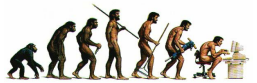
Human-Computer Interaction

Session 10
Natural **Dialog** Interaction

The evolution of user interfaces



Year	Paradigm	Implementation
1950s	None	Switches, punched cards
1970s	Typewriter	Command-line interface
1980s	Desktop	Graphical UI (GUI), direct manipulation
1980s+	Spoken Natural Language	Speech recognition/synthesis, Natural language processing, dialogue systems
1990s+	Natural interaction	Perceptual, multimodal, interactive, conversational, tangible, adaptive
2000s+	Social interaction	Agent-based, anthropomorphic,social, emotional, affective, collaborative

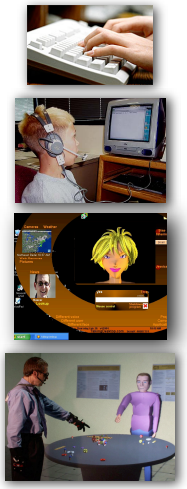
Overview: machines as...

tools ➜ operate

smart tools ➜ instruct

interactive interlocutors ➜ converse

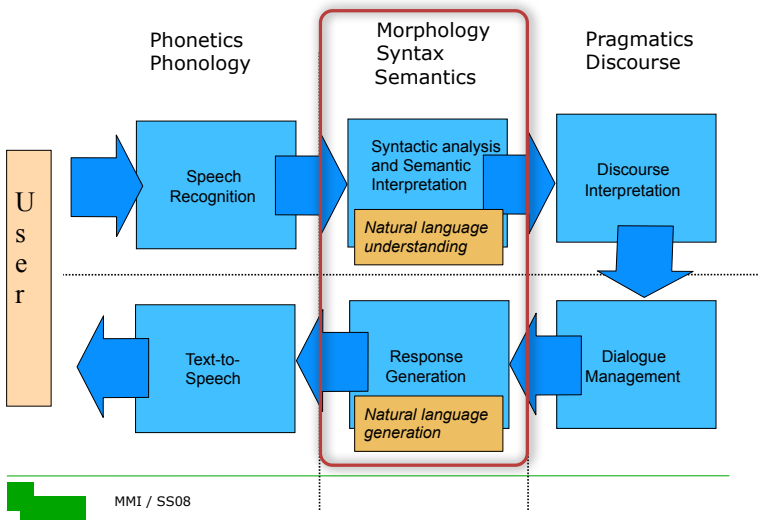
companions ➜ collaborate



Spoken Language Dialogue Systems (SLDS)

- A system that allows a user to *speak* his queries in natural language and receive useful spoken *responses* from it
- Provides an interface between the user and a computer-based application that permits *spoken interaction* with the application in a "relatively natural manner"

Spoken Language Dialogue System

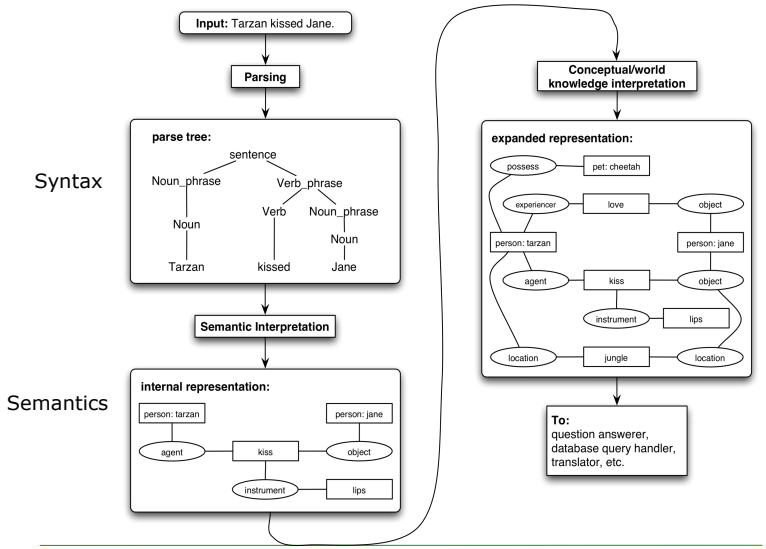


Natural language understanding

Tree classical steps:

1. **Syntax analysis/parsing:**
   - Determine sentence structure from sequence of words
2. **Semantic interpretation/understanding:**
   - Determine word meanings and the overall meaning of their composition in the sentence
3. **Discourse interpretation/pragmatic analysis:**
   - Use context information to complete and disambiguate sentence meaning
   - Determine intention behind the sentence

Allen J. (1995) Natural Language Understanding.

