

# Dialog Systems

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<https://laramartin.net/interactive-fiction-class>

*Slides modified from Chris Callison-Burch & João Sedoc*

# Learning Objectives

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Interpret difficulties in human communication

Distinguish between chatbots and task-oriented dialog systems

Link reinforcement learning to chatbots

Determine how task-oriented systems can be made with neural/ML-based methods

Tie task-oriented dialog back into IF/storytelling

# Conversational Agents aka Dialog Systems

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Digital Assistants

Answering questions on websites

Communicating with robots

Chatting for fun

Clinical uses

ChatGPT

# Challenging properties of human conversation

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- Turn taking
- Speech acts
- Grounding
- Dialogue structure
- Initiative
- Implicature

# Turn taking

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A conversation is a sequence of turns, where you take a turn and then I take a turn. A turn can be a sentence, or a single word.

A system must know when to start and stop talking.

Spoken dialogue systems must also detect whether a user is done speaking, so they can process the utterance and respond. This task of **endpoint detection** is tricky because people often pause mid-turn.

# Speech acts

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**Constatives:** committing the speaker to something's being the case (*answering, claiming, confirming, denying, disagreeing, stating*)

**Directives:** attempts by the speaker to get the addressee to do something (*advising, asking, forbidding, inviting, ordering, requesting*)

**Commissives:** committing the speaker to some future course of action (*promising, planning, vowing, betting, opposing*)

**Acknowledgments:** express the speaker's attitude regarding the hearer with respect to some social action (*apologizing, greeting, thanking, accepting an acknowledgment*)

# Conversational Implicature

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**Agent:** And, what day in May did you want to travel?

**Client:** I need to be there for a meeting that's from the 12th to the 15th.

Notice that the client does not in fact answer the agent's question. The speaker expects the hearer to draw certain inferences.

**Implicature** means certain kinds of inferences.

**Gricean maxims.** The *maxim of relevance* means that when the client mentions a meeting on the 12th, the agent reasons 'There must be some relevance for mentioning this meeting. What could it be?'

# Two Classes of Dialog Systems

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## 1. Chatbots

- Systems designed for extended conversations
- Chatting for fun and entertainment

## 2. Task-Oriented Dialogue Agents

- Goal-Based Agents
- Siri/Alexa, interface with robots, booking flights or hotels



# Part I: Chatbots

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Systems designed for extended conversations. Chatbots mimic unstructured conversations or 'chats' that are characteristic of informal human-human interaction

Architectures include:

Rule-Based

- Pattern-action rules

Corpus-Based

- Information Retrieval
- Neural networks

# Part I: Chatbots

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## **Rule-Based**

- **Pattern-action rules**

## Corpus-Based

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# ELIZA: Weizenbaum (1966)



Simulates a psychologist

Rogerian psychology is a rare type of conversation where “assume the pose of knowing almost nothing of the real world”

Draw the patient out by reflecting patient’s statements back at them

# ELIZA: Weizenbaum (1966)

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Men are all alike.

IN WHAT WAY

They're always bugging us about something or other.

CAN YOU THINK OF A SPECIFIC EXAMPLE

Well my boyfriend made me come here.

YOUR BOYFRIEND MADE YOU COME HERE

He says I'm depressed much of the time.

I AM SORRY TO HEAR YOU ARE DEPRESSED

::

WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU?

My father

YOUR FATHER

You are like my father in some ways.

# ELIZA: Weizenbaum (1966)

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WHAT RESEMBLANCE DO YOU SEE

You are not very aggressive but I think you don't want me to notice that.

WHAT MAKES YOU THINK I AM NOT AGGRESSIVE

You don't argue with me.

WHY DO YOU THINK I DON'T ARGUE WITH YOU

You are afraid of me.

DOES IT PLEASE YOU TO BELIEVE I'M AFRAID OF YOU

My father is afraid of everybody.

WHAT ELSE COMES TO MIND WHEN YOU THINK OF YOUR FATHER

Bullies.

DOES THAT HAVE ANYTHING TO DO WITH THE FACT THAT YOUR  
BOYFRIEND MADE YOU COME HERE

# ELIZA Pattern Transform Rules

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Pattern matching rules:

. \* YOU (.\* ) ME    →    WHAT MAKES YOU THINK I \$1 YOU?

This rule would transform

You **must really hate** me

into

WHAT MAKES YOU THINK I **MUST REALLY HATE** YOU?

