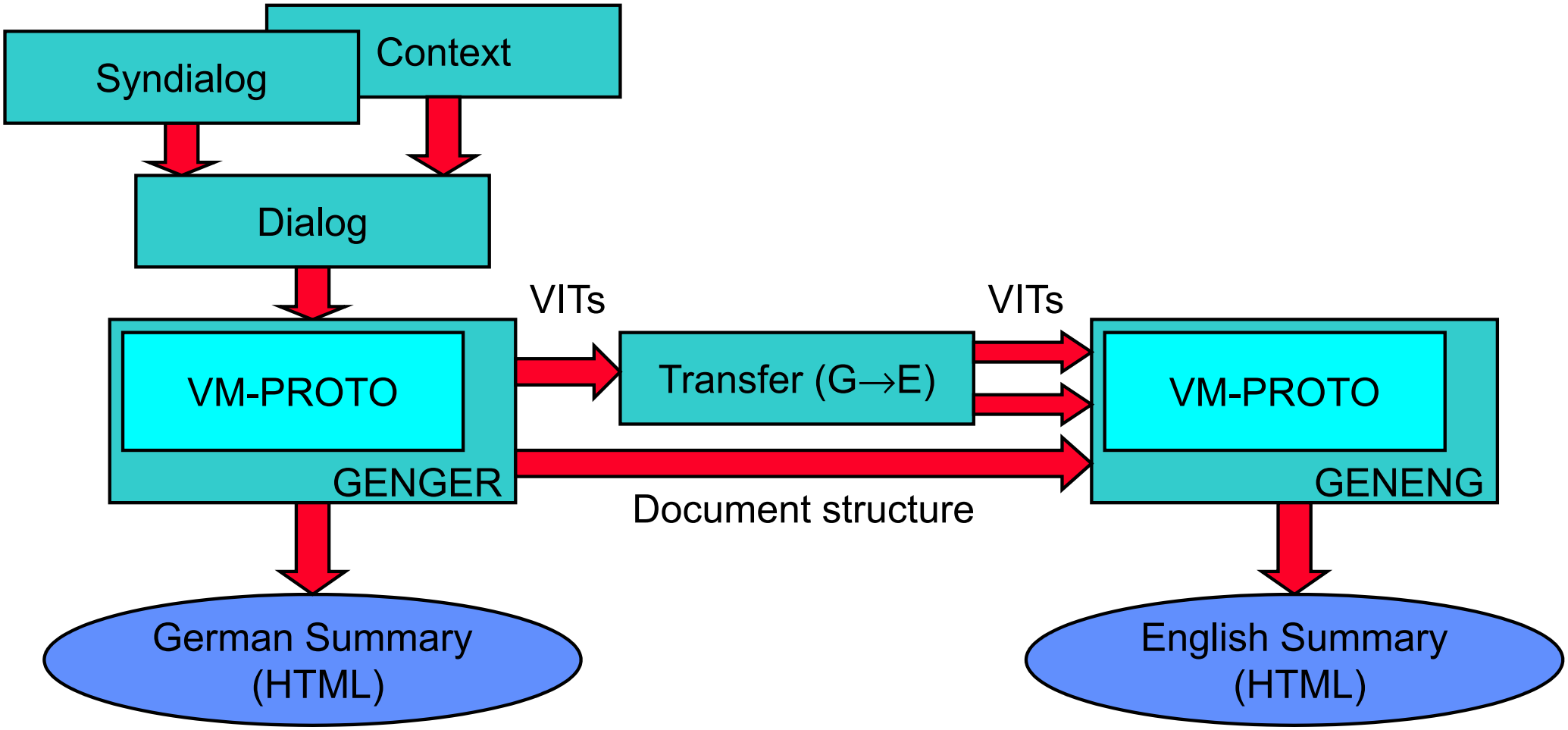
  dialog model, context extraction, translations: dialog history

- Three types of “protocols”:

- Minutes: relevant exchanges
- Summary: dialog results
- Scripts: complete dialog script

Multilingual Minutes and Summaries

- **Multilinguality: Integration of transfer module:**



Conclusion

- **Multilingual generation:**
  - kernel algorithms
  - multilingual knowledge sources
- **Robustness is necessary and useful**
  - within limits
- **Output of classified, graded quality**
- **Generation of minutes and summaries**

- **The Verbmobil book: 2 articles on Generation**

Selection and Speech Synthesis

Selection of Translations

- Task:

  Select the “best” translation out of all deep and shallow translation paths
- Input:

  Translations (text or content)
- Method:

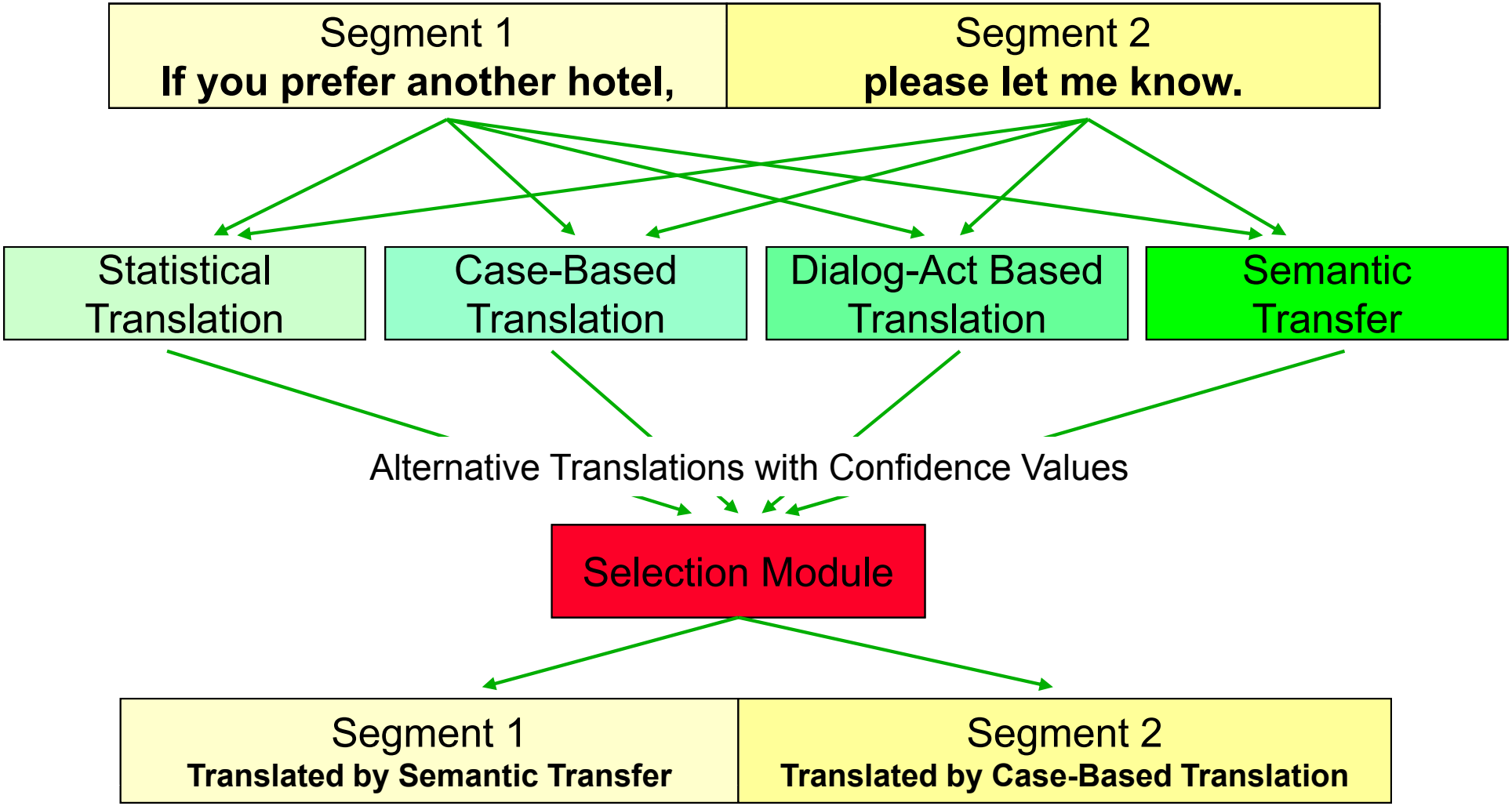
  Learning inequalities
- Result:

  Selected Translation (text or content)
- Benefit:

  Use the expertise of all translation paths for a particular utterance
- Responsible:

  TU Berlin

Integrating Deep and Shallow Processing



The Selection Problem

Selection is a difficult business:

- **confidence values are difficult to compare**
  - probabilistic vs. knowledge based approaches
  - no bird's eyes view possible
- **re-training necessary after changes in the engines**
- **training data must be produced**

Speech Synthesis

- Task:

  Synthesize the translation

- Input:

  text or content

- Method:

  Multilevel selection and concatenation of speech units from large speech corpora

- Result:

  Audio signal

- Benefit:

  “End of the chain” of the speech-to-speech system

- Responsible:

  Universität Bonn
  TU Dresden
  Universität Bochum
  Daimler Chrysler

Different Types of Synthesis

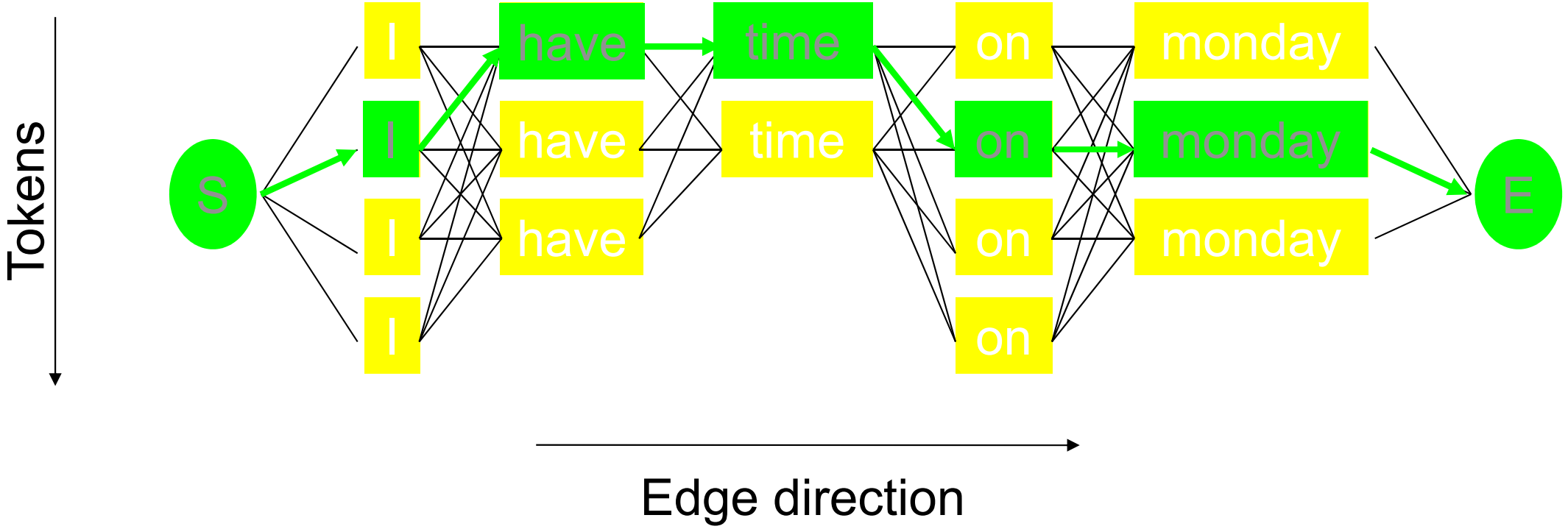
- ***Text-to-Speech (TTS):*** **reading machine from arbitrary text in orthographic form. Unlimited domain. The machine does not know what it is saying.**
- ***Concept-to-Speech*** **[or *content-to-speech*] *(CTS):* spoken out-put from a database inquiry or from a dialog system. The input of the synthesizer comes from a semantic representation via a generation module. The machine should have full knowledge of what it is saying.**
- ***Reproductive Speech Synthesis:*** **spoken output from pre-recorded samples. For strictly limited domains.**

Corpus-Based Synthesis

- Target utterances are synthesized from a corpus of utterances from within the domain.
- All units – whatever they are – have multiple instances in the corpus.
- No predefined units: the unit selection algorithm selects contiguous chunks of speech from the data base – the longer, the better.
- When units of word size and above are applied, much of the natural prosody is preserved.
- Problem: coverage. Words not in the database cannot be synthesized in this way.

Unit Selection Algorithm

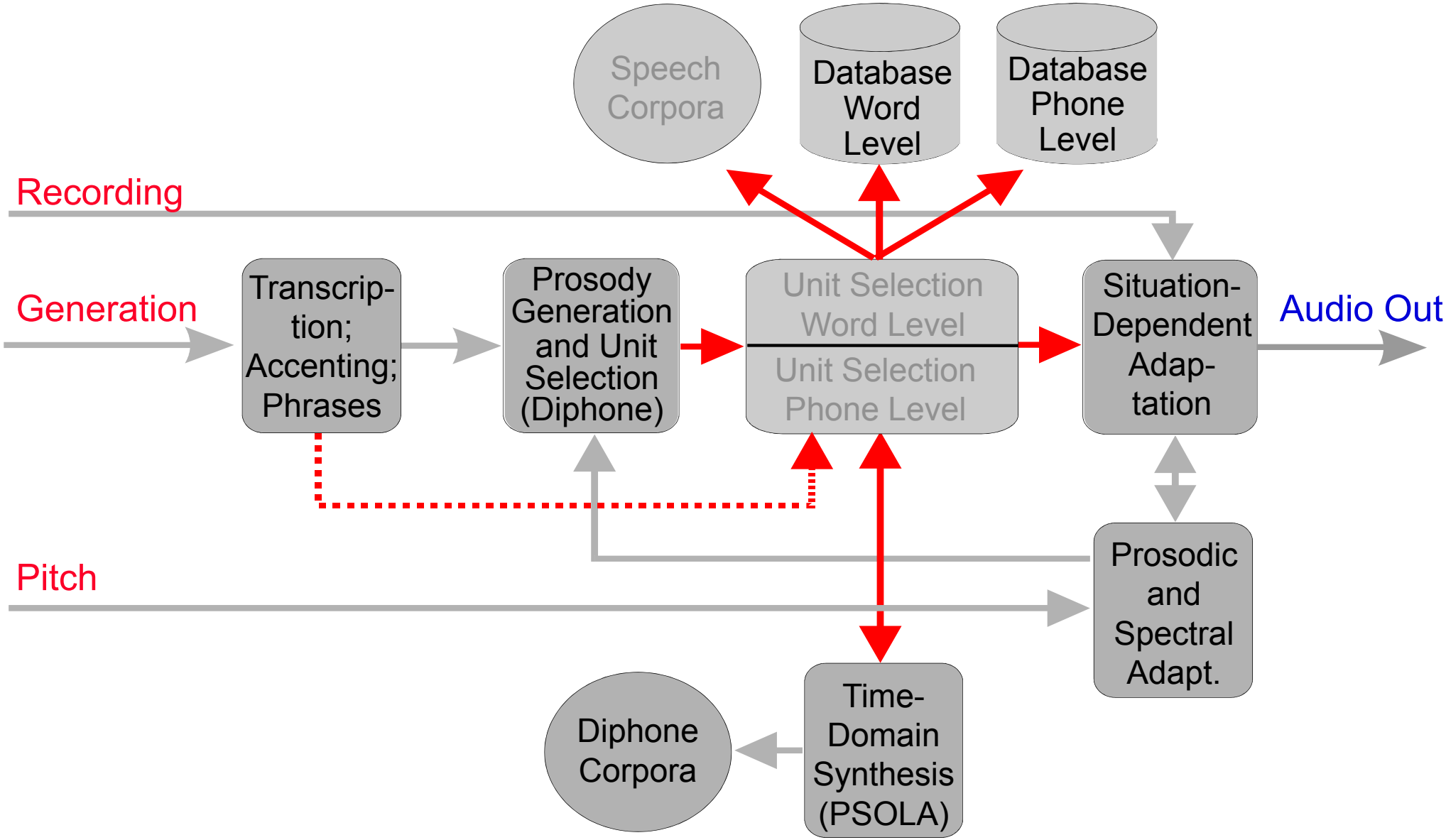
Sentence to synthesize: I have time on monday.



Implementation

- *Word* is the central unit and the starting point for all processing.
- Only if no suitable instance of a word is available in the database, an algorithm is invoked that composes a word from subword units which are currently phones.
- The principal strategy on both the word and the sub-word levels is to concatenate chunks that are as long as possible (up to a whole sentence).
- Like in CHATR, no prosodic manipulation is performed in this synthesis.
- In principle each word is needed in up to three positions (initial/medial, final declarative, final interrogative) and in both accented and unaccented mode.
- For Verbmobil this would mean that we need about 80000 word tokens to be recorded (which is prohibitive).
- Good coverage is reached by a selection of typical phrases from within the domain (dialogs from the Verbmobil dialog database).
- Additional utterances realize frequent words in relevant contexts (e.g., opening phrase, names of big cities).

Architecture



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Verbmobil From a Software Engineering Point of View

System Design and Software Integration

Software Technology Challenges

The goal

- Build an integrated system

The situation

- Researchers do research
- Using different programming languages
- Researchers don’t want to be bothered with technical details

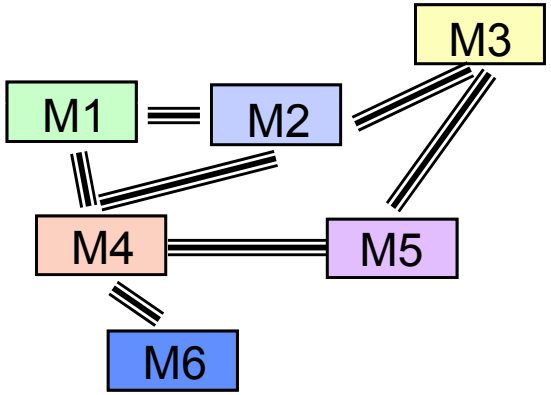
The solution

- Introducing: the System Group
- Maximal technical support for the researchers/developers

The System Architecture

Verbmobil I

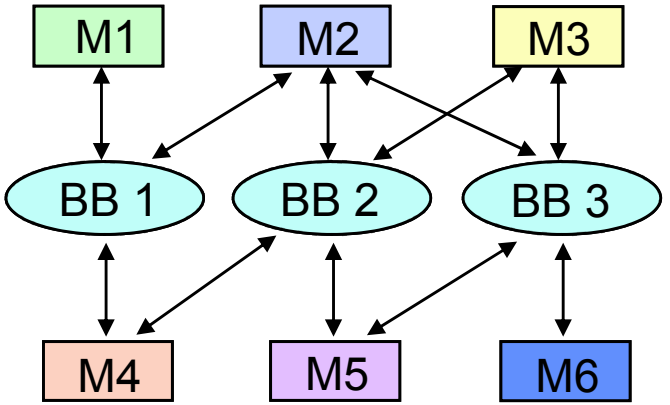
Multi-Agent Architecture



- Modules know all communication partners
- Direct communication between modules
- Reconfiguration difficult
- Software: ICE and ICE Master
- Basic Platform: PVM

Verbmobil II

Multi-Blackboard Architecture



Blackboards

- Modules know their I/O data pools
- No direct communication between modules
  198 blackboards vs. 2380 direct comm. paths
- Reconfiguration easy
- Several instances of one module/functionality
- Software: PCA and Module Manager
- Basic Platform: PVM

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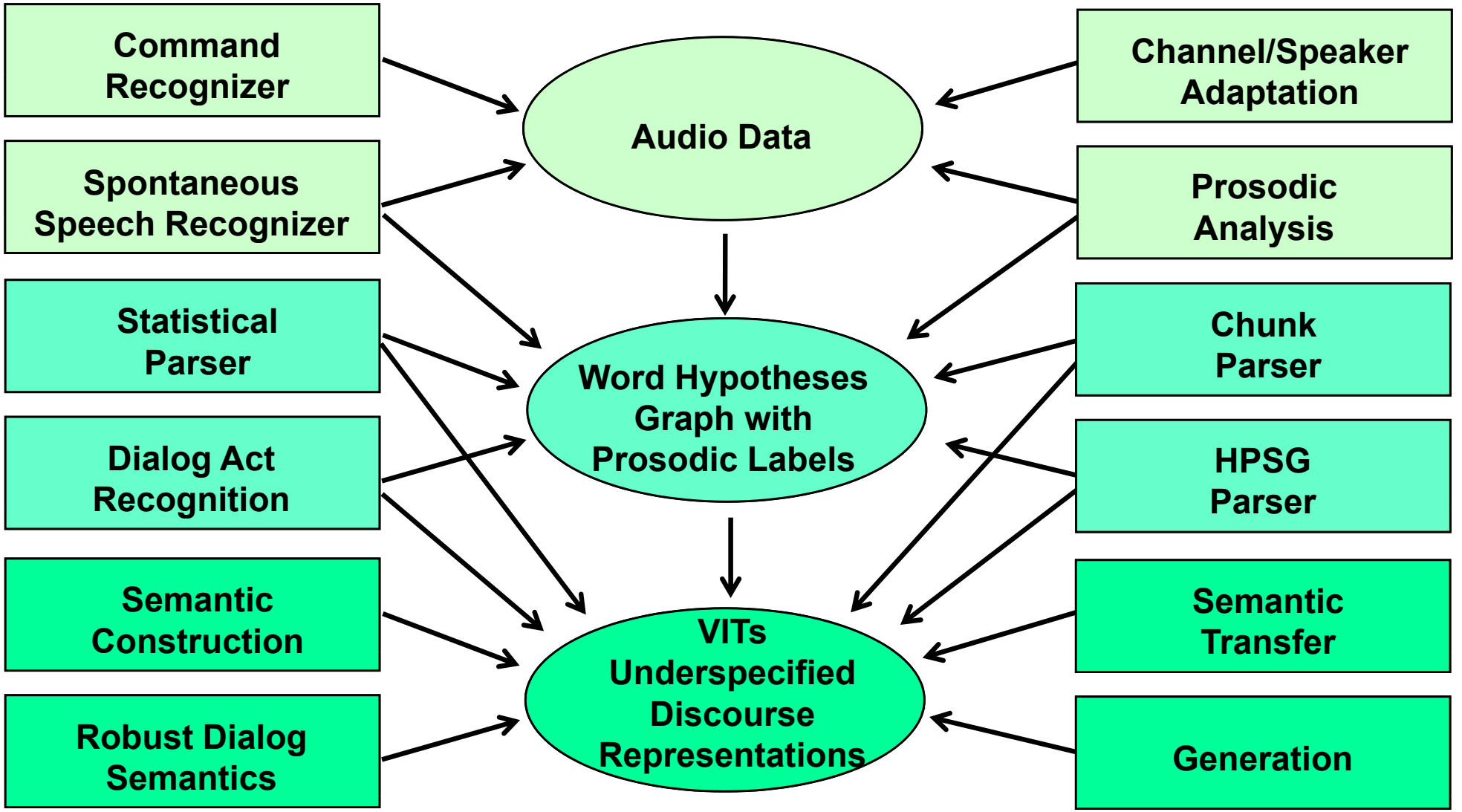
Sample Pool Structure