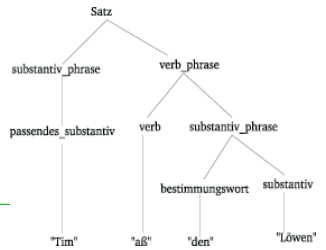


Syntax analysis - parsing

Ziel: Baumartige Zerlegung des sprachlichen Ausdrucks in seine Komponenten gemäß einer Grammatik

```
PARSE ("the dog is dead", G):
        [S: [NP: [Article: the][Noun: dog]]
        [VP: [Verb: is][Adjective: dead]]]
```

- Grammatik: Formale, endliche Beschreibung der *Struktur* aller Elemente einer (oft unendlichen) Sprache
- Parsing = Suchen nach einer möglichen Ableitung eines Satzes in einer Grammatik → Ableitungsbaum
- Beispiel für „Tim aß den Löwen“



Sprachverstehen - Interpretation

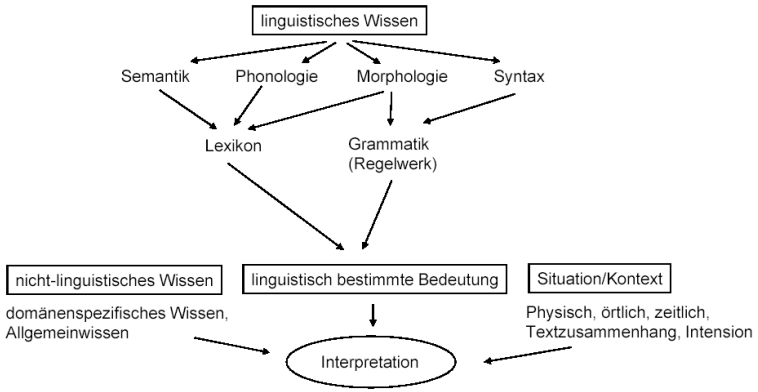
- Aufgabe: *Bedeutungsrekonstruktion*
  - Was ist die *Bedeutung* von *„Er beginnt um zwei im Raum V2-122."* ?
- Unterscheide:
  - **Semantisches Potential**: Linguistisch bestimmte Bedeutung, lässt sich allein mit linguistischem Wissen ermitteln

$$Begin(e,t,l) \wedge Event(e) \wedge Time(t) \wedge Location(l)$$
$$\wedge Equal(t,2) \wedge Room(l,V2-122,?b)$$

  - Aktueller **semantischer Wert**: Volle Interpretation unter Anwendung nicht-linguistischens Wissens (Kontext, Domäne, Welt):

$$Begin(e,t,l) \wedge Event(e) \wedge Time(t) \wedge Location(l)$$
$$\wedge Equal(t,2) \wedge Room(l,V2-122,?b)$$
$$\wedge Talk(e,s,l) \wedge Proffessor(s,Cambridge)$$
$$\wedge Name(s,Steven-Hawking) \wedge Building(b,Uni-Bielefeld) \wedge ...$$

Interpretation



Semantic interpretation/analysis

Ziel: Bestimmung des semantischen Potenzials

- Umformung des *Parse*-Baumes in eine *interne Repräsentation* (z.B. Prädikatenlogik, Frames, …)
- Zwei wesentliche Schritte:
  1. **Lexikalische Semantik**: Bestimmung der Bedeutung einzelner Wörter
     - Probleme: Homonymie, Polysemie (bank/bank), Synonyme (big/large), Antonyme (boy/girl, hot/cold)
     - Resourcen, z.B. *WordNet* (http://wordnet.princeton.edu/)
  2. **Satzsemantik**: Konstruktion der Gesamtbedeutung aus den Einzelbedeutungen (*kompositionelle* Semantik),
     - häufig anhand des *Parse*-Baums, erweitert mit sem. Kategorien (Name, Aktionsbeschreibung, etc.) *syntaktisch-semantisches Parsing*

Discourse interpretation

Ziel: Von Satzsemantik zu Text-/Diskurssemantik/sem. Wert

- Nötige Wissensquellen (über ling. Wissen hinaus):
  - Domänenwissen (banking transaction)
  - Diskurswissen (satzübergreifend)
  - Weltwissen (*Common-sense knowledge*, Situationswissen)
- Beispiel:

U: I would like to open a fixed deposit account.
S: For what amount?
U: Make it for 8000 Rupees.
S: For what duration?
U: What is the interest rate for 3 months?
S: Six percent.
U: Oh good then make it for that duration.

Zentrale Fragen der Diskursinterpret.

- *Referenzauflösung: Worauf wird Bezug genommen?*
  - Ellipsen: ausgelassene Wörtern oder Phrasen
  - Anaphern: "John likes that blue car. He buys it."
- *Intentionserkennung*: Was will der Sprecher?
  - "Do you have the time?" → will die Zeit wissen
  - "When is the last train to London?" → will nach London
- *Informationsstruktur*: Was ist bekannt und was neu?
- *Rhetorische* und *narrative Struktur*: Wie ist der Bezug zum vorher Gesagten?

⇨ Benötigt Diskurskontext; siehe unten

Geht's auch ohne Syntax und Semantik?