# Simplified sketch of ELIZA

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**function** ELIZA GENERATOR(*user sentence*) **returns** *response*

Find the word *w* in *sentence* that has the highest keyword rank

**if** *w* exists

Choose the highest ranked rule *r* for *w* that matches *sentence*

*response* Apply the transform in *r* to *sentence*

**if** *w* = 'my'

*future* Apply a transformation from the 'memory' rule list to *sentence*

Push *future* onto memory stack

**else** (no keyword

applies) **either**

*response* Apply the transform for the NONE keyword to *sentence*

**or**

*response* Pop the top response from the memory stack

**return**(*response*)

# PARRY: Colby (1971)

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ELIZA like regular expressions But a much richer –

- Control Structure
- Language Understanding Capabilities
- Mental Model : Parry has affective variables
  - Fear, Mistrust, Anger
  - If Anger level is high, respond with hostility

First system to pass the **Turing test (1971)**



# Turing Test

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“

*I propose to consider the question, ‘Can machines think?’*

”

- A human evaluator would judge text-based conversations between a human and a machine designed to generate human-like responses.
- If the evaluator cannot reliably tell the machine from the human, the machine is said to have passed the test.

# Part I: Chatbots

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Systems designed for extended conversations. Chatbots mimic unstructured conversations or 'chats' that are characteristic of informal human-human interaction

Architectures include:

## Rule-Based

- Pattern-action rules (Eliza)

## Corpus-Based

- Information Retrieval
- Neural networks

# Conversational Data

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Need: large collections of human conversations

Conversational threads on Twitter or Weibo (微博)

Retrieve dialog from movies, indexing subtitles

Recorded telephone conversations, collected for speech research

Crowdsourced conversations

What are some issues that might come from using each of these datasets?

# Information Retrieval based Chatbots

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Treat the human user's input as a query vector  $\mathbf{q}$

Search over a large corpus  $\mathbf{C}$  of conversation to find the closest matching turn  $\mathbf{t}'$  in those previous conversations.

Return the response  $\mathbf{r}$  to that conversational turn.

$$\mathbf{t}' = \arg \max_{\mathbf{t} \in \mathbf{C}} \text{cosine\_similarity}(\mathbf{q}, \mathbf{t})$$

$$\mathbf{r} = \text{response}(\mathbf{t}')$$

$\mathbf{q}$  = Have you watched Doctor Who?

$\mathbf{t}'$  = Do you like Doctor Who?