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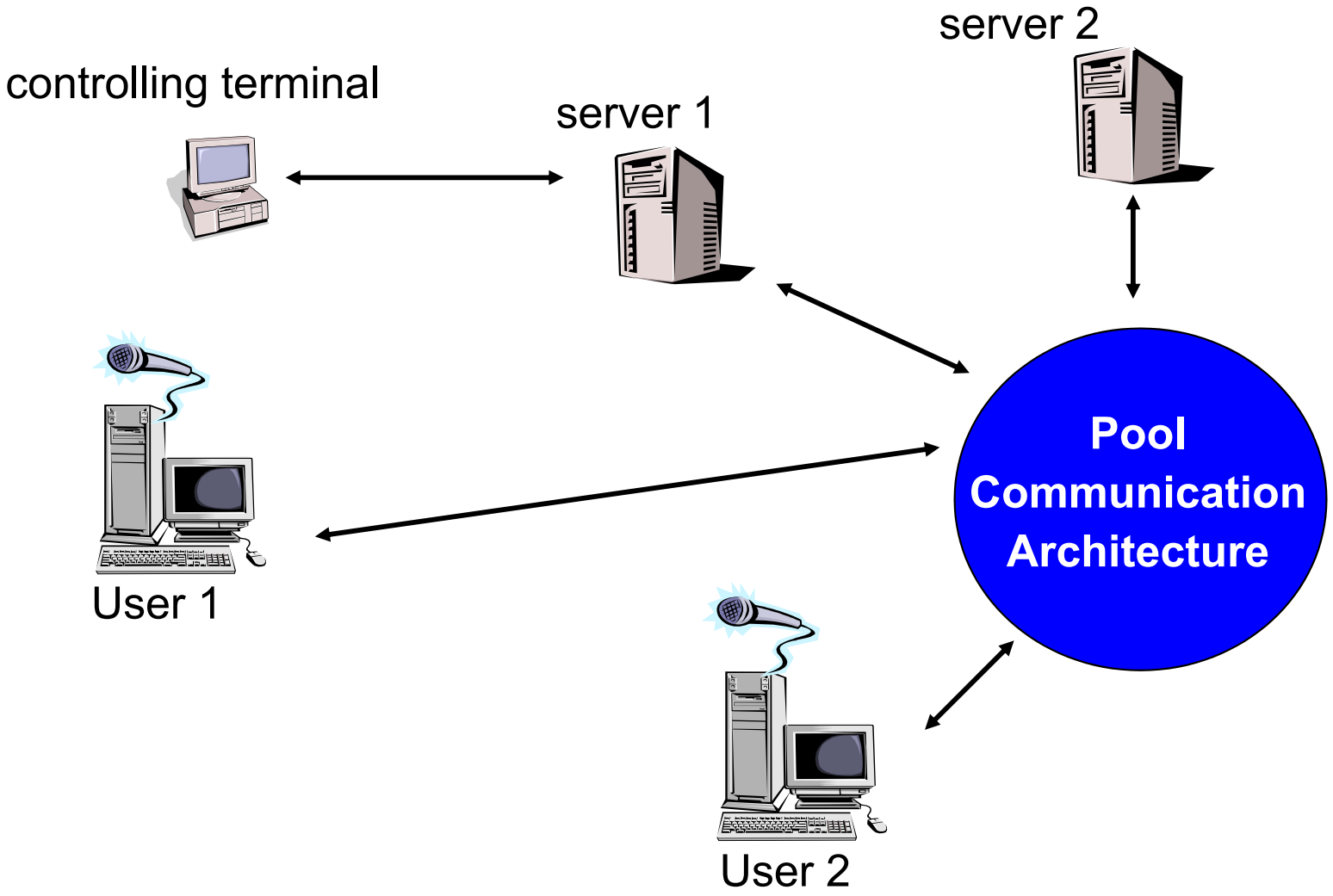
Distributed Execution Supports Distributed Development

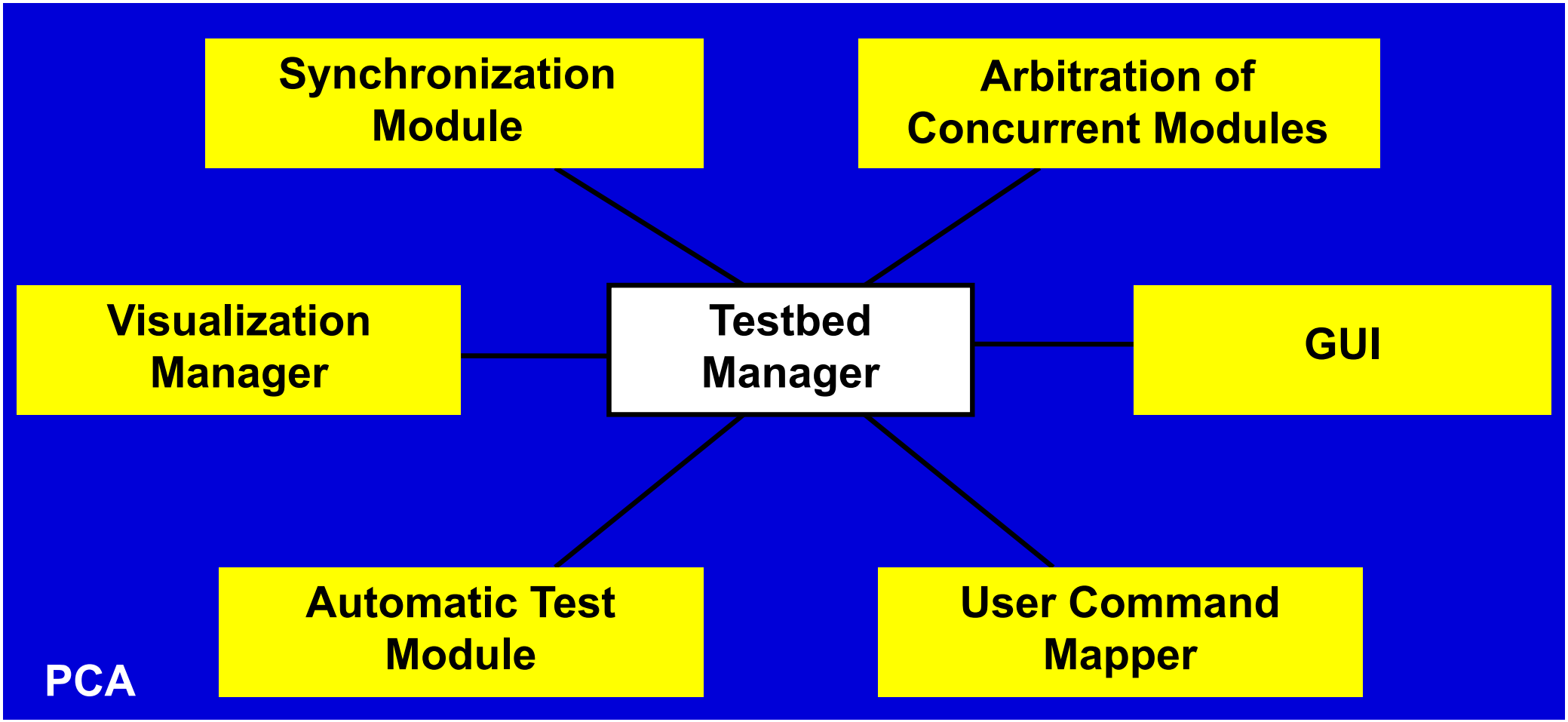


Support from the System Group (1)

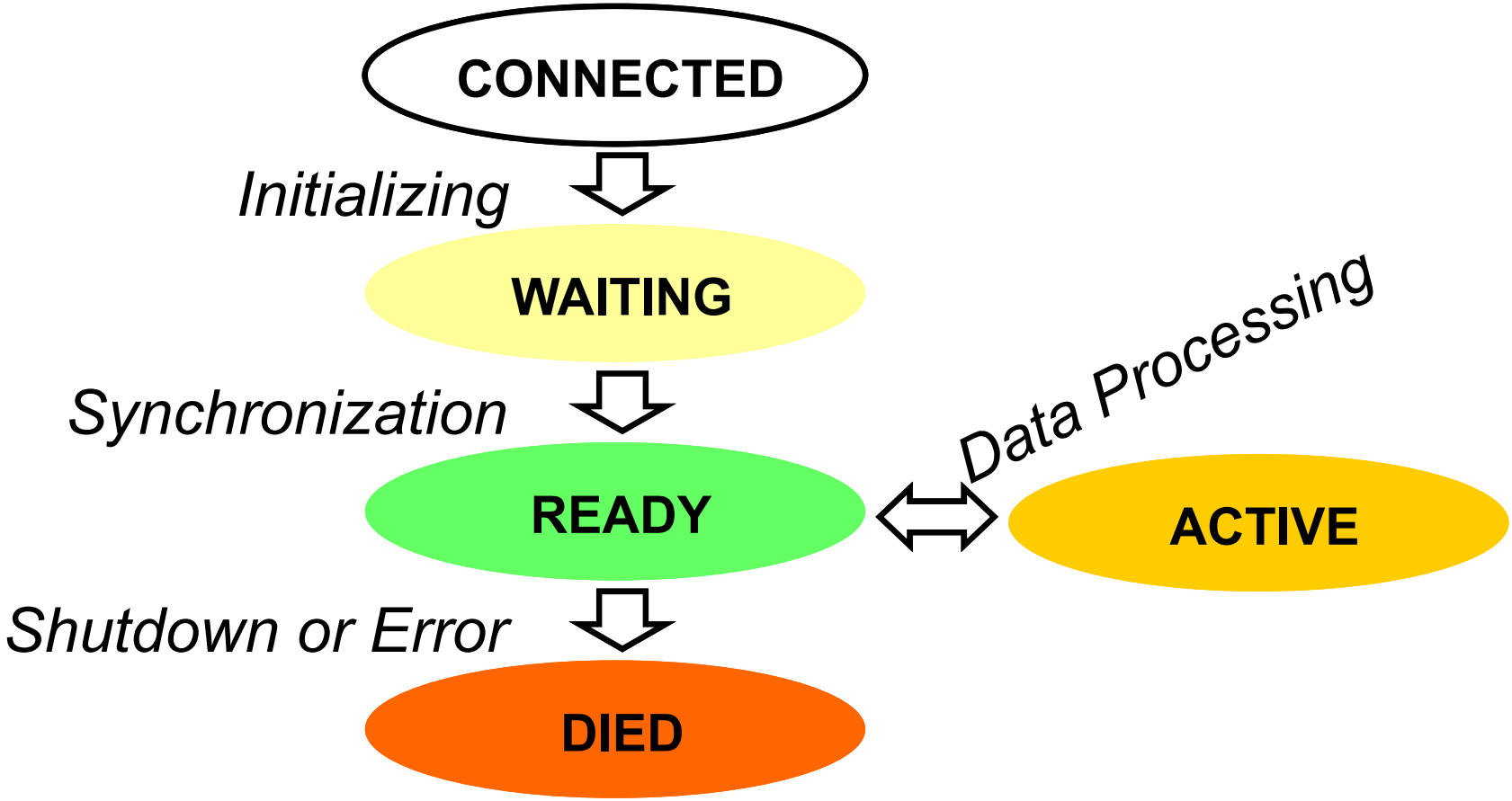
Integration framework (Testbed) with

- **common communication mechanism for all used programming languages (C, C++, Lisp, Prolog, Java, Fortran, Tcl/Tk)**
- **Narrow interface for all used programming languages**
- **Overall system control infrastructure**
- **Standards on various levels**
  - Installation
  - Compilation
  - Communication formats between modules
  - ...
- **Toolbox for recording, replaying, testing, inspecting data exchanged between modules, ...**

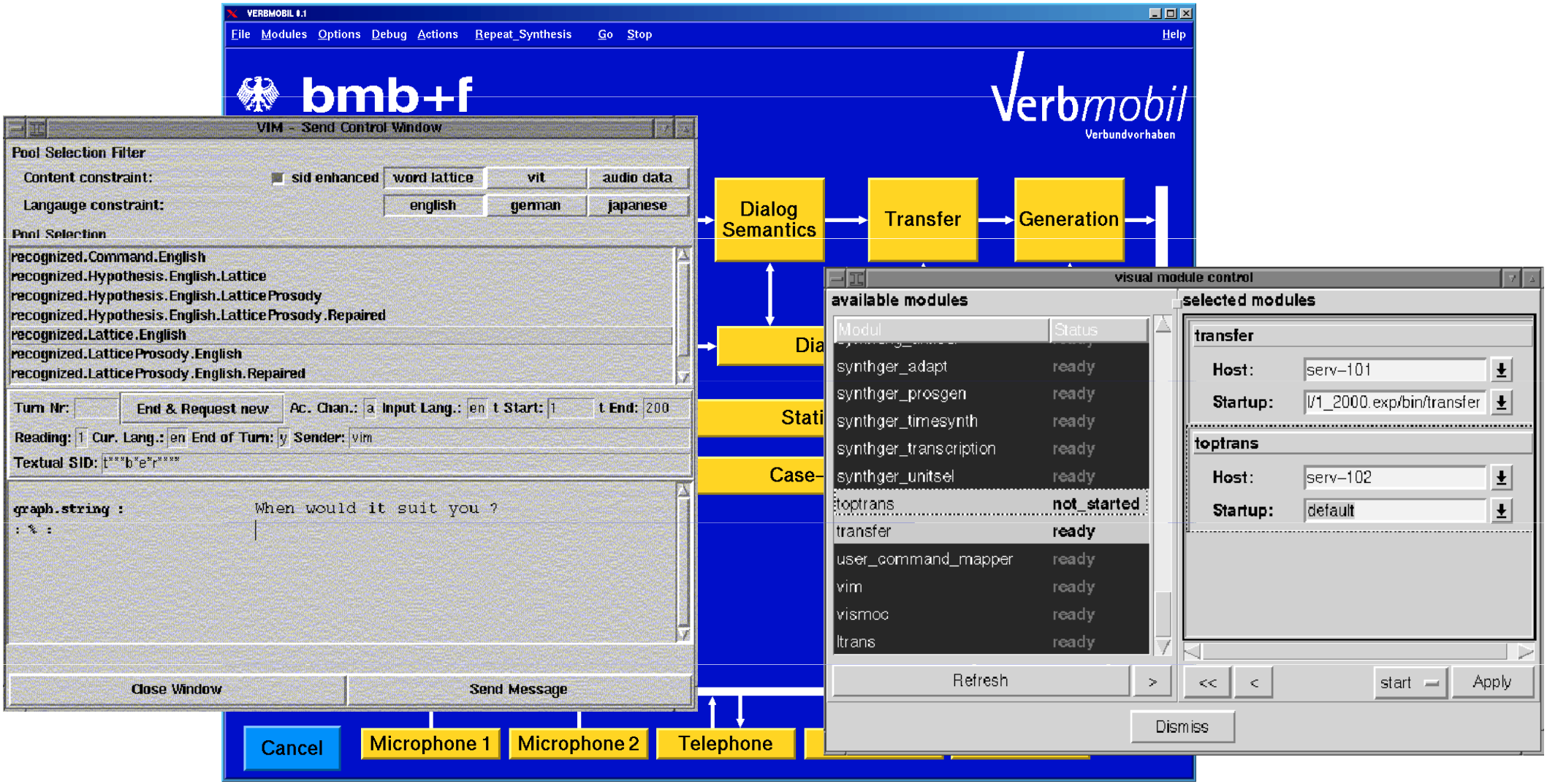
The Testbed is the Integration Framework for the Verbmobil System



The Testbed controls the System: Module States



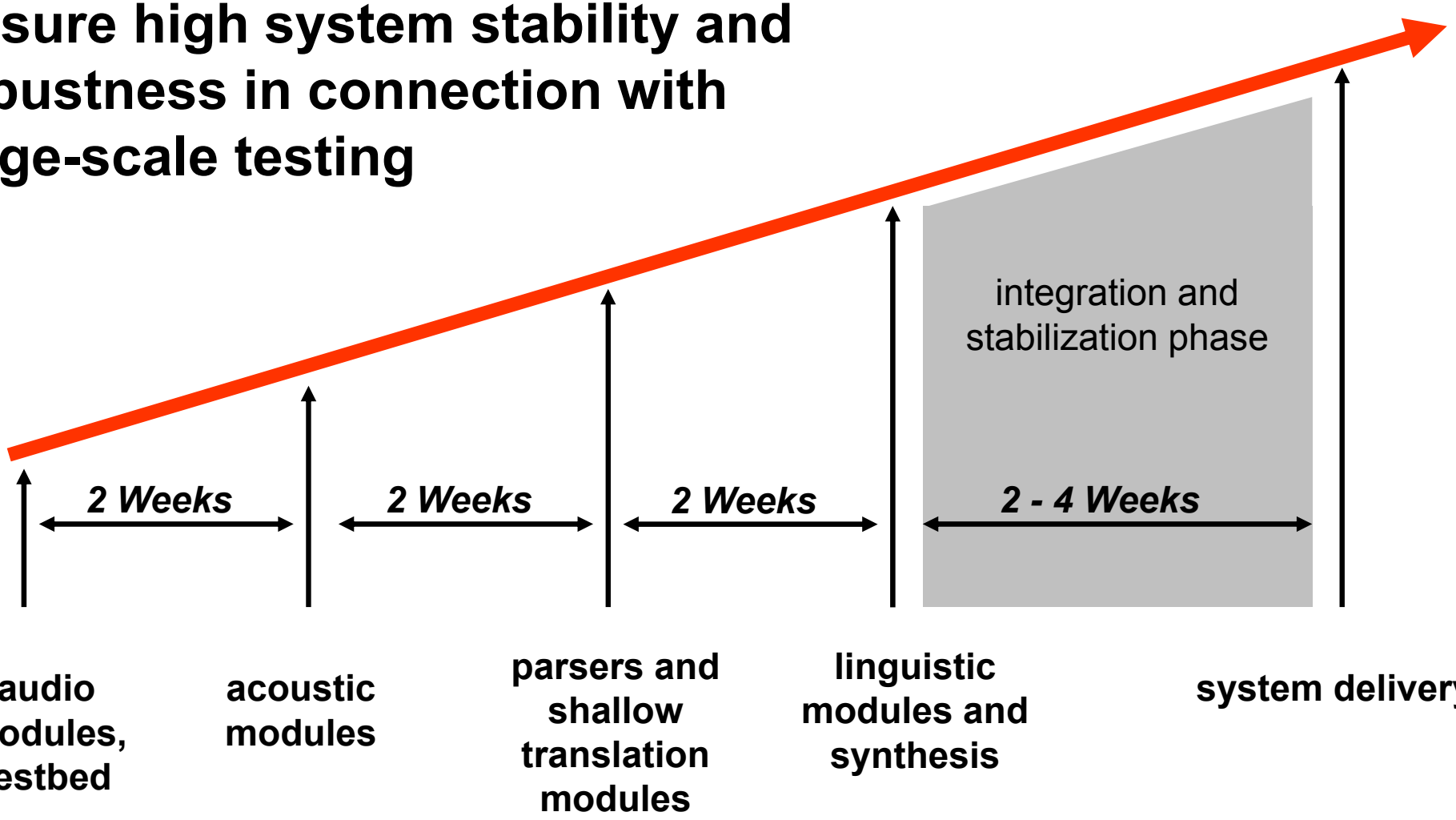
The GUI- Visualization and Debug Tool



.... and much more

Support from the System Group (2): Regular Integration Cycles

Assure high system stability and robustness in connection with large-scale testing



Human Factors

A Remark about Project Duration

8 years is a long time, especially since the invention of Internet time

1993

- "You will need special hardware!"
- "1500 words speaker independent is impossible!"
- "Aren't your goals unrealistic?"

2000

- "Does it run on my notebook?"
- "Only 10 000 words?"
- "Why can't it also translate in the domains X, Y, and Z?"

but

it is a unique chance for

- **large scale, continuous research and development**
- **training people, collaborating, gaining experience**
- **collecting and annotating data**

Management Challenges

The goal

- Build an integrated system

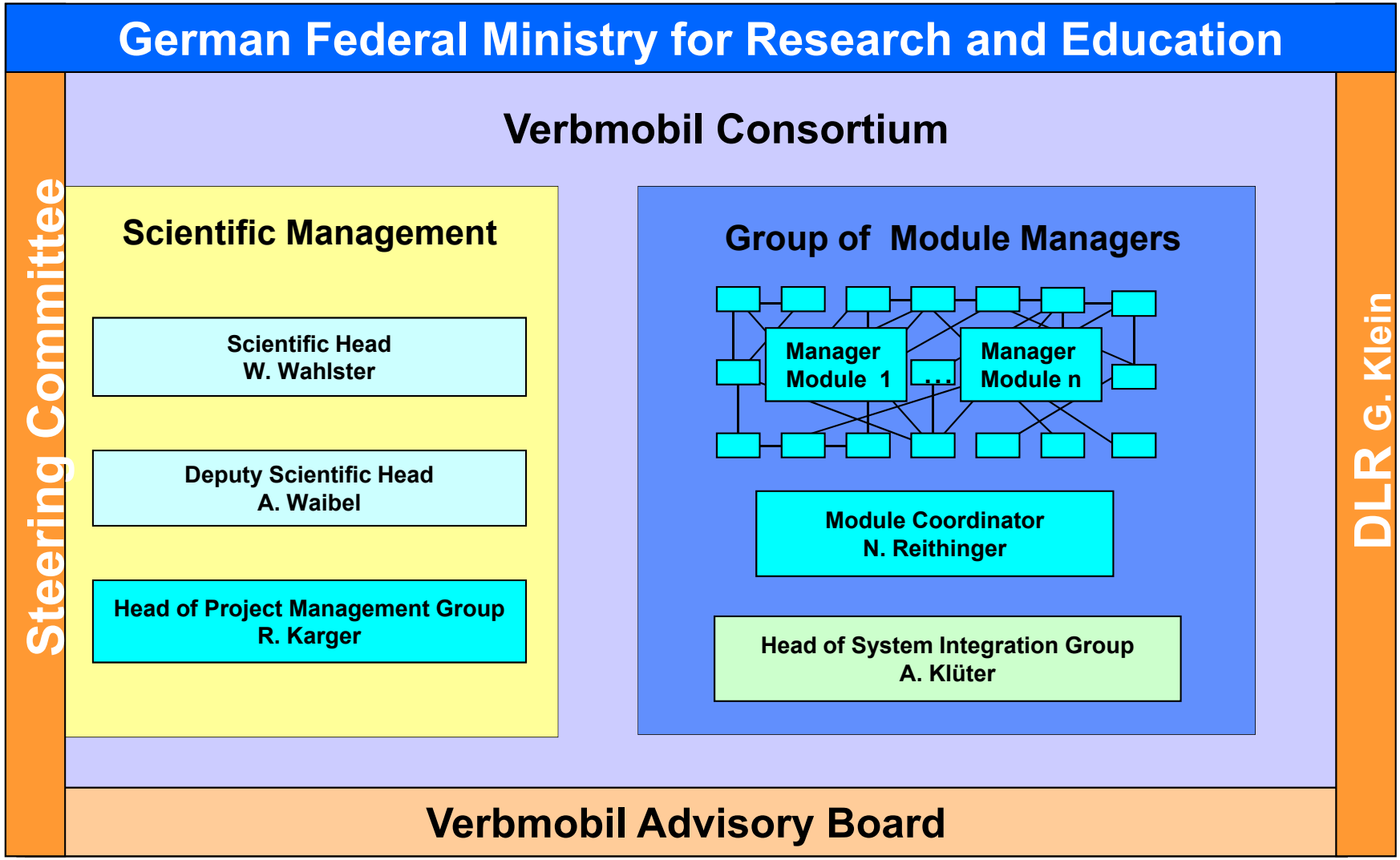
The situation

- Partners distributed and pretty independent
- Great variation in project and background experience
- Adjustment of project plan and goals over time needed

The solution

- Define a flat management structure
- Create a group spirit

Project Organization



Module Managers

- Have technical hands on experience
- Responsible for one module, even if it is developed at different sites
- Volunteers (sort of ...)
- Meet regularly, despite e-mail, phone and other devices
- Define next milestones
- Define data and software integration plans

Module coordinator coordinates the efforts and is the link to the scientific management

Example: Optimization Schedule 2000

- 21.02. Delivery of CeBit system
- 21.02. - 30.04. Optimization phase
  - 15.03. - 28.04. End-To-End evaluation with feedback to developers
  - 27.03. - 07.04. Workshop Deep Processing
- 09.05. Delivery Verbmobil System 1.0
- starting 09.05
  - speech recognizer evaluation
  - turn evaluation

Experience

- The group of module managers is a Good Thing™
- Common goals motivate
- Friendly peer pressure works most of the time
- Early problem detection and resolution in most cases
- Regular integration cycles focus and motivate

❑ Proactive consensus management (PCM)

Experience

- The System Group is a Good Thing™
- The multi blackboard architecture is a Good Thing™
- Crucial for the success of Verbmobil
- Software foundation for (almost) hassle free module development

❑ Controlled distributed development possible

Verbmobil-Symposium

30.7.2000, 10:30-18:00
Saarbrücken, Kongresshalle

Programm

(Keine Teilnahmegebühr)

Zeitraster für das Verbmobil-Abschlussymposium

Datum: 30.07.2000

Ort: Neue Congresshalle Saarbrücken

10:30 - 10:35 Eröffnung
10:35 - 10:45 Grußworte des BMBF (B. Reuse, BMBF)
10:45 - 11:30 Verbmobil (W. Wahlster)
11:30 - 12:00 Präsentation des Verbmobil-Systems (R. Karger)
12:00 - 12:45 Spracherkennung und Prosodieanalyse (A. Waibel, E. Nöth)

