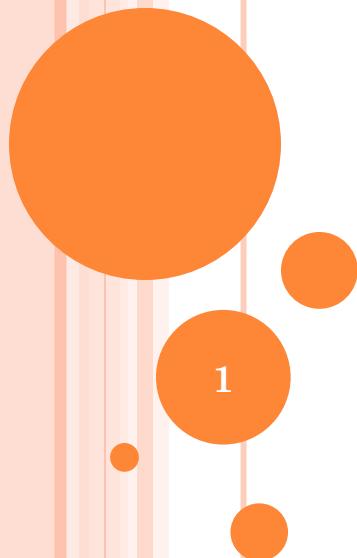




CSE 4392 SPECIAL TOPICS
NATURAL LANGUAGE PROCESSING

Dialogue Systems



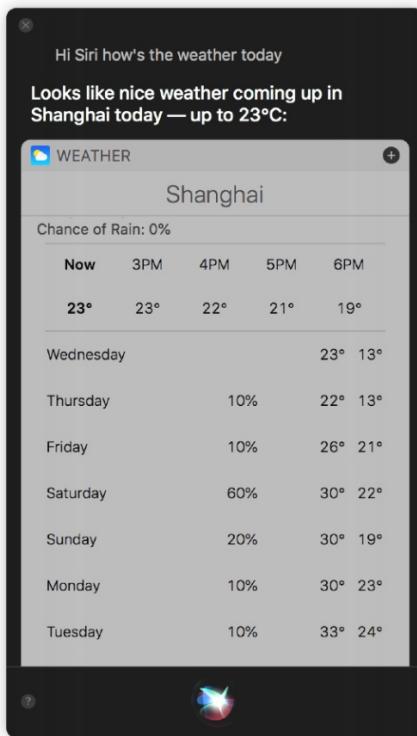
2024 Spring

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

WHAT'S A DIALOGUE SYSTEM?

- Dialogue system is everywhere. Did you use it?



WHAT IS DIALOGUE SYSTEM?

- Dialogue is the preferred mode of interaction:



Desktop



keyboard & mouse



**Smart Mobile
Embedded Devices**

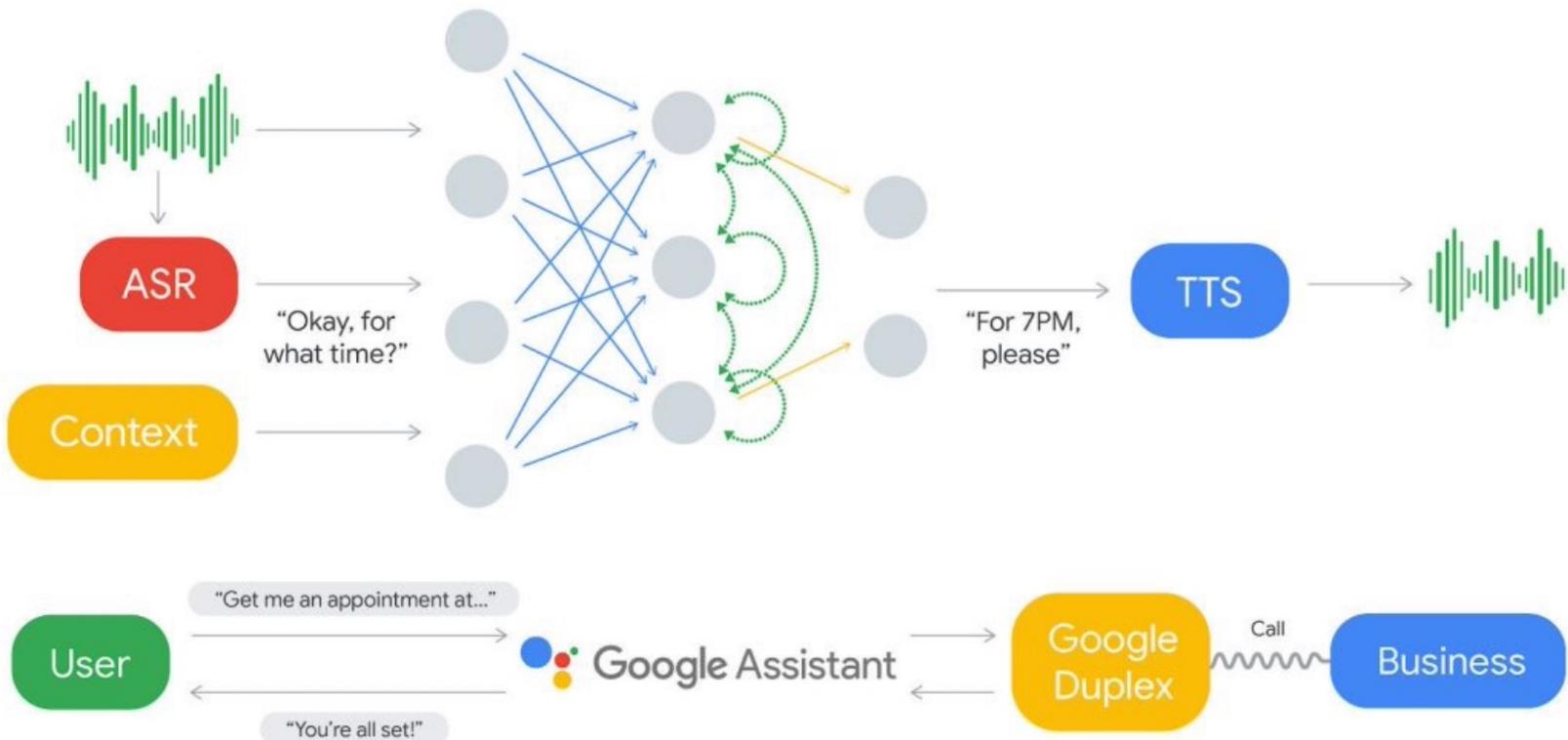
“turn off the light.”