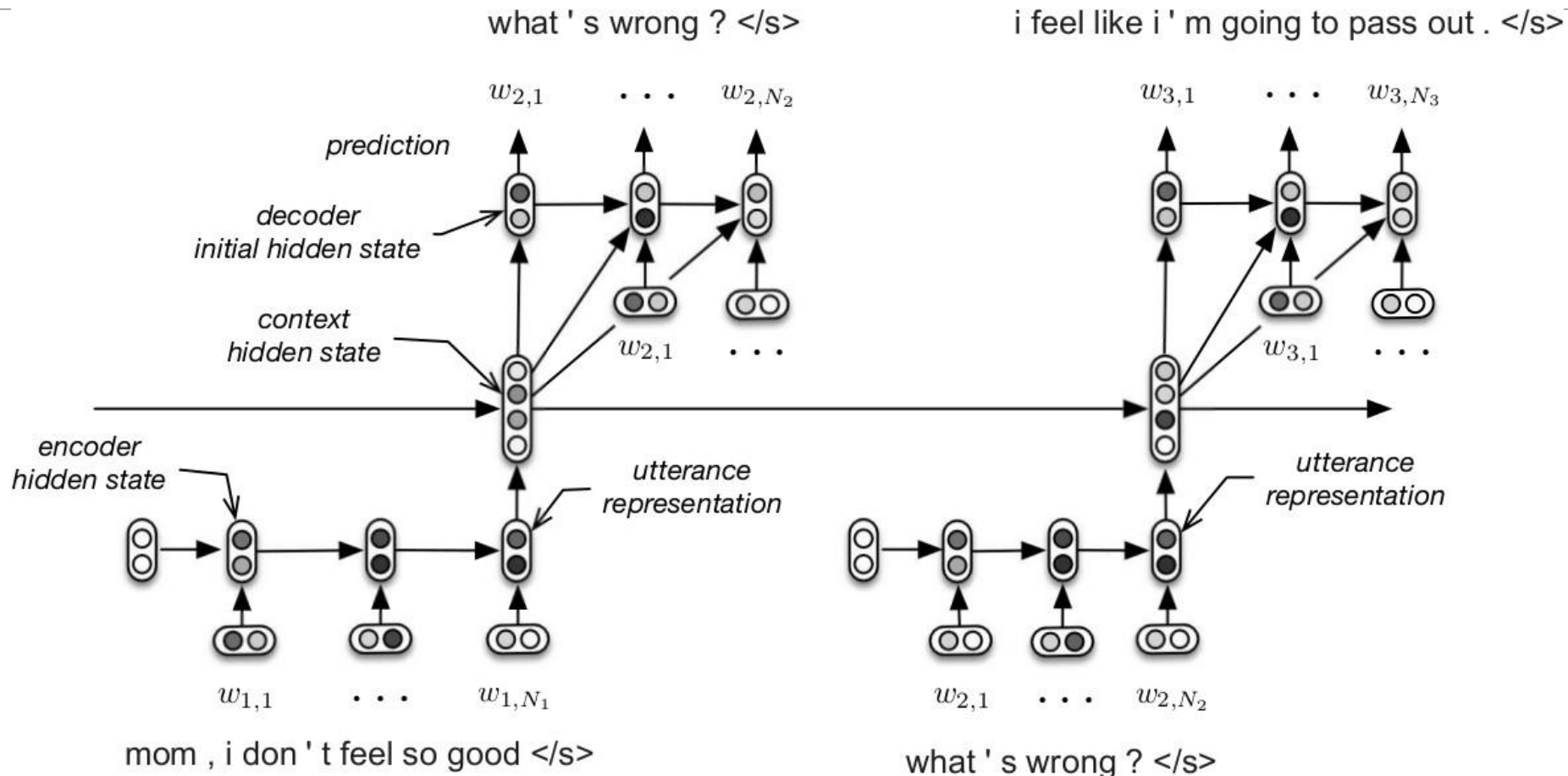
$\mathbf{r}$  = Yes, I love SciFi shows!

# IR-based Models

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- Can use more features than just words in query  $q$ 
  - User features - Information about the user or sentiment
  - Prior turns – Use conversation so far
  - Narrative (non-dialogue) text
    - COBOT chatbot (Isbell et al., 2000) :
      - Generate responses by selecting sentences from the Unabomber Manifesto by Theodore Kaczynski, articles on alien abduction, the scripts of “The Big Lebowski” and “Planet of the Apes”
      - Wikipedia Text

# Seq2Seq Encoder-Decoder Models



# Sample Responses: Enc-Dec RNN Model

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<b>Input</b>	tell me ... how long have you had this falling sickness ?
<b>Vanilla-SEQ2SEQ</b>	i'm not a doctor.
<b>Adversarial</b>	a few months, i guess .
<b>Input</b>	so i had the doctors test sammy 's response to conditioning .
<b>Vanilla-SEQ2SEQ</b>	sammy wrote the test sammy wrote the test .
<b>Adversarial</b>	so he took the pills .
<b>Input</b>	they didn 't have much success with this problem commander .
<b>Vanilla-SEQ2SEQ</b>	they 're not the only ones who have been in the system .
<b>Adversarial</b>	can we find someone else ?

