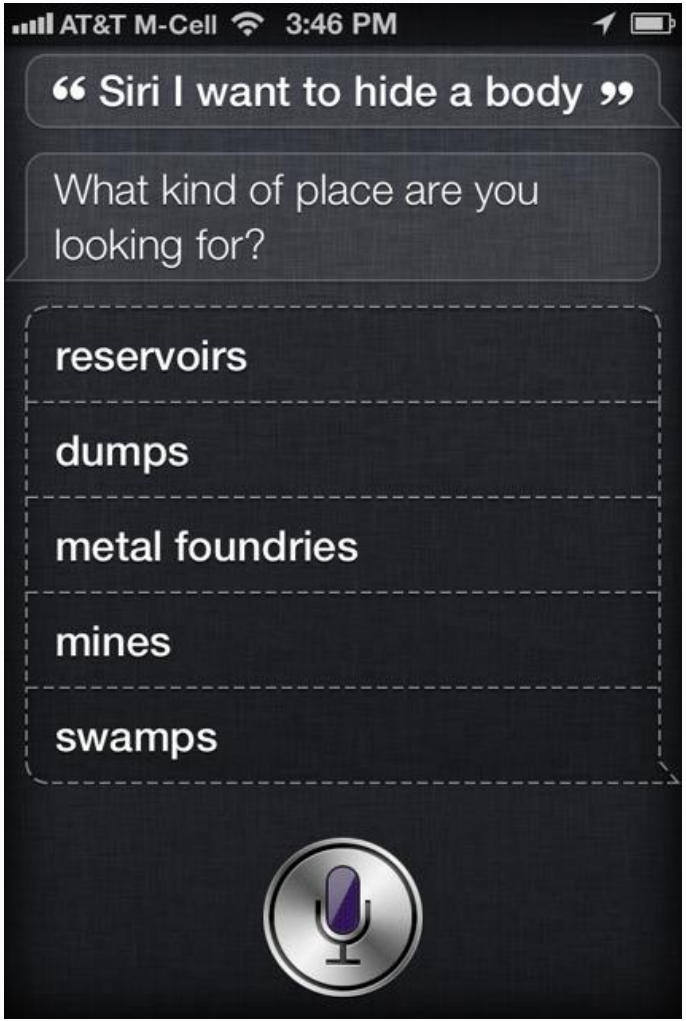

Image credit: PCWorld

CS 2731
Introduction to Natural Language Processing

Session 25: Dialogue systems, chatbots

Michael Miller Yoder

November 19, 2025

School of Computing and Information

Course logistics

- Homework 4 is due tomorrow, Thu Nov 20
  - More Hugging Face, this time BERT-based models for part-of-speech tagging
- Project presentation is in class Dec 8
  - Ungraded
  - Add slides to this shared presentation
- Project report is due Dec 9
  - See updated instructions and rubric on the website

CS Colloquium talk on safety in LLMs

- **This Fri Nov 21, 12-2pm at SENSQ 5317**
  - Lunch at 12, talk begins 12:30
- Title: Behind-the-Scenes of AI Safety in Language Models
- Yue Dong, University of California, Riverside
- More info: https://calendar.pitt.edu/event/behind-the-scenes-of-ai-safety-in-language-models

Learning objectives for this session

Students will be able to:

- List properties of human conversation
- Explain how the notion of “frames” and “slot-filling” plays a part in task-based dialogue systems
- Identify operations in dialogue-state architectures
    - Including natural language understanding, dialogue state tracking, dialogue policies
- Give examples of dialogue acts
- Evaluate specific aspects of task-based dialogue systems
- Identify common ethical considerations with dialogue systems

Properties of human conversation

C_1: . . . I need to travel in May.
A_2: And, what day in May did you want to travel?
C_3: OK uh I need to be there for a meeting that's from the 12th to the 15th.
A_4: And you're flying into what city?
C_5: Seattle.
A_6: And what time would you like to leave Pittsburgh?
C_7: Uh hmm I don't think there's many options for non-stop.
A_8: Right. There's three non-stops today.
C_9: What are they?
A_{10}: 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_{11}: OK I'll take the 5ish flight on the night before on the 11th.
A_{12}: On the 11th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115.
C_{13}: OK.
A_{14}: And you said returning on May 15th?
C_{15}: Uh, yeah, at the end of the day.
A_{16}: OK. There's #two non-stops . . . #
C_{17}: #Act. . . actually #, what day of the week is the 15th?
A_{18}: It's a Friday.
C_{19}: Uh hmm. I would consider staying there an extra day til Sunday.
A_{20}: OK. . . OK. On Sunday I have . . .