language

WHAT IS DIALOGUE SYSTEM?

- Google Duplex: can you distinguish between human and AI?



DIALOGUE SYSTEM IS A KILLER APP FOR NLP

They can



- give travel directions
- control home appliances
- find restaurants
- help make phone calls
- customer services
- ...



PROPERTIES OF HUMAN CONVERSATION

- C₁: ...I need to travel in May.
- A₁: And, what day in May did you want to travel?
- C₂: 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.
- C₅: 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.
- C₆: 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.
- C₇: OK.
- A₇: And you said returning on May 15th?
- C₈: 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.
- C₁₀: Uh hmm. I would consider staying there an extra day til Sunday.
- A₁₀: OK...OK. On Sunday I have ...

Turn structure:
C-A-C-A-....

Spoken DS:
end-point detection
Know when to
take the turn

PROPERTIES OF HUMAN CONVERSATION

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overlaps

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Asking
Answering

PROPERTIES OF HUMAN CONVERSATION

Constatives:	committing the speaker to something's being the case (<i>answering, claiming, confirming, denying, disagreeing, stating</i>)
Directives:	attempts by the speaker to get the addressee to do something (<i>advising, asking, forbidding, inviting, ordering, requesting</i>)
Commissives:	committing the speaker to some future course of action (<i>promising, planning, vowing, betting, opposing</i>)
Acknowledgments:	express the speaker's attitude regarding the hearer with respect to some social action (<i>apologizing, greeting, thanking, accepting an acknowledgment</i>)

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

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grounding:
acknowledge
that the
listener has
understood
the speaker

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local structure
between
dialog acts

correction
subdialogue 12

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mixed initiative:
conversation is not
controlled by
one participant

user-initiative
v.s.
system-initiative

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conversational
implicature

PROPERTIES OF HUMAN CONVERSATION

- 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**.

CHATBOTS VS. TASK-ORIENTED DIALOGUE SYSTEMS

Chatbot

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.