12:45 - 13:30 Imbiss

13:30 - 14:15 Multilinguale Analyse (U. Block, H. Uszkoreit)
14:15 - 15:00 Symbolische und Statistische Übersetzung (C. Rohrer, H.Ney)

15:00 - 15:30 Kaffee

15:30 - 16:15 Generierung und Synthese (T. Becker, W. Hess)
16:15 - 16:45 Evaluierung der End-to-End-Übersetzungsleistung des Systems (W. v.Hahn)

16:45 - 17:00 Verlesen des schriftlichen Abschlussgutachtens

17:00 - 18:00 Podiumsdiskussion: Sprachtechnologie und New Economy

Multilingual Processing of Spontaneous Speech

SmartKom

- Overview
- Architecture
- Core Areas: Analysis, Fusion, Generation, ...
- Dialogue Processing

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Overview

- **Introduction**
  - Why Multimodal Interaction Systems?
  - Reference Architecture for Multimodal Systems
- **SmartKom: A Multimodal Interaction System**
  - SmartKom: A Transportable Interface Agent
  - Situated Delegation-oriented Dialog Paradigm: Collaborative Problem Solving
  - Modes in SmartKom
  - More About the System
  - M3L: XML based Multimodal Markup Language
  - Multimodal Coordination

Why Multimodal Interaction Systems? (Oviatt&Cohen, CACM March 2000)

- **Accessibility for diverse users and usage contexts**
  - Selection of modes by the user and by the system
    e.g. lean- forward/lean-backward mode in a home environment, car
- **Performance stability and robustness**
  - Users can select robust mode
  - Mutual disambiguation and presentation
- **Expressive power and efficiency**
  - Interface more powerful
  - Faster
  - Increased task completion

Reference Architecture for Multimodal Systems

2 Nov. 2001
Dagstuhl Seminar
Fusion and Coordination
in Multimodal Interaction
edited by: M. Maybury

Media Input Processing

Biometrics

G
T
A
G
V

User(s)

A
G
A
V
G

Media Output Rendering

Mode Analysis
- Language
- Graphics
- Gesture
- Sound

Mode Design
- Language
- Graphics
- Gesture
- Sound
- Animated Presentation Agent

Mode Coordination

Multimodal Fusion
- Multimodal Reference Resolution

Presentation Design
- Select Content
- Design
- Allocate
- Coordinate
- Layout

Interaction Management

Discourse Management
- Reference Resolution

Context Management

Expectation Management

Intention Recognition

Action Planning

User Modeling
- User ID

Application Interface
- Initiate
- Terminate
- Request
- Respond
- Integrate

Information, Applications, People

User Model | Discourse Model | Context Model | Domain Model | Task Model | Media Models | Application Models

Representation and Inference, States and Histories

Overview

- **Introduction**
- **SmartKom: A Multimodal Interaction System**
  - SmartKom: A Transportable Interface Agent
  - Situated Delegation-oriented Dialog Paradigm: Collaborative Problem Solving
  - Modes in SmartKom
  - More About the System
  - M3L: XML based Multimodal Markup Language
  - Multimodal Coordination
- **MIAMM**
  - Main Objectives
  - Interaction using Haptics
- **Research Roadmap of Multimodality**
- **Conclusion**

Human-Technology Interaction Lead Projects

Project	Title	Coordinator	Funding Period
INVITE	Intuitive Mensch-Technik-Interakt. für die vernetzte Informationswelt der Zukunft	ISA GmbH, Stuttgart	07/99 - 06/03
MORPHA	Intelligente anthropomorphe Assistenzsysteme	Delmia GmbH, Fellbach	07/99 - 06/02
EMBASSI	Elektronische Multimediale Bedien- und Service-Assistenz	Grundig GmbH, Fürth	07/99 - 06/03
ARVIKA	Augmented Reality für Entwicklung, Produktion und Service	Siemens AG, Nürnberg	07/99 - 06/03
SMARTKOM	Dialogische Mensch-Technik-Interaktion durch koordinierte Analyse und Gener. multipler Modalitäten	DFKI GmbH, Saarbrücken	09/99 - 09/03
MAP	Multimedia Arbeitsplatz der Zukunft	AlcatelSel AG, Stuttgart	04/00 - 03/03

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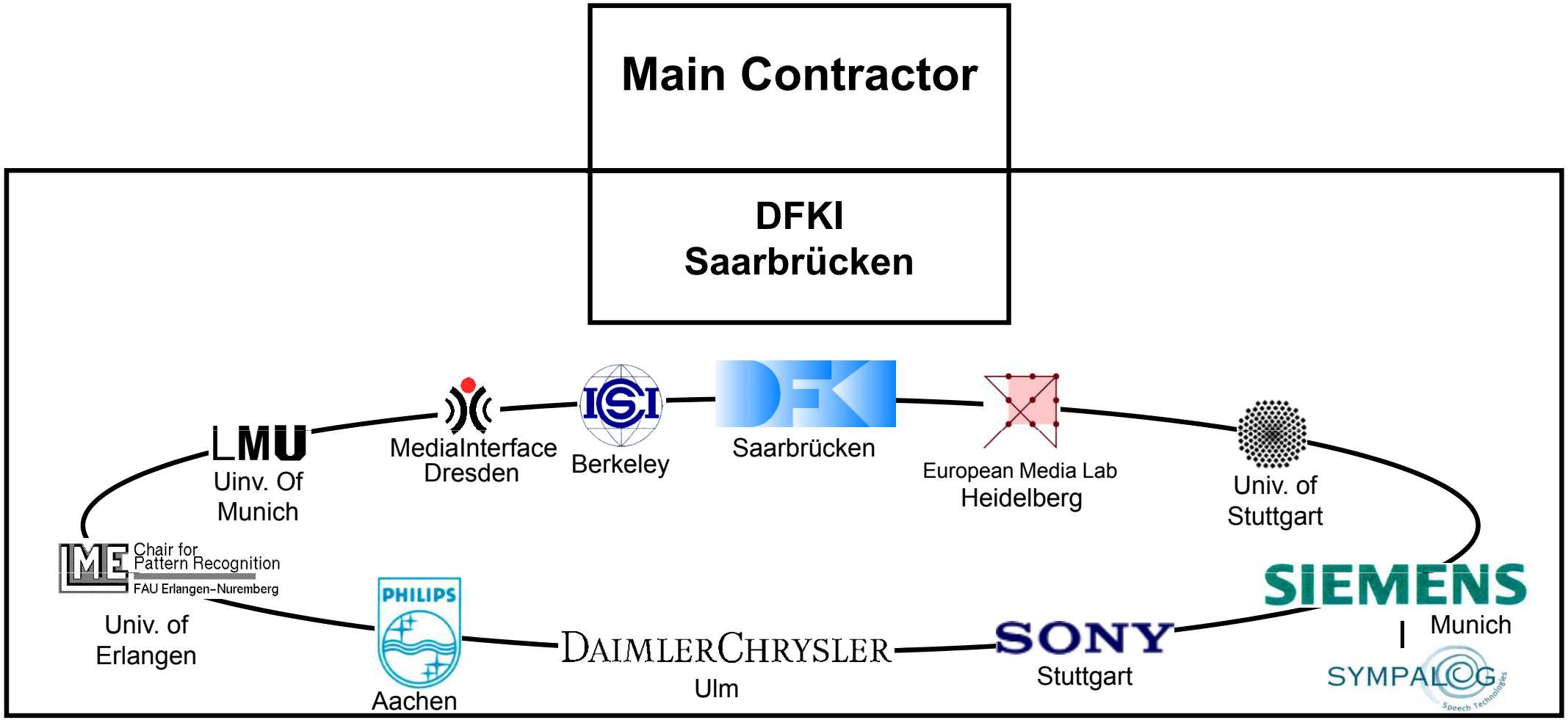
The SmartKom Consortium

Project Budget: € 25.5 million

Project Duration: 4 years (September 1999 – September 2003)



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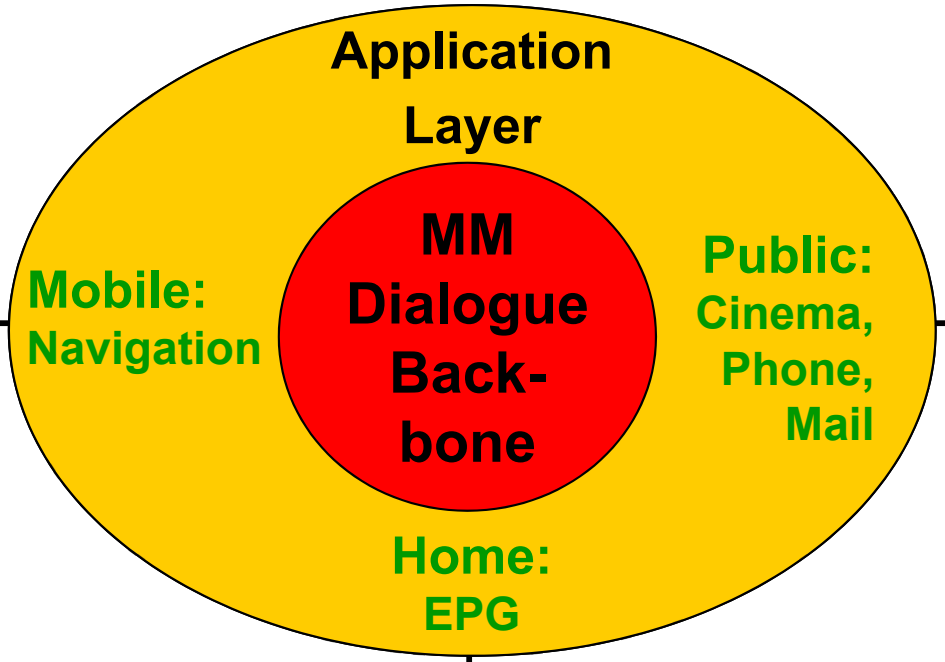
SmartKom: A Transportable Interface Agent

SmartKom-Mobile:
A Handheld
Communication
Assistant



SmartKom-Home/Office:
Multimodal Portal
to Information Services

SmartKom-Public:
A Multimodal
Communication
Kiosk

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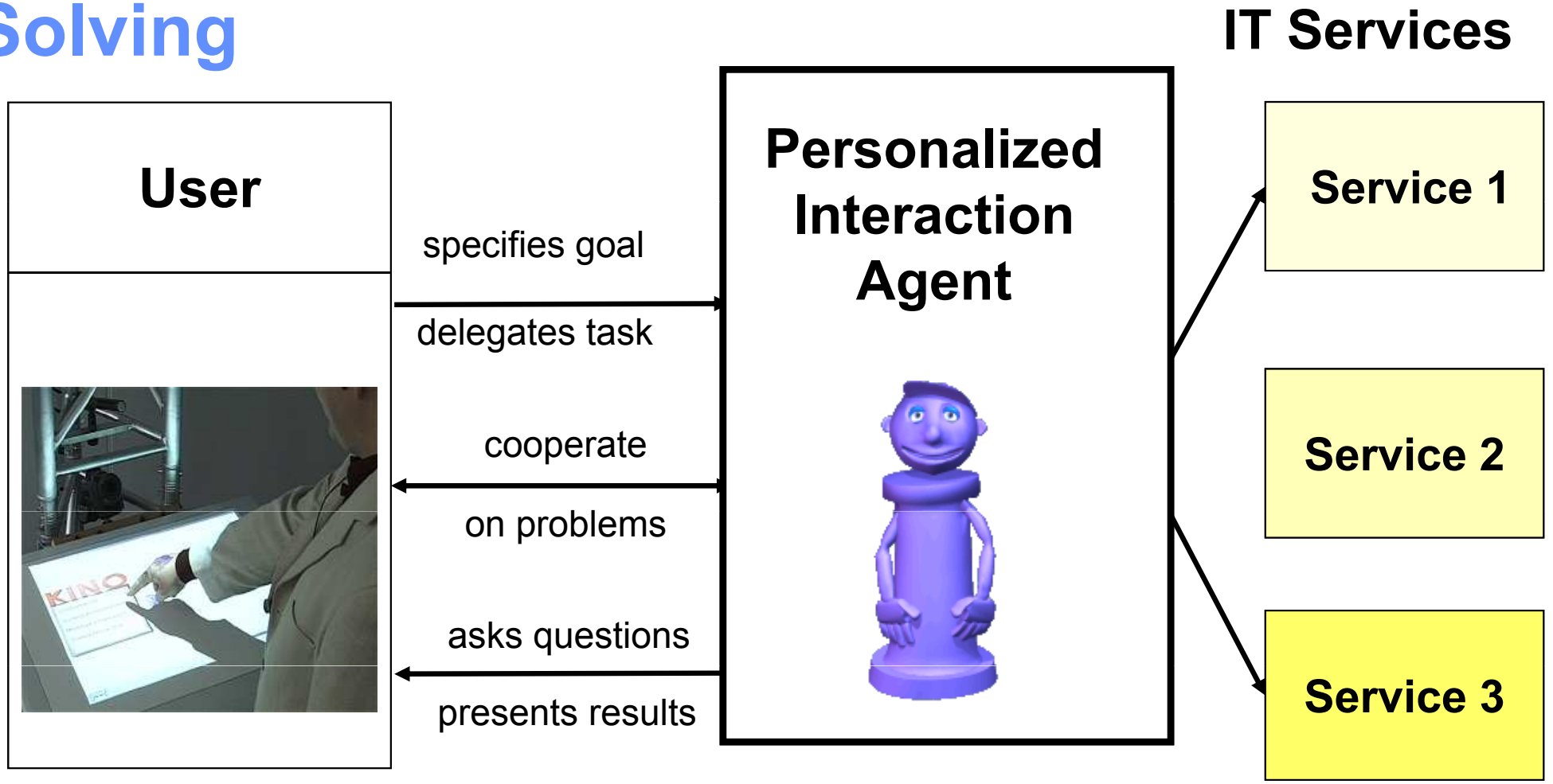
An Example Interaction with SmartKom Mobile

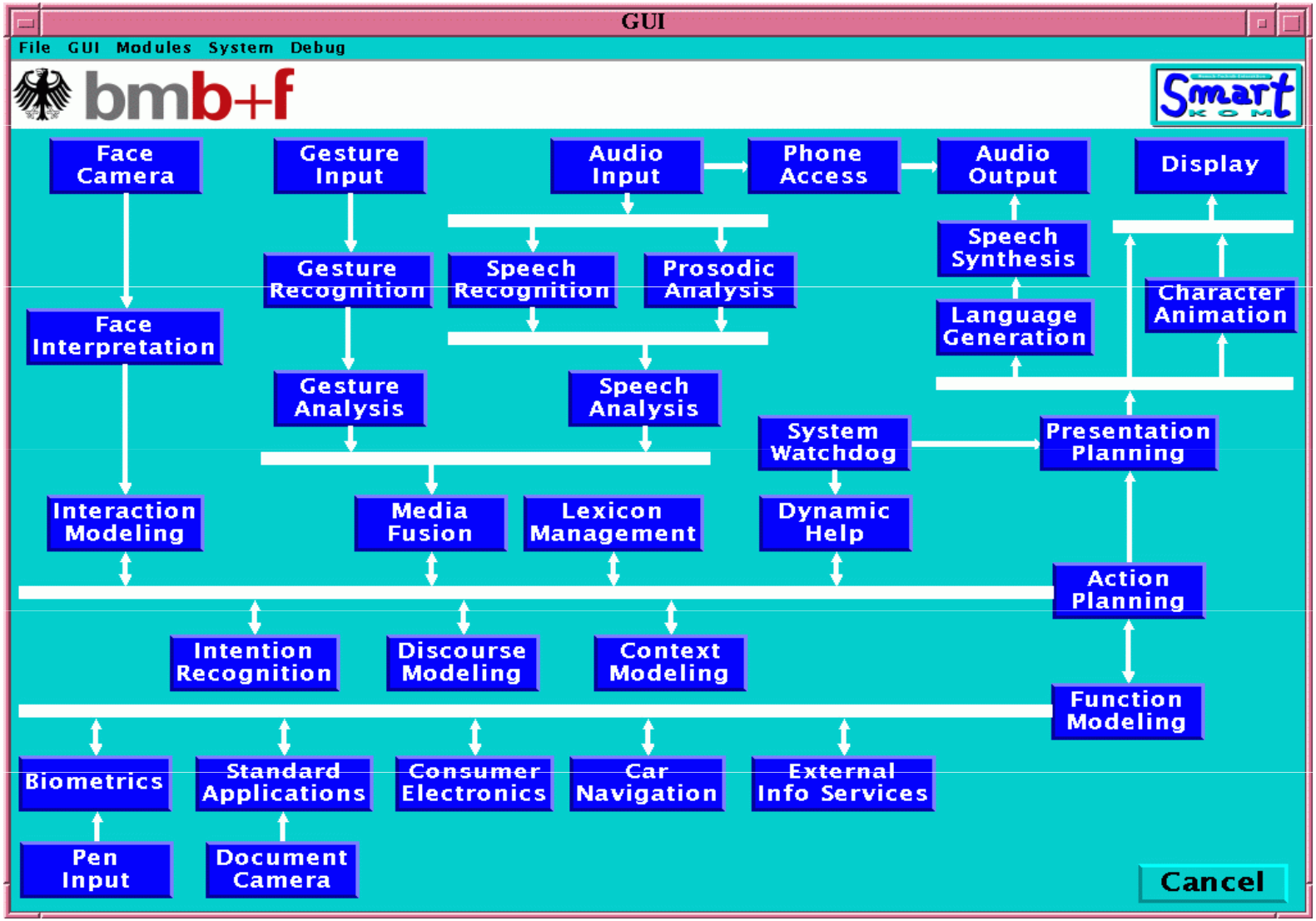
Situated Delegation-oriented Dialog Paradigm: Collaborative Problem Solving



Modes in SmartKom

- **Speech**
  - Speaker independent speech recognition
  - Prosodic input processing
  - Synthesis
- **Gesture**
  - Input
    - Natural gestures (SIVIT)
    - Pen-based
  - Presentation agent
- **Facial/body expression**
  - User state recognition
  - System state presentation

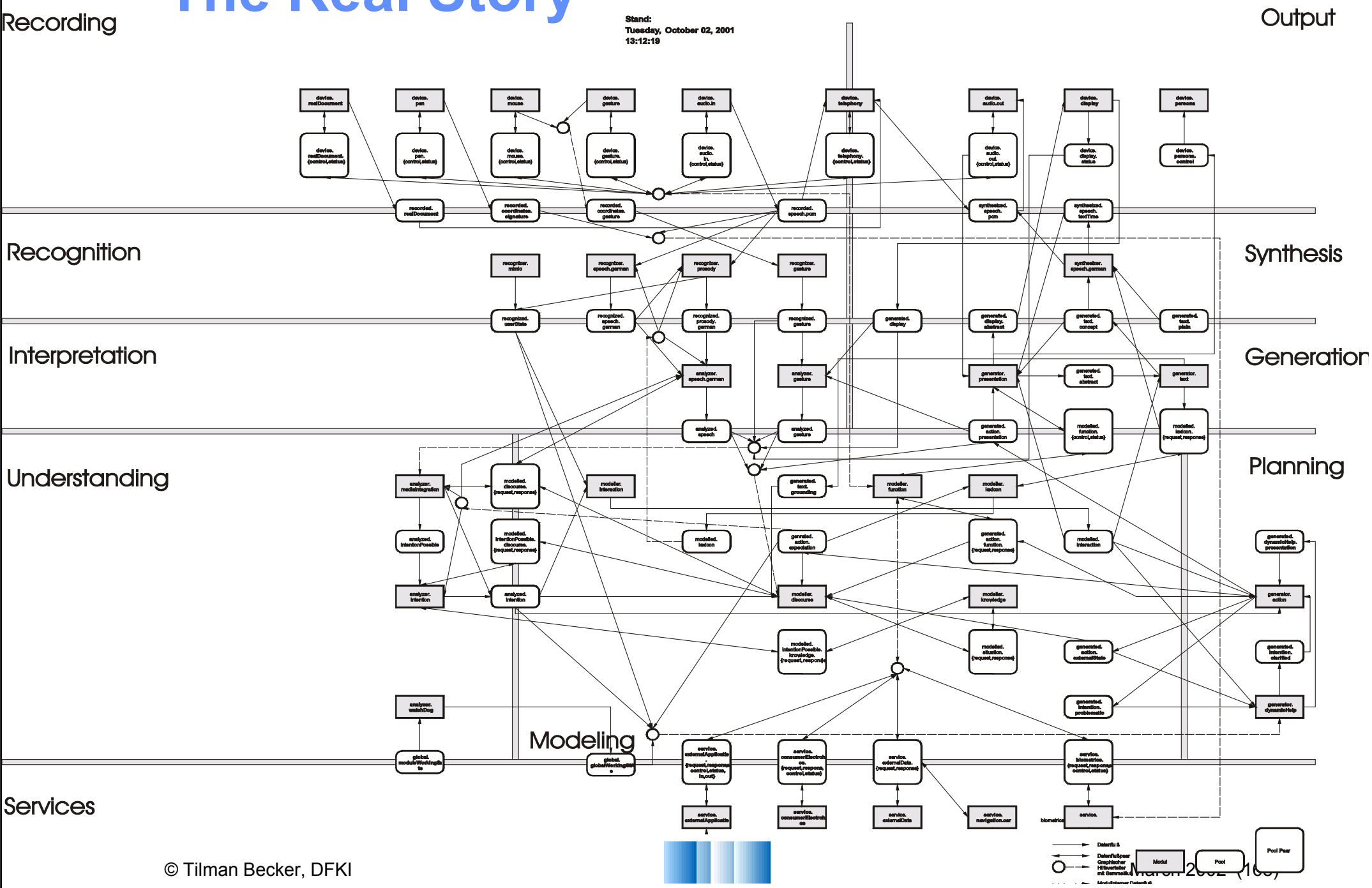
The Main Modules on the Control GUI



More About the System

- **Modules realized as independent processes**
- **Not all must be there (critical path: speech or graphic input to speech or graphic output)**
- **(Mostly) independent from display size**
- **Pool Communication Architecture (PCA) based on PVM for Linux and NT**
  - Modules know only about their I/O pools
  - Literature:
    - Andreas Klüter, Alassane Ndiaye, Heinz Kirchmann: *Verbmobil From a Software Engineering Point of View: System Design and Software Integration.* In Wolfgang Wahlster: *Verbmobil - Foundation of Speech-To-Speech Translation.* Springer, 2000.
- **Data exchanged using M3L documents**
- **All modules and pools are visualized here ...**