Figure 15.1 Part of a phone conversation between a human travel agent (A) and human client (C). The passages framed by # in A_{16} and C_{17} indicate overlaps in speech.

Figure from Jurafsky & Martin

C_1: . . . I need to travel in May.
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Figure 15.1 Part of a phone conversation between a human travel agent (A) and human client (C). The passages framed by # in A_{16} and C_{17} indicate overlaps in speech.

Turn-taking

- A turn is a single contribution from one speaker
- Turn-taking is complex
- When to take/yield the floor?
- People can detect when their conversation partner is about to stop talking
- People interrupt each other, resulting in overlapping speech

Slide adapted from David Mortensen, Jurafsky & Martin

C_1:	. . . I need to travel in May.
A_2:	And, what day in May did you want to travel?
C_3:	OK uh I need to be there for a meeting that's from the 12th to the 15th.
A_4:	And you're flying into what city?
C_5:	Seattle.
A_6:	And what time would you like to leave Pittsburgh?
C_7:	Uh hmm I don't think there's many options for non-stop.
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Figure 15.1 Part of a phone conversation between a human travel agent (A) and human client (C). The passages framed by # in A_{16} and C_{17} indicate overlaps in speech.

There are *vocal pauses* such as "uh".

Slide adapted from David Mortensen, Jurafsky & Martin

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Figure 15.1 Part of a phone conversation between a human travel agent (A) and human client (C). The passages framed by # in A_{16} and C_{17} indicate overlaps in speech.

There are *discourse markers* like "OK" and "Right".

Slide adapted from David Mortensen, Jurafsky & Martin

Grounding = acknowledgment

- Conversation participants need *common ground*: set of things mutually believed by both speaker and hearer
- Principle of closure: Agents performing an action require evidence, sufficient for current purposes, that they have succeeded in performing it (Clark 1996, Norman 1988)
- Speech is an action too! So speakers need to ground each other's utterances.
- Grounding: acknowledging that the hearer has understood

Slide adapted from Jurafsky & Martin

Grounding

Why do elevator buttons light up?

And what happens when pedestrian crosswalk buttons don’t?

Image: ABC News

Slide adapted from David Mortensen

Grounding with Discourse Markers

A: And you said returning on May 15th?
C: Uh, yeah, at the end of the day.
A: OK

C: OK I'll take the 5ish flight on the night before on the 11th.
A: On the 11th? OK.

C: ...I need to travel in May.
A: And, what day in May did you want to travel?

Slide credit: David Mortensen, Jurafsky & Martin

Grounding is important for computers too!

System: Did you want to review more of your profile?

User: No.

System: What's next? AWKWARD

System: Did you want to review more of your profile?

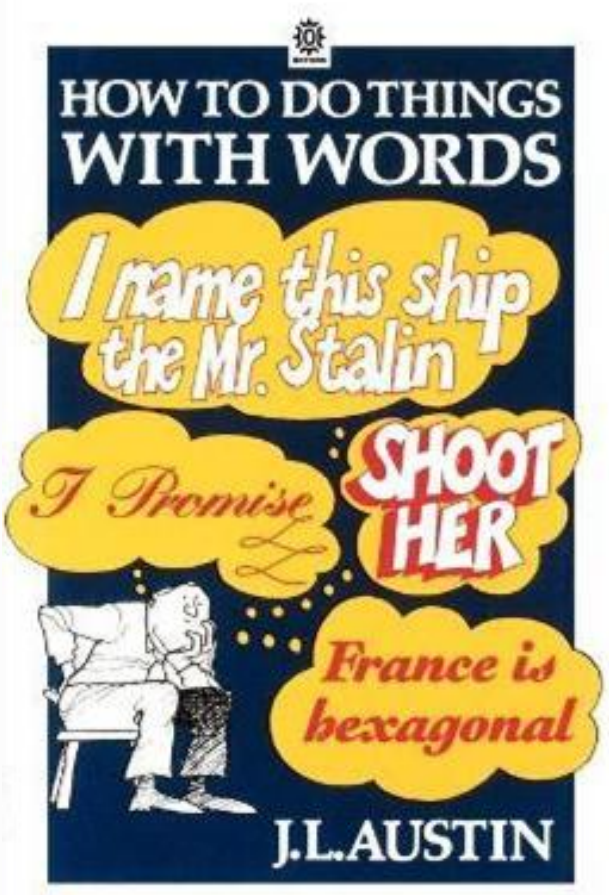
User: No.