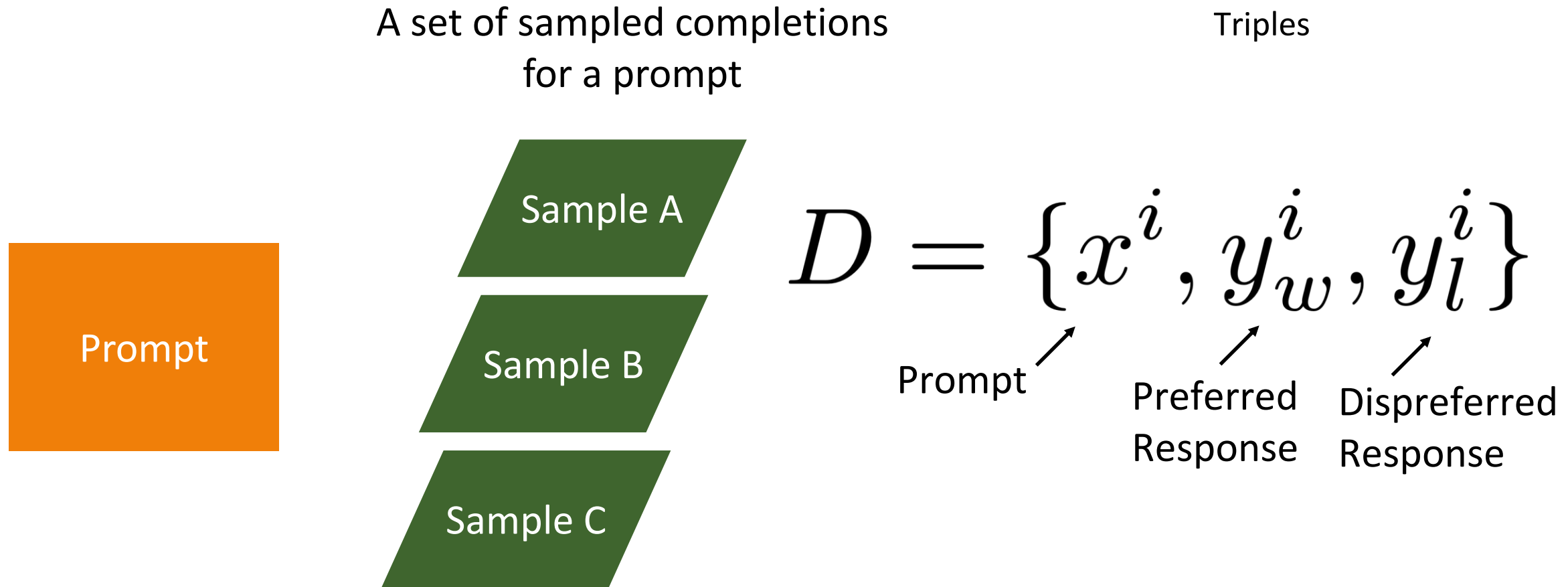
Responses that are harder to distinguish from human responses

# Remember RLHF?

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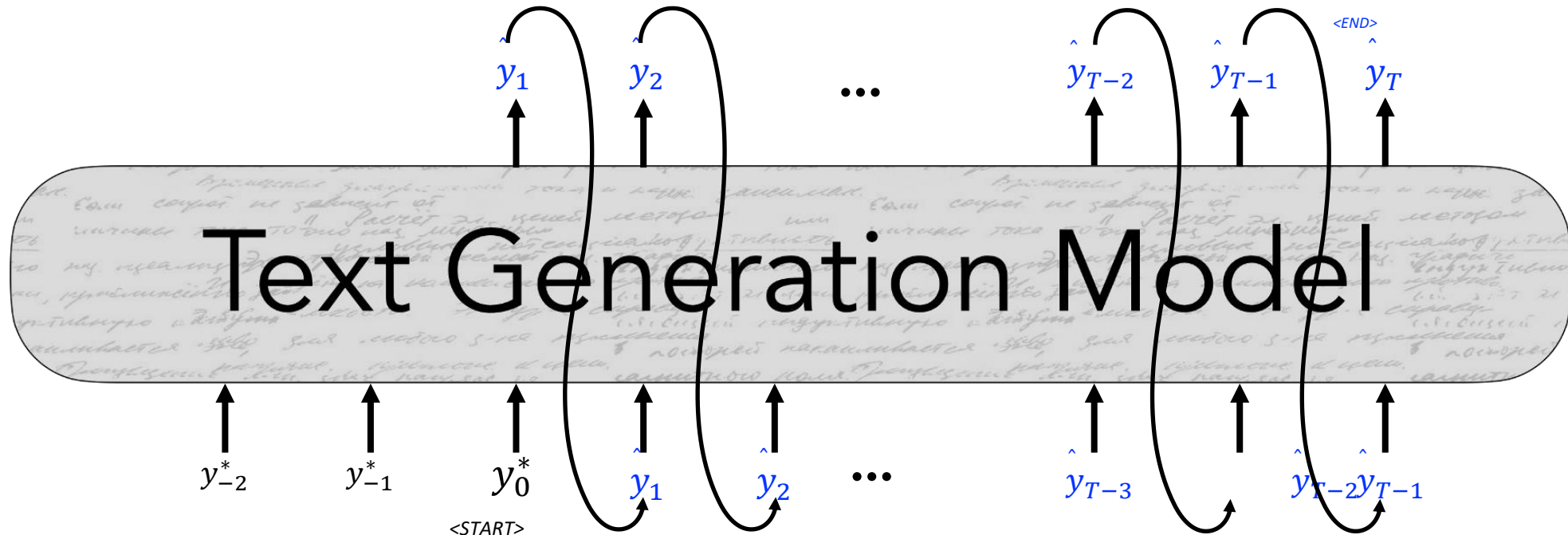
# Review: Human Preferences