The Real Story



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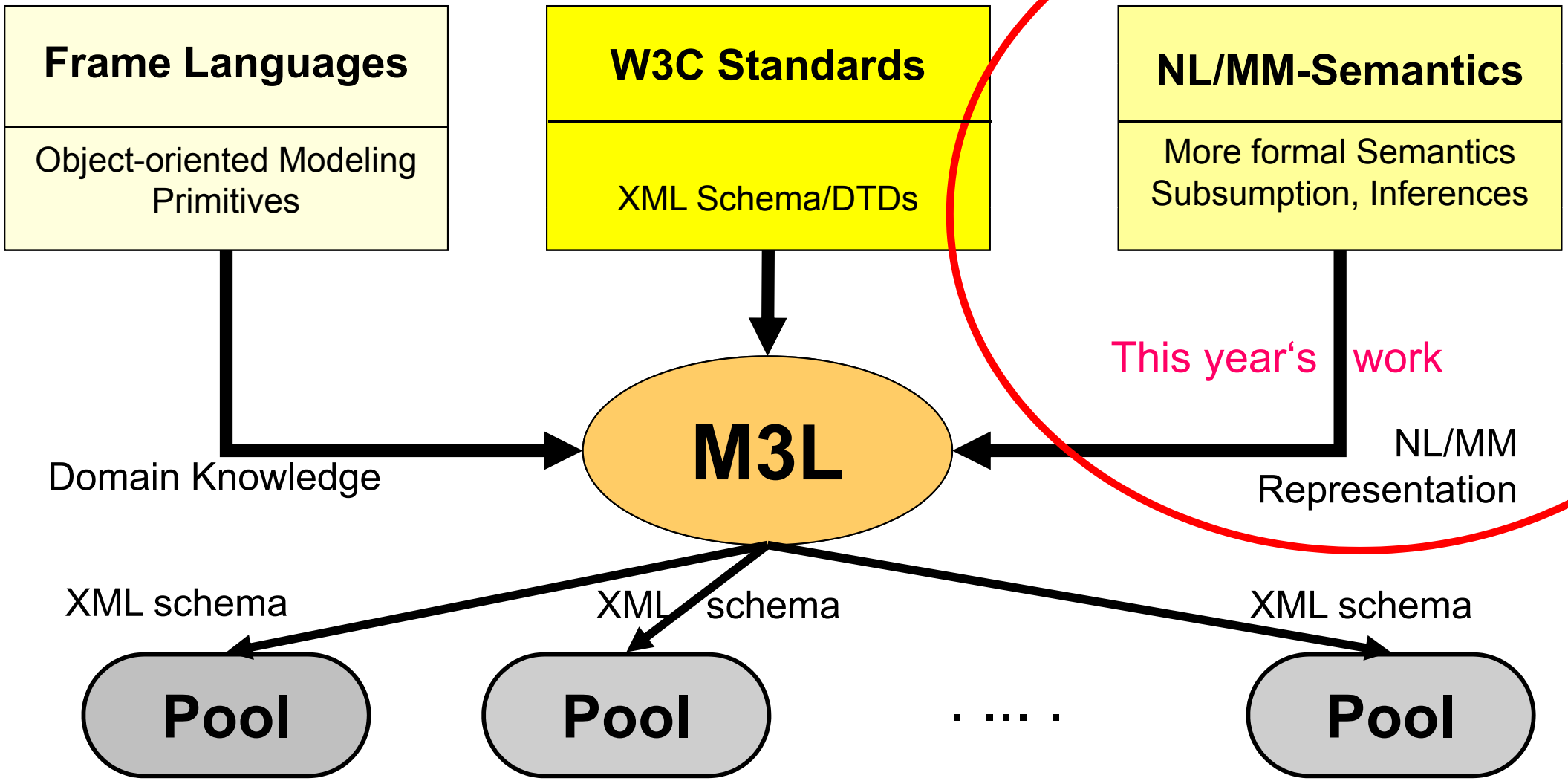
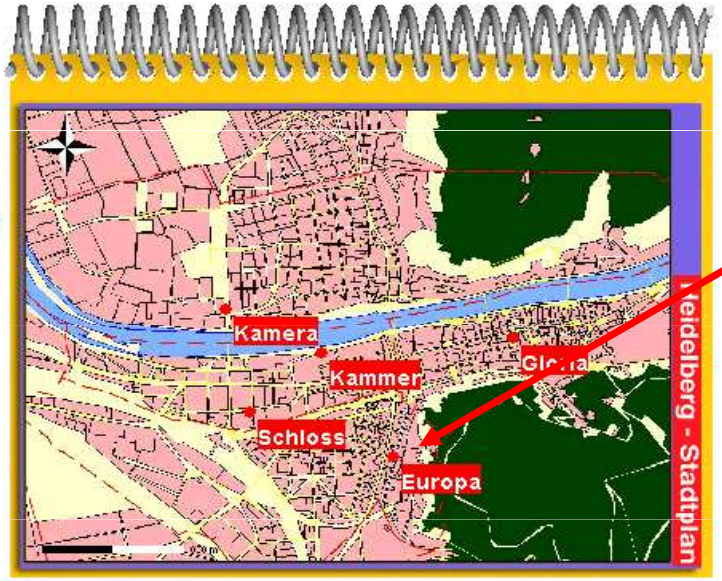
The “Glue“ - M3L: XML based Multimodal Markup Language



An Example of the M3L Representation of the Multimodal Discourse Context



„No presentation without representation!“

```
<?xml version="1.0"?>
<presentationContent>
[...]
   <abstractPresentationContent>
      <movieTheater structId=„pid3072”>
         <entityKey> cinema_17a </entityKey>
         <name> Europa  </name>
            <geoCoordinate>
             <x> 225 </x> <y> 230 </y>
            </geoCoordinate>
      </movieTheater>
   </abstractPresentationContent>
[...]
    <panelElement>
      <map  structId="PM23">
       <boundingShape>
        <leftTop>
         <x>  0.5542 </x>  <y>  0.1950 </y>
        </leftTop>
        <rightBottom>
         <x>  0.9892 </x>  <y>  0.7068 </y>
        </rightBottom>
       </boundingShape>
       <contentReference> pid3072 </contentReference>
      </map>
    </panelElement>
[...]
</presentationContent>
```

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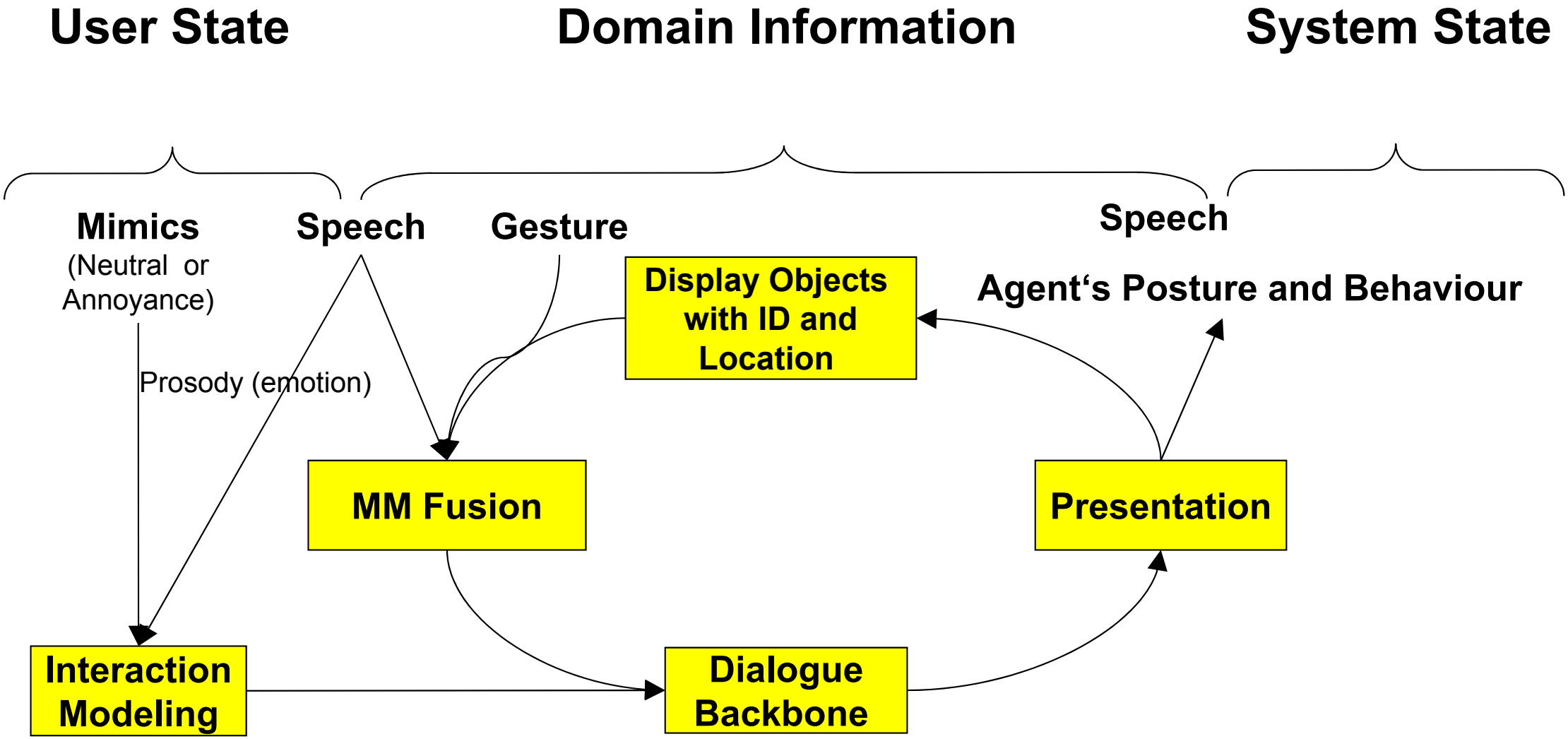
Mode Processing: The Data Flow



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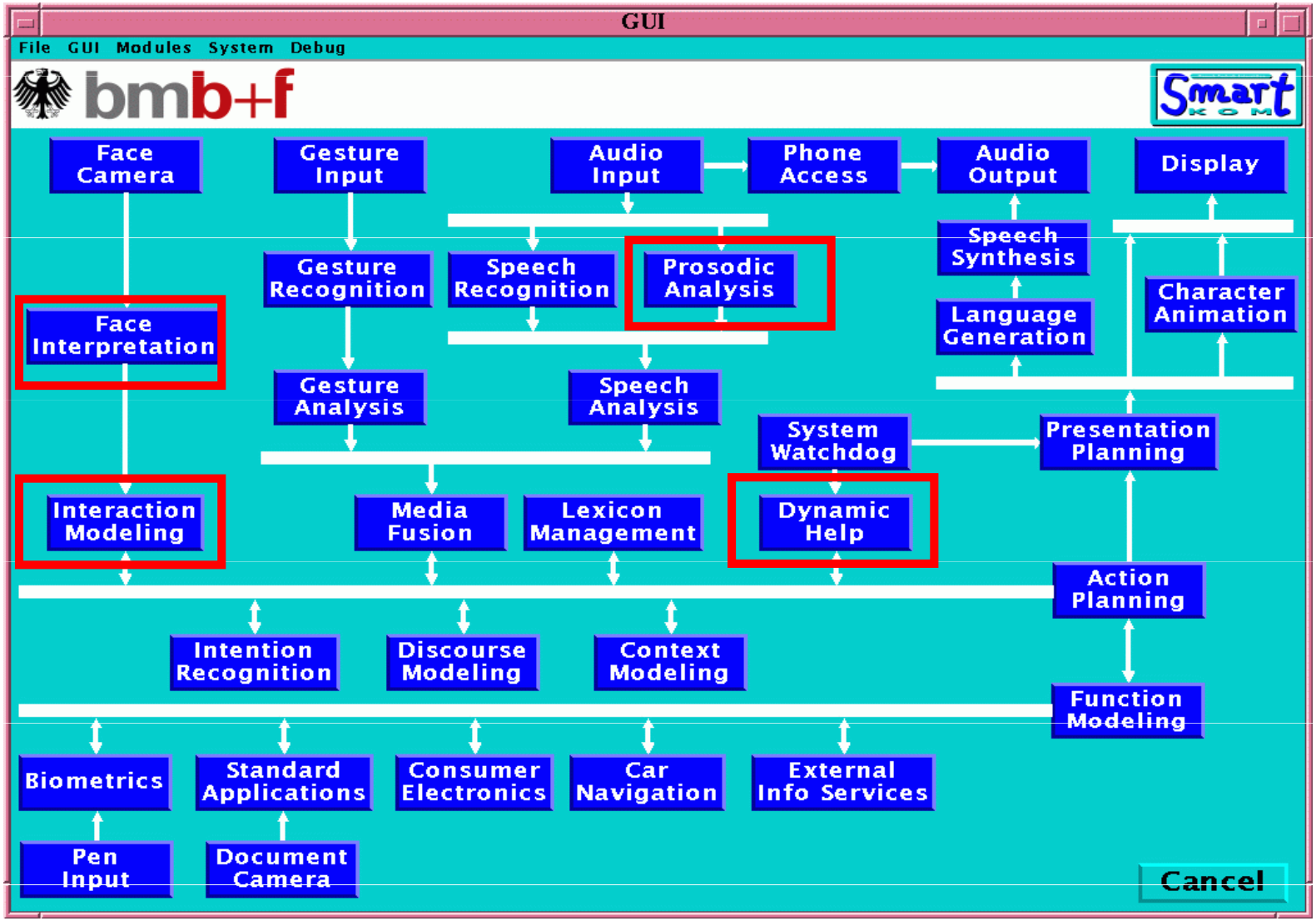
Processing the User‘s State



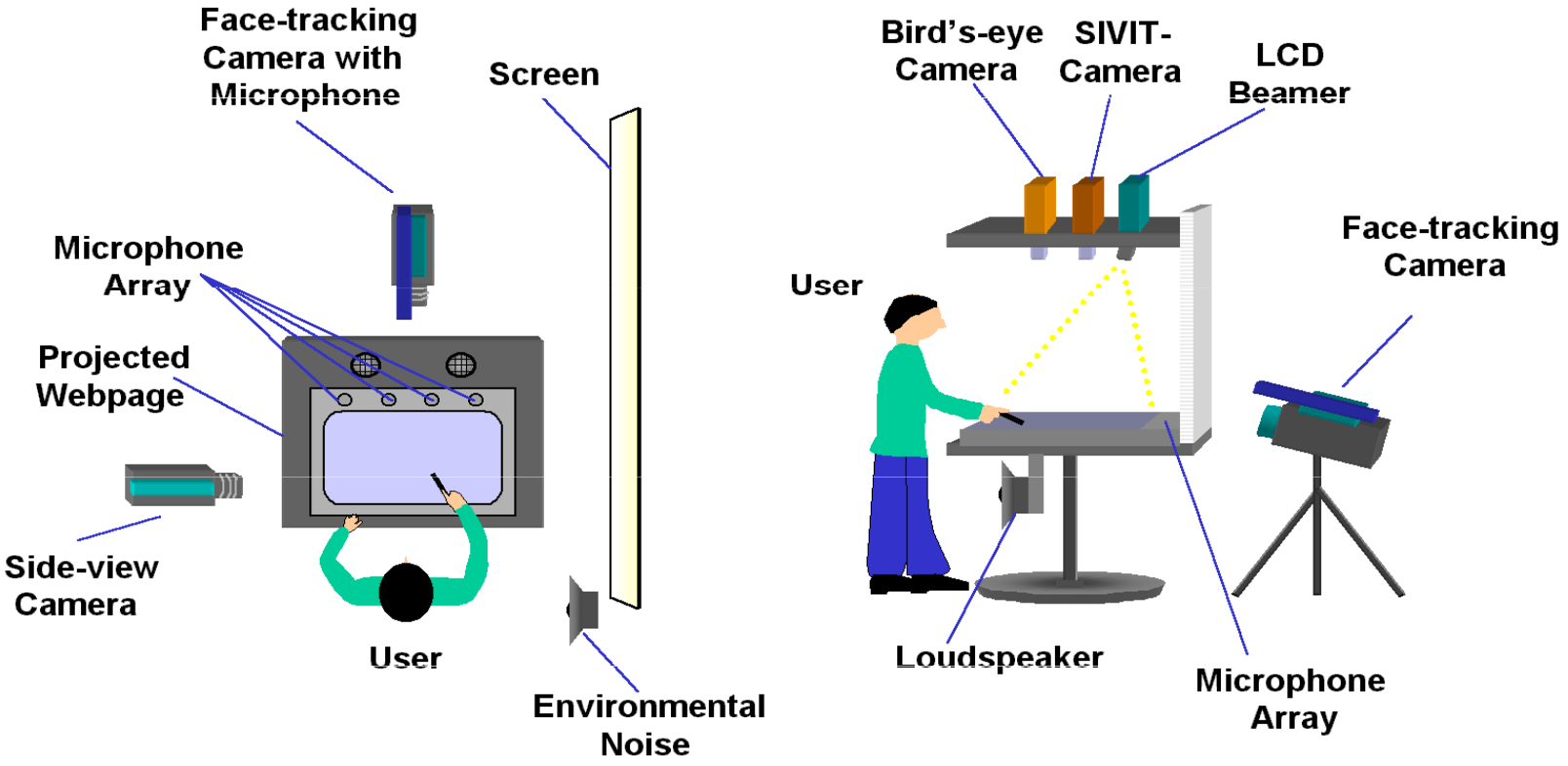
Processing the User's State

- **Different reference levels:**

Object level	Meta level
This is great! Show me more!	*That was quick!*
One moment, let me think.	*OK now, what are you doing?*
Oh no, that's ugly! A new one!	*What the .... is going on?*

- **Annotated in the data from the data collection**
- **Recognized using mimics and prosody**
- **In case of anger activate the dynamic help**

Wizard of Oz Data Collection (LMU Munich)



Data distributed on DVD (1 DVD per 5 minute dialogue)

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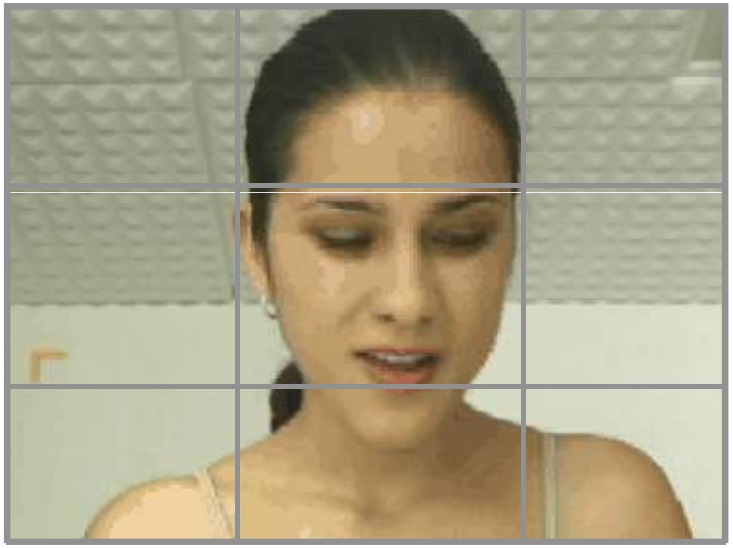
User States Annotated in 45 dialogues

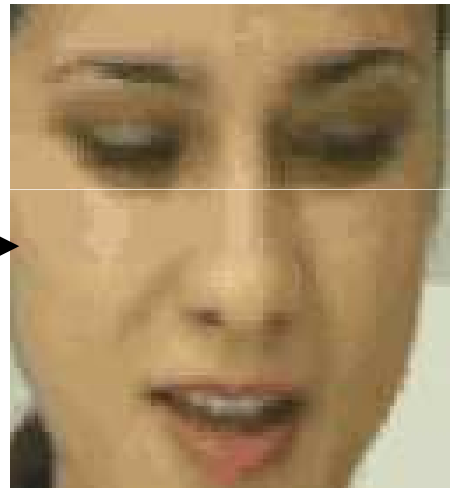
Neutral	681
Joy/success	31
Reflection	59
Perplexity	31
Surprise/Astonishment	11
Annoyance/Failure	16

Only about 18% emotional user state events

User Independent Classification of Facial Expressions
(Univ. Erlangen)



Localization



Annoyance

Rest (neutral)

Classification
(SVM, Eigenfaces)

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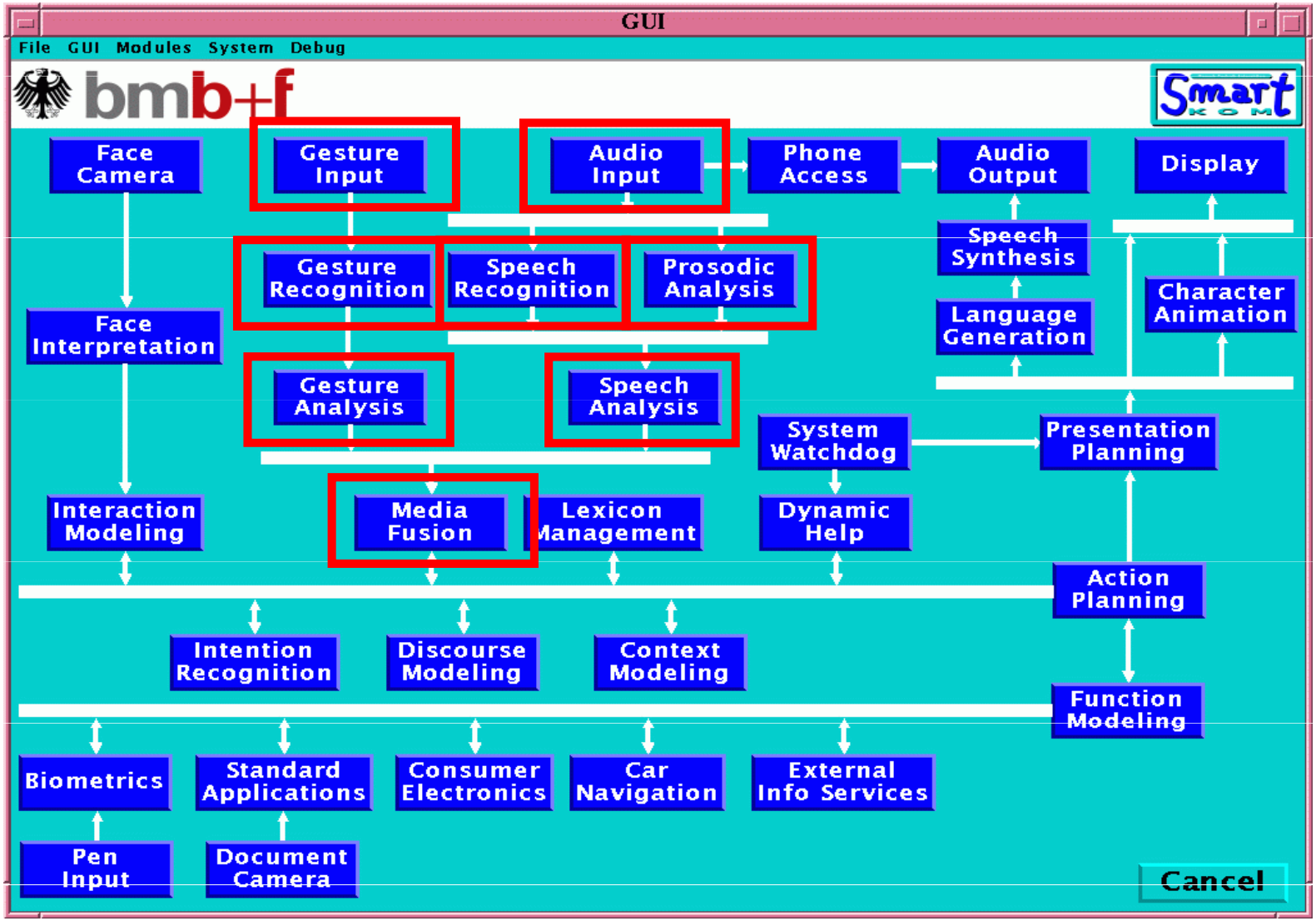
Media Fusion

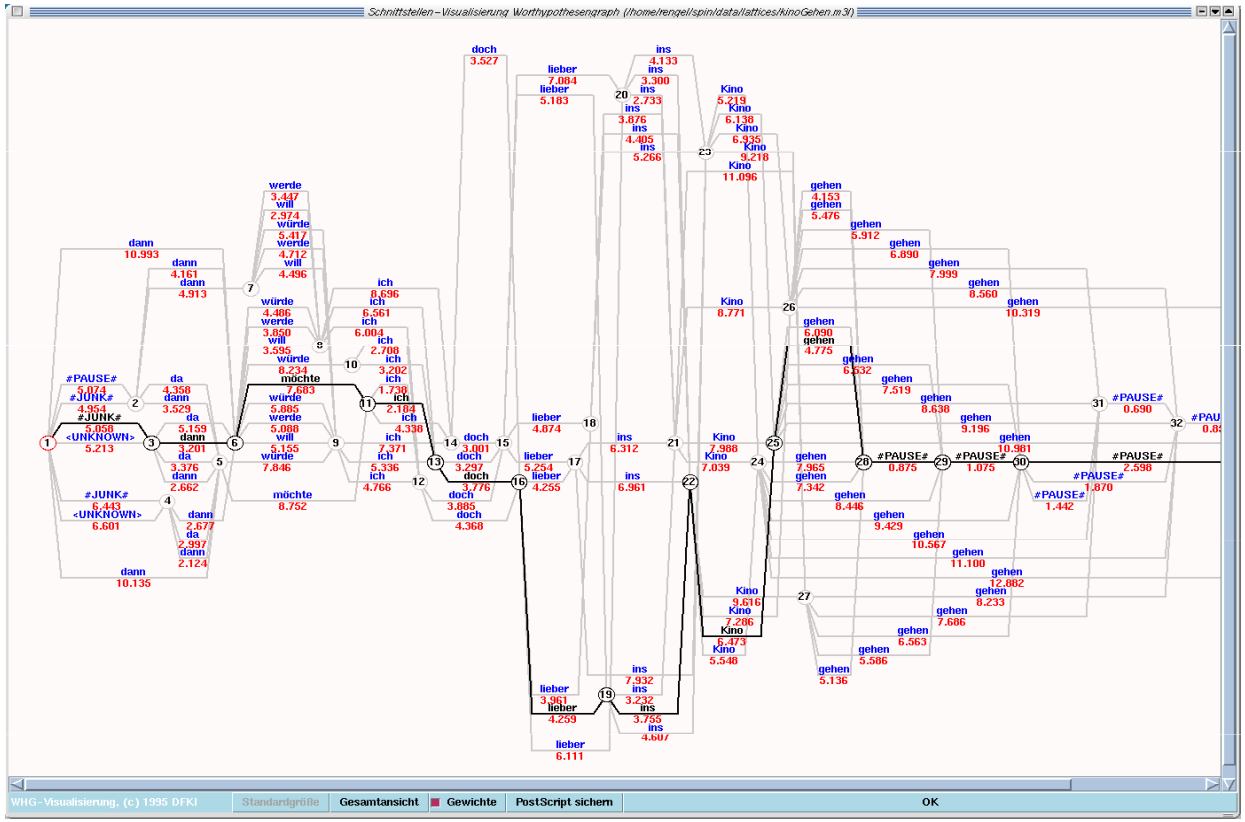


Gesture Processing

- **Objects on the screen are tagged with IDs and bounding boxes**
- **Gesture input**
  - Natural gestures recognized by SIVIT
  - Touch sensitive screen
- **Gesture recognition**
  - Location
  - Type of gesture: pointing, tarrying, encircling
- **Gesture Analysis**
  - Reference object in the display described as domain model (sub-)objects (M3L schemata)
  - Compute distance to bounding boxes
  - Output: gesture lattice with hypotheses