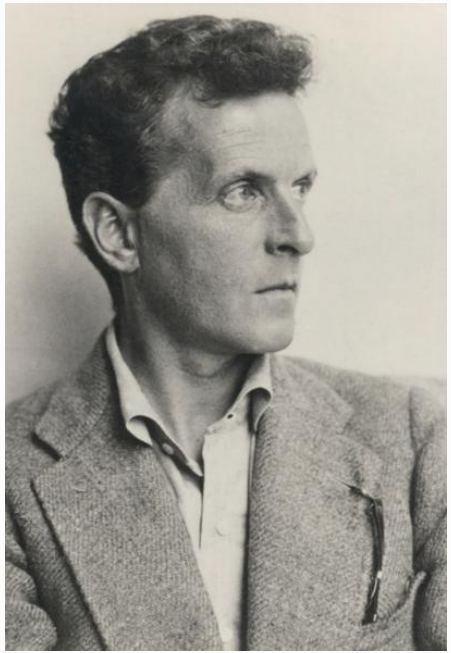
System: Okay, what's next? LESS AWKWARD!

Slide credit: Jurafsky & Martin

Speech acts: sentences that do things

Utterances as actions





Ludwig Wittgenstein

Each turn in a dialogue is a kind of action [Wittgenstein 1953, Austin 1962]

Slide adapted from David Mortensen, Jurafsky & Martin

Speech Acts: sentences that do things

Some sentences inform: *Today is Thursday*

Here are some *performative* sentences that change the state of the world:

- *I hereby name this ship the QE2.*
  The ship now has a name.
- *I hereby bequeath this cell phone to my son.*
  My son will now inherit the cell phone.
- *I hereby take this person to be my spouse.*
  I am now married.
- *I hereby declare war.*
  There is war.
- *I hereby excommunicate you.*
  You are excommunicated.

Slide credit: David Mortensen

Intent vs form

The following three sentences all have the same intent (to get the agent to book a flight to Seattle), but they take the form of a question, a command, and a statement.

- Can you book me a flight to Seattle?
- Book me a flight to Seattle.
- I'd like a flight to Seattle.

To respond appropriately, an automated conversational agent has to understand the user's intent. Task-oriented dialogue systems include classifiers for identifying the user's intent.

Slide credit: David Mortensen

Conversations have structure

Local structure between adjacent speech acts, from the field of conversation analysis [Sacks et al. 1974]

Called adjacency pairs:

- Question > Answer
- Proposal > Acceptance/Rejection
- Compliments ("Nice jacket!") > Downplayer ("Oh, this old thing?")

Slide adapted from Jurafsky & Martin

Subdialogues

Correction subdialogue

Agent: OK. There's #two non-stops#

Client: #Act- actually#, what day of the week is the 15th?

Agent: It’s a Friday.

Client: Uh hmm. I would consider staying there an extra day til Sunday.

Agent: OK...OK. On Sunday I have ...

Slide adapted from Jurafsky & Martin

Conversational implicature

- Implied information

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

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

Slide adapted from Jurafsky & Martin

Task-based dialogue systems

Task-based dialogue agents

"Task-based" or "goal-based" dialogue agents

- Systems that have the goal of helping a user solve a task
  - Setting a timer
  - Making a travel reservation
  - Playing a song
  - Buying a product

Slide adapted from Jurafsky & Martin

Frame-based dialogue systems

Frame-based dialogue systems: two basic architectures

The **GUS** architecture [Bobrow et al. 1977]

- Sometimes just called "**frame-based**" architecture
- Over 40 years old, but still used in some industrial task-based dialogue agents

The **dialogue-state** architecture

- Extension of GUS
- Keeps track of a “dialogue state” of the currently known information and last utterances

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

Figure 15.9 The travel domain: A transcript of an actual dialogue with the GUS system of Bobrow et al. (1977). P.S.A. and Air California were airlines of that period.

Figure credit: Jurafsky & Martin

Frames

A set of **slots**, to be filled with information of a given **type**

Each associated with a **question** to the user

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?