# Review: REINFORCE

Sample a sequence from your model, score the sequence, and use the score to train the model.

$$L_{RL} = - \sum_{t=1}^T r(\hat{y}_t) \log P(\hat{y}_t | \{y^*\}; \{\hat{y}\}_{<t})$$





Can you help me write a resignation letter to my current employer, while leaving on good terms and expressing gratitude for the opportunities provided?

## Review: Example Annotation



Here are two responses from the chatbot. (Please scroll down on the content to see the entire response if it is too long)

A

Sure, here is a resignation letter template that you can use:

Dear [manager],

It is with a heavy heart that I submit this letter of resignation from my position as [position] at [company]. I have enjoyed my time here and am grateful for the opportunities that have been provided to me.

I have accepted a new opportunity that presents a greater challenge and is more aligned with my long-term career goals. I have learned so much during my time at

B

Of course! Here is a sample resignation letter that you can use as a guide:

Dear [Manager's Name],

I am writing to inform you that I have decided to resign from [Company Name]. This was not an easy decision, as I have enjoyed my time here and have learned a lot from my colleagues.

I want to express my sincere gratitude for the opportunities and support that [Company Name] has provided me over the years. I have grown both

Annotator needs to choose whether they prefer A or B.

This is part of how ChatGPT was made

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# Part II: Frame-based Dialogue Systems

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- Task-based Dialogue Agents
- Based on “Domain Ontology”
  - A set of “Frames”
- Frame:
  - A knowledge structure representing user intentions
  - A collection of “slots”
  - Each “slot” having a set of “values”

# Example: Travel Domain

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Slot : Origin City

Type : City

Value : San Francisco

Slot	Type	Question
ORIGIN	city	What city are you leaving from?
DEST	city	Where are you going?
DEP DATE	date	What day would you like to leave?
DEP TIME	time	What time would you like to leave?
AIRLINE	line	What is your preferred airline?

# Evaluation

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## 1. Slot Error Rate for a Sentence

$$\frac{\text{\# of inserted/deleted/substituted slots}}{\text{\# of total reference slots for sentence}}$$

## 2. End-to-end evaluation (Task Success)

# Evaluation

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“Make an appointment with Lara at 10:30 in ITE 216”

Slot	Filler
PERSON	Lara
TIME	11:30 a.m.
ROOM	ITE 216

**Slot error rate:** 1/3

**Task success:** At end, was the correct meeting added to the calendar?



# Frame-based Dialogue Agents

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Artificial Intelligence Journal, 1977

## **GUS, A Frame-Driven Dialog System<sup>1</sup>**

**Daniel G. Bobrow, Ronald M. Kaplan, Martin Kay,  
Donald A. Norman, Henry Thompson and  
Terry Winograd**

*Xerox Palo Alto Research Center, 3333 Coyote Hill Road,  
Palo Alto, CA 94304, U.S.A.*

- Still the industrial state of the art
- Siri/Alexa based on GUS architecture

# GUS system : An actual dialogue

GUS: Hello. My name is GUS. I can help you plan a simple trip by air. Where do you want to go ?

Client: I want to go to San Diego on May 28

GUS: What time do you want to leave?

Client: I must be in San Diego before 10 am

GUS: Would you like P.S.A. flight 102 that arrives at 9.15 am ?

Client: What is the next flight ?

GUS: Air California flight 310 that leaves at 8.30am and arrives at 10.00am

Client: I'll take the first one

GUS: In what name should I make a reservation, please?

Client: Dan Bobrow

GUS: I have confirmed the following flight: P.S.A. flight 102 on Wednesday May 28 from San Jose to San Diego that leaves at 7.30 am and arrives at 9.15 am.

GUS: What date do you want to return on ?

Client: On Friday in the evening.

GUS: Would you like the flight that leaves at 7.45 pm ?

Client: That's fine.