Speech Processing

- **Word lattice**



- **Prosody inserts boundary and stress information**
- **Speech analysis creates intention hypotheses**

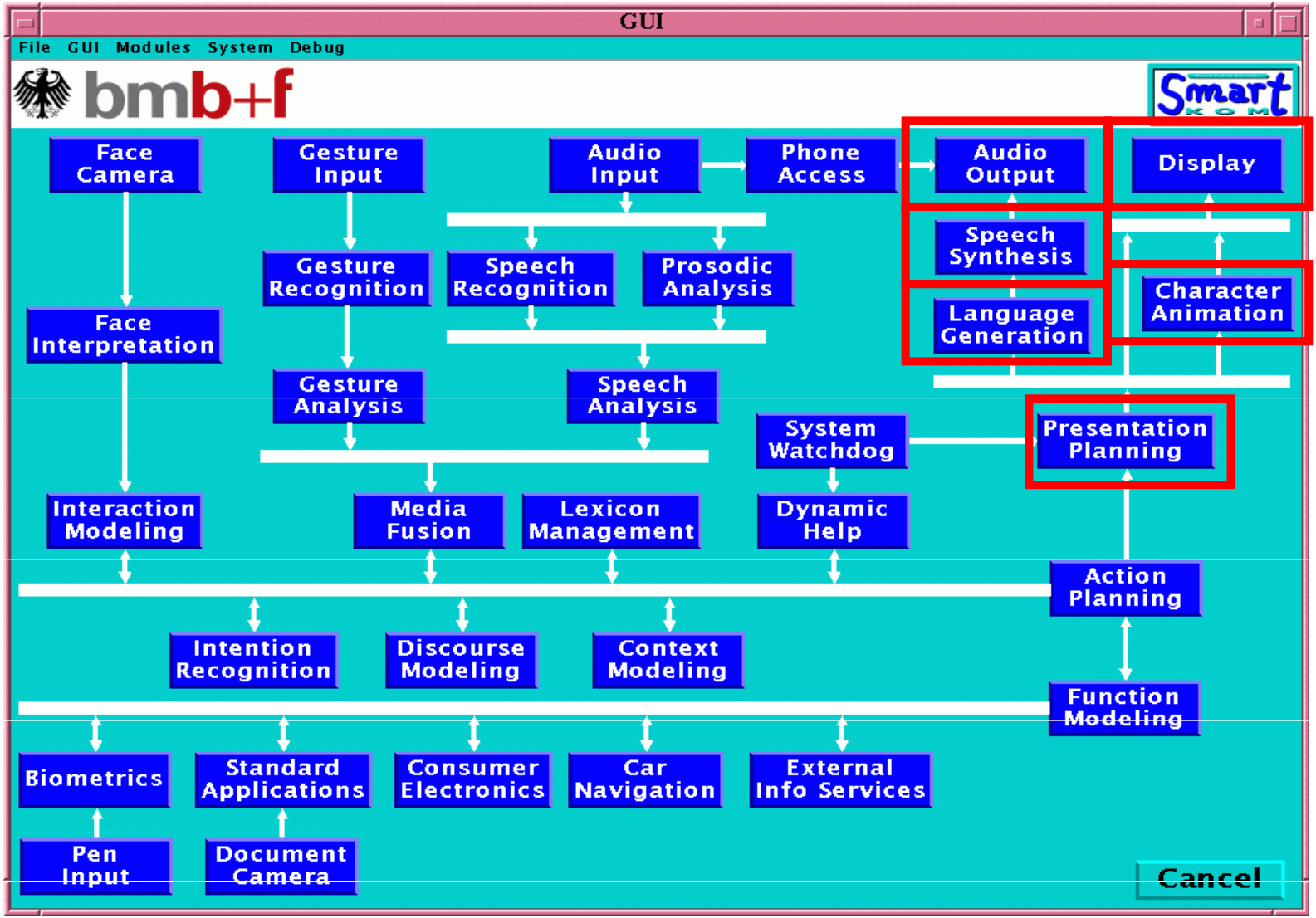
  which movies are playing at the Metropol

  hypothesis(action:info,performance(cinema(name:Metropol)) ..)

Media Fusion

- Integrates gesture hypotheses in the intention hypotheses of speech analysis
- Information restriction possible from both media
- Possible but not necessary correspondence of gestures and placeholders (deictic expressions/ anaphora) in the intention hypothesis
- Necessary: Time coordination of gesture and speech information
- Time stamps in *ALL* M3L documents!!
- Output: sequence of intention hypothesis

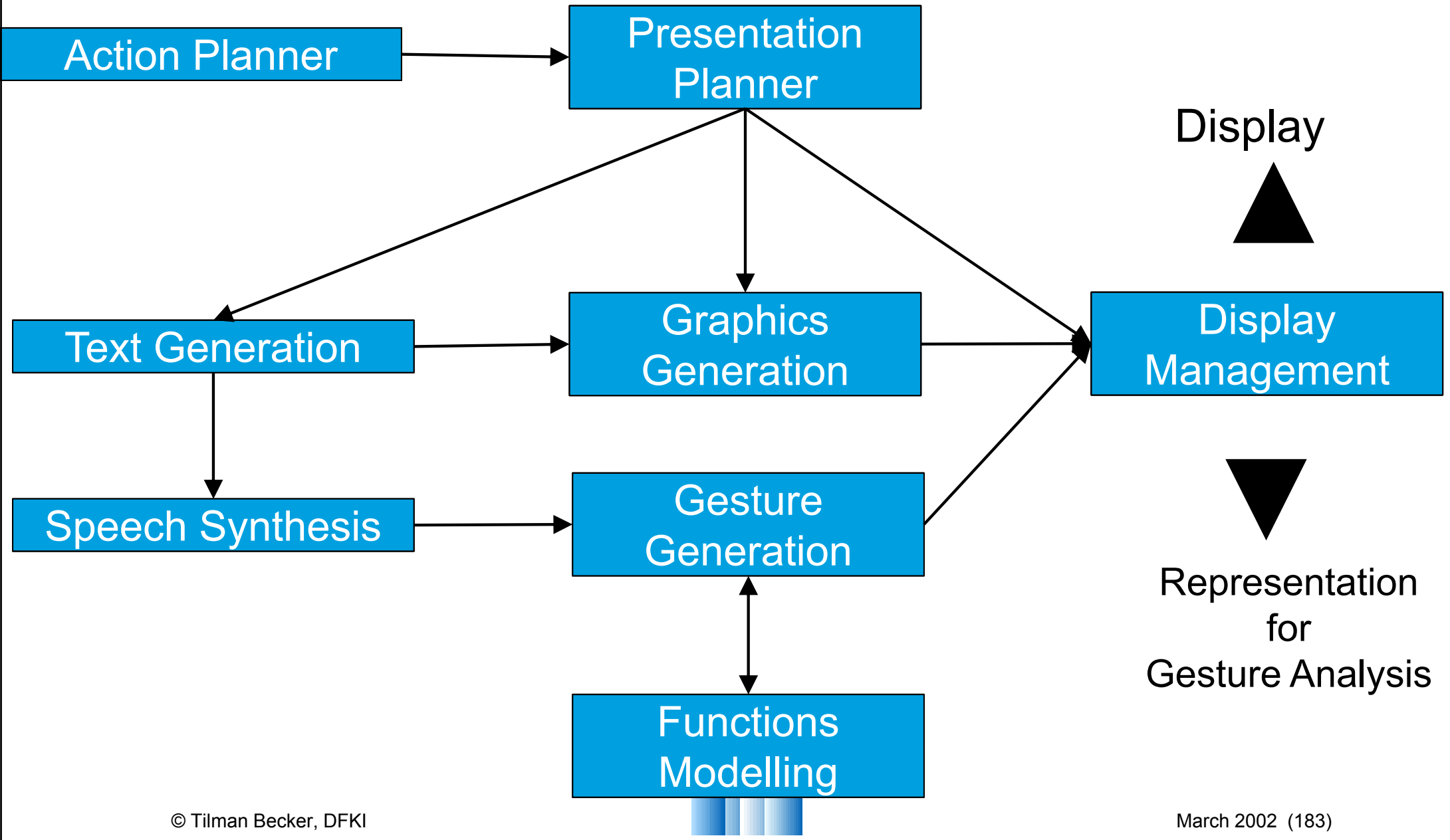
Presentation



Presentation

- **Starts with action planning**
- **Definition of an abstract presentation goal**
- **Presentation planner:**
  - Selects presentation, style, mode, and agent‘s general behaviour
  - Activates natural language generator which activates the speech synthesis which returns audio data and time-stamped phoneme/viseme sequence
- **Character animation realizes the agent‘s behaviour**
- **Synchronized presentation of audio and visual information**

Partial view of SK architecture: Multimodal Presentation



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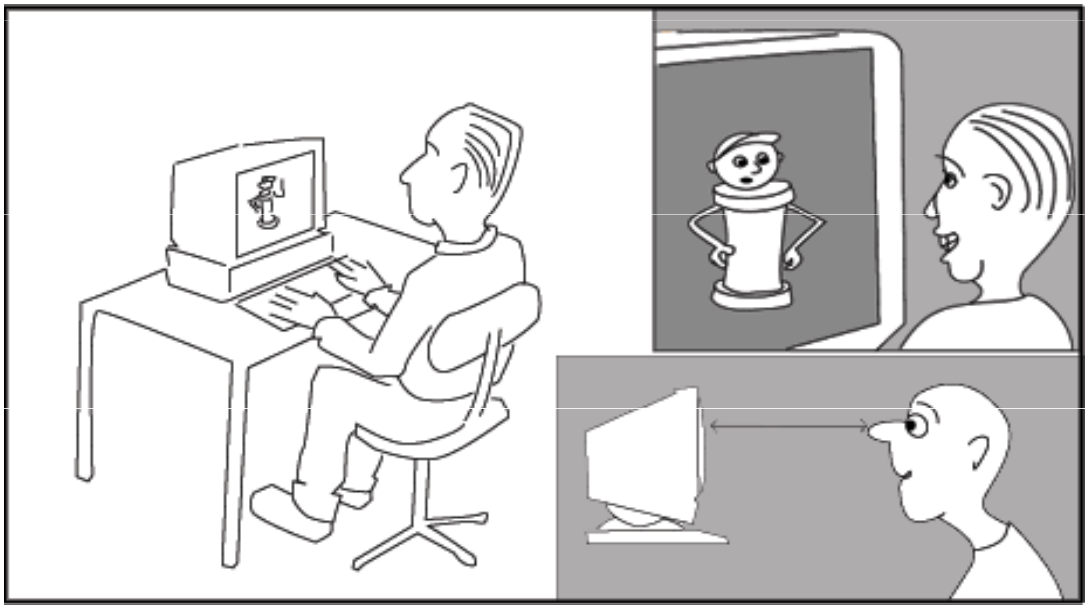
User Perspective



Monitor: frontal view

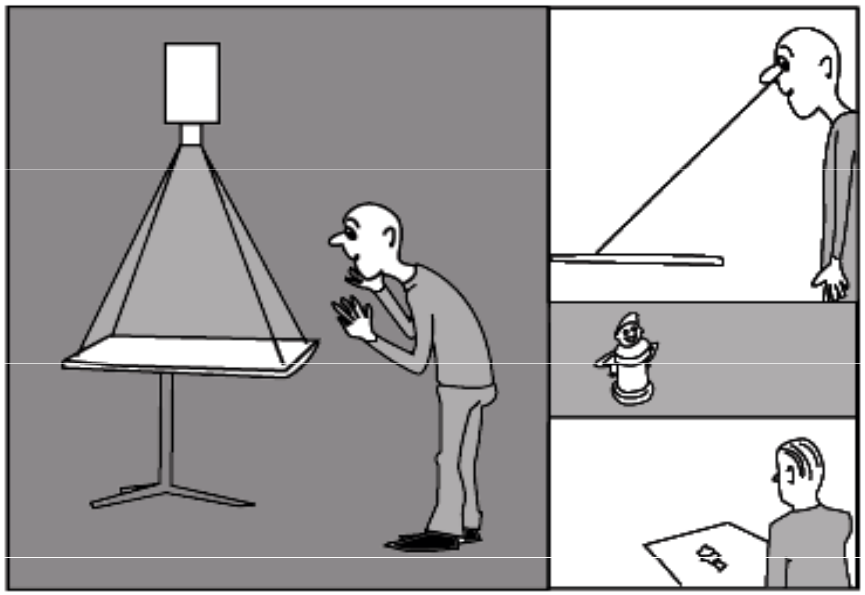


Table: angled view

Lip Synchronization with Visemes

- **Goal: present a speech prompt as natural as possible**
- **Viseme: elementary lip positions**
- **Correspondence of visemes and phonemes**
- **Examples:**

Behavioural Schemata

- **Goal: the agent (Smartakus) is always active to signal the state of the system**
- **Four main states**
  - Wait for user‘s input
  - User‘s input
  - Processing
  - System presentation

- **Current body movements**
  - 9 vital, 2 processing, 9 presentation (5 pointing, 2 movements, 2 face/mouth)
  - About 60 basic movements

New animations

Examples for complex movements and speech-synchronized gestures

Pointing to the right

Enumeration of items

Moving in a circle

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Example: Pointing Gestures

base position

preparation

stroke

retraction

composed gesture:

Details:

Natural Language Generation in SmartKom

Discourse Updates in Interactive Dialogues

AT&T Research
2 Aug 2001

Natural Language Generation in SmartKom

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Overview

- **Architecture**
- **Presentation Goals**
- **Natural Language Generation**

  for Speech Synthesis
  - Architecture
  - Selection of data, sentence templates
  - „fully specified templates“
  - Concept-To-Speech information
- A short look aside: graphics and gestures
- **Outlook**

Presentation Begins in Action Planning

- **Presentation as planning of a multi-modal dialog act**

- **Abstract presentation goals**

  (defined in an XML Schema

  `presentation.xsd`**)**

Natural Language Generation: Overview

- **Input, Output**
- **Architecture**
- **Knowledge Bases**
- **The steps of generation**
- **Templates**
  - Tree Adjoining Grammars
  - “fully specified templates”
- **Concept-To-Speech information**

Typical Abstract Presentation Goals

- **Presentation of information (usu. With an implicit request): “Here you can see...” : `<inform>`**
- **Explicit Request to fill a slot: “Please show me where you want to sit” : `<request>`**
- **Feedback: “Your reservation is secured...” `<feedback>`**
- **Canned presentations:**

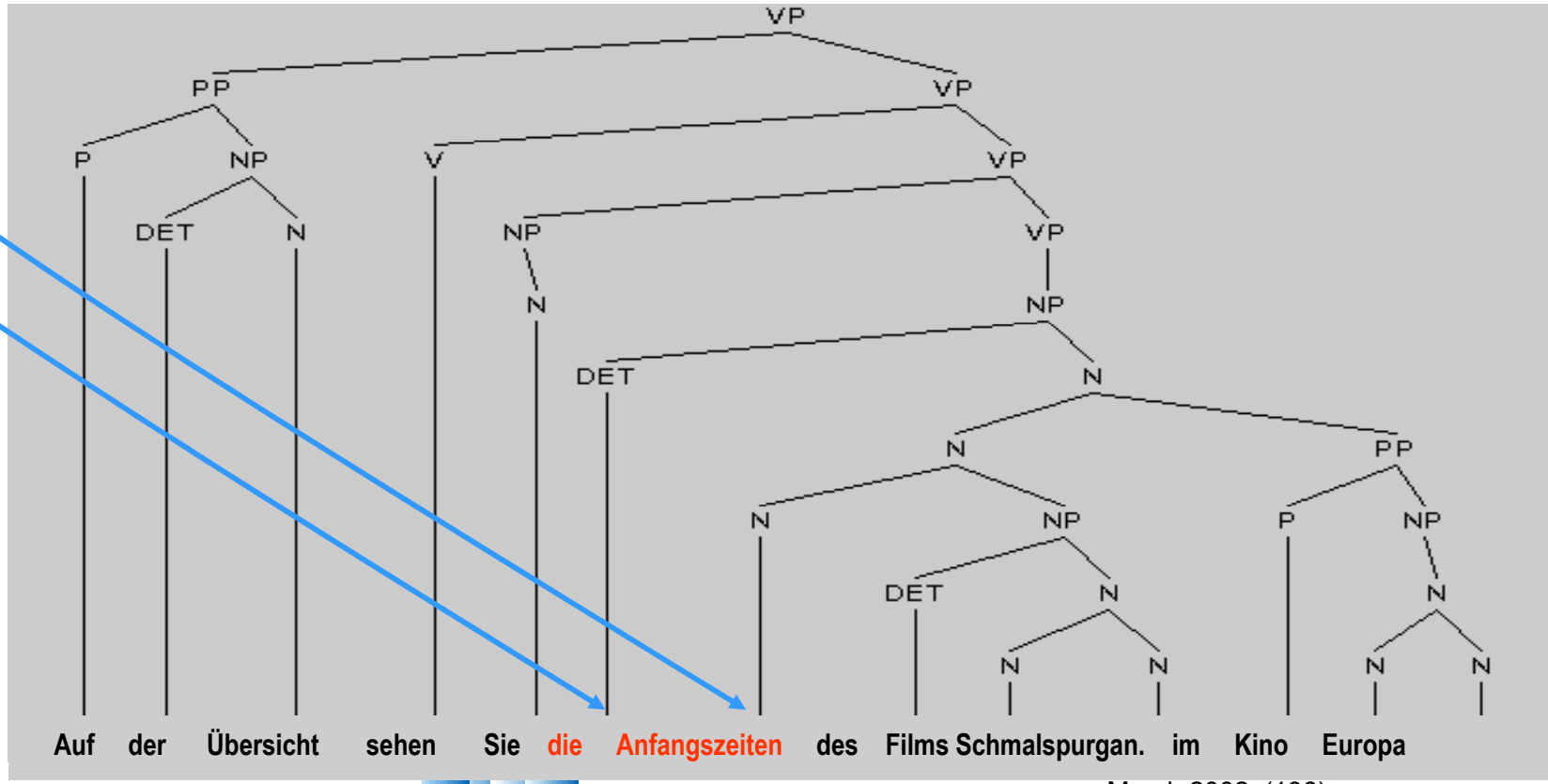
  `<goodbye>`

Input for Natural Language Generation

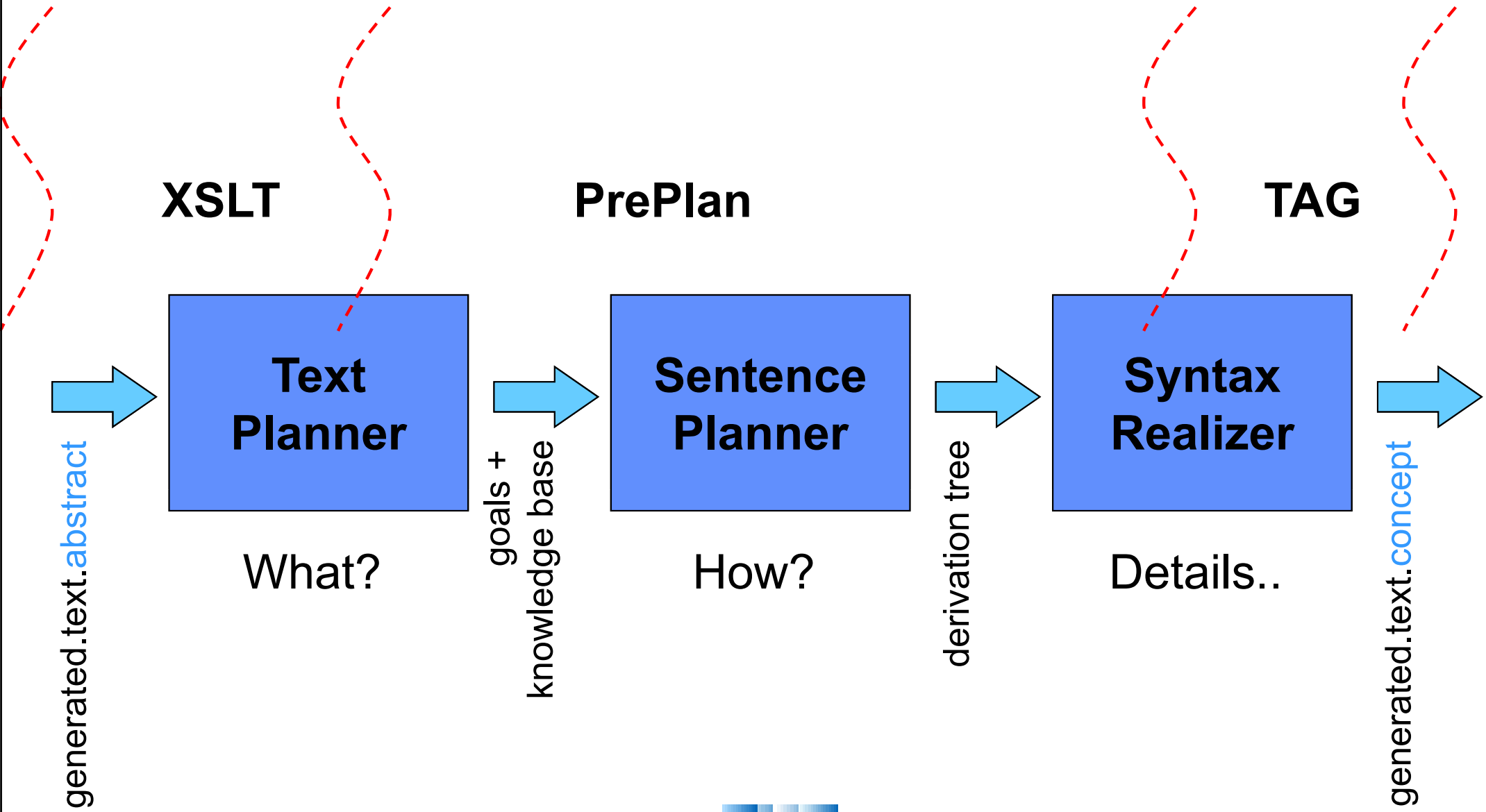
```
<speechGenerationTask  goalKey="11">
 <speechPresentationGoal>
  <inform>
   <comment       commentTyp="onGraphicalPresentation">
     <graphicalRealisationType>        list        </graphicalRealisationType>
     <deepFocus   structReference="struct201"/>
     <content       structReference="struct17"/>
     <content       structReference="struct18"/>
   </comment>
  </inform>
 </speechPresentationGoal>
 <abstractPresentationContent>
      <performance>
       <avMedium>
        <title structId="struct18"> Schmalspurganoven </title>
       </avMedium>
       <cinema>
        <movieTheatre structId="struct17">
         <name>   Europa    </name>
        </movieTheatre>
       </cinema>
      <beginTime structId="struct201"/>
     </performance>
[...]
 </abstractPresentationContent>
</speechGenerationTask>
```

```
<concept   sequence="11">
 <discourseElement     id="9011"  discourseRelation="simple">
  <sentence       id="tsen-9011"   sentenceMode="declarative">
[...]
        <syntaxElement  case="acc" argumentStatus="Object"  syntaxCategory="NP">
         <syntaxElement  syntaxCategory="Det">
          <lexicalElement   partOfSpeechTag="ART">
           <text>                die                </text>
          </lexicalElement>
         </syntaxElement>
         <syntaxElement   syntaxCategory="N">
            <lexicalElement    partOfSpeechTag="NN">
             <text>          Anfangszeiten     </text>
            </lexicalElement>
           </syntaxElement>
[...]
    </syntaxElement>
  </sentence>
 </discourseElement>
</concept>
```

Output of Natural Language Generation



Sketch of the Architecture



Knowledge Bases in NLG

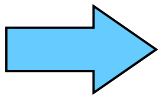
- Defining the goal (XSLT Stylesheet, What?)
- Planning rules (PrePlan, How?)
- (Template-)grammar (TAG, Realizer How?)
- (Morphology)
- Lexicon (TAG, Realizer)

- Discourse memory (anaphora etc.)
- User model (“Interaktionsmodellierung”) (register etc.)