Slide adapted from Jurafsky & Martin

Filling a Frame

Show me morning flights from Boston to SF on Tuesday

DOMAIN:	air-travel
INTENT:	show-flights
ORIGIN-CITY:	Boston
ORIGIN-DATE:	Tuesday
ORIGIN-TIME:	morning
DEST-CITY:	San Francisco

Wake me up tomorrow at six

DOMAIN:	alarm
INTENT:	set-alarm
TIME:	2022 12 1 0600

Slide credit: David Mortensen, Jurafsky & Martin

Dialogue-state architecture

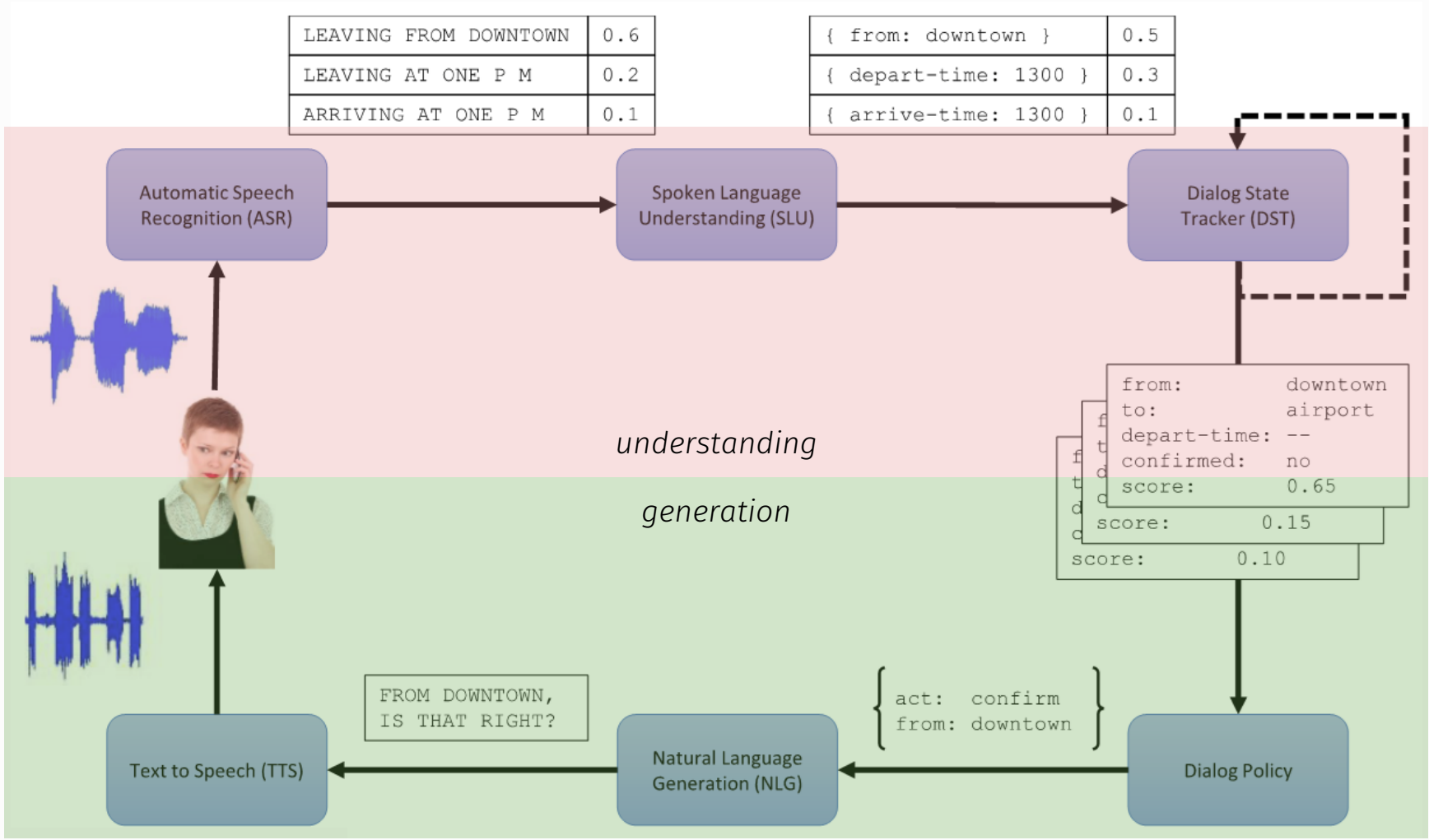


Figure from Williams et al. 2016

Components in a dialogue-state architecture

