The Computer and Natural Language (Ling 445/515)

Dialogue Systems

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What are dialogue systems good for?

- We can book airline tickets over the phone without dealing with error-prone humans.
- We can interact with our computer while keeping our hands free.
- We can talk to a system that won't have the same prejudices a human might (... depending on the programmer)
- When robots someday take over the world, we'll be able to understand their demands ;)

Before we look at dialogue systems, though, we need to understand something about human dialogue

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Human dialogue

How does dialogue, or **discourse** (= conversation), work?

We will look at a few aspects of human-human interactions:

- Basic facts about dialogues
- Rules of conversation: Gricean maxims
- What utterances do: Speech acts
- Organization of conversation: Discourse structure

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Basic facts about dialogues

Utterances

People do not necessarily speak in sentences

- **Utterances**: basic unit of conversation
  - may span over several turns
  - may have several utterances within one turn

AGENT:	Yeah yeah the um let me see here we've got you on American flight nine thirty eight
CUSTOMER:	Yep.
AGENT:	leaving on the twentieth of June out of Orange County John Wayne Airport at seven thirty p.m.
CUSTOMER:	Seven thirty.
AGENT:	and into uh San Fransisco at eight fifty seven.

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Basic facts about dialogues

Taking turns

How humans communicate is relatively systematic

- **Turn-taking**: must know when it's the right time to contribute your turn
  - Comes naturally to humans: overlaps and long pauses are actually somewhat rare
- **Adjacency pairs**: two-part conversational structures where turn-taking is usually quite clear
  - question/answer: question is looking for an answer from dialogue partner
  - greeting/greeting
  - request/grant
  - etc.

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Basic facts about dialogues

Common ground

Common ground: the set of things which both speakers believe to be true of the conversation.

- Part of classroom common ground is that we are at Indiana in a linguistics class. Not part of the common ground is what I had for lunch.
- People assess what others know before making a new contribution
  - Starting a conversation about Greg would be confusing because we have no *Greg* in our common ground
  - Starting a conversation by saying I was just thinking about an old friend of mine from Illinois named Greg is less confusing

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Grounding

In order to establish common ground, speakers do various things:

- **Backchannels** = short utterance which indicates the utterance was heard and that the speaker should continue.

  A: *That's a nice shirt.*
  B: *Mm-hmm.*

- Acknowledgment of utterance: continued attention, completing speaker's utterance, and so on
- Asking clarifying questions

Rules of Conversation: Gricean Maxims

People often speak "indirectly," but it's very clear what they mean.

⇒ They obey what Grice (1975) referred to as the four **maxims** (rules) or conversation

- All based on the **cooperative principle** = speakers are both trying to contribute to the purposes of the conversation.
- We use these to infer what a speaker is really saying

Gricean maxim 1: Quantity

Quantity: Be exactly as informative as is required.

- Make your contribution as informative as is required (for the current purposes of the exchange)

  A: *How many pencils do you have?*
  B: *Two.*

  → means exactly two (or would have said more)
- Do not make your contribution more informative than is required.

  Violation:
  (passing by somebody on the way to class)
  A: *How's it going?*
  B *It's complicated. Yesterday I was sick ...*

Gricean maxim 2: Quality

Quality: Try to make your contribution one that is true.

- Do not say what you believe to be false
- Do not say that for which you lack adequate evidence

  Violation:
  A: *Do you know how to drive a stick-shift?*
  B: *Yes, I do. I've seen my dad do it many times.*

Gricean maxim 3: Relevance

Relevance: Be relevant.

A: *Is Gail dating anyone these days?*
B: *Well, she goes to Cleveland every weekend.*

We make an inference that Gail is dating somebody in Cleveland

- Otherwise, B's statement doesn't make much sense.

Gricean maxim 4: Manner

Manner: Be perspicuous (easy to understand).