First Step: Defining the Goal

- **XSLT: Mapping abstract goals to realization goals, e.g.:**

```
<request>
  <slotFill><select>
     <modality>gesture</modality>
   </select></slotFill>
  <requestFocus>
    <deepFocus idReference="mf42"/>
  </requestFocus></request>
```



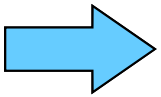
```
(showme mf42)
```

```
<xsl:template match="request/slotFill/select[normalize-space(modality/text())='gesture']">
  (showme
 <xsl:apply-templates select="requestFocus/deepFocus"/>
   )
</xsl:template>
```

First Step (2): Using Context Information

- **XSLT: Creation of a generation knowledge base from the input, e.g.:**

```
<performance id="mf745">
  <entityKey id="mf746">
    performance_1000030
  </entityKey>
  <avMedium id="mf747">
    <entityKey id="mf748">
      avMedium_1002535
    </entityKey>
    <title>
      O Brother, Where Art Thou?
    </title>
  </avMedium>
</performance>
```



```
(GKB (
 (performance mf745)
 (entitykey
   mf746
   performance_1000030)
 ...
 (title
   mf747
   "O Brother..")
 ...
)
```

Second Step: Sentence Planning with Templates

- **Result is a derivation tree**
- **PrePlan (a simple planning tool in Java):**
  - (Text and) sentence planning
  - Selection of templates and filling of slots, e.g.:

```
(overview mf42)
  ->
(select “You can see an overview”)
(adjoin “Node Overview-4711”)
(np-realize mf42)
```

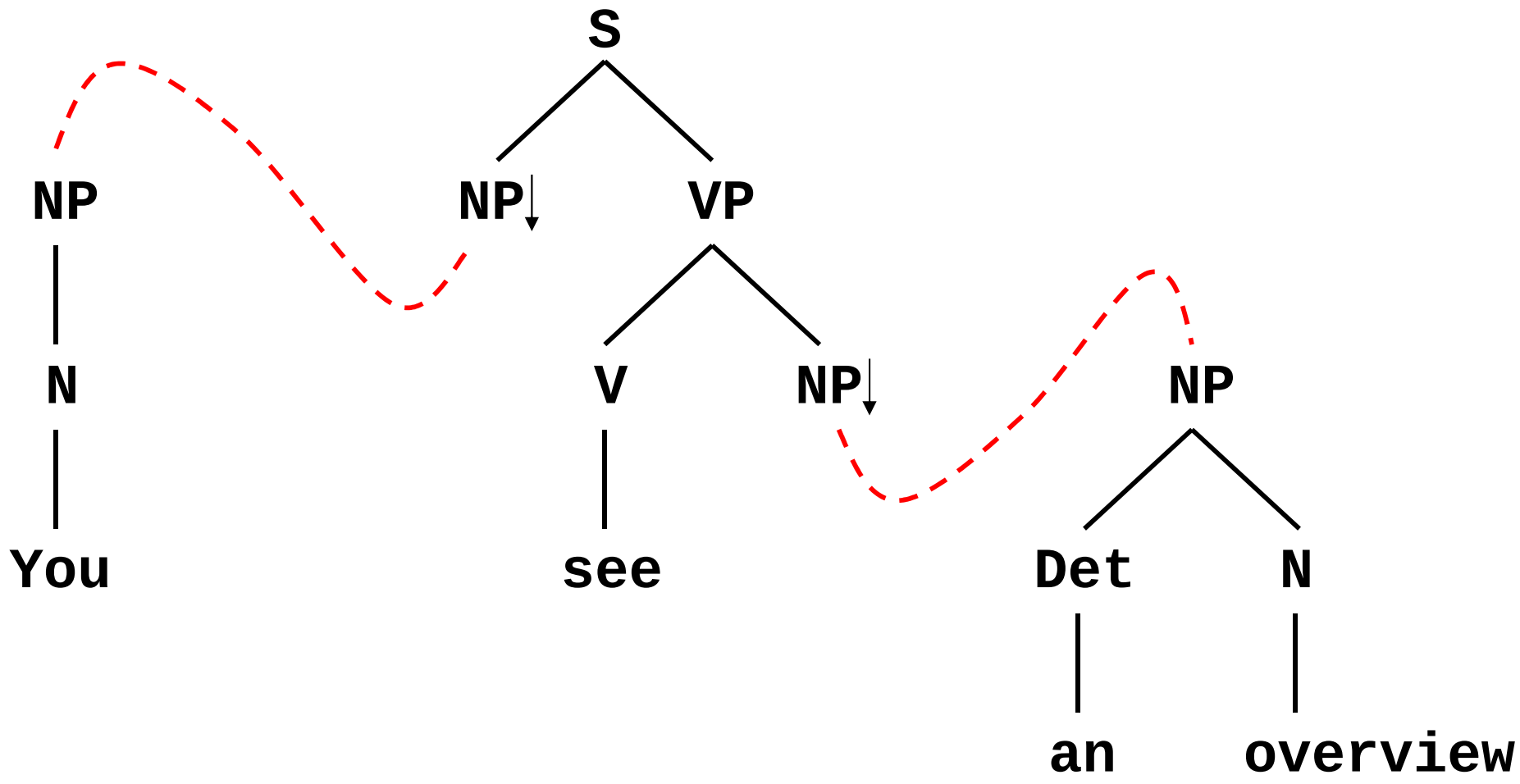
  - `Select` and `adjoin` refer to trees and nodes of the (TAG) Grammar

TAG Grammars

- **Tree Adjoining Grammars (Joshi et al 1975)**
- **A grammar**
  - consists of partial trees,
  - that are combined by two operations:
    - Adjunction
    - Substitution
  - Lexicalized grammars:
    - A set of possible partial trees for every word
    - Every partial tree is a “maximal projection” of the word

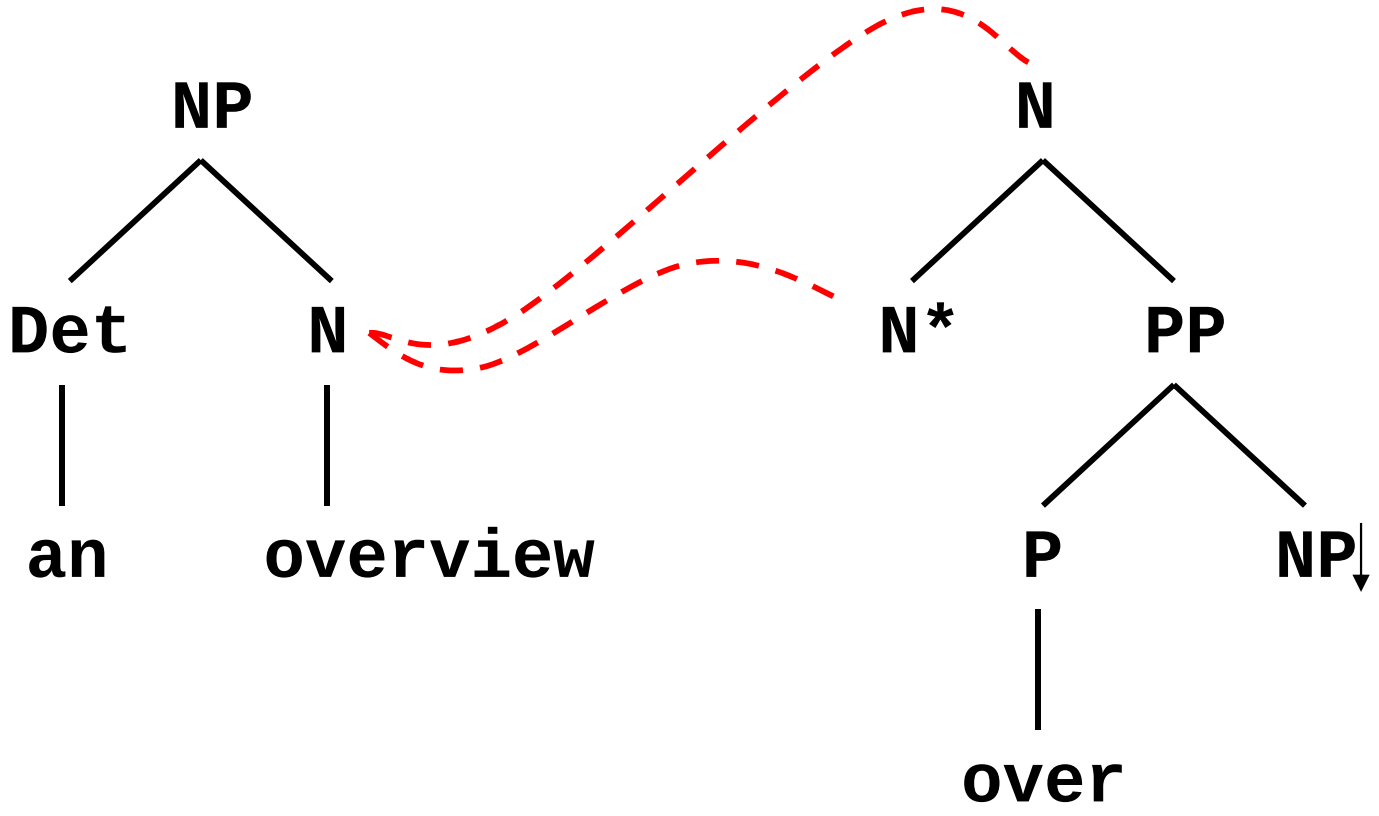
TAG: Initial Trees

Substitution as in context-free grammars:



TAG: Auxiliary Trees

Adjunction is more powerful than context-free grammars:

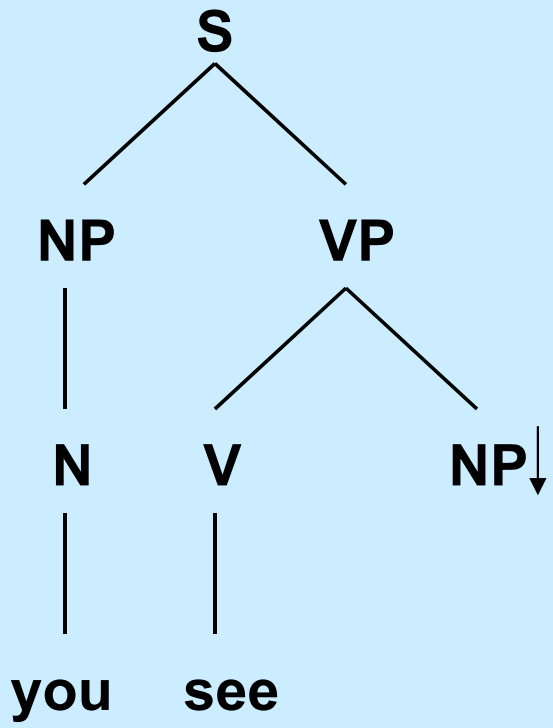


TAG with Templates

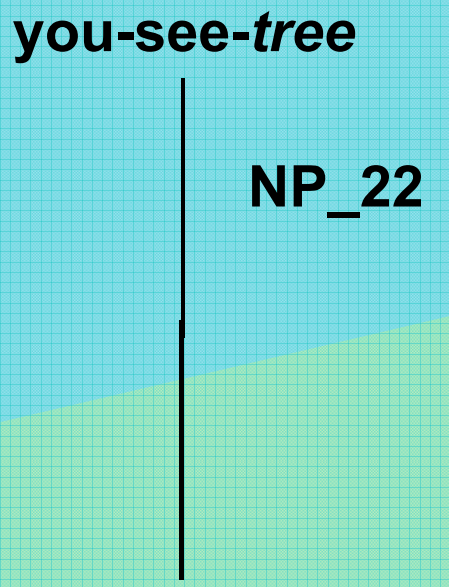
- **Instead of lexicalized trees:**
  - A template tree contains the entire structure of a template
  - …including all words
  - A simplistic „template Grammar“ consists of complete sentences
  - Can smoothly be developed into a complete grammar
- **Problem:**
  - What are the right syntactic(?) structures?
  - General problem with CTS

Planning a Derivation Tree

Commenting on a graphical presentation

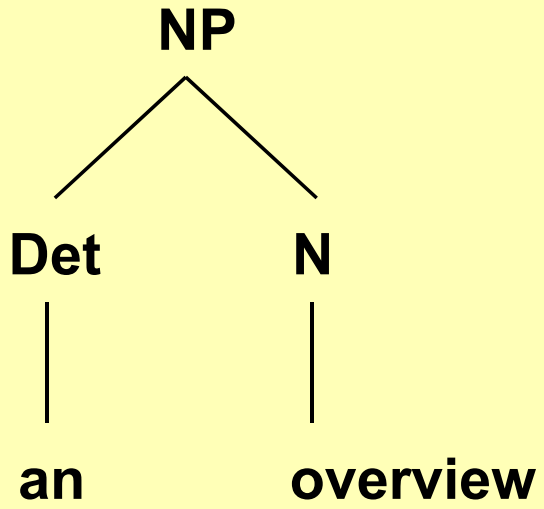


derived tree



derivation trees

Referring to a list



derived tree

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Concept-To-Speech

- Syntactic Information is used to compute Prosodic Information
- Sentences are combined to discourse tree
- Filtering of irrelevant syntactic features

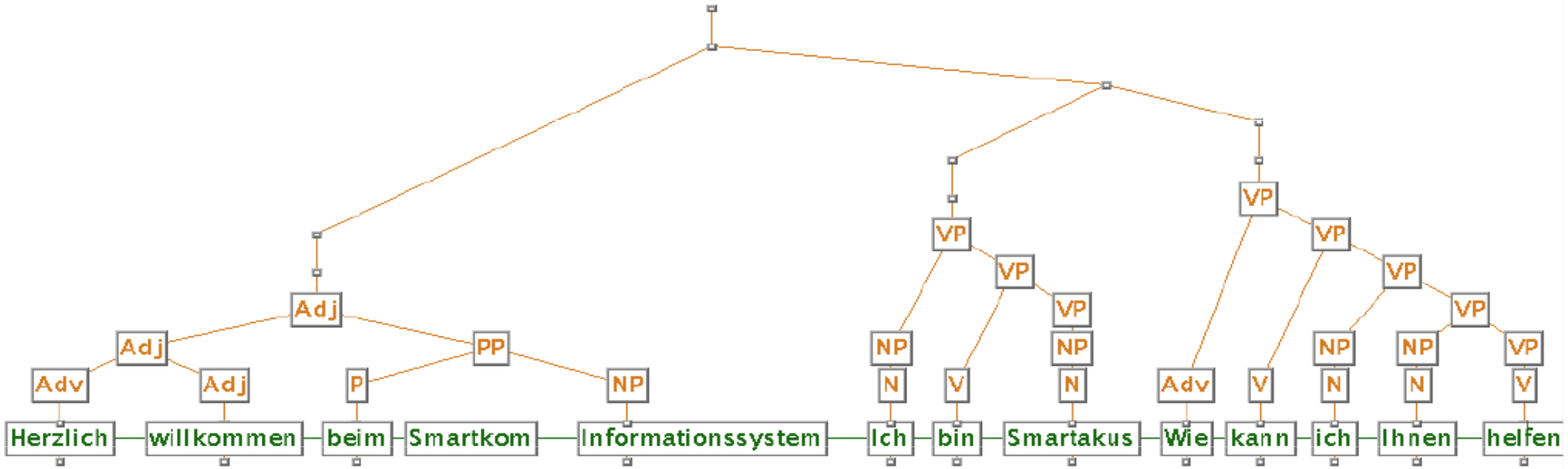
- Synthesis is based on Festival
- Preprocessing traverses syntactic structure (Scheme)

- Work carried out at IMS, Stuttgart, Germany
  Gregor Möhler, Antje Schweitzer
  (Prof. Dogil)

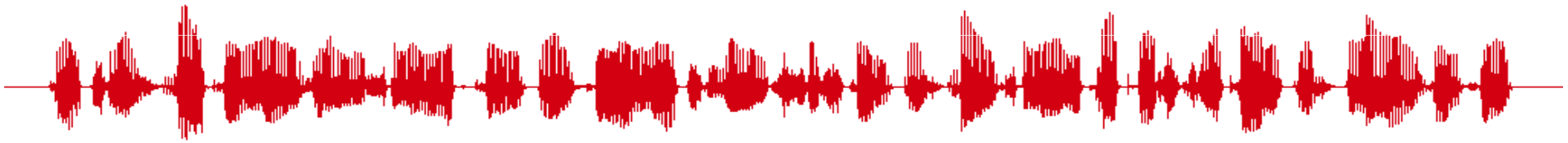
© Tilman Becker, DFKI

CTS versus TTS

Institut für Maschinelle Sprachverarbeitung
Universität Stuttgart



L*H H*L % H*L% L*H H%



© Gregor Möhler, IMS Stuttgart

Templates

- **Where do we get the templates from?**
  - Ideally from existing grammars:
    - consistent
    - short development time
    - no/less expertise required
  - Data collection for a new application:
    - example dialogues
    - Wizard of Oz experiments
    - dialogue models
  - Growing collection of “standard templates” (will lead to a real grammar)

Current work

- **Complete TAG implementation with unification:**
  - Porting an existing Unifier (LISP)
  - XML-Representation of the grammar:
    - Graphical tools
    - XSLT mapping to/from other formats (LISP)

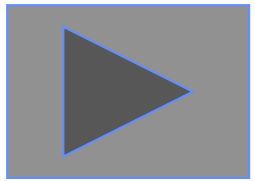
- **Structure of planning rules:**
  - Separate text and sentence planning
- **Extending the set of templates**

Future Work

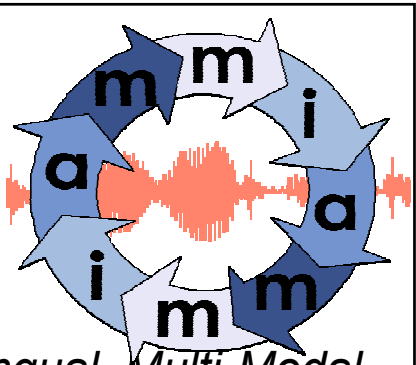
- **Generating referring expressions**
- **Generating text for graphics, esp. for mobile scenario “no audio”**
- **Text planning**
- **Abstract “sentence plans”:**
  - Module within syntactic realization
- **Various tools (next slide)**
- **Language independent steps of NLG**

Future Work

- **Tools for:**
  - PrePlan planning rules
  - Lexicon (morphology)
- **Template tree development scenario:**
  - Parser (with a German grammar -- Kim Gerdes) produces derivation trees
  - (Graphical) tool to
    - select correct analysis
    - relate to existing templates
    - mark fixed/variable parts



MIAMM



- **Multidimensional Information Access using Multiple Modalities (IST-2000-29487)**
  - **Cross Programme Action 2** *User Friendliness, Human Factors, Multi-Lingual, Multi-Modal dialog modes*
- **Duration: September 2001 - February 2004**
- **Participants**
  - **INRIA (Laboratoire Loria), FR [Coord.]**
    - Speech recognition, language analysis, contextual interpretation
  - **Deutsches Forschungszentrum für Künstliche Intelligenz, DE**
    - Graphical interface, language analysis, dialogue management
  - **Netherlands Organization for Applied Scientific Research (TNO), NL**
    - Task analysis, interaction scenarios, evaluation
  - **Sony International Europe GmbH, DE**
    - Multilingual speech recognition (en, de), software for haptic interaction, domain modeling, hardware interaction
  - **CANON Research Centre Europe (CRE), UK**
    - Multimedia database and search application

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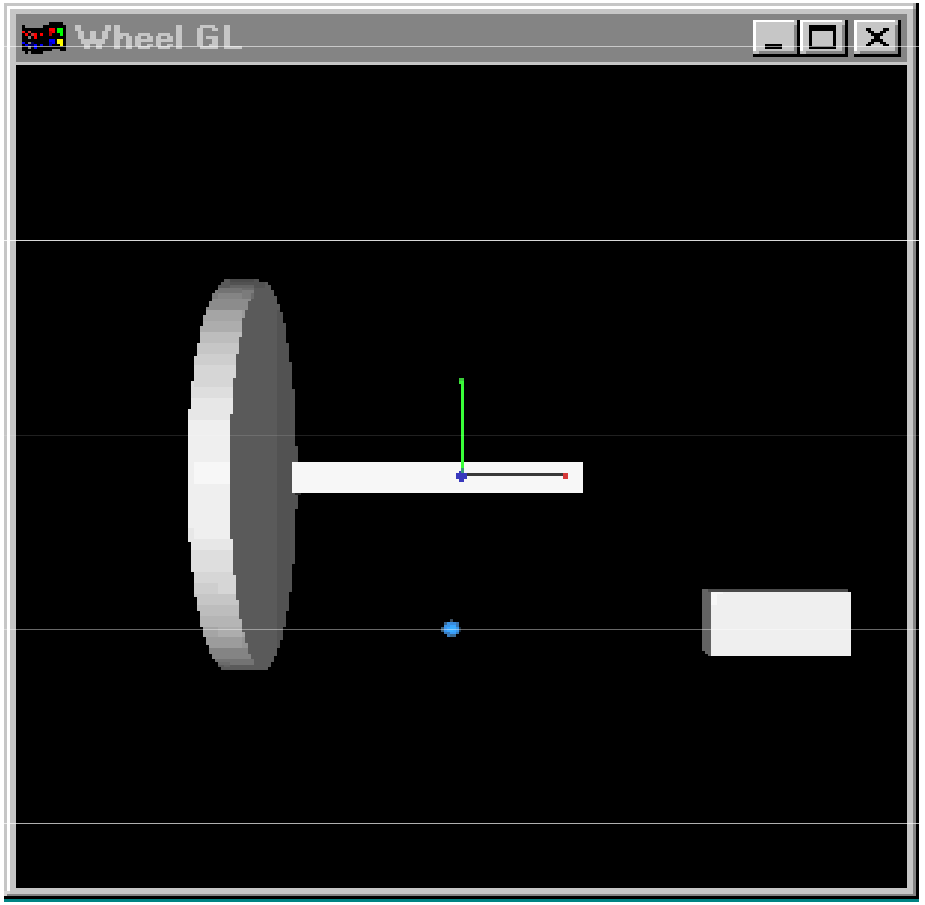
The Haptic Device

Phantom (www.sensable.com)