Task-oriented Dialogue System

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

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

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

CHATBOTS: RULE-BASED

```
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 \leftarrow Apply the transform in *r* to *sentence*

if *w* = ‘my’

future \leftarrow Apply a transformation from the ‘memory’ rule list to *sentence*

 Push *future* onto memory stack

else (no keyword applies)

either

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

or

response \leftarrow Pop the top response from the memory stack

return(*response*)

- A simplified sketch of the ELIZA algorithm. The power of the algorithm comes from the **particular transformations associated with each keyword**.

CHATBOTS: CORPUS-BASED

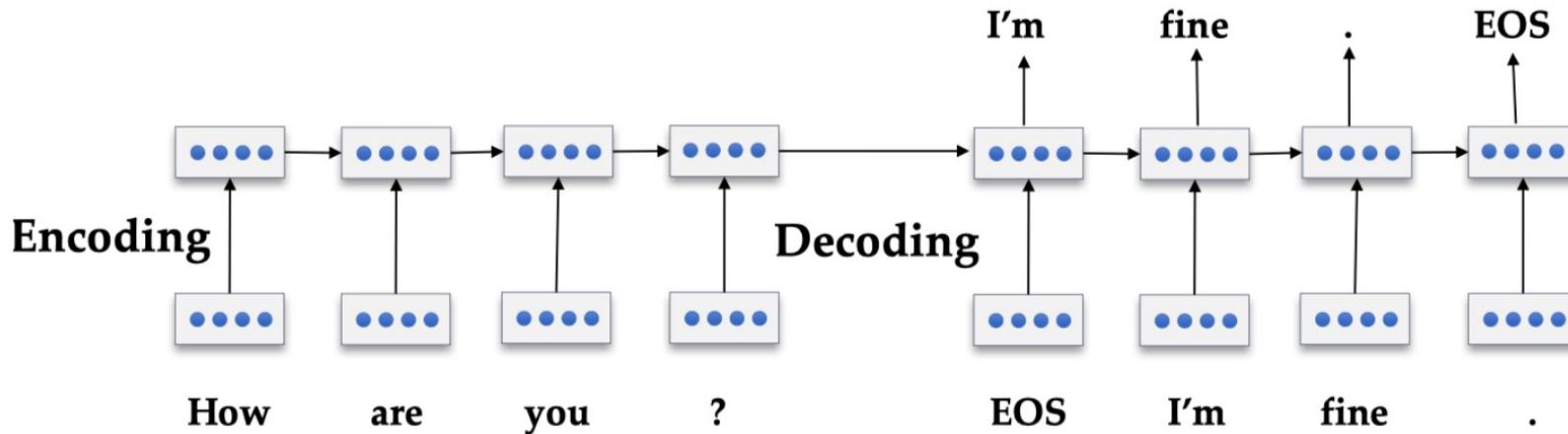
Given user query q and a conversational corpus C .

Find the turn t in C that is most similar to q , and
return the following turn.

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

- **Corpus-based method (Information Retrieval):** Return the response to the most similar turn. (Jafarpour et al. 2009, Leuski and Traum 2011)

CHATBOTS: CORPUS-BASED