GUS: I have confirmed the following flight: P.S.A. flight 307 on Friday May 30 from San Diego to San Jose that leaves at 7.45 pm and arrives at 9.30 pm Thank you for calling. Goodbye

# Slot types can be complex

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The type *DATE*

**DATE**

**MONTH:NAME    YEAR:INTEGER    DAY:(BOUNDED-INTEGER 1 31)**  
**WEEKDAY:(MEMBER (Sunday Monday Tuesday Wednesday**  
**Thursday Friday Saturday))**

How do you know what  
slot types or frames to  
use for your dialog  
system?

# Control structure for frame-based dialog

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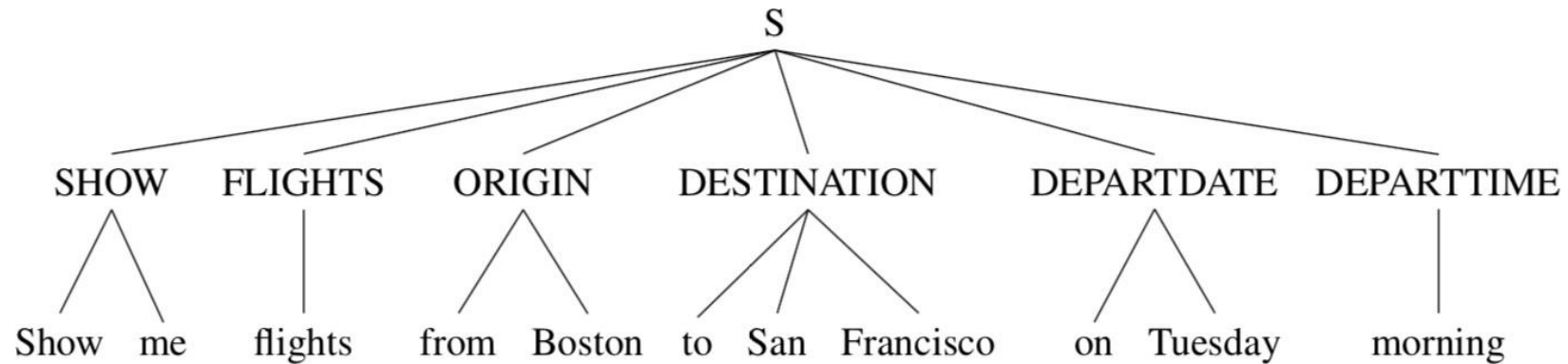
Consider a trivial airline travel system:

- Ask the user for a departure city
- Ask for a destination city
- Ask for a time
- Ask whether the trip is round-trip or not

# Rule-based Slot-filling

## ■ Semantic Grammar Rules or Regular Expressions

Wake me (up) | set (the|an) alarm | get me up



A semantic grammar parse for a user sentence, using slot names as the internal parse tree nodes

