Language and Computers (Ling 384)

Topic 6: Dialogue Systems

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Outline

Introduction

Early Systems

How Does Dialogue Work?

Dialogue System Components

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 predujices a human might (... depending on the programmer)
- When robots someday take over the world, we'll be able to understand their demands

The Turing Test

The **Turing Test**, developed by Alan Turing, distinguishes between a human and a computer in dialogue.

- If I can tell I am interacting with a computer, it has failed the Turing Test
- If I am convinced I am interacting with a human, yet it's a computer, then the program has passed the Turing Test.

ELIZA

ELIZA was a computer program written by Joseph Weizenbaum in the mid-1960s

- Simulation of a (Rogerian) therapist.
- User types questions, and ELIZA responds.

http://www.manifestation.com/neurotoys/eliza.php3

Example conversation

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
USER: I need some help, that much seems certain.

Example conversation (cont.)

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
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

Properties of ELIZA

What do you notice about ELIZA?

- Seems to show some understanding of English.
  e.g. "What resemblance do you see?"
- Seems to have some understanding of real-world problems.
  e.g. "Tell me more about your family."
- Seems to keep track of the conversation
  e.g. "Does that have anything to do with ..."

Four types of responses

1. A general question or statement
   Does that trouble you?, *Beware of addictions.*
2. A transformed version of the previous statement
   Your father.
3. A reponse relevant to the topic of the previous statement
   Do you think coming here will help you ...?

Four types of responses (cont.)

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4. A reproduction of an earlier statement
   ELIZA: FIRST TELL ME WHY YOU HAVE COME HERE
   USER: To talk to a computer
   ELIZA: TO TALK TO A COMPUTER
   USER: Yes, to talk to a computer
   http://www.cogs.sussex.ac.uk/local/books/computers-and-thought/chap2/node2.html

How ELIZA works

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

1. Transform input

- *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*.
  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* in user's statement → respond with: *can you do without*
- 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

3. Canned phrases

- 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.

Choices in ELIZA

User enters *I wouldn't pay money for a computer.*

- *money* matches one pattern
- *computer* matches another pattern

⇒ ELIZA picks one pattern at random

Why does ELIZA work so well?

- User assumptions/expectations: if you're looking for a Rogerian psychotherapist, you may find what you expected.
- In theory, pattern matching can match a lot of user statements, given a large database of patterns.
- The way conversation works was taken into account when creating ELIZA
  Respond with something related to the previous statement; use some of the same vocab the other person did; etc.

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

- 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

Effect of ELIZA

People became somewhat emotionally involved with the system.
Weizenbaum's secretary asked him to leave the room while she talked with ELIZA

PARRY

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PARRY (Colby et al 1971)

- 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

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SHRDLU (Winograd 1972)

- simulated a robot who could manipulate toy blocks ("The BLOCKS World")
- e.g. *Move the red block on top of the smaller green one.*
- 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

From Then Until Now

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ELIZA was a very simple pattern-matcher, and PARRY and SHRDLU were only somewhat more complex. They're just "chatterbots"

- There has been a push to add linguistic and real-world knowledge to dialogue systems
- So, instead of focusing on systems, we will focus on what a dialogue system needs to know in order to work.

How does dialogue work?

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How does **discourse** (= conversation) work?

- Basic facts about dialogues
- Gricean maxims
- Speech acts
- Plan recognition
- Discourse structure
- Reference

Basic facts about dialogues

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- **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
e.g. question/answer, greeting/greeting, request/grant

Basic facts about dialogues (cont.)

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- **Utterances**: don't exactly match up with sentences; 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.

Basic facts about dialogues (cont.)

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- **common ground**: the set of things which both speakers believe to be true of the conversation.
e.g. Part of classroom common ground is that we are at OSU in a linguistics class. Not part of the common ground is what I had for dinner last night.
- Gricean maxims: rules of conversation

Grounding

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

- acknowledgments and **backchannels** = short utterance which indicates the utterance was heard and that the speaker should continue.
That's a nice shirt.
Mm-hmm.
- continued attention, completing speaker's utterance, and so on can also indicate acknowledgment

H.P. Grice and Conversation

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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.
- Can use these to infer what a speaker is really getting at.