- Avoid obscurity of expression
  - In other words, avoid jargon when it's not a part of the common ground, e.g., words like *prolixity*
- Avoid ambiguity
- Be brief (avoid unnecessary prolixity)
  - Similar to maxim of quantity, but think here of long-winded conversations that provide the same amount of information as a shorter one
- Be orderly

Speech acts

So, what does each utterance do? How does it function?

- Utterances are often equated with **actions** (Austin 1962)

For example, there are **performative verbs**; by saying them, you actually do what you say

- I (hereby) christen this ship *The Swarthy*.
- I pronounce you man and wife.
- I second that motion.
- I bet you five dollars the Hoosiers will win the NCAA championship this year.

Kinds of speech acts

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Searle (1975) lists several different actions utterances have:

- Assertives = assert that something is the case
  e.g., *suggest, boast, conclude*
- Directives = commmand; attempt to get the listener to do something
  e.g., *ask, order, request*
- Commissives = commit to some future course of action
  e.g., *promise, plan, vow*
- Expressives = express psychological state of the speaker about some situation
  e.g., *thank, apologize, welcome*
- Declarations = bring about a different state of the world merely by saying them
  e.g., the performatives we saw earlier

Indirect Speech Acts

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Speech acts can be **direct** or **indirect**

- Direct: Form matches meaning.

  A: *Please take out the garbage.*
  imperative structure & imperative meaning

- Indirect: The form and the meaning are different.

  A: *The garbage isn't out yet.*
  declarative structure but imperative/directive meaning

  A: *Could you take out the garbage?*
  interrogative structure but imperative/request meaning

⇒ How do we encode such distinctions in a computer?

DAMSL

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People have marked up text with different labels for speech acts.

The **Dialogue Act Markup in Several Layers (DAMSL)** is a scheme of speech acts people use to annotate texts

- **forward-looking functions**: look for a response
  - question, request, etc.
- **backward-looking functions**: provide a response
  - answer, agreement, etc.

Note the resemblance to adjacency pairs.

Using DAMSL in a computer

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Using the DAMSL scheme,

- People annotate a text, or a **corpus**
- People can train a system on it and attempt to mark a new text with these labels.
- People can use the functions to tell a dialogue system what to do next
  - The system keeps track of the previous forward-looking function to know how to respond.
  - If a dialogue system needs an answer, it knows what kind of forward-looking function to use to get the human to provide one

But if a dialogue system wants to know what to do next, it needs more than forward and backward-looking functions ...

Discourse structure

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Discourse, or dialogue, has some structure to it—not just a bunch of random, loosely-connected statements.

- Every discourse has a **discourse purpose** = a reason for talking (Grosz and Sidner 1986)
- Purpose is clearer in **task-based dialogues** = speakers are trying to achieve some goal together
  e.g., giving directions or fixing a car

If we figure out the discourse structure automatically, the computer can keep track of what's going on.

- Know what topics are appropriate
- Better able to know what pronouns and definite noun phrases (e.g., *the dog*) refer to.

ELIZA

We'll start our tour of early dialogue systems with a quick tour of **ELIZA**

- Written by Joseph Weizenbaum in the mid-1960s
- Simulation of a (Rogerian) psychotherapist.
  - Rogerian therapist asks questions and gives backchannels more than providing advice
- User types questions, and ELIZA responds.

For some, the test of such a system is how human-like it is:

- If I can tell I am interacting with a computer, it has failed the **Turing Test**

Example conversation

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Taken from Weizenbaum's 1966 paper:

USER: Men are all alike.
ELIZA: IN WHAT WAY?
USER: They're always bugging us about something or other.
ELIZA: CAN YOU THINK OF A SPECIFIC EXAMPLE?
USER: Well, my boyfriend made me come here.
ELIZA: YOUR BOYFRIEND MADE YOU COME HERE
USER: He says I'm depressed much of the time.
ELIZA: I AM SORRY TO HEAR YOU ARE DEPRESSED
USER: It's true. I am unhappy
ELIZA: DO YOU THINK COMING HERE WILL HELP YOU NOT TO BE UNHAPPY

Example conversation (cont.)

