

COS 484: Natural Language Processing

Dialogue

Fall 2019

Overview

- What's a dialogue system?
- Properties of Human Conversation
- Chatbots v.s. Task-oriented dialogues systems
- Rule-based v.s. Data-driven
- Remaining Challenges



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Dialog Systems are HOT . — Did you use it?



Siri



Hi, how can I help?

Dialog Systems are HOT . — Preferable user interface.



Dialog Systems are **HOT** . — Killer apps for NLP.



Google Duplex: Can you distinguish human and AI?



(https://techeology.com/what-is-google-duplex/)

Google Duplex: Can you distinguish human and AI?

Dialog Systems are **HOT (b)**. — Killer apps for NLP.

They can

×

- give travel directions
- control home appliances

- help make phone calls
- customer services

• find restaurants

• • • •



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- C_1 : ... I need to travel in May.
- A₁: And, what day in May did you want to travel?
- C_2 : OK uh I need to be there for a meeting that's from the 12th to the 15th.
- A₂: And you're flying into what city?
- C₃: Seattle.
- A₃: And what time would you like to leave Pittsburgh?
- C₄: Uh hmm I don't think there's many options for non-stop.
- A₄: Right. There's three non-stops today.
- C_5 : What are they?
- A₅: The first one departs PGH at 10:00am arrives Seattle at 12:05 their time. The second flight departs PGH at 5:55pm, arrives Seattle at 8pm. And the last flight departs PGH at 8:15pm arrives Seattle at 10:28pm.
- C_6 : OK I'll take the 5ish flight on the night before on the 11th.
- A₆: On the 11th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115.
- C_7 : OK.
- A₇: And you said returning on May 15th?
- C_8 : Uh, yeah, at the end of the day.
- A₈: OK. There's #two non-stops ... #
- C₉: #Act...actually #, what day of the week is the 15th?
- A₉: It's a Friday.
- C_{10} : Uh hmm. I would consider staying there an extra day til Sunday.
- A₁₀: OK...OK. On Sunday I have ...

A: travel agent C: human client

\mathbf{C}_1 :	I need to travel in May.
A_1 :	And, what day in May did you want to travel?
C ₂ :	OK uh I need to be there for a meeting that's from the 12th to the 15th.
A ₂ :	And you're flying into what city?
C ₃ :	Seattle.
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C9:	#Actactually #, what day of the week is the 15th?
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Turn structure: (C-A-C-A-C...)

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A ₁ :	And, what day in May did you want to travel?	
C ₂ :	OK uh I need to be there for a meeting that's from the 12th to the 15th.	
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C ₃ :	Seattle.	
A ₃ :	And what time would you like to leave Pittsburgh?	 . .
C ₄ :	Uh hmm I don't think there's many options for non-stop.	Spoken DS:
A4:	Right. There's three non-stops today.	endpoint detection
C ₅ :	What are they?	(know when to start talking)
A ₅ :	The first one departs PGH at 10:00am arrives Seattle at 12:05 their time. The	
	second flight departs PGH at 5:55pm, arrives Seattle at 8pm. And the last	
	flight departs PGH at 8:15pm arrives Seattle at 10:28pm.	Turna aturnaturna.
C ₆ :	OK I'll take the 5ish flight on the night before on the 11th.	iurn structure:
A ₆ :	On the 11th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115.	(C-A-C-A-C)
C ₇ :	OK.	
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#: overlap

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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, ask-	
	ing, 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 so-	
	cial action (apologizing, greeting, thanking, accepting an acknowledgment)	

A taxonomy of **dialog acts** (Bach and Harnish, 1979)

- C_1 : ... I need to travel in May.
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grounding:

acknowledge that the listener has understood the speaker

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A_1 :	And, what day in May did you want to travel?		
C ₂ :	OK uh I need to be there for a meeting that's from the 12th to the 15th.		
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A ₃ :	And what time would you like to leave Pittsburgh?		
C_4 :	Uh hmm I don't think there's many options for non-stop.		
A4:	Right. There's three non-stops today.		
C ₅ :	What are they?		
A ₅ :	The first one departs PGH at 10:00am arrives Seattle at 12:05 their time. The	local structure	
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C ₆ :	OK I'll take the 5ish flight on the night before on the 11th.	dialog acts	
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A ₈ :	OK. There's #two non-stops #		
C ₉ :	#Actactually #, what day of the week is the 15th?	correction	
A9:	It's a Friday.	subdialogue	
C ₁₀ :	Uh hmm. I would consider staying there an extra day til Sunday.	Junulaiugue	
A ₁₀ :	OKOK. On Sunday I have		

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... I need to travel in May.