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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)
    How many pencils do you have?
    Two. → means exactly two (or would have said more)
  - Do not make your contribution more informative than is required.
    (passing by somebody on the way to class)
    How's it going?
    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
    Do you know how to drive a stick-shift?
    Yes, I do. I've seen my dad do it many times.

Gricean maxim 3: Relevance

- Relevance: Be relevant.
  Is Gail dating anyone these days?
  Well, she goes to Cleveland every weekend.

Gricean maxim 4: Manner

- Manner: Be perspicuous (easy to understand).
  - Avoid obscurity of expression
  - Avoid ambiguity
  - Be brief (avoid unnecessary prolixity)
  - Be orderly

Speech acts

Utterances are equated with **actions** in a dialogue (Austin 1962)
For example, there are **performative verbs**, as in these sentences:

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

Kinds of speech acts

Searle 1975

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

Indirect Speech Acts

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

- Direct: Form matches meaning.
  e.g. Please take out the garbage. (declarative structure; declarative meaning)
- Indirect: The form and the meaning are different.
  e.g. The garbage isn't out yet. (declarative structure; imperative/directive meaning)
  Could you take out the garbage? (interrogative structure; imperative/request meaning)

How do we account for this with a computer?

DAMSL

We can try to define these speech acts and automatically figure out each utterance.
So, people have marked up text with different labels for speech acts.
DAMSL (Dialogue Act Markup in Several Layers) is a scheme of speech acts which people mark up texts with.

- forward-looking functions → question, request, etc., looking for a response
- backward-looking functions → answer, agreement, etc., providing a response

(Note the resemblance to adjacency pairs.)

Using DAMSL

- Using the DAMSL scheme, people can train a system on it, and then attempt to mark a new text with these labels.
- People can also have a dialogue system keep track of the previous forward-looking function to know how to respond.

Plan recognition

One thing a computer can do is to try to match what a speaker says with what it's looking for, i.e. a computer can be trying to fill a **template**, or **schema**
e.g. If I call up a flight system, it knows that there is certain information which needs to be filled in: departure city, arrival city, dates of travel, etc.

Template

```
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?
```

- So, when a customer says, *I want to leave Dallas on March 3*, the DEPARTURE-DATE and DEPARTURE-CITY both get filled in.
- Only when all of the template has been filled in is the flight acutally booked.

Inferring Intention

Computers can try to infer what a user intended, or what a user is intending to do next.
⇒ Convert an indirect speech act into something a computer can use.
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.

Confirmation and repair strategies

Sometimes the system will have to **confirm** what a user said.
e.g. 'So you want to travel from Amsterdam to Utrecht?' (explicit)
'When do you want to travel from Amsterdam to Utrecht?' (implicit)
(http://www.compuleer.nl/Nimes.html)
Sometimes the system will have to account for a **repair** that the human made.
e.g. I'd like to take the D Train, um, no, the A Train.

Discourse structure

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

- This is even more the case when the speakers are trying to achieve some purpose, or task, like giving directions or fixing a car → task-based dialogues
- Every discourse has a **discourse purpose** = a reason for talking (Grosz and Sidner 1986)

The problem is trying to figure out the intentions of the speakers.

Subdialogues

And within the overall dialogue, there are **subdialogues**

- e.g. in order to book a flight, you must ask me where I want to go.
- Or I may have to correct you in a subdialogue (*I said Columbus, not Columbia*)

Determining structure

- If we can figure out the discourse structure automatically, the computer is better able to keep track of what's going on.
  ⇒ When you know the structure, you're better able to know what pronouns (and definite noun phrases) refer to.
- Determining structure is not always clear-cut, and humans can disagree as to the correct structure.