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

USER: I need some help, that much seems certain.
ELIZA: WHAT WOULD IT MEAN TO YOU IF YOU GOT SOME HELP
USER: Perhaps I could learn to get along with my mother.
ELIZA: TELL ME MORE ABOUT YOUR FAMILY
USER: My mother takes care of me.
ELIZA: WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU
USER: My father.
ELIZA: YOUR FATHER
USER: You are like my father in some ways.
ELIZA: WHAT RESEMBLANCE DO YOU SEE

Example conversation (cont.)

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

USER: You are not very aggressive but I think you don't want me to notice that.
ELIZA: WHAT MAKES YOU THINK I AM NOT VERY AGGRESSIVE
USER: You don't argue with me.
ELIZA: WHY DO YOU THINK I DON'T ARGUE WITH YOU
USER: You are afraid of me.
ELIZA: DOES IT PLEASE YOU TO BELIEVE I AM AFRAID OF YOU
USER: My father is afraid of everybody.
ELIZA: WHAT ELSE COMES TO YOUR MIND WHEN YOU THINK OF YOUR FATHER
USER: Bullies.
ELIZA: DOES THAT HAVE ANYTHING TO DO WITH THE FACT THAT YOUR BOYFRIEND MADE YOU COME HERE

How ELIZA works

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

They are many different **implementations** of ELIZA out there, but they all work in the same general way:

1. Transform input to change the point of view (*I* and *you*)
2. Perform **pattern recognition** (pattern matching)
3. Substitute keywords into **canned phrases**, or submit a general canned phrase

They can also more or less include some history of the conversation

1. Transform input

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

ELIZA has to be ready to give a response with the appropriate pronouns about itself or the user:

- *you* becomes *I* (and vice versa)
- *my* becomes *your* (and vice versa)
- adjustments are made for *I* to be turned into *me* → if a sentence ends in *I*, change it to *me*.
  - This doesn't always work right:

USER: If I could explain to you I could explain anything to anyone
ELIZA: IF YOU COULD EXPLAIN TO I YOU COULD EXPLAIN ANYTHING TO ANYONE

2. Pattern recognition

If a pattern matches the transformed input, choose one of those reponses. Otherwise choose a general purpose response.

- See *want* in user's statement
  → respond with: BEWARE OF ADDICTIONS
- See *need X* in user's statement
  → respond with: CAN YOU DO WITHOUT X
- user's statement *eliza is a very simple program* matches the template *X is Y*
  - **template** = a specified pattern with slots to be filled in

If no template is matched, just say something like TELL ME MORE.

- For multiple matches, select one at random.

3. Canned phrases

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Everything ELIZA says is some sort of canned phrase.

- ELIZA does not "build up" a sentence from words; rather, it spits out a single phrase, perhaps composed of a few patterns.

ELIZA will either give a complete canned phrase or a mixture of a canned phrase with something you said—e.g., TELL ME MORE ABOUT *X*

How can we tell that ELIZA isn't a human?

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

A number of clues tell us that ELIZA is a computer:

- Lack of initiative
- Lack of knowledge
  ELIZA knows nothing about the real world
- Lack of common sense
- Lack of true grammar/**syntax** = structure of sentences
  - Say *you peabrain* to it and you might get ME PEABRAIN back.
  - Need two separate patterns for *Computers worry me very little.* and *I'm not worried much by computers.*
- Doesn't have (much of) a memory

Still, ELIZA also started a whole phenomenon of **chatterbots**

PARRY

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

PARRY (Colby et al 1971)

- More verbal than ELIZA in some ways, i.e., talks for longer durations
- keeps track of "global" emotional state
  - when the *anger* variable is high, for example, PARRY will choose from a set of "hostile" options.