- **Corpus-based method (Seq2Seq):** An encoder-decoder model for neural response generation in dialogue. RNN in the above diagram can be replaced with transformer.

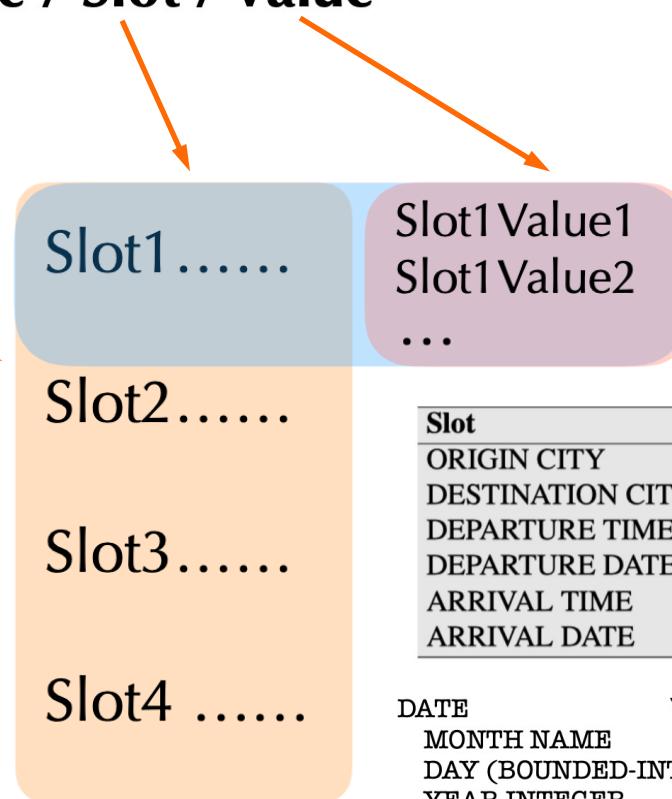
TASK-ORIENTED DIALOGUE SYSTEM

- 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.

contains one or more frames. A frame is a set of slot-value pairs to establish an intent.



DATE
MONTH NAME
DAY (BOUNDED-INTEGER 1 31)
YEAR INTEGER

TASK-ORIENTED DIALOGUE SYSTEM

- 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

INTENT: SHOW-FLIGHTS

Step#3: slot filling

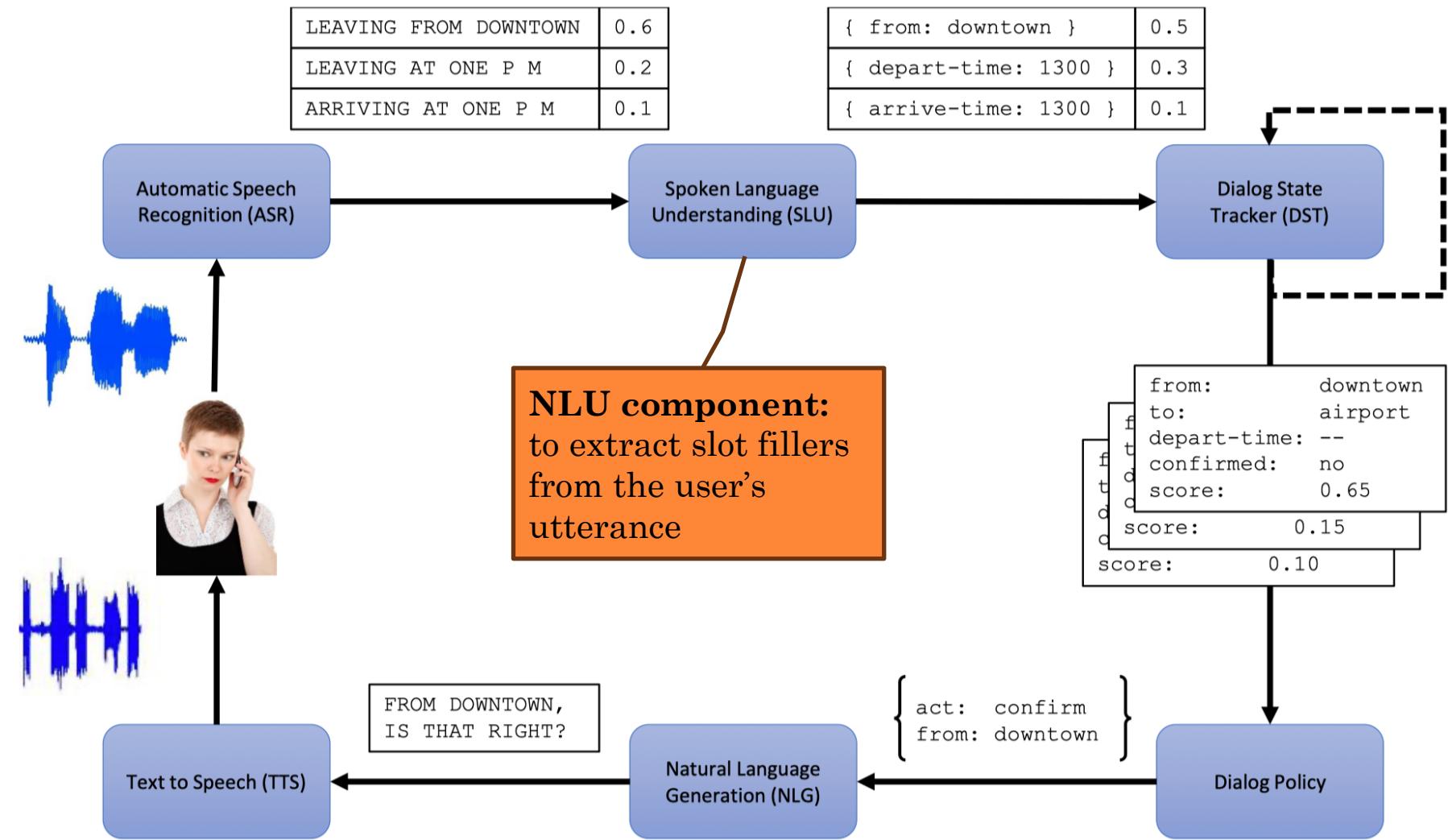
ORIGIN-CITY: Boston
