Speech recognition and synthesis

Introduction

Successful *Automatic Dialog Systems* must

- Handle numerous different users
- Incite effective user expectations
- Fail gracefully (eg, with human back-up)
- Allow multimodal interaction, if at all possible
- Allow user initiative
- *Automatic Dialog Systems* are as much an *ergonomic* as a *speech* technology problem

Many pictures (and their copyrights) are from [Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Introduction

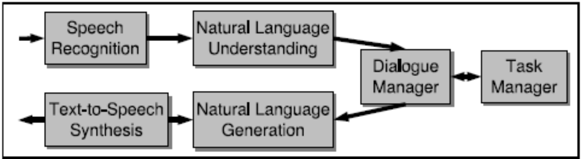


Figure 19.5 Simplified architecture of the components of a conversational agent.

Automatic Dialog Systems have the combined limitations of:

- **ASR + NLP**: The real bottleneck
- **NLG + TTS**: Normally not a problem
- **Dialog management + database**: A bottleneck in complex tasks

[Jurafsky and Martin(2000)]

Conversational Human-Computer Interaction: Practical dialogs

General conversations are much too complex. Limit *Automatic Dialog Systems* to practical dialogues

Dialogues that are focused on a concrete task, eg,

- Task-oriented
- Information seeking
- Advice and tutoring
- Command and control

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Conversational Human-Computer Interaction

The Practical Dialogue Hypothesis

The conversational competence required for practical dialogues, while still complex, is significantly simpler to achieve than general human conversational competence

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Conversational Human-Computer Interaction

The Domain-Independence Hypothesis

Within the genre of practical dialogue, the bulk of the complexity in the language interpretation and dialogue management is independent of the task being performed

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Conversational Human-Computer Interaction

Technique Used	Example Task	Task Complexity	Dialogue Phenomena handled
Finite-state Script	Long-distance dialing	least complex	User answers questions
Frame-based	Getting train arrival and departure information		User asks questions, simple clarifications by system
Sets of Contexts	Travel booking agent		Shifts between predetermined topics
Plan-based Models	Kitchen design consultant		Dynamically generated topic structures, collaborative negotiation subdialogues
Agent-based Models	Disaster relief management	most complex	Different modalities (e.g., planned world and actual world)

Dialogue and task complexity

- Practical Dialogues
- Frame based (form-filling) is currently most used
- Set of frames complex due to switch (going back)
- Plan and Agent based require model-of-the-world

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Conversational Human-Computer Interaction

Parameter	Possible Values
The train ID?	BN101, ...
The event?	Departure, arrival
The location?	Avon, Bath, Corning, ...
The date/time range?	Monday, Aug 3, afternoon, ...

Context for a train information task

- Frame based dialogue system
- Fill in forms, send query when ready
- Simple and robust
- Simplifies ASR+NLP tasks (pattern matching)

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Spoken Dialogue Systems

Challenges for Dialogue Systems

- Parsing Language in Practical Dialogues
- Integrating Dialogue and Task Performance
- Intention Recognition
- Mixed Initiative Dialogue

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Spoken Dialogue Systems: Challenges

Parsing Language in Practical Dialogues

- Detailed semantic, “deep”, representation
- Broad coverage NL grammars fail due to ambiguity
- Semantic restrictions could work
- Add domain-specific restrictions for tasks
- Apply *Grice's Maxims*
- Parsing based on *Speech Acts*

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Spoken Dialogue Systems: Challenges

Integrating Dialogue and Task Performance

- Complex tasks based on Agents
- Abstract **problem-solving** model:
- **Objectives**: The way we want the world to be
- **Solutions**: Courses of action to achieve objectives
- **Resources**: Objects and abstractions available
- **Situations**: The way the world currently might be

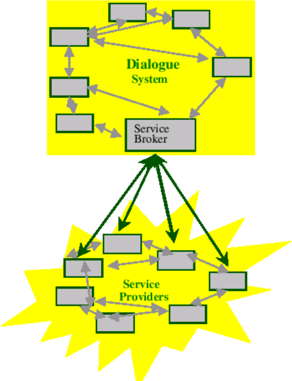


Figure 4: The Agent-based Architecture

Agent based architecture

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Spoken Dialogue Systems: Challenges

Intention Recognition

- Determine the goal of the user
- Can switch with every utterance
- Use implicatures
- Extrapolate from preceding actions
- Interpolate from "parent" (sub-)goals
- Is a probabilistic framework possible?