3 degrees of freedom force feedback unit

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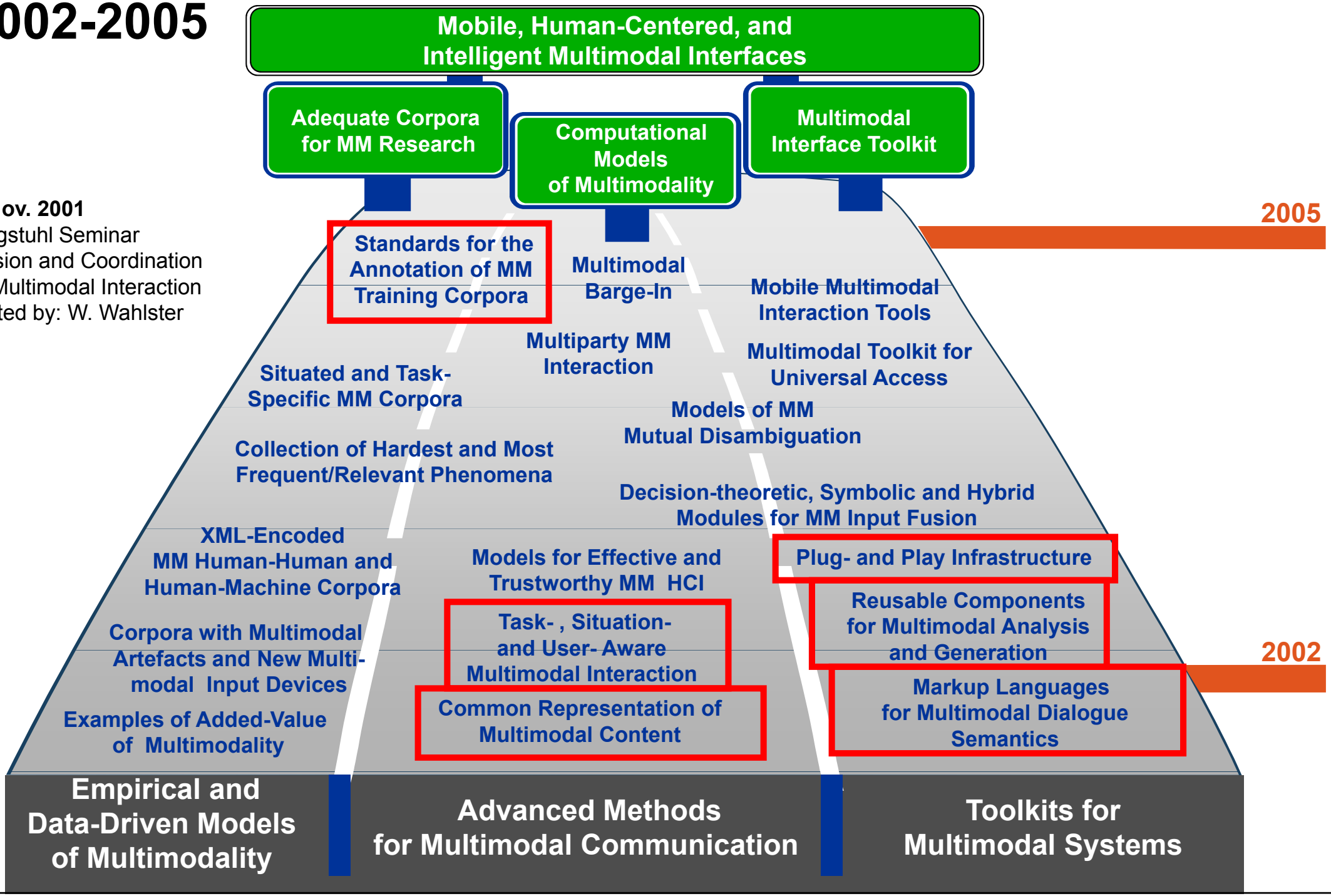
Research Roadmap of Multimodality

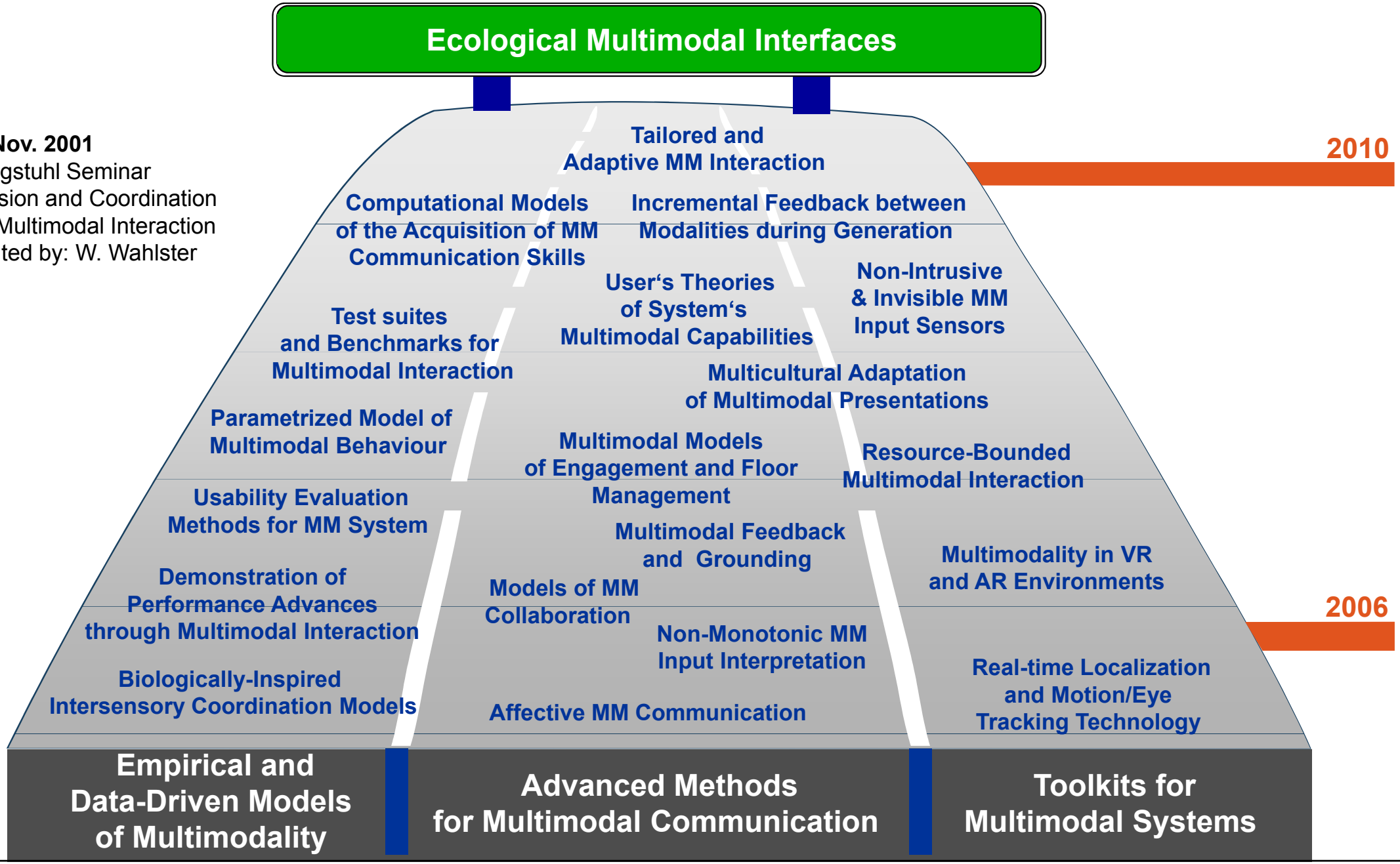
2002-2005



2 Nov. 2001
Dagstuhl Seminar
Fusion and Coordination
in Multimodal Interaction
edited by: W. Wahlster

Research Roadmap of Multimodality

2006-2010



Research Roadmap of Multimodality 2001-2010

Enabling Technologies and Important Contributing Research Areas

2 Nov. 2001
Dagstuhl Seminar
Fusion and Coordination
in Multimodal Interaction
edited by: W. Wahlster

Multimodal Input	Multimodal Interaction	Multimodal Output
● Sensor Technologies	● User Modelling	● Smart Graphics
● Vision	● Cognitive Science	● Design Theory
● Speech & Audio Technology	● Discourse Theory	● Embodied Conversational Agents
● Biometrics	● Ergonomics	● Speech Synthesis

● Machine Learning ● Formal Ontologies ● Pattern Recognition ● Planning

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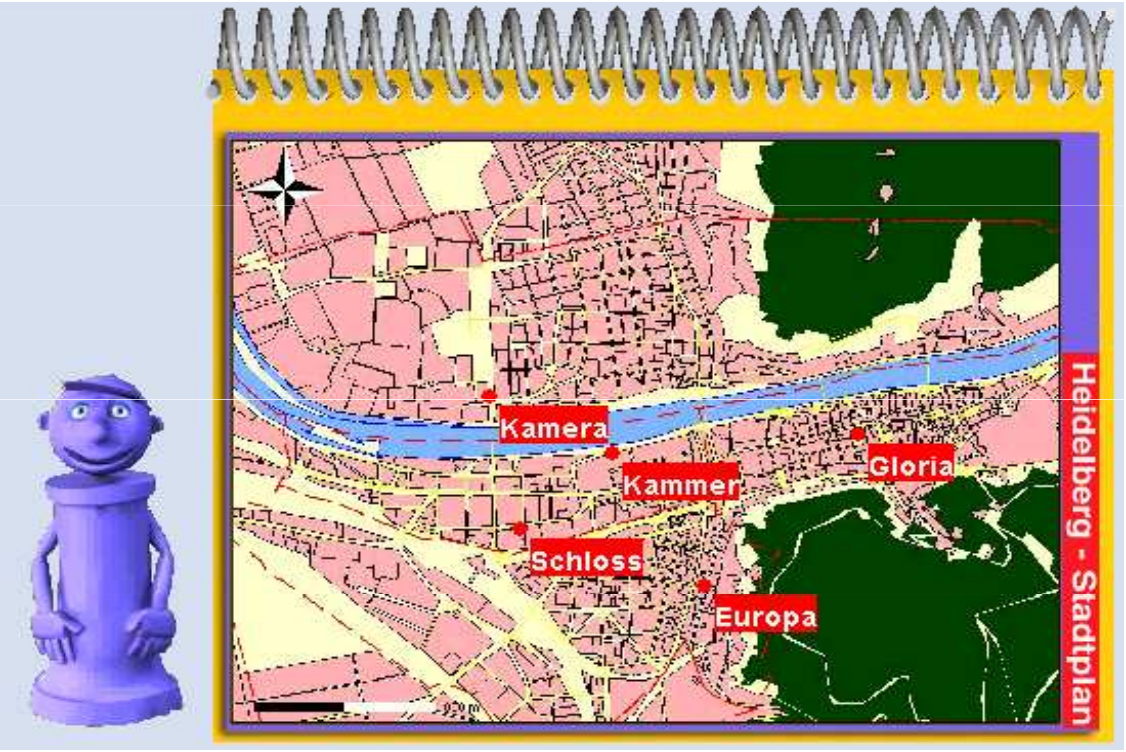
Multimodal Interaction in SmartKom

Scenario:
public (mobile, home)
Application:
movie information
(EPG, email, phone, fax,
address book,
tv and vcr control,
routing/tourist info)



U: ***I want to make a reservation in (☼) this movie theater***

S: This theater does not take reservations

U: ***Then a different one, (☼) this one perhaps***

IJCAI 2001
Workshop TASK-4
Seattle, WA, USA

Overlay as the basic operation in discourse processing

Jan Alexandersson

Tilman Becker

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Email: {janal,becker}@dfki.de
www.dfki.de

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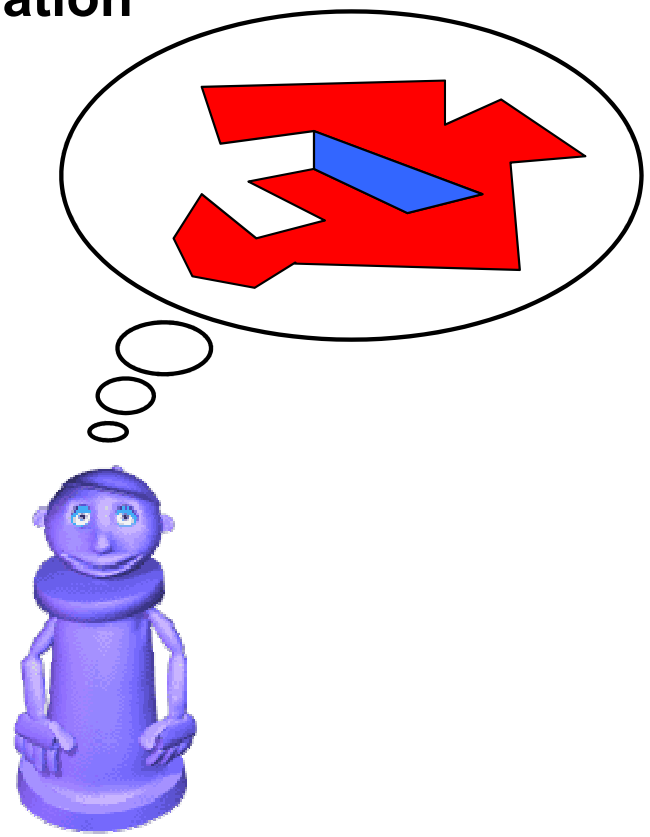
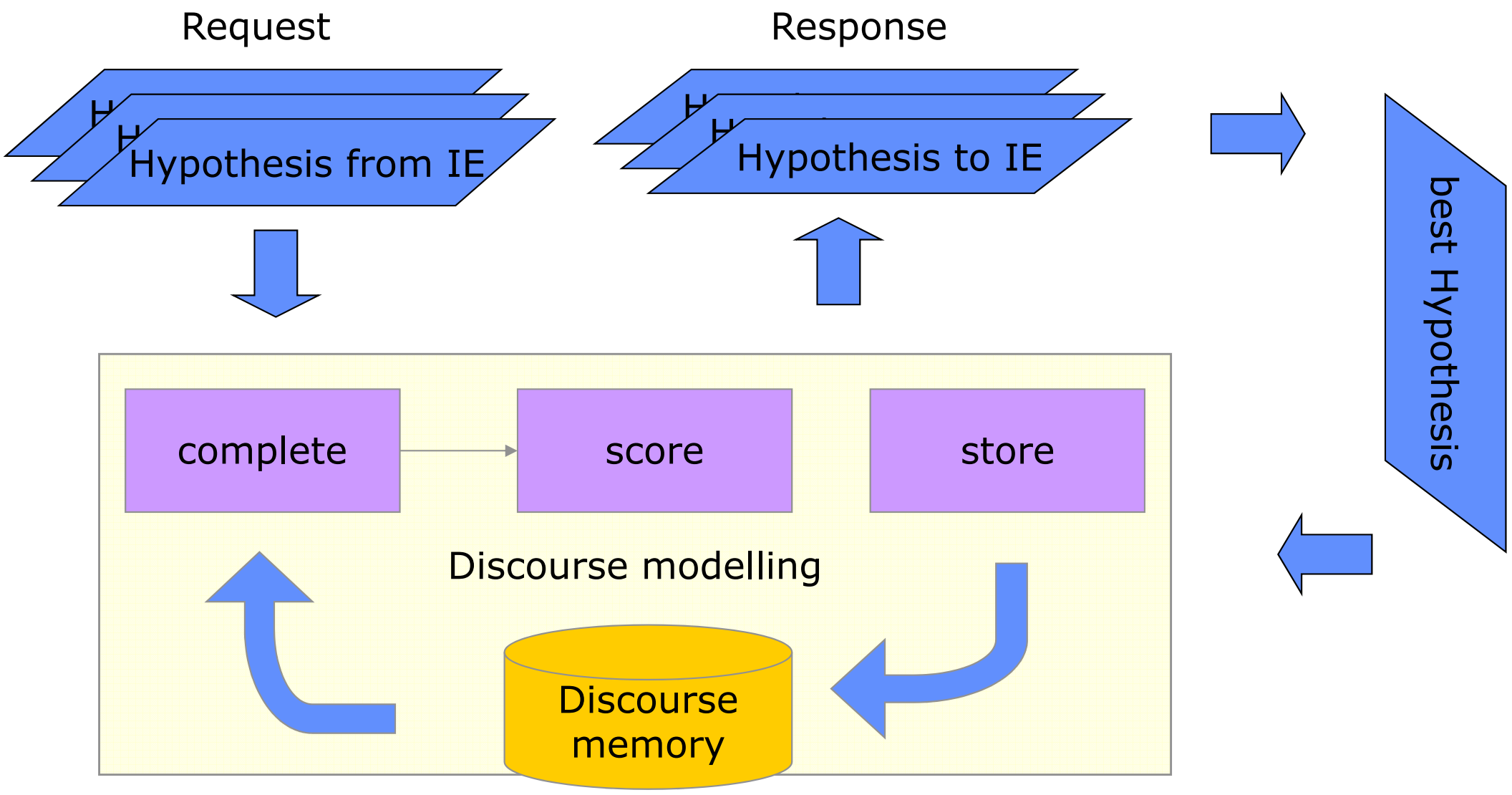
Discourse modelling tasks

- **Construct a discourse memory of contextual information**
- **Hypotheses:**
  - enrich w/ context information
  - compute scores
- **discourse memory:**
  - enrich
  - retract
  - (partially) overwrite



Architecture



Dialog memory

- **A typical dialog situation:**
  - **User**: *I want to see Matrix*
  - **Sytem**: Ok, it runs at 8 and at 10
  - **User**: *At 8*
- **Dialog memory:**
  - structured storage for utterances (and their meaning)
- **“current context:”**
  - data structure representing the currently active context
  - e.g.: Matrix at 8

Putting the user in context

- New information is added to current context,
- Result:

  updated current context
- used, e.g. for a database query

Unification-based Integration of Speech and Gesture

MVPQ, AT&T
Johnston 2000

Speech recognition

Gesture recognition

Speech analysis

Gesture analysis

Multimodal Chart Parser

Unification-based multimodal Grammar

Application interface

© Tilman Becker, DFKI

Updating current context with Unification

- **Representing complex discourse objects as typed feature structures (TFS), e.g. Johnston 1998**
- **Used, e.g. in media fusion:**
  - **User**: *I want to see this one* [pointing to movie “Matrix”]
  - Speech: “I want to see X”
  - Gesture: “When is Matrix showing?” “I want to see Matrix.” ....
  - Media Fusion: “I want to see Matrix.”
- **Problem: enumeration of all structures (in deixis)**

Typed feature structures and XML

- **In the SmartKom project, discourse objects are represented in XML**
- **Mapping from XML to TFS assumed**
- **Example:**

```
<performance>
        <time>...</time>
        <film>
                <title>Matrix</title>
        </film>
...
</performance>
```

⇔

$$\begin{bmatrix} type{:}cinemaEntertainment \\ time{:}... \\ film{:}[title{:}\text{Matrix}] \\ ... \end{bmatrix}$$

The limits of unification

- **Not all new information is consistent with current context**
- **Even for Mediafusion:**
  - User: This one, (but) in green
- **Some parts must be kept, some be overwritten**
  - “keep and overwrite”, M. Streit

- **Provide a principled method,**

  based on unification

Overlay to the rescue

- Unification is monotonic, reflexive operation
- old information from the current context can be changed, new information is more important

❑ we need a non-monotonic, non-reflexive operation: overlay

Overlay to the rescue

- **Task: compare new (intention) hypothesis against discourse history**
- **new information consistent with focus:**

  ✞ **Unifikation**

- **new in formation (partially) inconsistent with focus:**

  ✞ **Overlay**

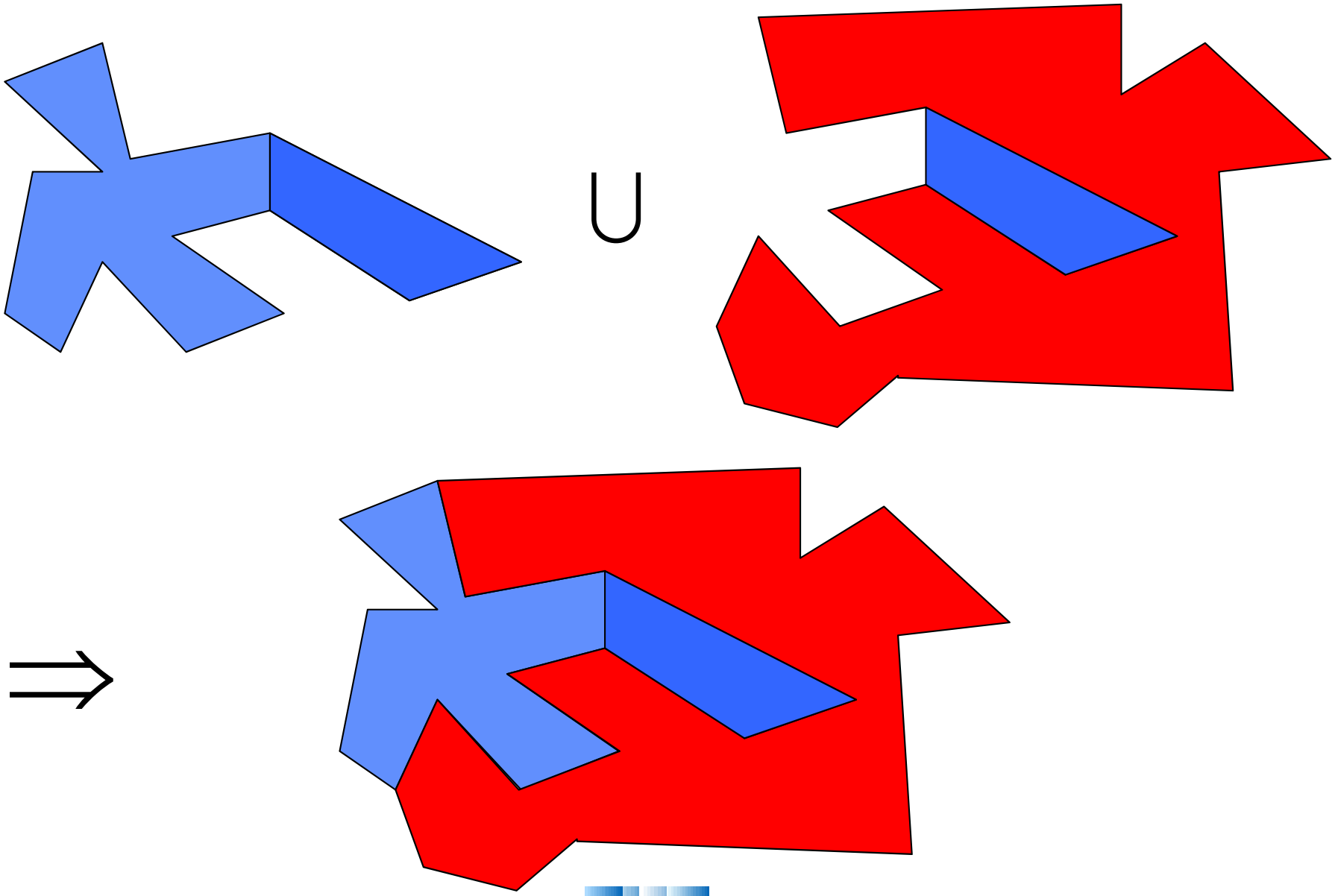
Example for Unification

U: ***I want to go to the movies tonight***

S: Here is a list of the films that are shown in Heidelberg tonight**: (SmartKom shows a list)**

U: ***I want to see (☼) this one, where is it playing?***

Unification: monotonic operation



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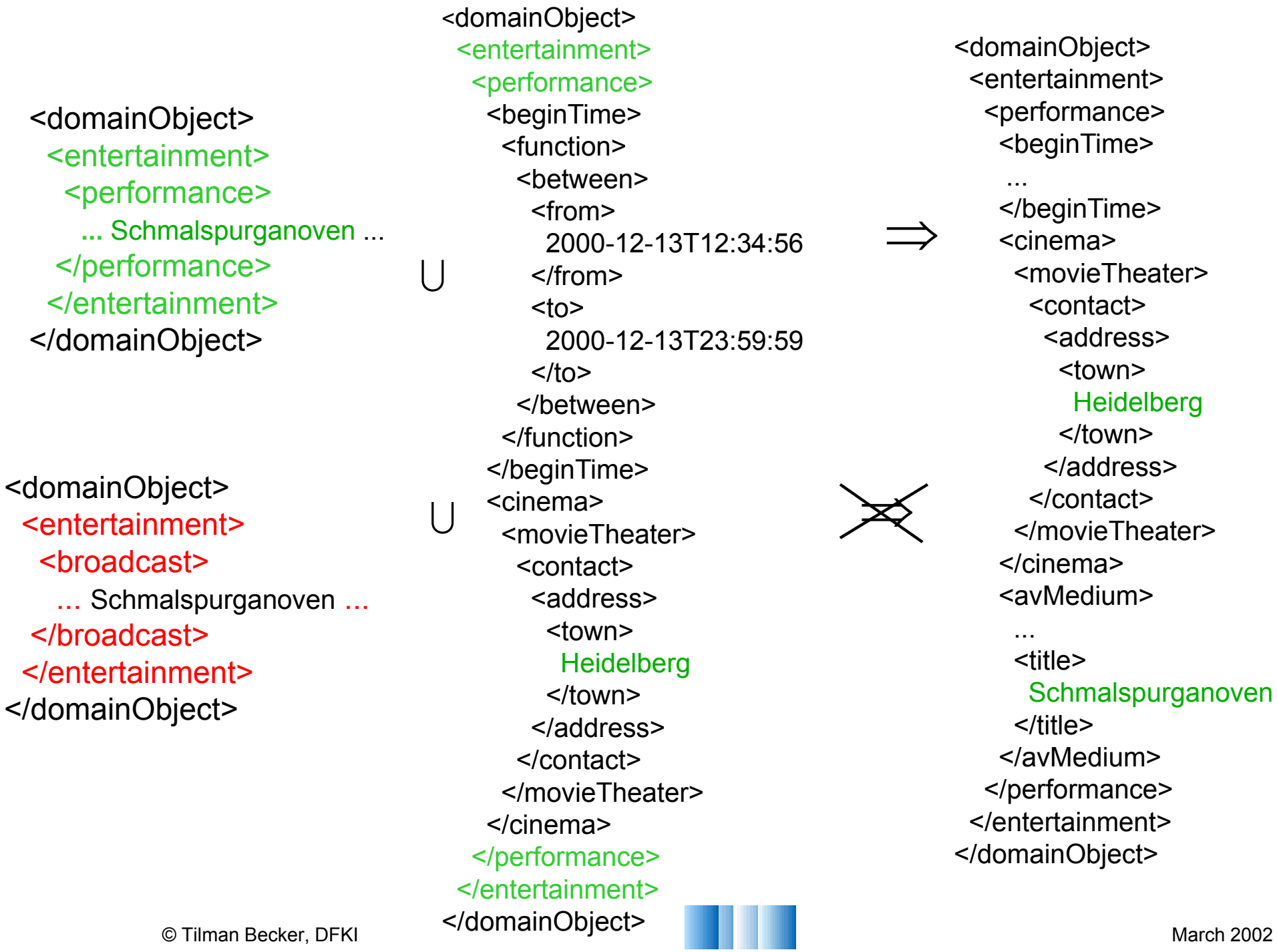