NLU: extracts slot fillers from the user's utterance using machine learning

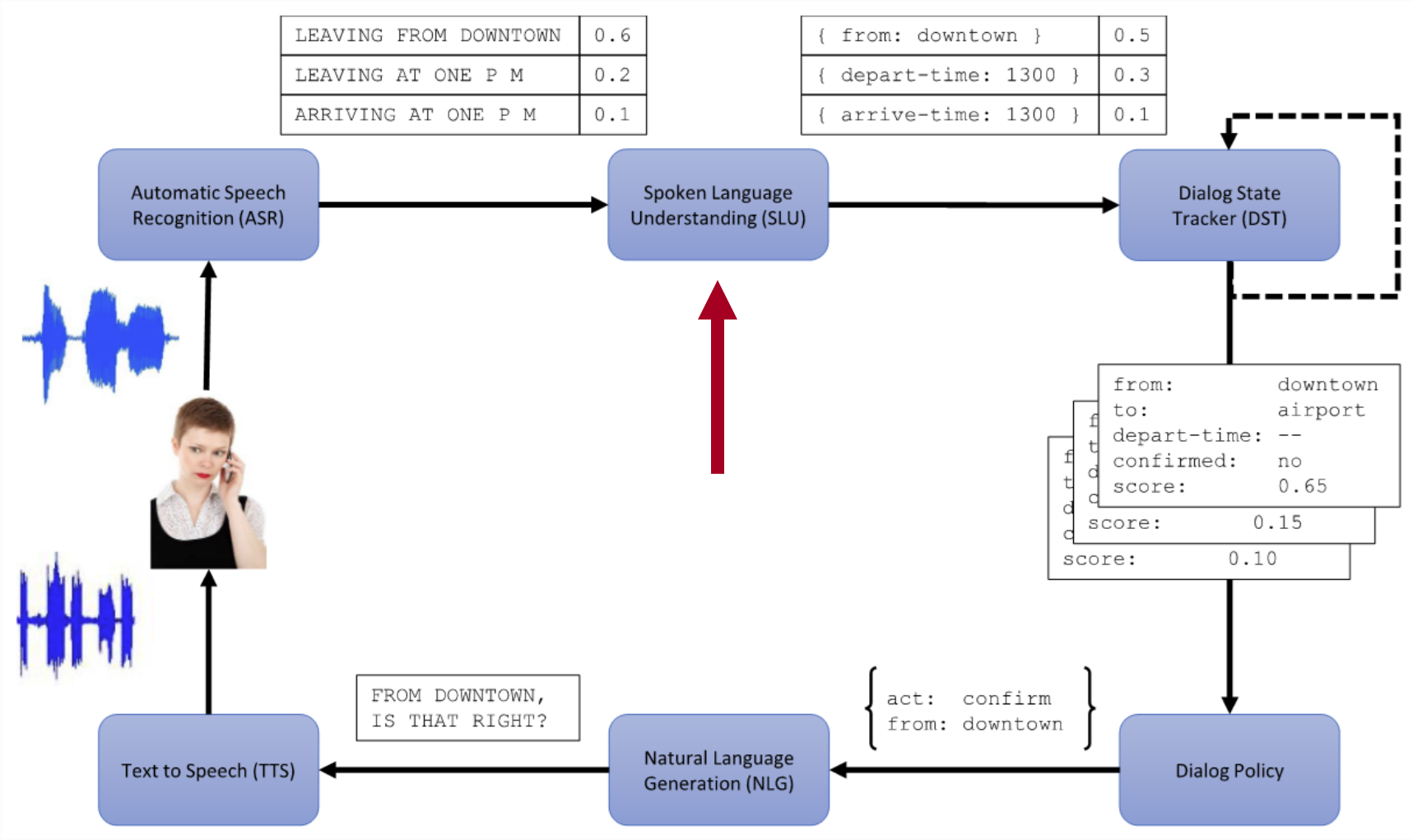
Dialogue state tracker: maintains the current state of the dialogue (user's most recent dialogue act, set of slot-filler constraints from user)

Dialogue policy: decides what the system should do or say next

- GUS policy: ask questions until the frame was full then report back
- More sophisticated: know when to answer questions, when to ask a clarification question, etc.