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Spoken Dialogue Systems: Challenges

Mixed Initiative Dialogue

- Finite-state: typically fixed system-initiative
- Frame based: Fixed user/system-initiative (eg, Query-Answer)
- Fixed user-initiative: User does not know what information is needed
- Solution: Limited mixed initiative
- Full mixed-initiative: Both user and system can *barge-in*
- Mixed-initiative: Weight costs of interruption and system goals

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

Spoken Dialogue Systems

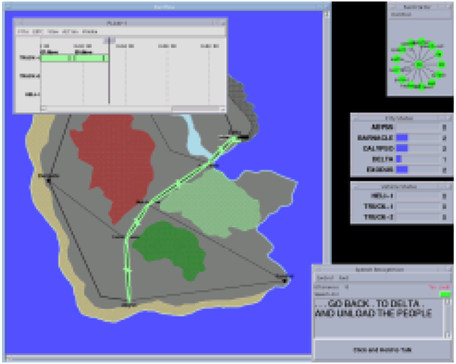
1. *USR: We need to get the woman in Penfield to Strong*
2. *SYS: OK*
3. *USR: What vehicles are available?*
4. *SYS: There are ambulances in Pittsford and Webster*
5. *USR: OK. Use one from Pittsford*
6. *SYS: Do you know that Route 96 is blocked due to construction?*
7. *USR: Oh*
8. *USR: Let's use the interstate instead*
9. *SYS: OK. I'll dispatch the crew*

A short example of a practical dialog

- Both speakers use acknowledgements (*OK*, *Oh*)
- Semantic representation
- Intention recognition
- Goal driven
- System interrupts dialog (barge-in)

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

TRIPS

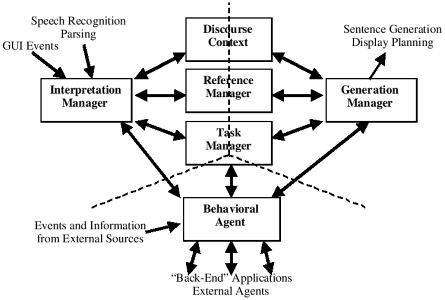


Interacting with TRIPS

- Multi modal interaction with current state shown
- Emergency Response System

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

TRIPS



TRIPS system architecture

- Interpretation
- Generation
- Behavior

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

TRIPS

1. USR: *We* need to get *the woman in Penfield* to *Strong*

Reference resolution

- SS1: The set consisting of *USR* and *SYS* (general dialogue setting)
- WOM1: The Injured woman in Penfield previously discussed (discourse history)
- Strong Memorial Hospital (general world knowledge)

[Allen et al.(2001)Allen, Byron, Dzikovska, Ferguson, Galescu, and Stent]

OVIS

Public Transport Information System

- Deliver train travel information (station-to-station)
- Telephone based application
- Speech only
- Replaced existing human based service
- Based on an existing German system (Philips Aachen)
- Has been in active service (still is)
- Frame-based

[Strik et al.(1997)Strik, Russel, van den Heuvel, Cucchiarini, and Boves]

OVIS

Spoken Dialogue System (SDS) components

1. Continuous HMM based Speech Recognition (CSR)
2. Natural Language Processing (NLP)
3. Dialogue Management (DM)
4. Text-To-Speech (TTS)

OVIS

Skip *Wizard-of-Oz* or *Green-curtain* scenarios and build a working system from scratch.

Stages to build and train SDS

1. Make a first version of the SDS with available data (which need not be application-specific)
2. Ask a limited group of people to use this system, and store the dialogues
3. Use the recorded data (which are application-specific) to improve the SDS
4. Gradually increase the data and the number of users
5. Repeat steps [2], [3], and [4] until the system works satisfactorily

OVIS: Continuous Speech Recognition

Start training with the Polyphone multi-speaker corpus

- 2500 utterances
- Read speech
- Semi-spontaneous (read) speech
- Recorded over the phone
- For each speaker, 5 out 50 *Polyphone* sentences selected
- Phonetically rich sentences (*all* Dutch phonemes)
- 50 Dutch phone models (2 for each of /r/ and /l/)

OVIS: Pronunciation lexicon

Phoneme representations

- Names of stations from the ONOMASTICA database
- Lemma forms of other words from the CELEX database
- Remaining generated by a grapheme-to-phoneme converter
- Pronunciation variation initially not modelled

OVIS: NLP and DM

NLP and DM taken from German original

- Date and time conventions adapted
- Interface with different train table format (eg, start of *tomorrow*)
- Adaptations for user preferences, eg, train numbers
- Collect volunteer queries from keyboard simulation
- Form based database query system with feed-back
- Allows user to correct the system

OVIS: TTS

Speech generation (TTS)

- German original could not be used
- Concatenate utterance fragments
- Female voice