Reference

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.

Coreference

These different kinds of noun phrases can refer to the same thing, i.e. **coreference**
I saw **a monkey** yesterday. **The dumb thing** was wily, and **it** kept throwing things at me.
→ *a monkey*, *the dumb thing*, and *it* all refer to the same real-world creature.

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Preferences for Pronoun Reference

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

The task is to find the previous noun phrase (NP) in the discourse which the current pronoun (or definite NP) refers to.

Syntactic and Semantic Constraints

- Number, gender, and person agreement: co-referents must agree in all of these properties
  John has a new car. It/*They is red. (number)
  John has a new car. He (=John) is attractive. (gender)
  John and I have new cars. We/*They love these cars. (person)
- Syntactic constraints: reflexives (*himself*, *herself*, ...) generally refer to subject of sentence
  John bought him/himself a new car.

Selectional restrictions

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

General Preferences/Heuristics

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

- Recency: pronoun refers to most recent possible NP
  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.
  John hit Bill. Then I asked **him** to come with me.

General Preferences/Heuristics (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.
  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

How do we get our knowledge about how dialogue works?

Look at **human-human interaction**, i.e. how humans have interacted with computers
Look at **human-computer interaction**, i.e. how humans have interacted with computers
Also HH psycho-linguistic experiments (Jurafsky & Martin, 18.4 (p. 707-712))

Human-human and human-computer interaction

We look at **corpora** = large texts of collected data, often **annotated** with linguistic properties.
e.g. A corpus of dialogues about giving directions from a map.

- **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.

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Wizard of Oz dialogues

“Computer” is actually a human in disguise.
Pluses:

- Provide insights on human-computer interaction (HCI) without having to set up a computer which is capable of HCI.
- Allow freedom in the range of tasks you can cover.

Wizard of Oz dialogues: downside

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

Modeling discourse

Now that we know how dialogue works, we want to know how to model it, what kind of **architecture** it will have.
⇒ depends on what we want to do.

- State transition networks
- Frame-based systems

State transition networks

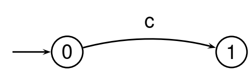
Well-structured dialogue can be modeled with a **state transition network**.
e.g. Dialogue system where the user only has to answer questions → very constrained

- 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

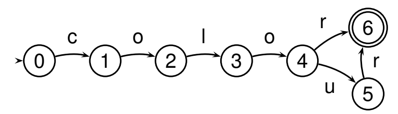
A state transition network is basically just a **finite-state automaton** (FSA) = network of states and transitions between states. (Also called a **finite-state machine**.)

- By moving through the FSA, you try to match an input string.
- The idea is that you can move from state to state, when conditions on the arcs are met.
  e.g. Move from state 0 to state 1 if I encounter the letter *c*. (Otherwise, do nothing.)



FSAs continued

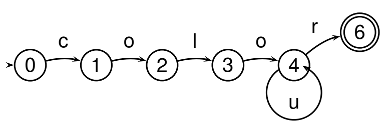
We represent states with **nodes** (circles) and transitions with **arcs** (arrows) in a picture. (Note that the numbers on the nodes are just for our convenience; they don’t really “mean” anything.)



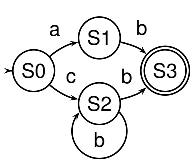
The FSA above matches (or generates) the string *color* or the string *colour*. The double lines around node 6 means that this is a **final state** = can end at this state. i.e. If you match *colo*, you are not done. (you have to get to a double circle or else it fails.) What regular expression does this match?

FSAs continued

What do the following FSAs do?



This corresponds to the regular expression: colou*r



This corresponds to the regular expression: (ab|cb+)

Drawing FSAs

Things to remember:

- You have to have a single start node, but you can have more than one end node.
- The nodes don’t necessarily have to go in order from left to right.
- FSAs are what are used to match regular expressions. Logically, they are equivalent.