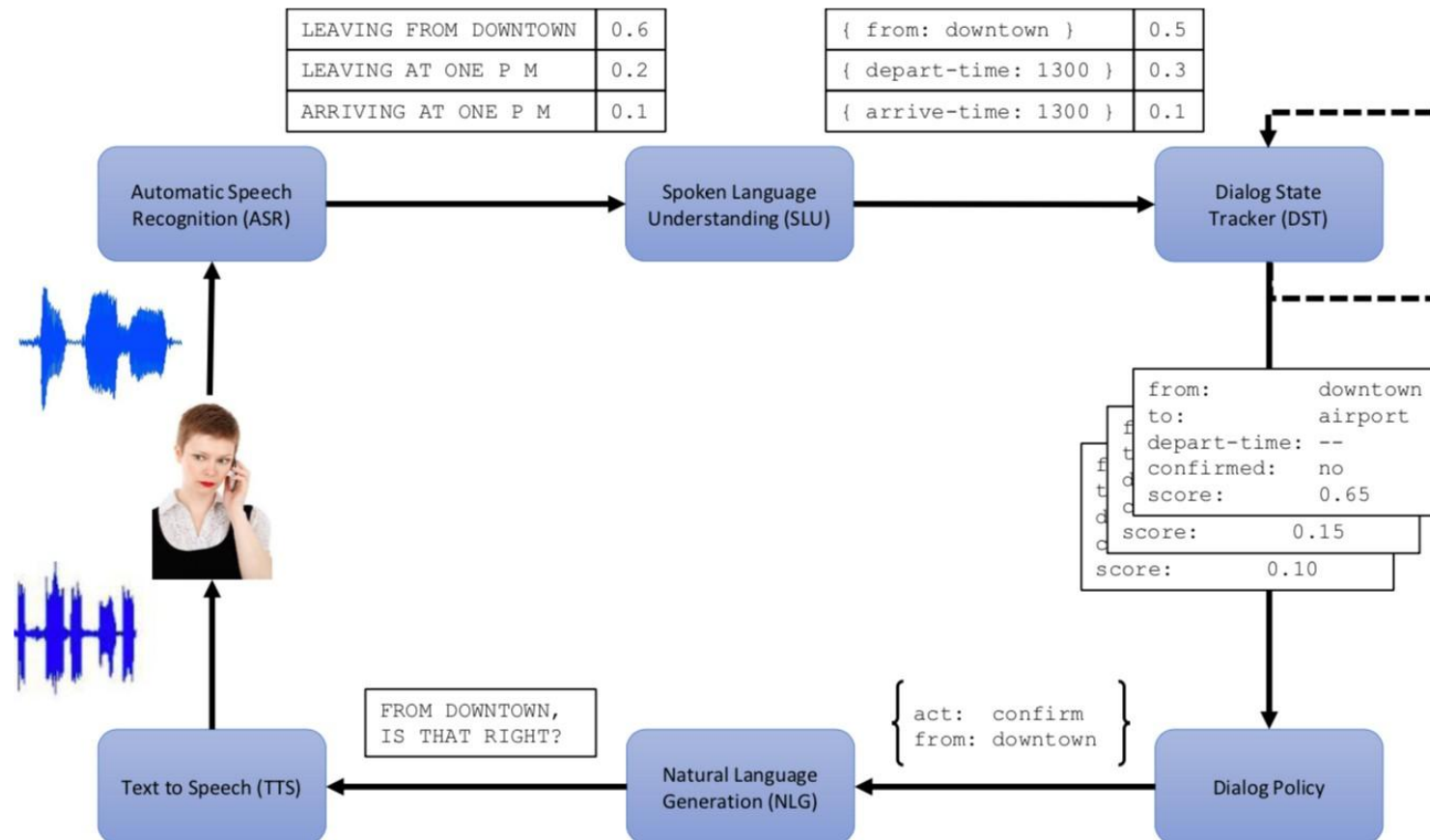
# Rule Sets

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- Collections of **rules** consisting of:
  - condition
  - action
- When user input is processed, facts added to store and
  - rule conditions are evaluated
  - relevant actions executed

# Dialogue-State Architecture

More sophisticated version of frame-based architecture



Williams et al. (2016)

## ■ NLU Component:

- Extract slot fillers using machine learning rather than rules

## ■ Dialogue State Tracker:

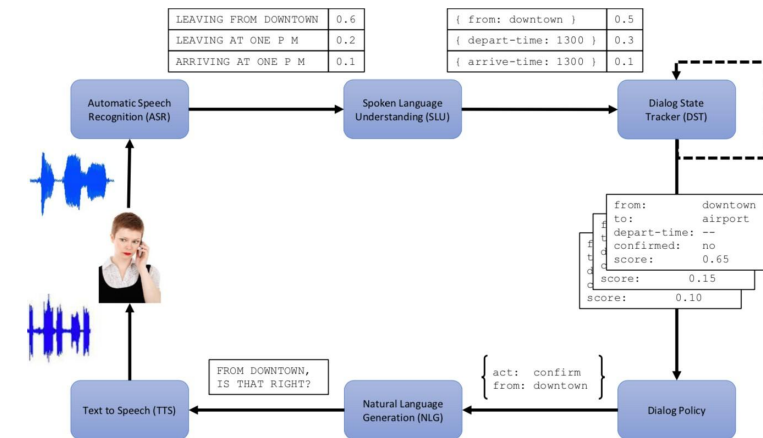
- Maintains current state of dialogue, user's most recent dialogue act

## ■ Dialogue policy:

- Decides what the system should do or say next
- When to answer user's questions, when to make a suggestion