ORIGIN-DATE: Tuesday
ORIGIN-TIME: morning
DEST-CITY: San Francisco

TASK-ORIENTED DIALOGUE SYSTEM

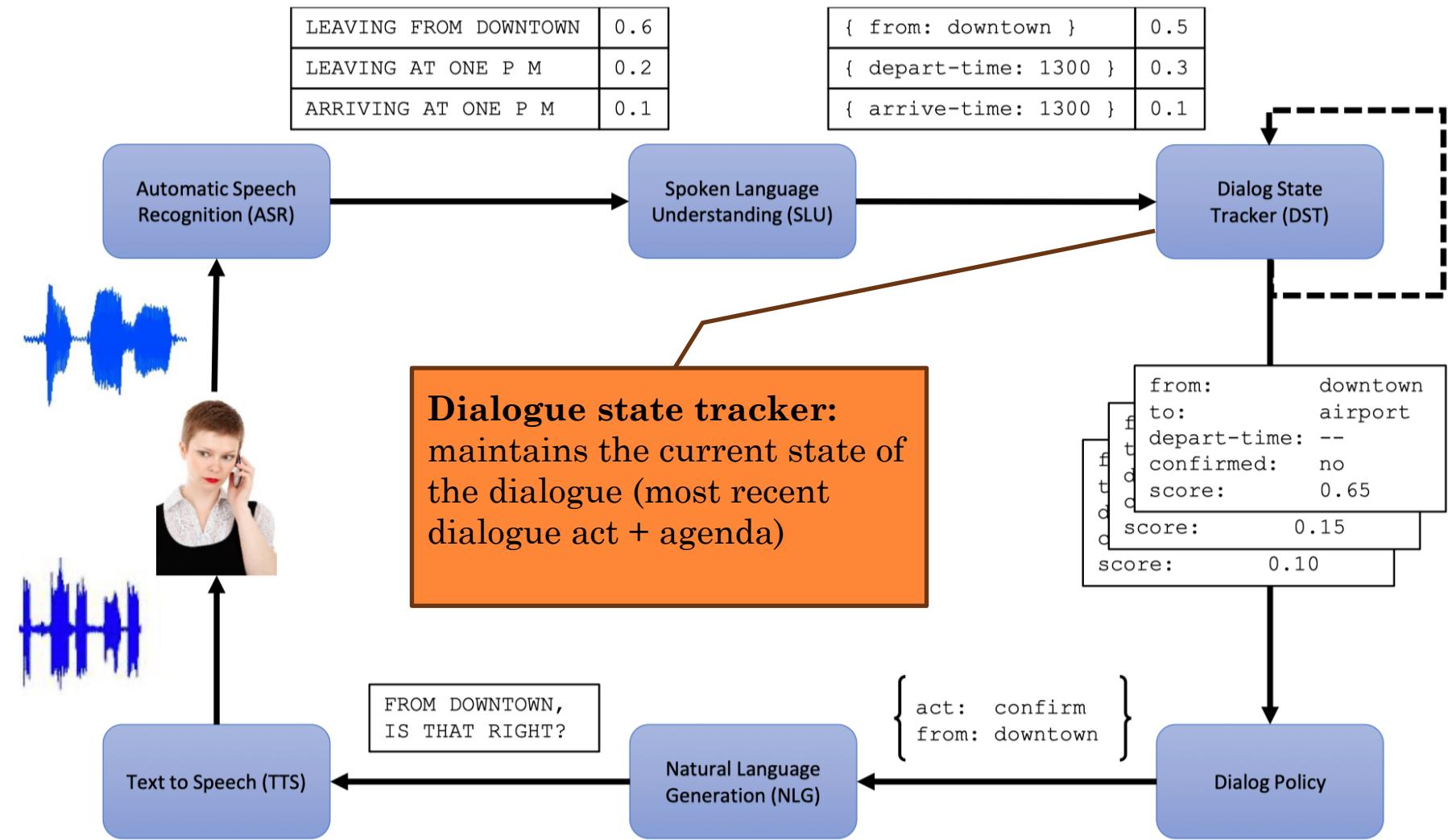
- How to incorporate task related knowledge?

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

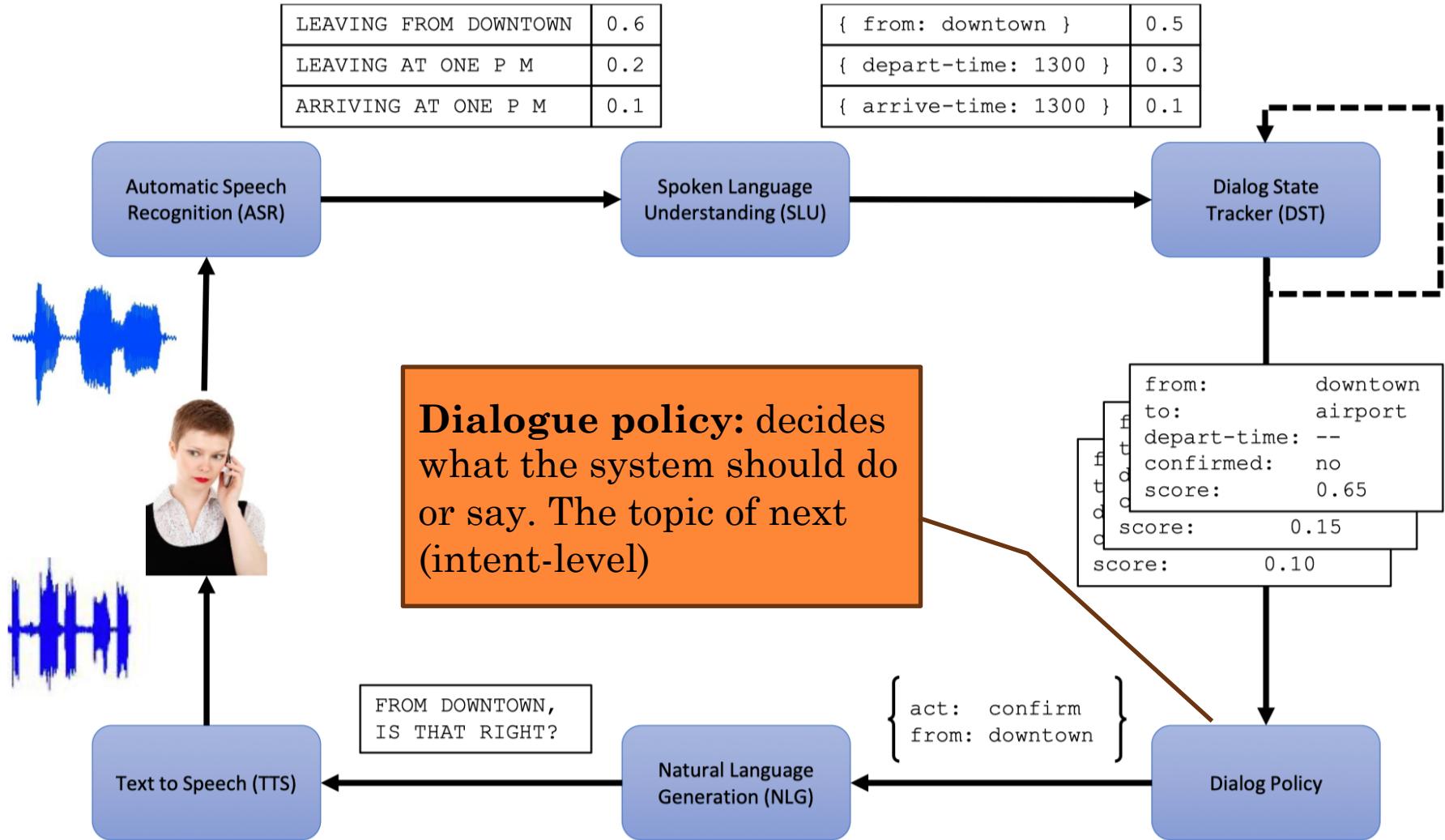
ARCHITECTURE OF TASK-ORIENTED DS



ARCHITECTURE OF TASK-ORIENTED DS



ARCHITECTURE OF TASK-ORIENTED DS



RULE-BASED VS. DATA-DRIVEN

- How to build a task-oriented dialog system?

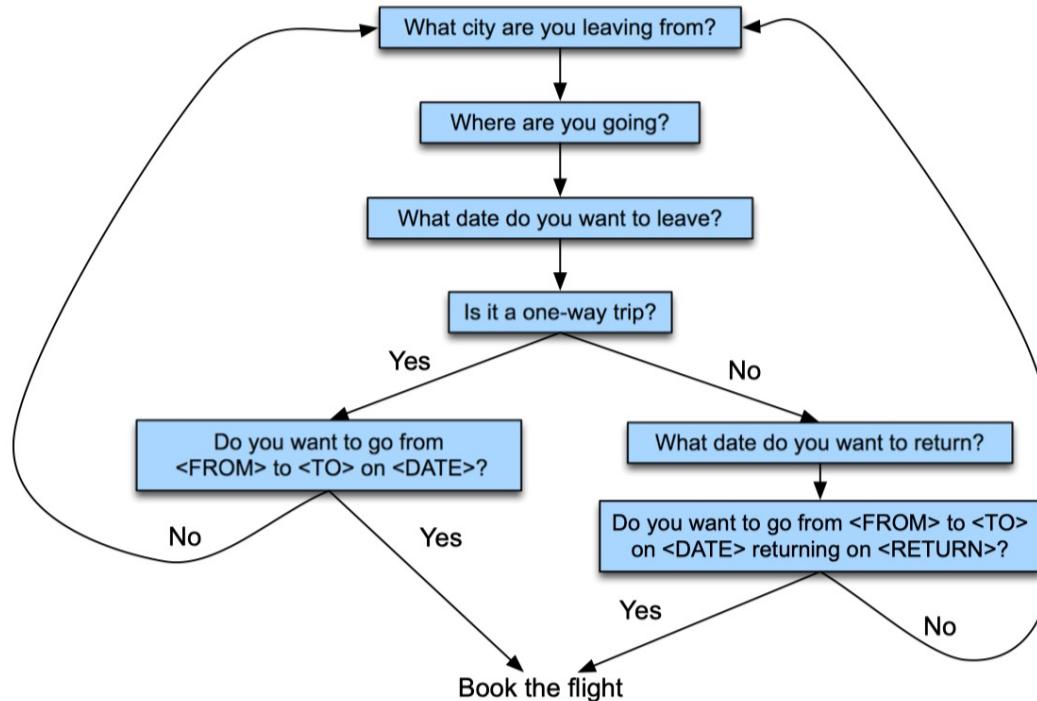
SHOW	→ show me i want can i see ...
DEPART_TIME_RANGE	→ (after around before) HOUR morning afternoon evening