Z.B. mit "*keyword-spotting*":

- durchsuchen der Benutzereingabe nach bestimmten Schlüsselworten, z.B. "Wetter", und generieren einer Antwort, die zum Schlüsselwort passt
- Einfach, aber besser skalierbar (grosse Zahl an Regeln)
- Grundlage vieler *Chatterbots*
  - Eliza (Weizenbaum, 1969)
  - ALICE (http://www.alicebot.org/)
  - Jabberwacky.com
  - Anna (www.ikea.de)
- bereits bei einfachen syntaktischen Kniffen überfordert

```
Benutzer: "Ich möchte auf keinen Fall über's Wetter reden!"
Bot: "Gern! Hier in Bielefeld regnet es mal wieder."
```


Natural Language generation

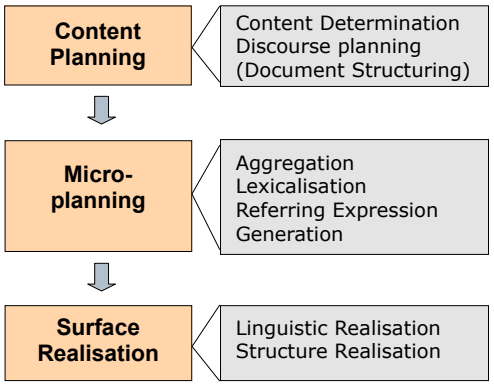
- **Goal**:
  - produce understandable and appropriate output in natural language, along with prosodic information
- **Input**:
  - some underlying non-linguistic representation of information
- **Result**:
  - text to speak, prosodic information
- Knowledge sources required:
  - linguistic knowledge (of language)
  - domain and world knowledge

E. Reiter & R. Dale (2000) *Building Natural Language Generation Systems*. Cambridge University Press.

Language Generation

- Simplest generation method is using *templates*, mapping representation straight to text template (with variables/ slots to fill in).
  - loves(X, Y) → X "loves" Y
  - gives(X, Y, Z) → X "gives the" Y "to" Z
- Templates are very rigid, much more to NLG in general..
  - Consider "John eats the cheese. John eats the apple. John sneezes. John laughs."
  - Better: "John eats the cheese and apple, then sneezes. He then laughs."
- Getting good *style* involves working out how to map many facts to one sentence, when to use pronouns, when to use connectives like "then" etc.

Tasks in NLG



- what to say, how to order and structure it
- how to break it up into sentences and words, how to refer to objects
- How to express things in terms of grammatically correct sentences

1. Content Planning

Goals:

- determine *what* information to communicate (content)
- determine *structure* of this information to make a coherent text/discourse

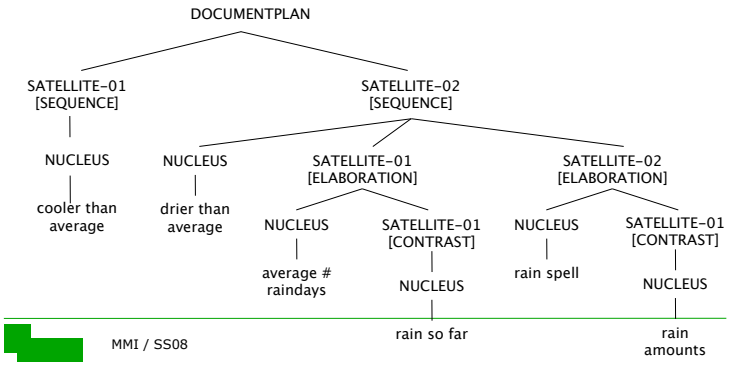
Results: *messages*, predefined data structures that…

- correspond to informational elements (units)
- collect underlying data in ways convenient for ling. expression

- Essentially, a domain-dependent expert-system task
- Common approaches:
  1. based on observations about common utterance structures
  2. based on reasoning about discourse coherence and the purpose of the utterance

Content plan (aka. document plan)

- Tree structure with messages at its leaf nodes
- **Rhetorical Structure** (RST): distinction between *nucleus,* the central segment, and the *satellite*, the more peripheral one, and relations between them (e.g. elaboration, contrast, ...)
- Example from *WeatherReporter* system (Reiter et al.):



2. Microplanning

Goal:

- convert a content plan into a sequence of sentence or phrase specifications

Tasks:

- *Aggregation* via *conjunction, ellipsis, or embedding*
  - `Heavy rain fell on the 27th and [] on the 28th.`
- *Lexicalisation:* choosing word lemmas
- *Reference*: how to refer to entities
  - `initially: full name, relate to salient object, specify location`
  - `subsequently: Pronouns, definite NPs, proper names, possibly abbreviated`

3. Surface realisation

Goal:

convert text specifications into actual text

Purpose:

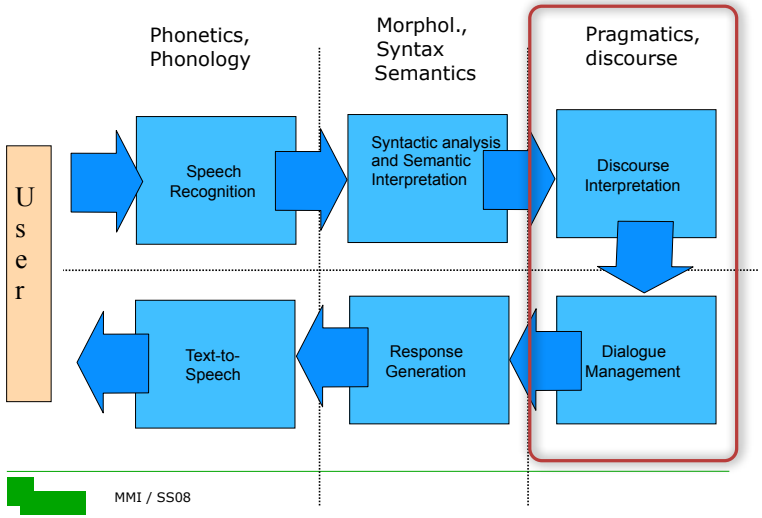
hide peculiarities of English (or whatever the target language is) from the rest of the NLG system

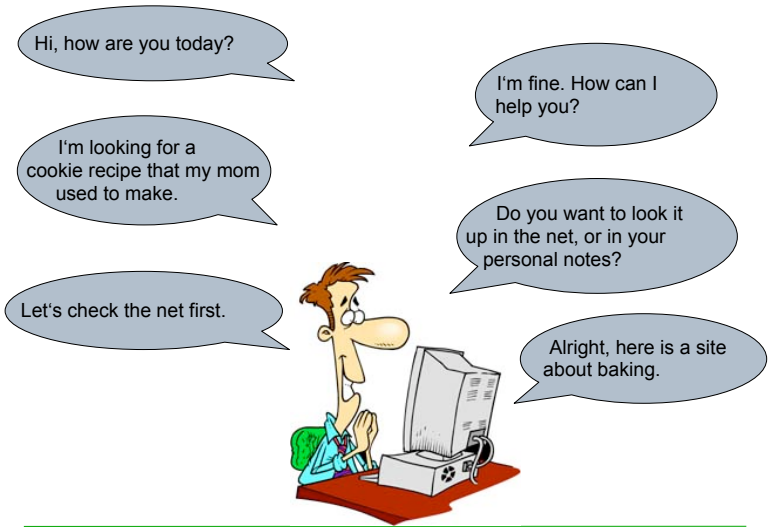
Tasks:

- *Structure realisation*
  - Choose markup to convey document structure
- *Linguistic realisation* using specialized grammars
  - Insert function words
  - Choose correct inflection of content words
  - Order words within a sentence
  - Apply orthographic rules

Conducting natural dialogue?

Classical Spoken Lang. Dialog Sys.





What is a dialogue?

- multiple *participants* exchange information
- all participants pursue (ideally) the same *goal*
- *discourse* develops with the dialogue
- some *conventions* and *protocols* exist
- general structure
  - Dialogue = [episodes]+ (topic changes)
  - Episodes = [turn]+ (speaker changes)
  - Turn = [utterance]+ (function changes)

There is a lot to handle for a *perfect* SLDS

- in both monologue and dialogue
  - information status: what is given, what is new?
  - coherence: how do the utterances fit together?
  - references: what is being referred to?
  - speech acts: what is the intention of the speaker?
  - implicature: what can be inferred from it?
- +only in dialogue
  - turn-taking: who has the the right to speak?
  - initiative: who is seizing control of the dialogue?
  - grounding: what info is settled between the speakers?
  - repair: how to detect and repair misunderstandings?

Reference

- Ellipsis
  - People often utter partial phrases to avoid repetition
    A: At what time is "Titanic" playing?
    B: 8pm
    A: And "The 5th Element"?
  - Necessary to keep track of the conversation to complete such phrases
- Some words are only interpretable in conext
  - Anaphora: "I'll take it", he said.
  - Temporal/spatial: "The man behind me will be dead tomorrow."

Speech acts

- Every utterance is an action performed by the speaker in a real speech situation
- Obvious in *performative* sentences: „I name this ship titanic.", „I bet you 5 bugs."
- Any sentence in a speech situation constitutes three kinds of acts:
  - Locutionary act: the utterance of the sentence „I'm cold."
  - Illocutionary act: the action in uttering it (asking, answering, commanding, …) → informing that I'm cold.
  - Perlocutionary act: the production of effects upon the addressee and ultimately the world → get window closed
- speech act explicates the illocutionary act

Austin (1962), Searle (1975)

Indirect meaning

S: „What day in May do you want to travel?"
U: „Uh, I need to be there for a meeting that's from the 12th the 15th."