OVIS: Training

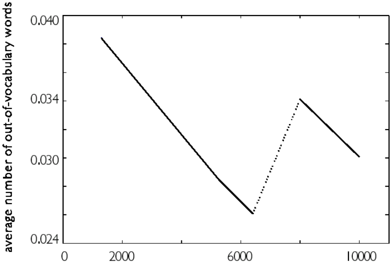
Database	utterances	source	duration (hours:min)
DB0	2500	Polyphone	4:42
DB1	1301	application	0:41
DB2	5496	application	3:47
DB3	6401	application	4:35
DB4	8000	application	5:55
DB5	10003	application	7:20

Databases used during development of the SDS

- Start with the *Polyphone* database (DB0)
- Collect volunteer responses from this system
- Retrain the system with the new speech and repeat
- DB1-5 are incremental, i.e. DB5 contains all of DB4 etc.

[Strik et al.(1997)Strik, Russel, van den Heuvel, Cucchiarini, and Boves]

OVIS: Training



number of utterances in database

Out-of-vocabulary words per utterance vs. corpus size

- Number of OOV words is small
- DB0-DB3 small number of users
- After DB3 (6401 utterances) new users recruited

[Strik et al.(1997)Strik, Russel, van den Heuvel, Cucchiarini, and Boves]

OVIS: Training

System	P0 + L0	P02 + L0	P02 + L2
WG - WER	20.59	18.36	6.72
WG - SER	40.00	36.60	16.00
BS - WER	39.87	31.45	14.73
BS - SER	65.00	54.20	28.00

Performance level for different phoneme models (Pi) and language models (Lj). Evaluation is done with test database 1

- Training phoneme models on both DB0 (polyphone) and DB2 (application) reduced error rates
- Training language model on DB2 (application) reduced errors more
- Application specific data is more important for language modelling than phoneme modelling

[Strik et al.(1997)Strik, Russel, van den Heuvel, Cucchiarini, and Boves]

OVIS: Training

System	P02 + L2	P03 + L2	P03 + L3	P3 + L2	P3 + L3
WG - WER	6.72	6.94	6.94	6.94	6.94
WG - SER	16.00	15.20	15.60	16.20	15.40
BS - WER	14.73	15.43	15.70	16.41	14.84
BS - SER	28.00	29.00	28.60	26.00	26.40

Performance level for different phoneme models (P02/3 vs P3) and language models (L2 vs L3). Evaluation is done with test database 1

- Increasing DB size from 5496 to 6401 utterances had little effect
- Leaving out Polyphone data (DB0) hardly had an effect
- Leaving out DB0 even decreased WER a little

WG: word-graph, BS: best sentence, [Strik et al.(1997)Strik, Russel, van den Heuvel, Cucchiarini, and Boves]

OVIS: Training

testDB	old	new		
System	P3 + L3	P3 + L3	P4 + L4	P5 + L5
WG - WER	6.94	8.87	6.81	6.69
WG - SER	15.40	17.80	14.40	13.80
BS - WER	14.84	15.27	12.93	14.02
BS - SER	26.40	25.40	24.20	24.60

Performance levels for different phoneme models (Pi) and language models (Lj). Evaluation is done with test database 1 (column 2: old) and 2 (columns 3-5: new)

- Test database 2 induced more errors
- DB4 (8,000 utterances) had lower WER again
- Increase to 10,000 utterances (DB5) had little effect

WG: word-graph, BS: best sentence, [Strik et al.(1997)Strik, Russel, van den Heuvel, Cucchiarini, and Boves]

OVIS

Pronunciation variation and non-speech sounds

- A single pronunciation per word gives problems
- Eg, /ɣɛldərɔp/ vs. /ɣɛldrɔp/ and /ɑmsədɑm/ vs. /ɑmstərdɑm/
- Different sources causes inconsistencies
- People use several different variants
- Variant in lexicon not the “best” one

OVIS: Conclusions

It actually worked!

- Adapt an existing frame-based system
- Bootstrap on actual usage
- Collect and train more
- Use robust DM
- Use human fall-back

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Appendix A: Implicatures

Conversations contain rules of inference

Conversational Maxims of Grice

- **Quantity**: Be *exactly* as informative as required
  - Not *less* informative
  - Not *more* informative
- **Quality**: Speak the*truth*
  - Do not say what you believe is *false*
  - Do not say that for which you lack *evidence*
- **Relevance**: Be relevant
- **Manner**: Be *perspicuous*
  - Avoid *obscurity*
  - Avoid *ambiguity*
  - Be *brief*
  - Be *orderly*

Back to Challenges

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