HOUR	→ one two three four... twelve (AMPM)
FLIGHTS	→ (a) flight flights
AMPM	→ am pm
ORIGIN	→ from CITY
DESTINATION	→ to CITY
CITY	→ Boston San Francisco Denver Washington

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

Rule-based system (SLU/DST)

RULE-BASED VS. DATA-DRIVEN

- How to build a task-oriented dialog system?

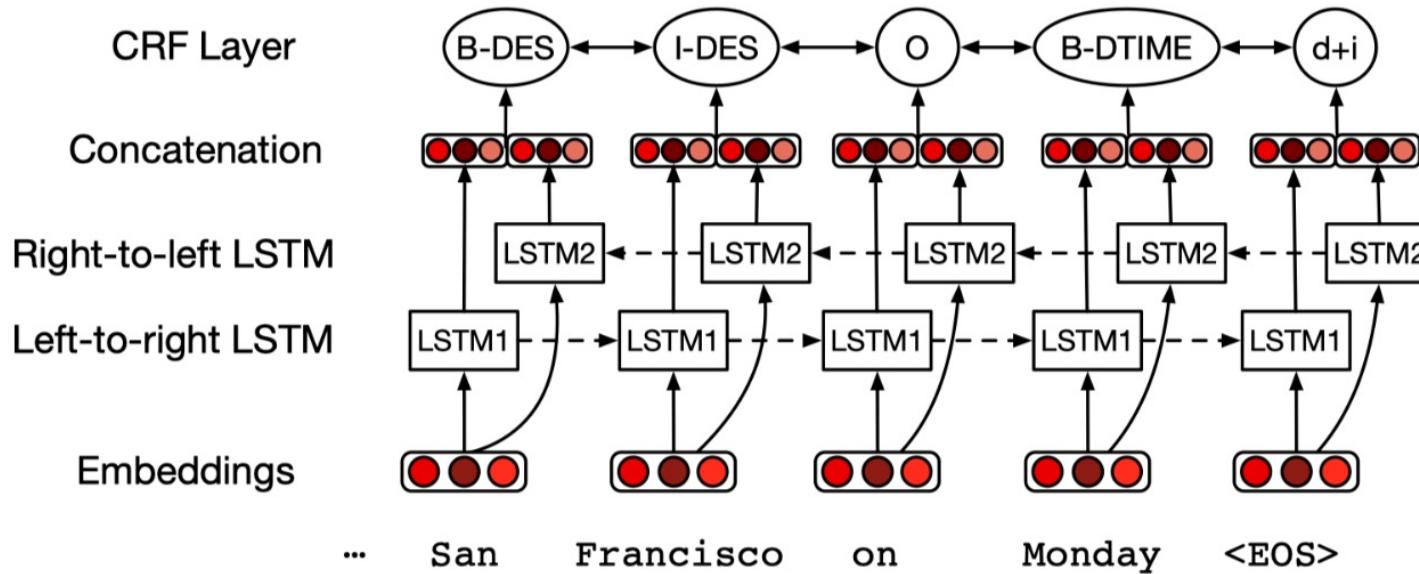


A simple finite-state automaton architecture for frame-based dialog.

Rule-based system (Dialogue policy)

RULE-BASED VS. DATA-DRIVEN

- How to build a task-oriented dialog system?



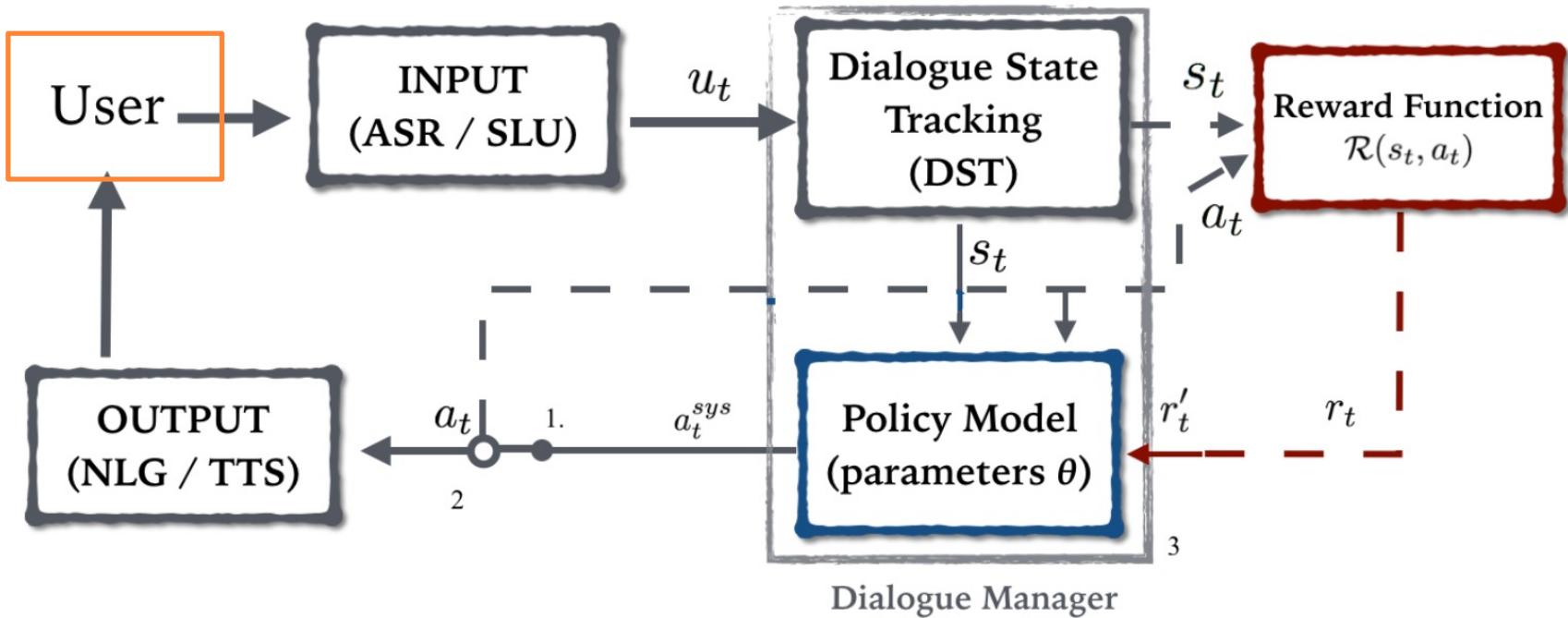
An LSTM architecture for slot filling, mapping the words in the input to a series of IOB tags plus a final state consisting of a domain concatenated with an intent.

Data-driven system (SLU/DST)

RULE-BASED VS. DATA-DRIVEN

- How to build a task-oriented dialog system?

Simulator?



Rule-based system (Dialogue policy)

RULE-BASED VS. DATA-DRIVEN

- Pros and 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

REMAINING CHALLENGES

- Understanding the context (better with LLMs)
- Domain adaptation
- Data scarcity (chat data is very hard to obtain)
- Privacy protection
- Accuracy/Reliability (LLM's hallucination problem)
- Biases and toxicity