- U does not answer the question, expects hearer to draw certain inferences
- Theory of conversational implicature: hearer can draw inferences because they assume the conversation follows four maxims (Grice, 1975):
  - Maxim of Quantity: Be exactly as informative as required
  - Maxim of Quality: Make your contribution one that is true
  - Maxim of Relevance: Be relevant.
  - Maxim of Manner: Be understandable, unambiguous, brief, and orderly

→ Maxim of Relevance allows S to know that U wants to travel by the 12th.

Turns and utterances

- Turn = [utterance]+
- But what is an utterance?
  - Not a syntactic sentence (may span several turns)
    A: We've got you on USAir flight 99
    B: Yep
    A: leaving on December 1.
  - Not a turn (multiple utterances may occur in one turn)
    A: We've got you on USAir flight 99 leaving on December. Do you need a rental car?
- Dialogue is characterized by *turn-taking*
  - Who should talk next?
  - When should they talk?

Turn-taking

- People know well *when* they can take the turn
  - Little speaker overlap (~ 5% in English)
  - But little silence between turns either, a few of 1/10 s
    - Less than needed to plan motor routines for speaking
    - Speakers usually start motor planning before previous speaker has finished talking !!
- How do we know when to speak?
  - Sacks et al. (1974): *transition-relevance places* and rules that govern turn-taking, e.g.
    - If current speaker does not select next speaker, any other speaker may take next turn
  - Schegloff (1968): *Adjacency pairs* set up speaker expectations and give rise to discourse obligations
    - QUESTION → ANSWER, REQUEST → GRANT, ...
    - Silence inbetween is dispreferred → pauses disturb users!

Grounding

- Interlocutors are trying to establish common ground, a set of mutual beliefs
- Hearers must ground a speaker's contribution by signaling understanding or agreement thru *feedback*
- Various ways to do this:

S: „I can upgrade you to an SUV at that rate."
- Continued attention/permission to proceed - U gazes appreciatively at S
- Relevant next contribution - U: „Do you have an Explorer available?"
- Acknowledgement, "backchanneling" - U: „Ok/Mhm/Great!"
- Display/repetition - U: „You can upgrade me to an SUV at the same rate?"
- Request for repair- U: „Huh?"

Allwood, 1976;
Clark & Shaefer, 1989

Initiative

Control - the ability/license to bring up new topics, to start tasks, to pose questions, etc.

- System-initiative:
  system always has control, user only responds to system questions

- User-initiative:
  user always has control, system passively answers user questions

- Mixed-initiative:
  control switches between system and user either using fixed rules or dynamically based on participant roles, dialogue history, etc.

Initiative strategies

- System initiative (spoken "form filling")
  - S: Please give me your arrival city name.
  - U: Baltimore.
  - S: Please give me your departure city name
  - U: Boston
  - S:…

Rigid, restricted vocabulary, rigid, NLP easy and more accurat,

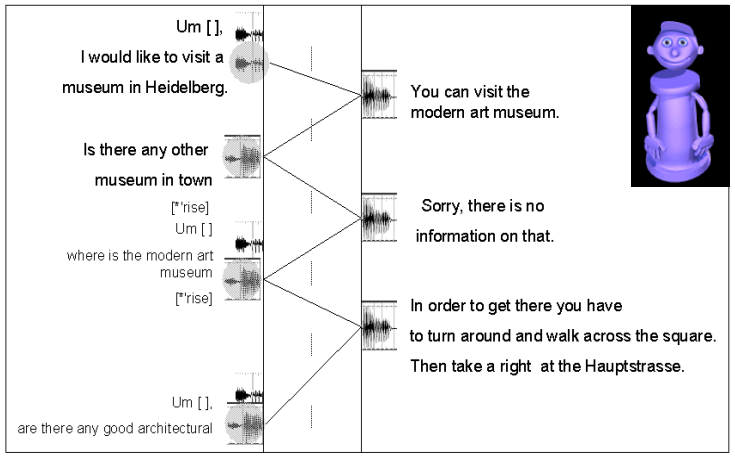
- User initiative
  - U: When do flights to Boston leave?
  - S: At 8:30 AM and 3:45 PM.
  - U: How much are they?
  - S:…

requires good NLP, users must be aware of possible words

- Mixed initiative
  - S: Where are you traveling to?
  - U: I want to go to Boston.
  - S: At time do you want to fly?
  - U: Are there any cheap flights?

natural, open, unpredictable, hard to model, requires NLP and complex dialogue manag.