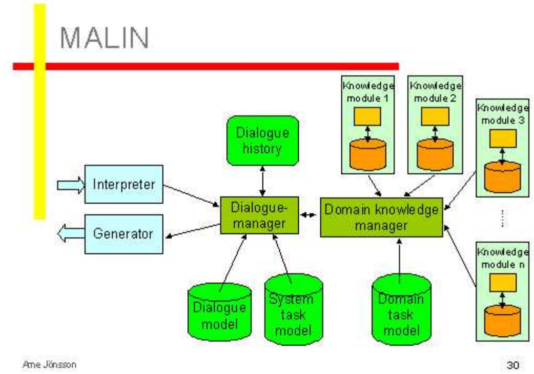
Frame-based systems

Dialogues with a little more complexity—e.g. the user can ask questions, too—can be modeled with **frame-based systems** = systems based on frames, or templates.
We saw these earlier:

```
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?
```

Components of a dialogue system

- Interface (media/mode)
- Discourse manager
- Context manager
- User model
- Knowledge sources
- Language Interpreter & Generator



Interface (media/mode)

If it's a spoken dialogue system, need an automatic speech recognizer.
If it's a written dialogue system, simply need a keyboard.
Can also consider the aesthetics of the system, if someone is communicating with a talking picture on a computer screen, for instance.

Discourse manager

a.k.a. Dialogue manager

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

Context manager

Pay attention to the surrounding context:

- What time it is
- Where the user is, what the conditions are there
- If the user is looking at something (e.g. a map), what does that map look like?

User model

Who is the user? What is the user thinking?
Try to deduce various facets of the user:

- Beliefs = what do they believe to be true about this conversation?
- Intentions = what are they trying to do?
- Capabilities = what are they capable of doing?

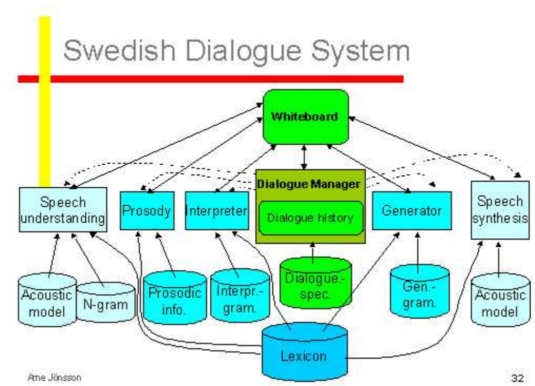
Knowledge sources

Keep track of knowledge about the world the system might need

- If the user is looking at something (e.g. a map), what does that map look like?
- A database of flights: what flights are being offered by this airline?
- A listing of road closings

Language Interpreter & Generator

And of course, we need to convert what the user says into some form of meaning representation (natural language understander).
And we need to convert the system's (meaning) response into some form of language (natural language generator)
A great deal of knowledge about how sounds, words, and sentences are formed is needed.



Development of dialogue systems

- Define what the task is.
- Define what modules/components are needed for this task, and split up the work.
  e.g. Input for you will be X, and we expect Y as the output
- Start to build the components.
- Iteratively, or incrementally, test each component with gradually more complex user demands.
- Make changes where necessary.
- Put all the components back together.

Example system: TRIPS

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

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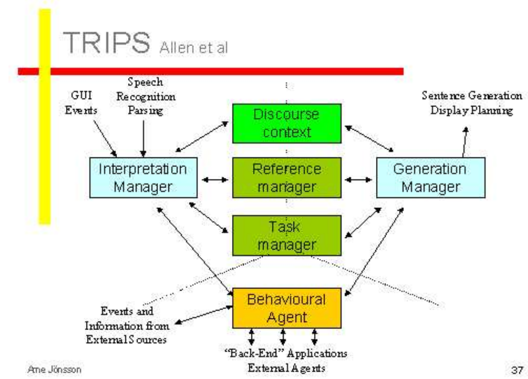

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Corpora
Modeling discourse
Dialogue System Components
TRIPS