"With Parry, Dr. Colby established that a computer chip could be programmed to imitate a paranoid schizophrenic."
http://www.edu-cyberpg.com/Linguistics/Parry.html

SHRDLU

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

SHRDLU (Winograd 1972)

- simulated a robot who could manipulate toy blocks ("The BLOCKS World")
  - Given input such as: *Move the red block on top of the smaller green one.*
  - SHRDLU would then hopefully move the red block as indicated
- used an extensive English grammar
- used some logical representation of meaning
  http://hci.stanford.edu/~winograd/shrdlu/

p.s. Name comes from the fact that some keyboards used to represent the more frequent letters in English together: ETAOIN SHRDLU

ALICE

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

ALICE is a more advanced chatterbot, which won the 2004 Loebner Prize

- Loebner Prize = instantiation of the Turing Test: $100,000 for the first computer to pass the Turing Test (hasn't happened yet)
- Each year, the most human-like computer wins $2000

You can chat with ALICE at: http://www.pandorabots.com/pandora/talk?botid=f5d922d97e345aa1

Making your own chatterbot

http://www.alicebot.org/aiml.html contains information on downloading ALICE and creating your own chatterbot

- Can define the personality of the bot
- Can define the exact knowledge base
- Can define new patterns and templates

But remember that in all that you are doing, it is still just a pattern-matcher!

From Then Until Now

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

All of these chatterbots are just pattern-matchers, albeit of varying complexity

- There has been a push to add linguistic and real-world knowledge to dialogue systems
- Which is why we spent so much time talking about how real dialogue works

Modern dialogue systems

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

- Overview of a basic dialogue system: TRIPS system
- Dialogue manager: Finite-state machines
- Natural Language Understanding: Frame-based systems
- Natural Language Generation
- A Relevant Task: Pronoun Resolution
- Obtaining Data: Spoken language corpora

Example dialogue system: TRIPS

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

TRIPS: extension of the earlier TRAINS system at the University of Rochester

- Human works with TRIPS in order to construct plans in a crisis situation: a hurricane is approaching the island of Pacifica, and the people must be evacuated.
- Features:
  - Task is clear
  - Quality of task is easily measured
  - Can vary the complexity of the task
- Complex model of collaborative problem-solving

Other dialogue systems resemble TRIPS in their layout

Dialogue system set-up

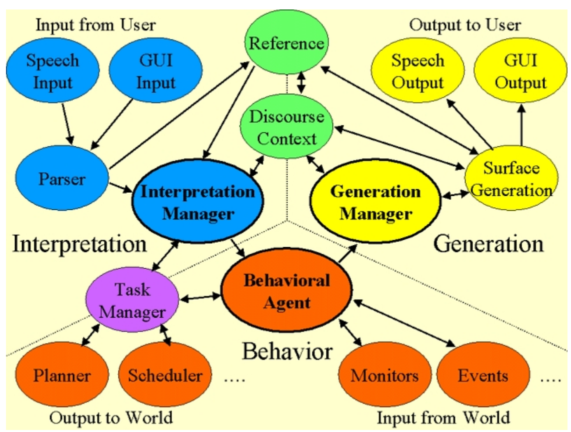
Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Typically, a dialogue system has different **modules** = independent systems which interact with each other

1. ASR system takes speech and gives it to Natural Language Understanding (NLU) system
2. The NLU system interprets the language and feeds that to a Dialogue Manager
3. The Dialogue Manager consults its internal databases (Task Manager, maybe Flight Info database, etc.) and figures out what to do next
4. The system's response is given to the Natural Language Generation system, which creates a real sentence
5. And this real sentence is given to a TTS system

TRIPS system

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction



http://www.cs.rochester.edu/research/cisd/projects/trips/architecture/

Dialogue manager

Dialogue manager, or discourse manager (behavioral agent), controls the flow of a conversation =

- Decide whose turn it is
- Decide what items need attention
- Feed input and output to the linguistic systems.