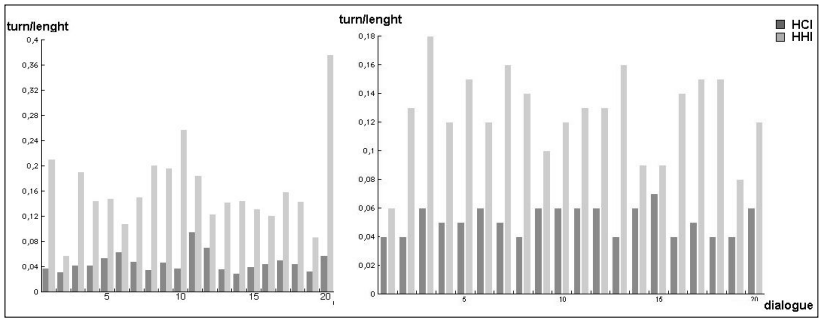
Structure of current HCI dialogues



Overall Dialogue Efficiency

Highly significant loss of dialogical efficiency in HCI vs. HHI using the PARADISE metric: Walker et al (2001) - dialogue turns / dialogue length

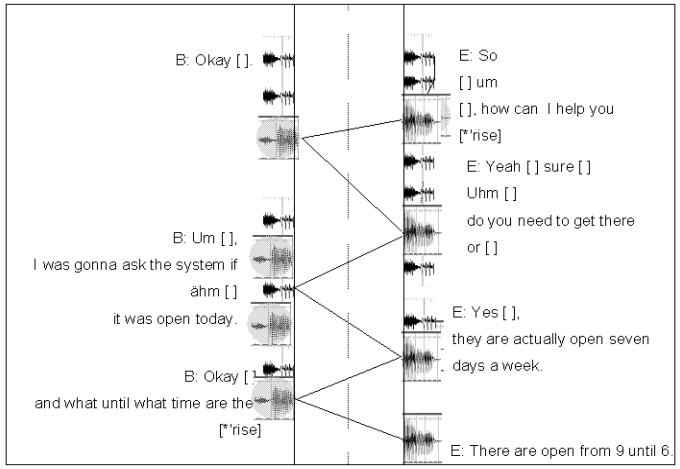
Robert Porzel, Uni Bremen

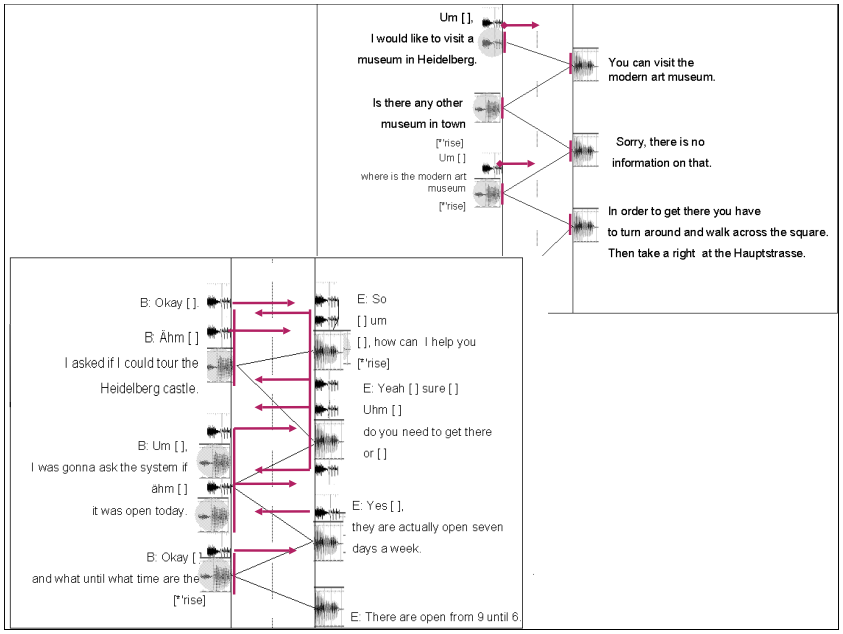


English Data

German Data

Something Missing Perhaps





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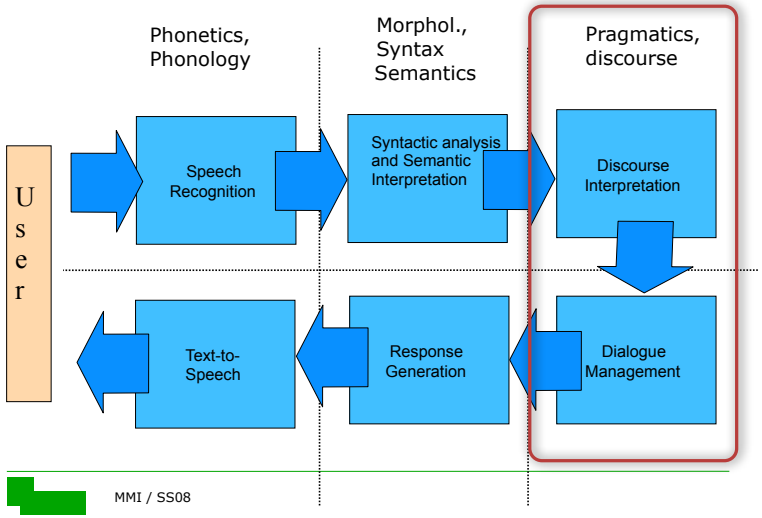