NLG: produce more natural, less templated utterances than GUS

Slide adapted from Jurafsky & Martin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Dialog Policy

Dialogue Acts

Combine the ideas of **speech acts** and **grounding** into a single representation

	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?	`confreq(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()`

Slide adapted from Jurafsky & Martin. Figure credit: Young et al. 2010

NLU: slot filling with machine learning

Machine learning classifiers to map words to semantic frame-fillers:

Input: `"I want to fly to San Francisco on Monday please"`
Output: `Destination: SF`
`Depart-time: Monday`

Requirements: Lots of labeled data

Slide adapted from Jurafsky & Martin

Slot filling as sequence labeling: BIO tagging

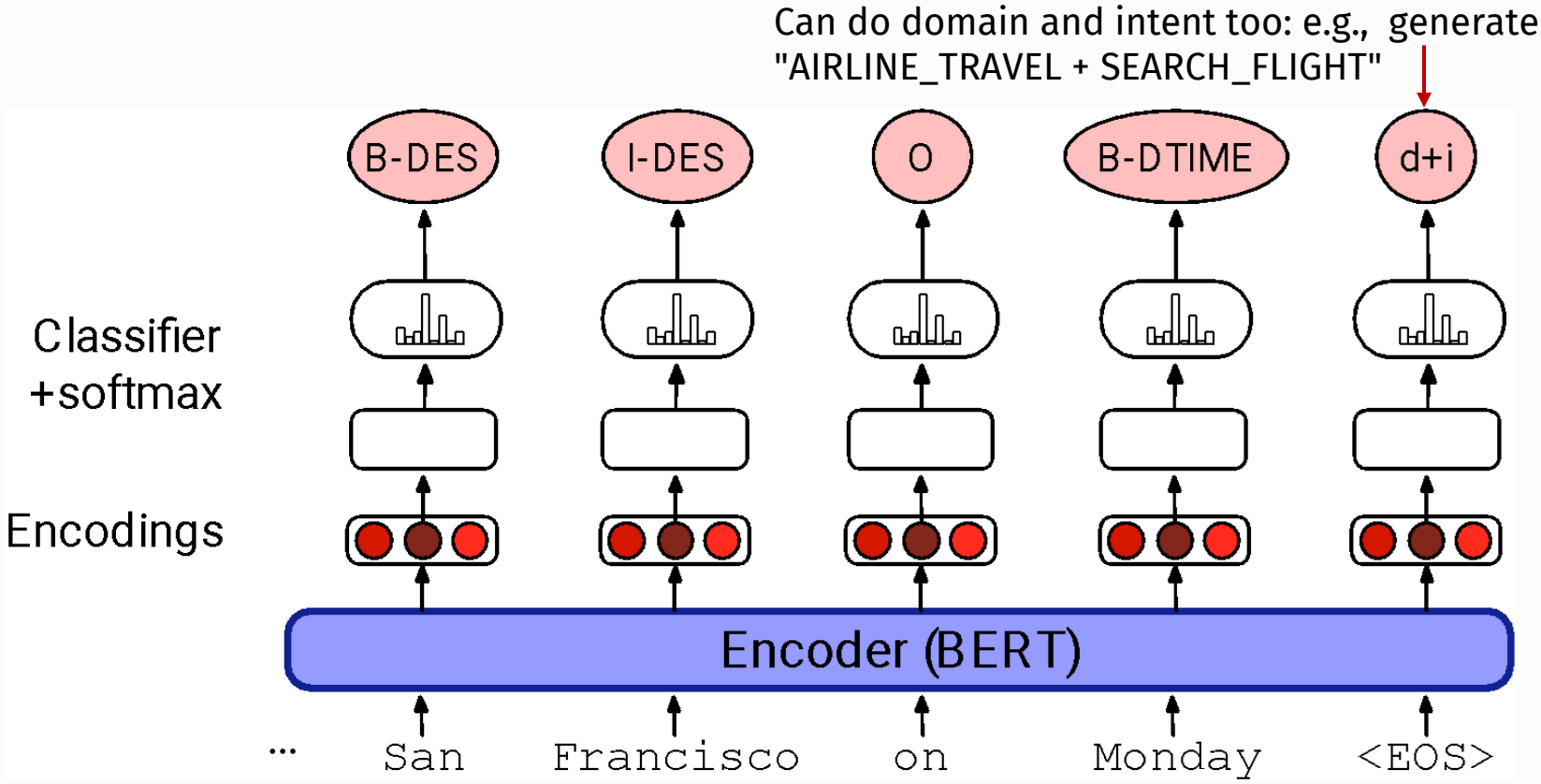
Train a classifier to label each input word with a tag that tells us what slot (if any) it fills

O	O	O	O	O	B-DES	I-DES	O	B-DEPTIME	I-DEPTIME	O	
I	want	to	fly	to	San	Francisco	on	Monday	afternoon	please	