One way to implement a dialogue manager is to use state transition networks

State transition networks

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Well-structured dialogue can be modeled with a **state transition network**.

Works best when the user only has to answer questions, i.e., is very constrained

- State 1: I know nothing, so I need to ask for the user's name.
  - If the user gives me a name, go to State 2
  - If the user does not give me a name, go back to State 1
- State 2: I know the user's name, so I ask for the user's birthday.
  - If a birthday is given, go to State 3.
  - If a non-birthday is given, go to State 2.
  - If the user claims their name was wrong, go back to State 1.

Finite-state automata

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

A state transition network is basically just a **finite-state automaton** (FSA) = network of states and transitions between states.

- Move from state to state when conditions on the arcs are met
- In this way, can model what course of action to take when presented with an input

There is a whole theory of FSAs, and it turns out that they are equivalent to regular expressions

Natural Language Understanding

Frame-based systems

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Dialogue systems allowing more complexity can be modeled by using frames, or **templates**

```
BOOK-FLIGHT(Customer, Flight):
    DEPARTURE-DATE(Flight) = ?
    DEPARTURE-TIME(Flight) = ?
    PAYMENT-METHOD(Customer) = ?
    NUMBER-OF-REQUESTED-SEATS = ?
    NUMBER-OF-OPEN-SEATS(Flight) = ?
    ...
Effect: FLIGHT-BOOKED(Customer, Flight) = Yes?/No?
```

- When a user says, *I want to leave Dallas on March 3*, DEPARTURE-DATE & DEPARTURE-CITY get filled in
- Only when all of the template has been filled in is the flight acutally booked

Semantic grammars

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

But how do we figure out what to put into the template?

People often use **semantic grammars** → akin to context-free grammars, but they use semantic concepts

SHOW	→	show me | i want | can i see
DEPART-TIME	→	(after|around|before) HOUR| morning | afternoon | evening
HOUR	→	one|two|three|four|...|twelve (AMPM)
AMPM	→	am | pm
FLIGHTS	→	(a) flight | flights
ORIGIN	→	from CITY
DESTINATION	→	to CITY
CITY	→	Boston |San Francisco |...

Parsing difficulties

Confirmation and repair strategies

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Aside from needing restricted input, parsing with a semantic grammar faces other challenges from spoken language

- The system has to account for ill-formed input and possibly **repairs** that humans make.

  A: I'd like to take the D Train, um, no, the A Train.

- Sometimes the system will have to **confirm** what a user said.

EXPLICIT	So you want to travel from Amsterdam to Utrecht?
IMPLICIT	When do you want to travel from Amsterdam to Utrecht?

Parsing difficulties

Inferring Intention

And, of course, there are Gricean-type inferences that we'd like a computer to make

- Convert an indirect speech act into something a computer can use.

  A: Can you give me a list of flights from Atlanta?

- If the user asks if I'm capable of doing something, it probably wants me to do that thing.

Natural Language Generation

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

Once the system has some information, it will want to give a response.

The dialogue manager will tell the natural language generation (NLG) unit what needs to be said

- NLG could just use a template to respond:
  - What time do you want to leave CITY-ORIG?
- Or the dialogue manager could build a semantic representation, which is then fed into a sentence builder (which uses a grammar and so forth)
  - Similar to generating MT sentences from a semantic representation

Pronoun resolution

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

For both the NLU (input) and NLG (output) units, there is a need to understand how pronouns work

Consider the difference in following system outputs:

A1: Please say the start time.
...
A1: Please say the duration.
...
A1: Please say the subject.

A2: First, tell me the date.
...
A2: Next, I'll need the time **it** starts.
...
A2: Thanks ... Now, how long is **it** supposed to last?
...

Reference

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

We call what a word refers to its **reference** = using expressions to refer to things

- **Indefinite noun phrases**: new to the discourse, e.g. *a book*, *some books*
- **Definite noun phrases**: something identifiable to the listener, e.g. *the book*, *those books*
- **Pronouns**: replacement for a noun phrase, e.g. *it*, *she*, etc.