Dialogue Manager

Central tasks

- Interpretation of input
- Maintenance of discourse context
- Determine if information suffices to identify the task, handle repairs
- Determine what is expected or reasonable given context, planning of system responses
- Communicate with external applications (database, etc.)
- Manage communication flow

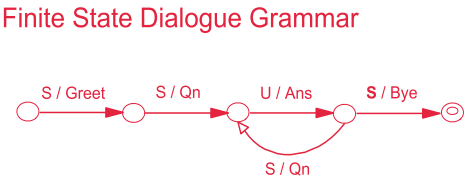
```
DIALOGUE_MANAGER
  while conversation is not finished
    if user has completed a turn
    then interpret user's utterance
    if system has obligations
    then address obligations
    else if system has turn
    then if system has intended conversation acts
       then call generator to produce NL utterances
       else if some material is ungrounded
       then address grounding situation
       else if high-level goals are unsatisfied
       then address goals
       else release turn or attempt to end conversation
    else if no one has turn
    then take turn
    else if long pause
    then take turn
```


Jurafsky & Martin, 2000

Some dialogues systems

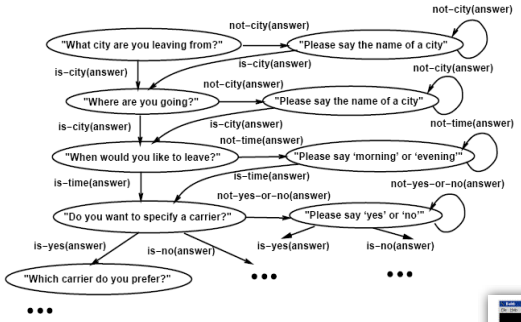
- Commercial Sytems:
  - small vocabulary (~100 words)
  - closed domain
  - system initiative
- Research systems:
  - Larger (but still limited) vocabulary (~1000 words)
  - closed domain
  - (limited) mixed initiative
- Some important applied research systems
  - TRAINS [1991-2000]: flight/train timetables
  - Verbmobil [1993-2000]: translation, scheduling
  - TRINDI, GODIS [1998-2000]: SmartHome
  - …

FSA dialogue manager

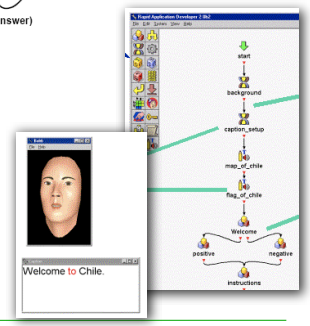


- Graph specifies all legal dialogues ("dialogue grammar")
  - Nodes: system's questions
  - Transitions: possible paths through the network
  - Each state represents a stage in the dialogue ("now"), rarely with complete dialogue history
- System has initiative
- Context is fixed by the question being asked
- Used widely in commercial applications

FSA dialogue manager



(Jurafsky & Martin, 2000)



Do-it-yourself example: CSLU Toolkit
http://cslu.cse.ogi.edu/toolkit/

Frame-based dialogue manger

Prompt: Where and when do you want to travel?
Grammar: <input of departure and arrival city, date and time>
Help: Please specify the departure and arrival city, date and time

FROM
Prompt: From which city are you leaving?
Grammar: <input of a city>
Help: Tell me the name of the city you want to leave from

TO
Prompt: To which city do you want to travel?
Grammar: <input of a city>
Help: Tell me the name of the city you want to travel to

WHEN
Prompt: When do you want to travel?
Grammar: <input of date and time>
Help: Please specify date and time of your journey

Filled: SELECT * FROM connections WHERE departure like 'FROM' AND destination like 'TO' *AND* time like *'WHEN'*

Frame-based dialogue manger

- template (frame) containing slots to be filled
  - destination: London, date: unknown, time of departure: 9
- questions to fill slots, conditions under which they can be asked
  - condition: unknown(origin) & unknown(destination)
    question: "Which route do you want to travel?"
  - condition: unknown(destination)
    question: "Where do you want to travel to?"
- system loops and decides next question based on what information has been elicited and what not yet
- system has initiative, dialogue more flexible, develops based on the current state of the system
- Commercially used, parts of standards: VoiceXML, SALT
- bad for negotiation, planning, mixed-initiative

Agent-based/plan-based control

- **Idea**: dialogue arises from the collaboration of two or more agents in solving a task
  - there are goals to be reached
  - plans are made to reach those goals
  - the goals and plans of the other participants must be inferred or predicted
  - goals may involve changing the beliefs of others
  - models of the mental state of participants are used
- draws on methods from Artificial Intelligence
- permits more complex interaction between user, system, and underlying application
- allows for mixed-initiative dialogue

Example of an agent-based system

U: I'm looking for a job in the Calais area. Are there any servers?