## ■ Natural Language Generation Component:

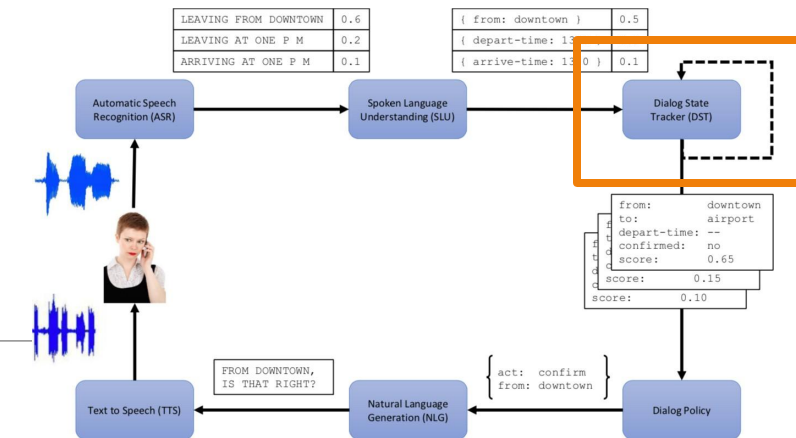
- Condition on exact context to produce turns that seem much more natural





# Dialogue State Tracking

- Keep track of
  - Current state of the frame (the fillers of each slot)
  - User's most recent dialogue act



User: I'm looking for a cheaper restaurant  
 inform(price=cheap)

System: Sure. What kind - and where?

User: Thai food, somewhere downtown  
 inform(price=cheap, food=Thai, area=centre)

System: The House serves cheap Thai food

User: Where is it?  
 inform(price=cheap, food=Thai, area=centre); request(address)

System: The House is at 106 Regent Street

Sample output of a dialogue state tracker after each turn

# Dialogue Acts

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Combining idea of speech acts and grounding into a single representation

Utterance	Dialogue act
U: Hi, I am looking for somewhere to eat.	<code>hello(task = find,type=restaurant)</code>
S: You are looking for a restaurant. What type of food do you like?	<code>confreq(type = restaurant, food)</code>
U: I'd like an Italian somewhere near the museum.	<code>inform(food = Italian, near=museum)</code>
S: Roma is a nice Italian restaurant near the museum.	<code>inform(name = "Roma", type = restaurant, food = Italian, near = museum)</code>
U: Is it reasonably priced?	<code>confirm(pricerange = moderate)</code>
S: Yes, Roma is in the moderate price range.	<code>affirm(name = "Roma", pricerange = moderate)</code>
U: What is the phone number?	<code>request(phone)</code>
S: The number of Roma is 385456.	<code>inform(name = "Roma", phone = "385456")</code>
U: Ok, thank you goodbye.	<code>bye()</code>

Sample dialogue from the recommender system of Young et al. (2010)

# Dialogue Policy

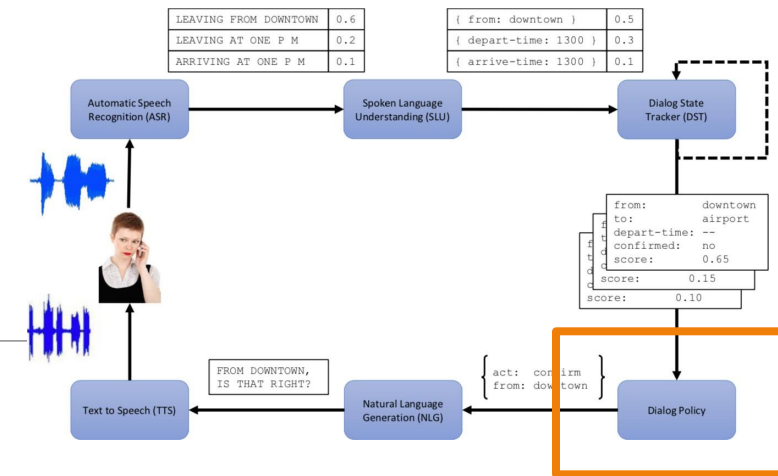
- What action the system should take next
- What dialogue act to generate
- Predict which action  $A_i$  to take

$$\hat{A}_i = \operatorname{argmax}_{A_i \in A} P(A_i | (A_1, U_1, \dots, A_{i-1}, U_{i-1}))$$

A = Dialogue Acts from System; U = Dialogue Acts from User

- Simplification: Condition just on the current dialogue state

$$\hat{A}_i = \operatorname{argmax}_{A_i \in A} P(A_i | (\text{Frame}_{i-1}, A_{i-1}, U_{i-1}))$$



# Think-Pair-Share

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How would you know if your dialog policy\* is good?

\*What action the system should take next