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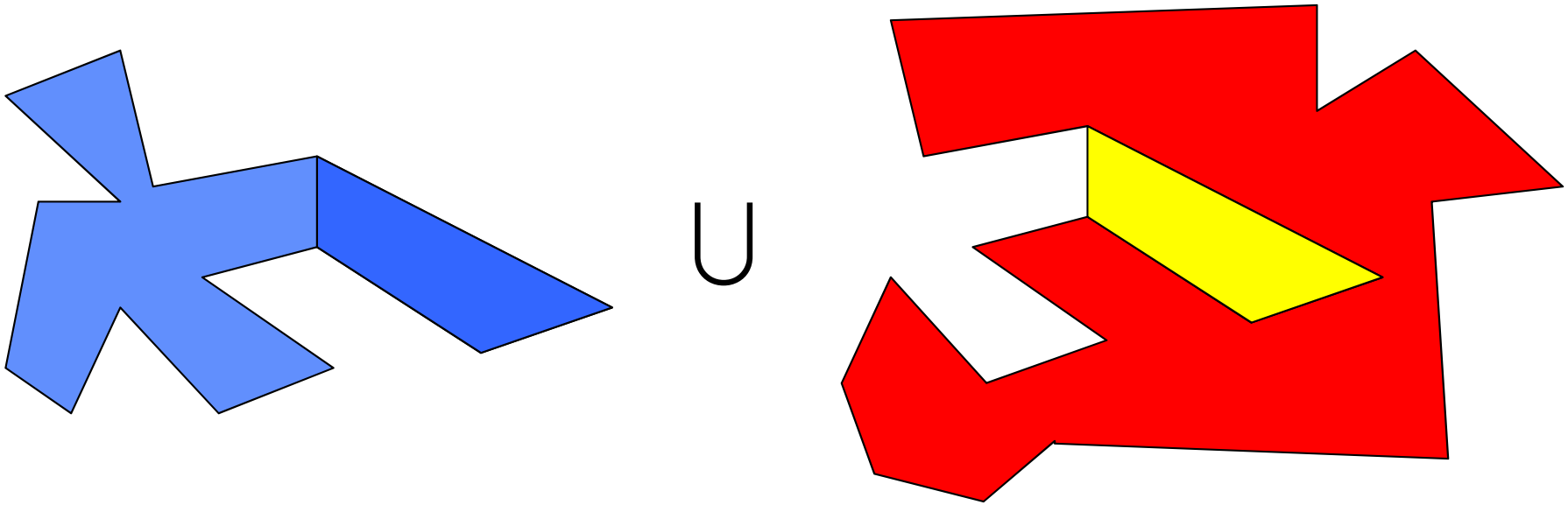
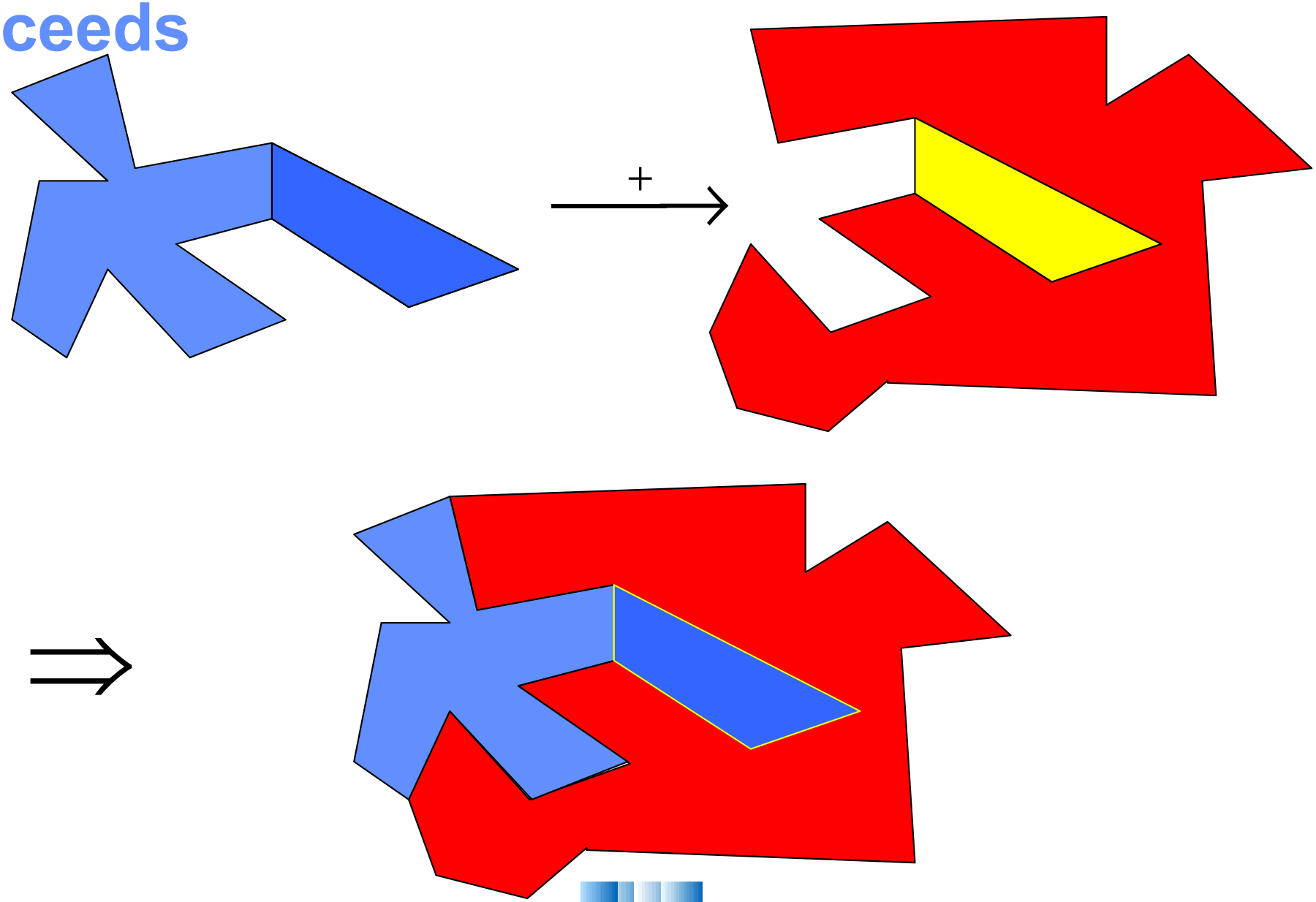
Unification: compatibility condition



$\Rightarrow$ **fail**

Overlay: nonmonotonic operation, that always succeeds



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Example for Overlay

U: ***I want to make a reservation in (☼) this movie theater***

S: This theater does not take reservations

U: ***Then a different one, (☼) this one perhaps***

<domainObject>
<entertainment>
<performance>
<cinema>
<movieTheater>
...
<name>Studio Europa</name>
<contact>
...
</contact>
</movieTheater>
</cinema>
</performance>
</entertainment>
<movieTheater/>
</domainObject>

+ →

<domainObject>
<entertainment>
<performance>
<beginTime>
<function>
...
</function>
</beginTime>
<cinema>
<movieTheater>
...
<name> Kamera </name>
<contact>
...
</contact>
</movieTheater>
</cinema>
<avMedium>
...
<title>
Schmalspurganoven
</title>
</avMedium>
</performance>
</entertainment>
</domainObject>

⇒

<domainObject>
<entertainment>
<performance>
<beginTime>
...
</beginTime>
<cinema>
<movieTheater>
...
<name> **Studio Europa**
</name>
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</contact>
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</domainObject>

P=0.7

<domainObject>
<movieTheater>
...
<name> Studio Europa </name>
<contact>
...
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</domainObject>

+ →

<domainObject>
<movieTheater>
...
<name> Studio Europa </name>
<contact>
...
</contact>
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<movieTheater/>
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⇒

<domainObject>
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...
<name> Studio Europa </name>
<contact>
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<movieTheater/>
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P=0.3

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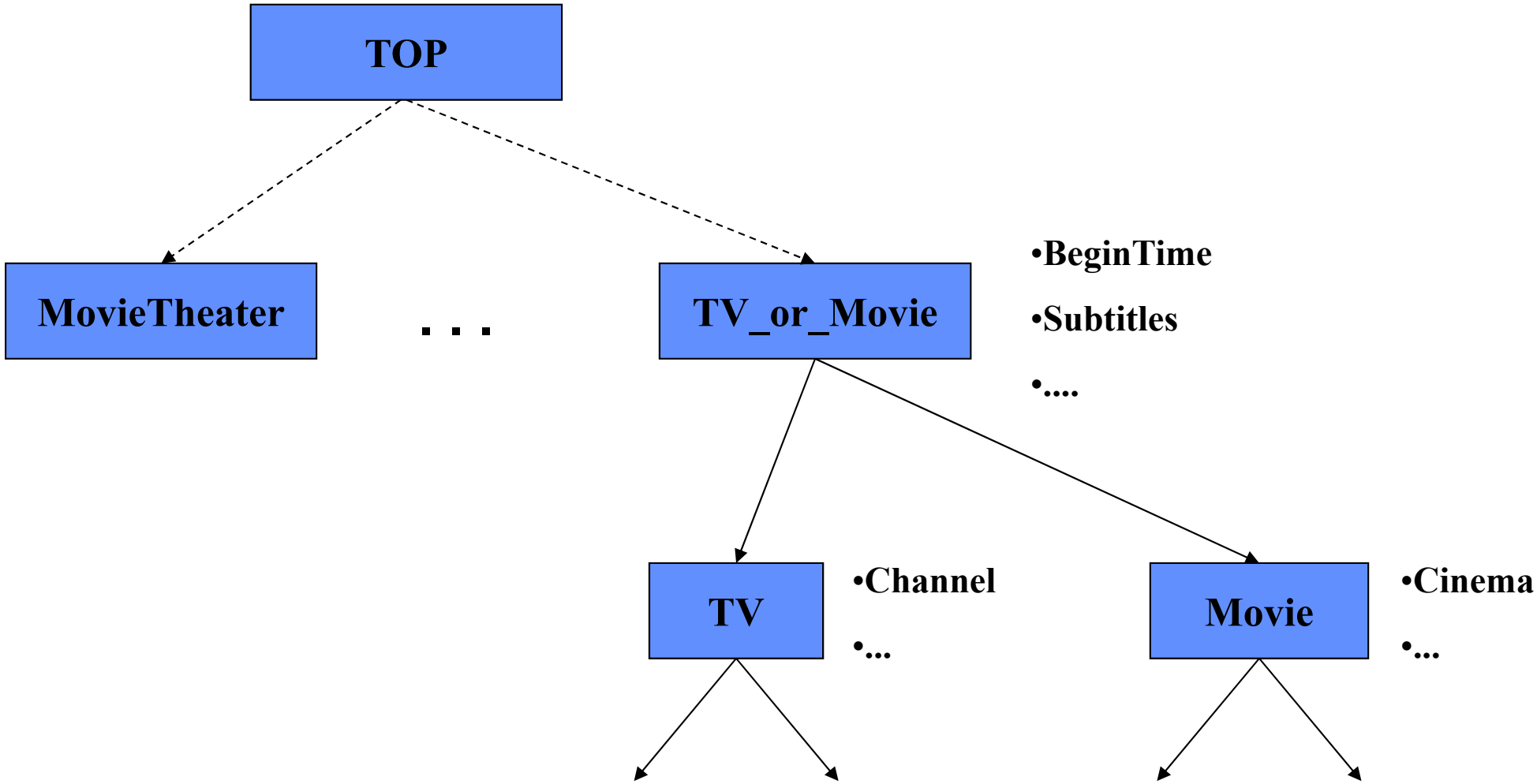
Type Hierarchy



Overlay and Typed Feature Structures (TFS)

- **Two non-unifiable structures (type clash):**
  - Cover is more important than background
  - Keep information from background:
    - Find lub (most specific common supertype)
    - “reduce” background to this type
    - recursively apply overlay on features
    - for atomic values: ignore background

An Example

U: ***What films are showing on TV tonight?***

S: [shows list of films]

U: ***That‘s a boring program, I‘ll rather go to the movies.***

Q: How do we save *“tonight”* ?

An Example

U: ***What films are showing on TV tonight?***

⇒ Context of type *TV*

S: [shows list of films]

U: ***That's a boring program, I'll rather go to the movies.***

⇒ Analysis finds data of type *Movie*

- **incompatible with context**
- **abstract context to lub *TV_or_Movie***

  (keeps *"tonight"*)
- **unifiable with analysis**

Does TFS solve all your problems?

- **An adequate type hierarchy must exist**
  - "most specific common supertype"
  - Carpenter and others on **default unification**
- **Overlay (and unification) of lists and sequences is not well defined -- and content dependent**
- **What about "semantics", e.g. DRS, Verbmobil VIT/MRS?**

Implementation

- **Mapping of XML Schema to Java classes**

  see data binding:

  - Castor Project
  - Java 1.4: JAXB
- **XML documents are represented internally as instances of these classes**
- **Unification and overlay are realized using the Java meta protocol**

Next steps

- **Treatment of subobjects**
  - find relation to context
- **Grounding**
  - model the presentation-acceptance cycle of discourse objects
- **Inclusion of dialog management plans**
  - expected vs. Possible next states
  - better interpretation in context
- **Fully formalize XML schema to tfs mapping**

Summary of the Talk

- **Two large-scale spoken dialogue projects: Verbmobil, SmartKom**
- **Spotlight on Aspects of NLG, Discourse Processing**

- **Conclusion:**
  - Large Scale projects offer new insights‘
    See also upcoming 6th framework of EU
  - Modular Architecture (data pool driven middleware)
  - combine shallow and deep approaches
    - multi-engine approach
    - fully specified template approach
  - emerging multi-modal markup language

Finally

Thank you very much
for your kind attention.

Verbmobil -The Project

Some information for those who haven´t heard of Verbmobil recently

- **speaker independent speech-to-speech translation system for appointment scheduling and travel planning:**
  German ↔ English (10 175 words German, 6871 words English)
  German ↔ Japanese (2566 words Japanese)
- **69 modules, full configuration 3.5 GB**
- **23 participating institutions (in Verbmobil II)**
- **over 900 full workers and students involved**
- **project duration: 1993 - 2000**

❑ **scientific, software technology, and management challenges**

Scientific Results

There are over 600 refereed papers on the various aspects of and achievements in Verbmobil.
See also *W. Wahlster (ed.): Verbmobil: Foundations of Speech-to-Speech Translation, Springer Verlag,* **to appear July 2000** ... at any shop near your office :-)

Some highlights

- **Speaker independent speech recognition over various channels**
- **Language ID**
- **Unknown words**
- **Prosodic information (segmentation, stress etc.) used in various modules**
- **Repair of hesitations, repetitions**
- **Combination of parser analysis fragments**
- **Semantic representation: VIT**
- **Context and dialog knowledge supports translation**
- **Efficient semantic transfer**
- **Content to speech generation**
- **Word concatenative speech synthesis**
- **Dialog minutes and summaries**
- **Large data collection with annotation on various levels (e.g. tree-banks, dialog acts)**
- **....**

Multi-Engine for Translation (DIE)

- Large-Scale Web-based Evaluation: 25 345 Translations, 65 Evaluators
- Sentence Length 1 - 60 Words

Translation Thread	*Word Accuracy ≥ 50% 5069 Turns*	*Word Accuracy ≥ 75% 3267 Turns*	*Word Accuracy ≥ 80% 2723 Turns*
Case-based Translation	37%	44%	46%
Statistical Translation	69%	79%	81%
Dialog-Act based Translation	40%	45%	46%
Semantic Transfer	40%	47%	49%
Substring-based Translation	65%	75%	79%
Automatic Selection	**57% / 78% ***	**66% / 83% ***	**68% / 85% ***
Manual Selection	**88%**	**95%**	**97%**

*** After Training with Instance-based Learning Algorithm**

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Agreement between Different Labels

	B3	-B3	D3	-D3
M3	79	**21**	52	**48**
-M3	**3**	97	**0**	100

	B3	-B3	M3	-M3
D3	91	**9**	97	**48**
-D3	**8**	92	**7**	93

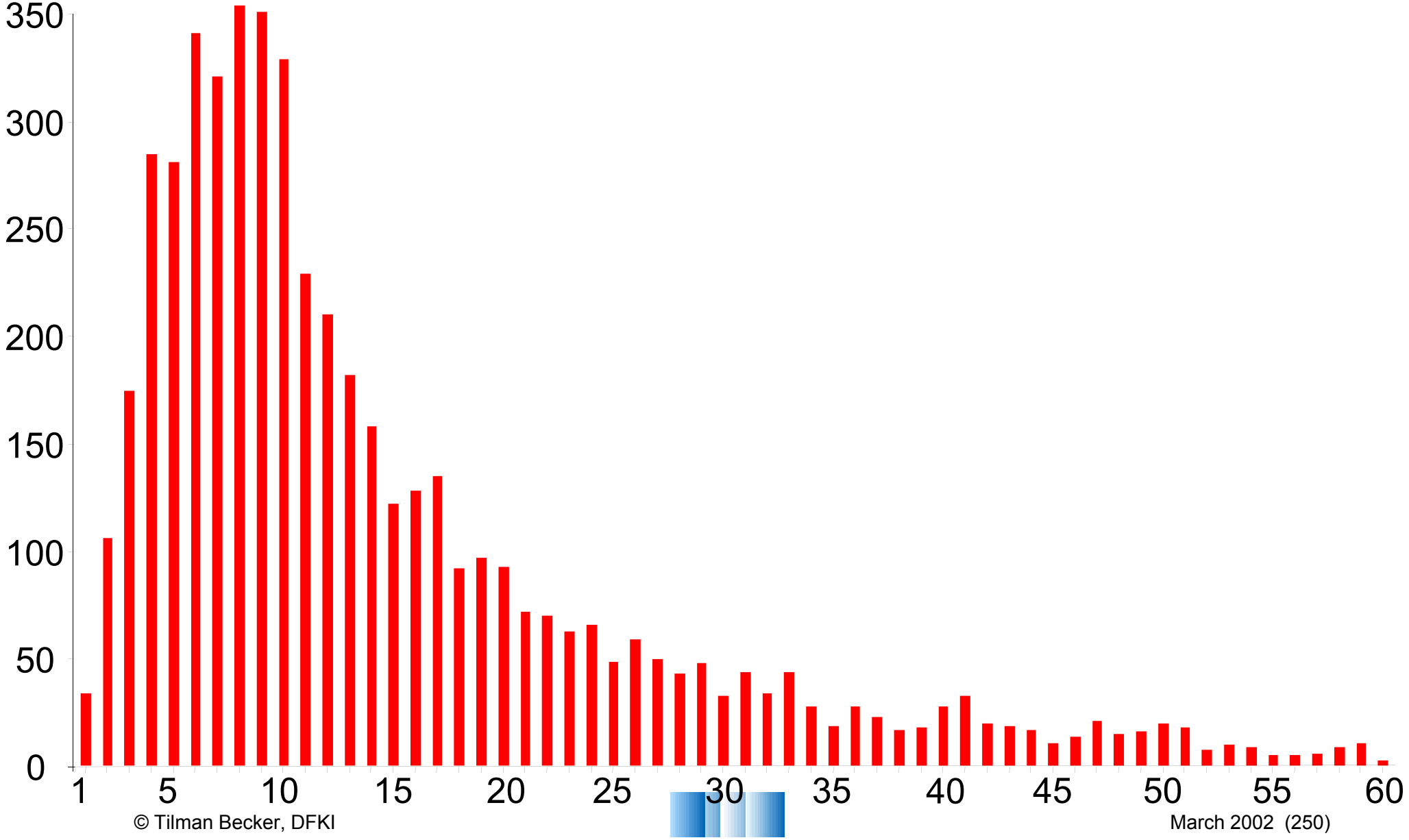
B3 **prosodic boundary**

M3 **syntactic boundary**

D3 **dialog act boundary**

- **Most M- (79%) and D-bound. (91%) are prosodically marked**
- **About half of the M-boundaries (52%) are D-boundaries**
- **Practically all D-boundaries (97%) are M-boundaries**
- **High agreement between the non-boundaries (92-100%)**
- **Even a prosody with a recognition rate of 100% will not find 21% of the M-boundaries and 9% of the D-boundaries!**

Distribution of Sentence Length in Large-Scale Evaluation



Results of End-to-End Evaluation Based on Dialog Task Completion for 31 Trials

Topic	Successful Completions	Attempts	Percentage of Successful Task Completions	Frequency-Based Weighting Factor
Meeting time	25	28	89,3	0,90
Meeting place	21	27	77,8	0,87
Means of transport	30	30	100	0,97
Departure place	22	25	88	0,81
Arrival time	22	26	84,6	0,84
Place of arrival	17	19	89,5	0,61
Who reserves the hotel	28	31	90,3	1
How to get to departure place	7	9	77,8	0,29
Means of return transportation	23	24	95,8	0,77
Departure place for return trip	16	17	94,1	0,55
Meeting time for return trip	3	4	75	0,13
Meeting place for return trip	3	4	75	0,13
Arriving place for return trip	10	11	90,9	0,35
Total Number of Dialog Tasks	227	255		
Average Percentage of Successful Task Completions			86,8	
Weighted Average Percentage of Successful Task Completions			89,6	

Test Results for the current Repair Module

	Detection		Correct scope		gen. correct scope	
	Recall	Precision	Recall	Precision	Recall	Precision
Test 1	49%	70%	47 %	70%	–	–
Test 2	71%	85%	62%	83%	64%	84%

Remember:

The output of the Repair module are additional hypotheses for the linguistic analysis. The original hypotheses remain in the WHG

Examples

Text	Wie wäre es denn mit dem achtzehnten, weil ich am siebzehnten noch verhindert bin.
Transl.	How about the eighteenth, because I am still booked on the seventeenth.
Speech	Wie wäre es denn mit dem achtzehnten, weil ich am siebzehnten noch verhindert, dann
Transl.	How about the eighteenth, because I still booked on the seventeenth then.
Text	Sehr gut, ja. dann fahren wir da los. alles klar. danke schön.
Transl.	Very good, yes. then we will go then leave. all right. thank you.
Speech	Sehr gut , ja ich dann fahren wir da uns , alles klar dann schon
Transl.	Very good, well then we will go then I us, all right then already.
Text	Mittwoch, den sechsten, geht nicht. Montag, der elfte.
Transl.	Wednesday, the sixth, isn't possible. Monday, the eleventh.
Speech	Wie Mittwoch den sechsten geht, nicht, Montag , der elfte?
Transl.	How is, not Wednesday the sixth, Monday, the eleventh?
Text	Ah, ja, ja, die haben einen guten Service.
Transl.	Oh, well, well, they have a good service.
Speech	Ah, ja, die ja guten Service.
Transl.	Oh, yes, good yes the service.
Text	Genau, das wäre dann eine Übernachtung.
Transl.	Exactly, then , that would be an overnight stay.
Speech	Genau, das wäre dann eine Übernachtung.
Transl.	Exactly, then, that would be an overnight stay.