S: No, there aren't any employment servers for Calais. However, there is an employment server for Pas-de Calais and an employment sever for Lille. Are you interested in one of these?

- system recognizes user's needs and attempts to provide a more co-operative response

Example: TRAINS (Traum, Allen, 1996)

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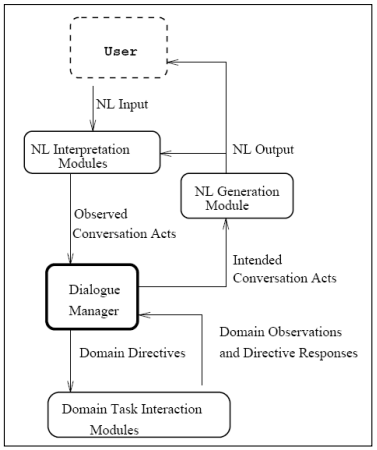
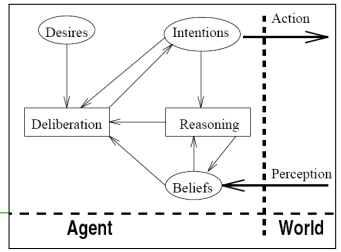


- Design system as agent with own mental states (Bratman, 1987)
  - Beliefs: world model
  - Desires: goals
  - Intentions: plans to pursue

Reasoning: derive new beliefs

Deliberation: decide actions



„Conversational Agency" (Traum)

- Extending BDI to social attitudes that link one agent to others in dialogue
  - about the conversational partner, including mutual beliefs about the other's mental state

REQUEST(speaker,hearer,act)
body: MB(hearer, speaker, speaker WANT hearer DO act)
effect: hearer WANT hearer DO act

→ hearer thinks that speaker wants him to do an act

- about what the agent *should* do, but not necessarily wants to: discourse obligations that inform deliberation

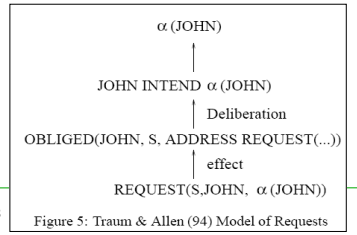


Figure 5: Traum & Allen (94) Model of Requests

TRAINS dialogue manager

- Explicit representation of **conversational state**
  - private and mutual beliefs, beliefs about user beliefs
  - proposals (to represent insincere or tentative acts)
  - domain plans (goals+actions+objects+constraints), either private, proposed or shared
  - discourse goals, represented as scripts specifying goals in different phases of conversation
  - obligations
  - intended acts to be generated
  - local initiative (who is expected to speak next)
  - stack of accessible discourse units
  - discourse structure information

Example

U: "I want to go to Pittsburgh in May." (INFORM1)

- Conversational state
  - Discourse obligations: NONE
  - Turn holder: system
  - Intended acts: NONE
  - Unacknowledged speech acts: INFORM1
  - Discourse goals: get-travel-goal, create-travel-plan
- Conversational state update
  - Intended acts: REQUEST1, ACKNOWLEDGE-INFORM1

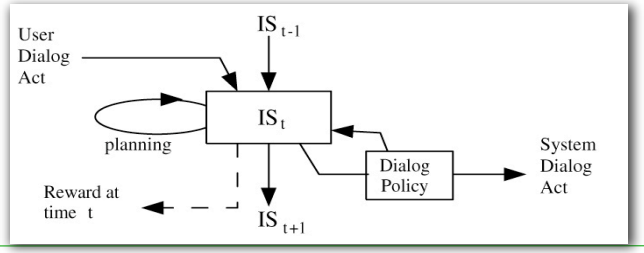
S: "And, what day in May did you want to travel?"

TRAINS dialogue manager

- Reactive: system will deliberate as little as possible until it can act, running in cycles
- No long-range plans, one step at a time
- Prioritized list of sources for deliberations
  1. Discourse obligations
  2. Weak obligation: don't interrupt user's turn
  3. Intended speech act (→ NLG + state update)
  4. Weak obligation: grounding (acknowledge, repair)
  5. Discourse goals: proposal negotiation
  6. High-level discourse goals (domain reasoning)

Information State approach

- Central data structure(s) to define conversational state
  - employed in deciding on next actions
  - updated in effect of dialogue acts by either speaker
- operational semantics of plans stated as update rules
- dialogue manager = definition of the contents of the IS + description of update processes



(Traum & Larsson, 2003)

Summary

Features/ dialogue control	State-based	Frame-based	Agent-based
Input	Single words or phrases	NL with concept spotting	Unrestricted NL
Verification	Explicit confirmation of each turn or at end	Explicit & implicit confirmation	Grounding
Dialogue Context	Implicitly in dialogue states	Explicitly represented Control represented with algorithm	Model of System's BDI + dialogue history
User Model	Simple model of user characteristics / preferences	Simple model of user characteristics / preferences	Model of User's BDI

next session: multimodal interaction

speech recognition
& lip reading