 C_1 :

A₁:

C₂:

A₂:

C₃:

A₃:

 C_4 :

A4:

C₅:

 A_5 :

C₆:

A₆:

 C_7 :

A₇:

 C_8 :

A₈:

C₉:

A9:

mixed initiative:

conversation is not controlled by one participant

\mathbf{C}_1 :	I need to travel in May.	
A ₁ :	And, what day in May did you want to travel?	
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C ₃ :	Seattle.	
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C4:	Uh hmm I don't think there's many options for non-stop.	
A4:	Right. There's three non-stops today.	
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C ₆ :	OK I'll take the 5ish flight on the night before on the 11th.	one participant
A ₆ :	On the 11th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115.	
C ₇ :	OK.	user-initiative
A ₇ :	And you said returning on May 15th?	VS
C ₈ :	Uh, yeah, at the end of the day.	V•J•
A ₈ :	OK. There's #two non-stops #	system-initiative
C9:	#Actactually #, what day of the week is the 15th?	
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conversational implicature

- Turn structure
- Dialog acts
- Grounding
- Dialogue structure
- Initiative
- Implicature

These **subtle characteristics of human conversations** are among the reasons it is difficult to build dialogue systems that can carry on **natural conversations with humans**.

Overview

- What's a dialog system?
- Properties of Human Conversation
- Chatbots v.s. Task-oriented dialog systems
- Rule-based v.s. Data-driven
- Remaining Challenges



User:	Do you like Doctor Who?
Cleverbot:	Yes, so funny.
User:	What's your favorite show?
Cleverbot:	I don't have one.
User:	What's your name?
Cleverbot:	Jason I already told you.
User:	No your real name.
Cleverbot:	Stephanie IS my real name.
User:	I thought it was Jason?
Cleverbot:	How did you come to that conclusion.
User:	Because you said so.
Cleverbot:	I have to do my homework.

GOAL

mimicking the **unstructured conversational** characteristic of **human-human interaction**

Chatbots:

A conversation between a user and Cleverbot, an IR-based chatbot (Carpenter, 2017).

```
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)
```

Rule-based method: A simplified sketch of the ELIZA algorithm. The power of the algorithm comes from the **particular transforms associated with each keyword**.

Given user query q and a conversational corpus C. Find the turn t in C that is most similar to q, and return the following turn.

$$r = response\left(\operatorname*{argmax}_{t \in C} \frac{q^{T}t}{||q||t||} \right)$$

Corpus-based method (Information Retrieval):

Return the response to the most similar turn. (Jafarpour et al. 2009, Leuski and Traum 2011)



Corpus-based method (Seq2Seq):

An encoder decoder model for neural response generation in dialogue.

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

Corpus-based method (Seq2Seq):

Sample responses generated by a Seq2Seq model trained either with a maximum likelihood objective, or adversarially trained to produce sentences that are hard for an adversary to distinguish from human sentences (Li et al., 2017).

- Goal:
 - mimicking the unstructured conversational characteristic of human-human interaction
- Methods:
 - Rule-based
 - Corpus-based (IR, Seq2Seq)
- Evaluation:
 - Chatbots are generally evaluated by humans
 - Adversarial evaluation: train a "Turing-like" evaluator classifier to distinguish between human-generated responses and machine-generated responses.

GUS:	Hello. My name is GUS. I can help you plan a simple trip by air. Where do you want to go 2		
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		

Task-Oriented Dialog System (Travel):

A transcript of an actual dialog with the GUS system of *Bobrow et al*. (1977) P.S.A. and Air California were airlines of that period.

GOAL

get information from the user to help **complete the specific task**.

How to incorporate task related knowledge?

Domain-Specific Knowledge: Ontology / Frame / Slot / Value

How to incorporate task related knowledge?

Domain-Specific Knowledge: Ontology / Frame / Slot / Value

a knowledge structure representing the kinds of intentions the system can extract from user sentences.

How to incorporate task related knowledge?



contains one or more frames.

a knowledge structure representing the kinds of intentions the system can extract from user sentences.

How to incorporate task related knowledge?

Domain-Specific Knowledge: Ontology / Frame / Slot / Value

a collection of slots

Slot1.....

Slot2.....

Slot3.....

Slot4

How to incorporate task related knowledge?

Domain-Specific Knowledge: Ontology / Frame / Slot / Value

Also defines the values that each slot can take.



How to incorporate task related knowledge?

Domain-Specific Knowledge: Ontology / Frame / Slot / Value

Slot1	Slot1Value1 Slot1Value2 	Slot ORIGIN CITY DESTINATION CITY	Type city city
Slot2		DEPARTURE TIME DEPARTURE DATE ARRIVAL DATE	time date time
Slot3		DATE	date
Slot4		MONTH NAME DAY (BOUNDED-INTE) YEAR INTEGER	GER 1

How to incorporate task related knowledge?

"Show me morning flights from Boston to San Francisco on Tuesday"

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Step#1: domain classification

DOMAIN: AIR-TRAVEL

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"Show me morning flights from Boston to San Francisco on Tuesday"

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Step#2: intent determination

INTENT: SHOW-FLIGHTS

How to incorporate task related knowledge?