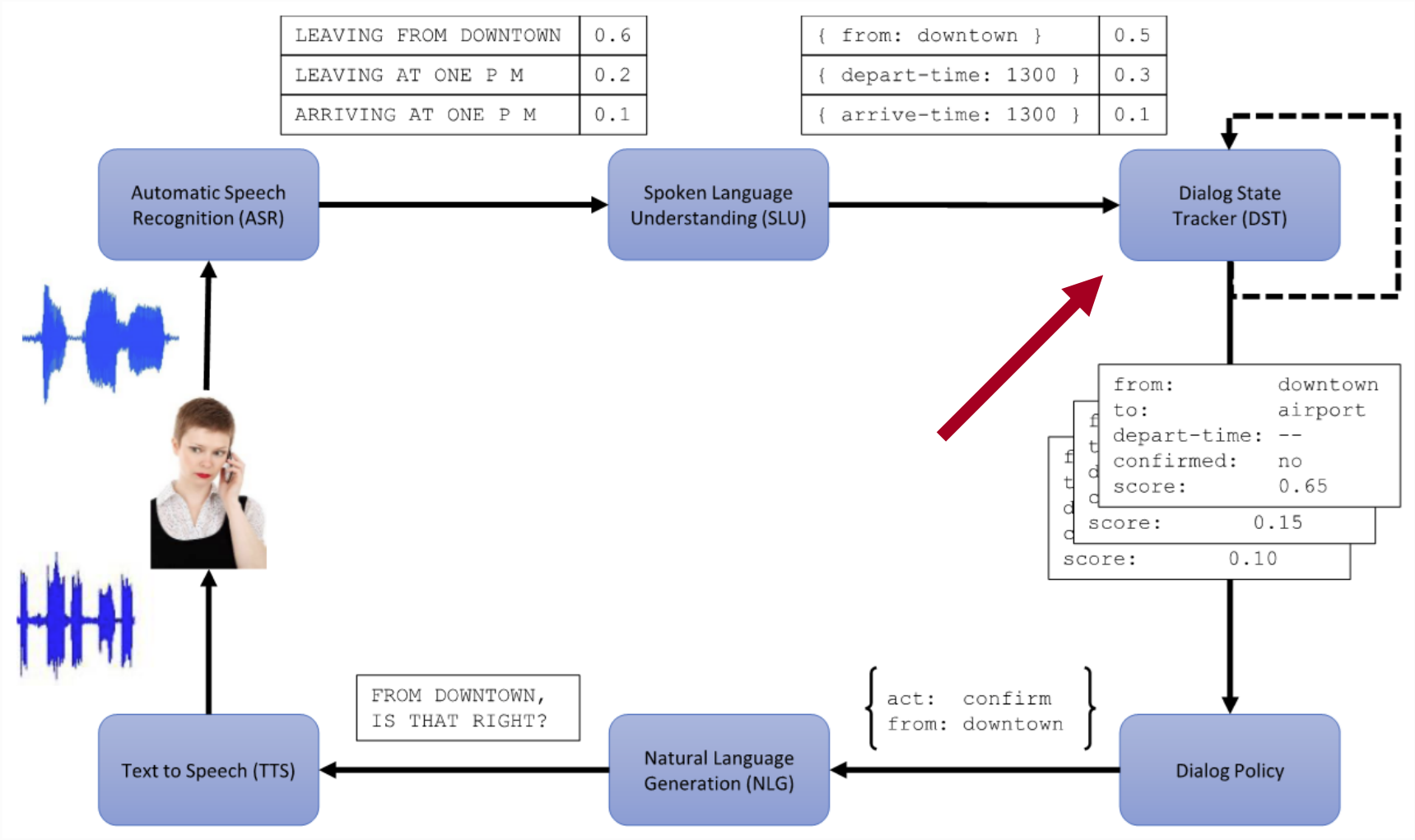
Convert the training data to this format

Slide adapted from Jurafsky & Martin

Slot filling using contextual embeddings



Slide adapted from Jurafsky & Martin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The task of dialogue state tracking

Dialogue state:

1. Current state of the frame (slots)
2. User's most recent dialogue act
    a. Classify based on encodings of current sentence + prior dialogue acts

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

Slide adapted from Jurafsky & Martin. Example from Mrkšić et al. 2017

A special case of dialogue act detection: correction acts

- If system misrecognizes an utterance
- User might make a correction
  - Repeat themselves
  - Rephrasing
  - Saying “no” to a confirmation question

Slide adapted from Jurafsky & Martin

Corrections are harder to recognize!