Getting the reference right will make the system sound more natural

- **coreference** = two NPs referring to the same entity

Preferences for Pronoun Reference

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
Human-computer interaction

We know they all co-refer, but how can a computer tell? How does it go about solving the task of **pronoun resolution**?

- Syntactic and Semantic Constraints
- General Preferences/Heuristics

Task: find the previous noun phrase (NP) in the discourse which the current pronoun (or definite NP) refers to.

Preferences for Pronoun Reference

Syntactic and Semantic Constraints

Computers and Language
Dialogue Systems
Introduction
Human dialogue
Basic facts
Rules
Speech acts
Discourse structure
Early dialogue systems
ELIZA
Other chatterbots
Modern dialogue systems
TRIPS system
Dialogue manager
NLU
NLG
Pronoun resolution
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- Number, gender, and person agreement: co-referents must agree in all of these properties

  (1) a. John has a new car. **It**/***They** is red. (number)
      b. John has a new car. **He** (=John) is attractive. (gender)
      c. John and I have new cars. **We**/***They** love these cars. (person)

- Syntactic constraints: reflexives (*himself*, *herself*, ...) generally refer to subject of sentence

  (2) John bought **him**/**himself** a new car.

Preferences for Pronoun Reference
Selectional restrictions

- **Selectional restrictions**: verbs pick out what kinds of nouns they can have for subjects and objects.
  - *drive* needs a human object and a drivable object.

(3) John parked his car in the garage. **He** had driven **it** around for a bit.

Note that these restrictions can be extended: *The White House said yesterday ...*

Preferences for Pronoun Reference
General Preferences

After filtering out unwanted referents due to agreement and so on, we use various heuristics to find the referent.

- **Recency:** pronoun refers to most recent possible NP

(4) John bought a cookie, and I bought a cake. Mary ate **it**.

- **Subject over Object:** prefer matching the pronoun to a previous subject of a sentence over the sentence's pronoun.

(5) John hit Bill. Then I asked **him** to come with me.

Preferences for Pronoun Reference
General Preferences (cont.)

- **Repeated mention:** if someone keeps getting mentioned, they're more likely to be the referent of a pronoun.
- **Parallelism:** Back-to-back sentences with similar structures can help pick out the referent.

(6) Jim went with Carl to the supermarket. And I went with **him** to the gas station.

Resolving Pronouns

So, we can combine all this knowledge into a system for resolving pronouns.

1. Take all nouns in a sentence and make a list of possible referents.
2. Rank the nouns in terms of recency, frequency, subjecthood, and so on.
3. In the next sentence, try to match the pronoun with something in that list, starting with the most probable.
4. Rule out any "match" which violates agreement or other syntactic and semantic constraints

Human-computer interaction

To figure out how a system should work, we look at **human-computer interaction**

- We look at **corpora** = large texts of collected data, often **annotated** with linguistic properties

A couple kinds of dialogue corpora:

- **Natural dialogues** = A record of two (or more) humans speaking with one another, often about a task
- **Wizard of Oz dialogues** = A person talks to a "computer", which is actually a human (thus the WOZ analogy)

Natural dialogues

Pluses:

- Natural user tasks and needs
- Easy to set up and record

Minuses:

- These record human-human interactions, not human-computer interactions
  - People often speak differently to a computer, will often adapt to the way a computer is talking to them.

Wizard of Oz dialogues

"Computer" (wizard) is actually a human in disguise.

Pluses:

- Provide insights on human-computer interaction (HCI) without seting up a computer capable of HCI
- Allow freedom in the range of tasks you can cover

Minuses:

- Often an artificial task
- Can take a lot of computing resources to set up
- Need wizards who can type fast, accurately, and in a rather stiff manner, if they are to emulate a computer
- May not get consistent behavior from the wizard across different attempts