"Show me morning flights from Boston to San Francisco on Tuesday"

Step#1: domain classification

DOMAIN: AIR-TRAVEL

Step#2: intent determination

Step#3: slot filling

INTENT: SHOW-FLIGHTS

ORIGIN-CITY: Boston ORIGIN-DATE: Tuesday ORIGIN-TIME: morning DEST-CITY: San Francisco

How to incorporate task related knowledge?

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

A sample dialogue from the HIS System of Young et al. (2010) using the **dialog acts**









- Goal:
 - get information from the user to help complete the specific task.
- Domain-Specific Knowledge:
 - Ontology / Frame / Slot / Value
 - Slot Filling and Dialogue State Tracking
- Architecture:
 - ASR / SLU / DST / Dialogue Policy / NLG / TTS
- Evaluation:
 - Task completion success (slot error rate / task error rate)
 - Efficiency cost (#turns)
 - Quality cost (more comprehensive)

Group Discussion!

Information Retrieval Question Answering

Chatbot

Task-Oriented Dialog System

What are their differences?

	Information Retrieval	Question Answering	Chatbot	Task-Oriented Dialog System
Input	structured	unstructured	unstructured	unstructured

	Information Retrieval	Question Answering	Chatbot	Task-Oriented Dialog System	
Input	structured	unstructured	unstructured	unstructured	
Interaction	single-round	single-round	multi-round	multi-round	

	Information Retrieval	Question Answering	Chatbot	Task-Oriented Dialog System	
Input	structured	unstructured	unstructured	unstructured	
Interaction	single-round	single-round	multi-round	multi-round	
supervision	available	available	sparse, delayed	sparse, delayed	

	Information Retrieval	Question Answering	Chatbot	Task-Oriented Dialog System
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Interaction	single-round	single-round	multi-round	multi-round
supervision	available	available	sparse, delayed	sparse, delayed
dataset	synthesis, collected	collected	collected	wizard-of-oz

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Overview

- What's a dialogue system?
- Properties of Human Conversation
- Chatbots v.s. Task-oriented dialogues systems
- Rule-based v.s. Data-driven
- Remaining Challenges



How to build a task-oriented dialog system?

Rule-based system v.s. Data-driven system

How to build a task-oriented dialog system?

SHOW	\rightarrow	show me	e i want ca	n i	see	
DEPART_TIME_RANGE	\rightarrow	(after are	ound before)	HC	DUR	
		morning	afternoon	ev	ening	
HOUR	\rightarrow	onetwo	three four	twe	elve (AM)	PM)
FLIGHTS	\rightarrow	(a) flight	flights			r.
AMPM	\rightarrow	am pm				
ORIGIN	\rightarrow	from CI	ГҮ			
DESTINATION	\rightarrow	to CITY				
CITY	\rightarrow	Boston	San Francis	co	Denver	Washington

Semantic grammars can be parsed by any Context-Free Grammar parsing algorithm.

Rule-based system (SLU/DST)

How to build a task-oriented dialog system?



A simple finite-state automaton architecture for frame-based dialog.

Rule-based system (Dialog Policy)

How to build a task-oriented dialog system?



An LSTM architecture for slot filling, mapping the words in the input to a series of IOB tags plus a final state consisting of a domain concatenated with an intent.

Data-driven system (SLU/DST)

How to build a task-oriented dialog system?



Data-driven system (Dialog Policy)

How to build a task-oriented dialog system?



Data-driven system (Dialog Policy)

How to build a task-oriented dialog system?

Rule-based v.s. Data-driven Pros & cons?

How to build a task-oriented dialog system?

Rule-based v.s. Data-driven Pros & cons?

Rule-Based Methods

- hand-craft rules, "safe" but not "flexible".
- cheap in terms of dataset.
- expensive in terms of engineering.

Data-Driven Methods

- learn from interactions, dialogue manager is evolvable.
- uncontrolled behavior in unseen situation.
- cheap in terms of engineering, but expensive in terms of data/interaction

Overview

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Understanding the Context



Two sets of interactions with Siri in 2014.

* 86% 🗔

second one'

tap to edit



Understanding the Context







100%

Sec. A

The same follow-up questions that Siri couldn't answer in 2014 receive appropriate responses when posed to Siri in 2017.

Challenges

• • •

Understanding the Context

Uncertainty / Ambiguity

Reward Design

Knowledge Embedding

Domain Adaptation

Data/Interaction Scarcity

Next Tuesday

Jason Weston's guest lecture:



Putting together the threads of conversational AI

Maybe we don't have enough threads yet to knit together the whole, but let's try anyway! We present our view of what is necessary for conversational AI, and the pieces we have worked on so far to get there. In particular: software (ParlAI, a unified platform for dialogue research), various neural architectures for memory, reasoning, retrieval and generation, and interactive learning, tasks for employing personality (Persona-Chat), knowledge (Wizard of Wikipedia) and perception (Image-Chat), evaluation studies & techniques (Acute-Eval), and a recent competition (ConvAI2). We'll try not to be too pessimistic (!), but we'll also discuss how far we still have to go.