- From speech, corrections are misrecognized twice as often (in terms of word error rate) as non-corrections! [Swerts et al. 2000]
- Hyperarticulation (exaggerated prosody) is a large factor [Shriberg et al. 1992]

  "I said BAL-TI-MORE, not Boston"

- Features for detecting corrections:
  - Lexical: “no”, “correction”, “I don’t”, swear words, utterance length
  - Repeating things: high similarity between candidate correction act and user’s prior utterance (word overlap or embedding dot product)
  - Hyperarticulation, ASR confidence, language model probability

Slide adapted from Jurafsky & Martin

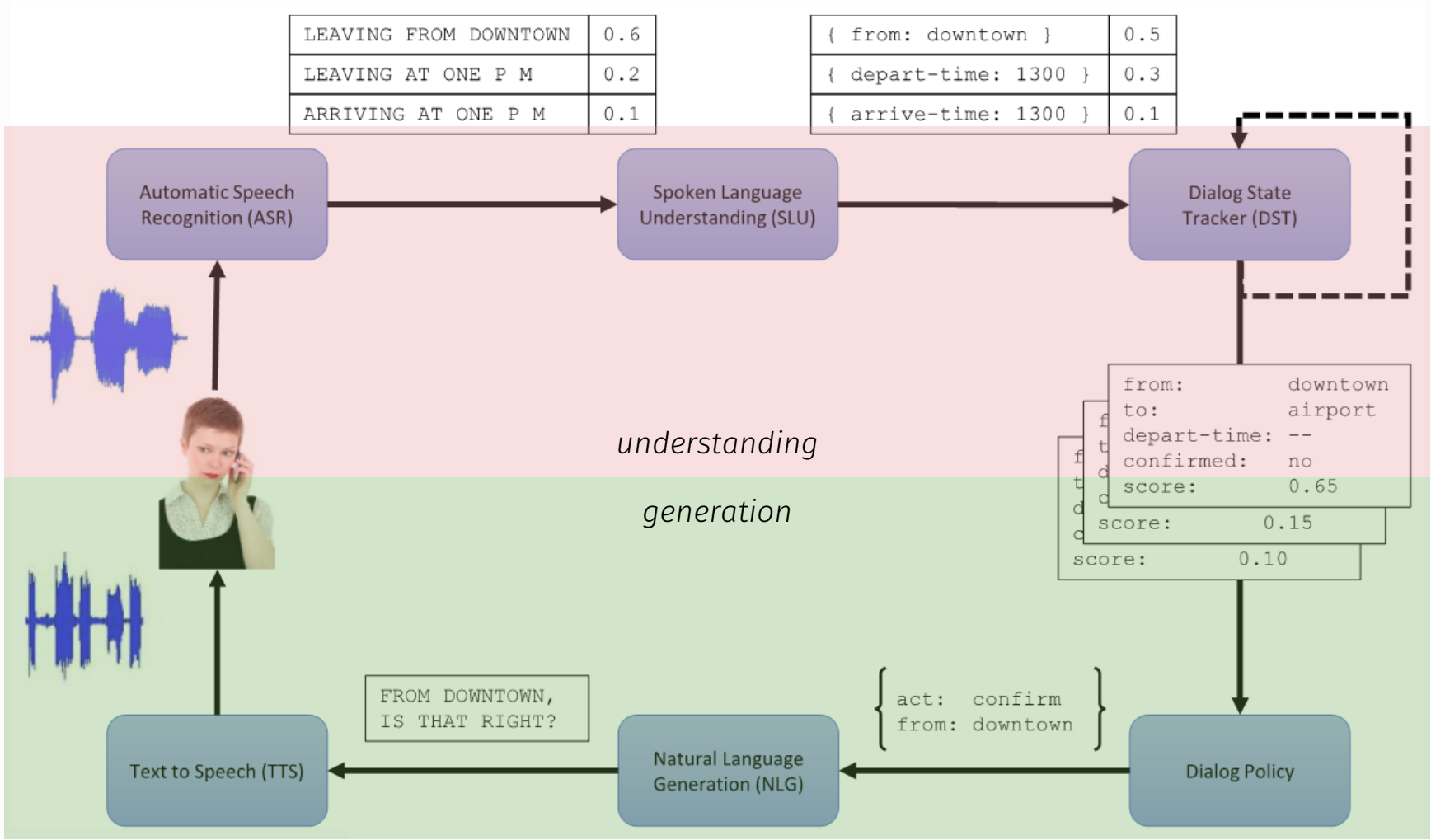
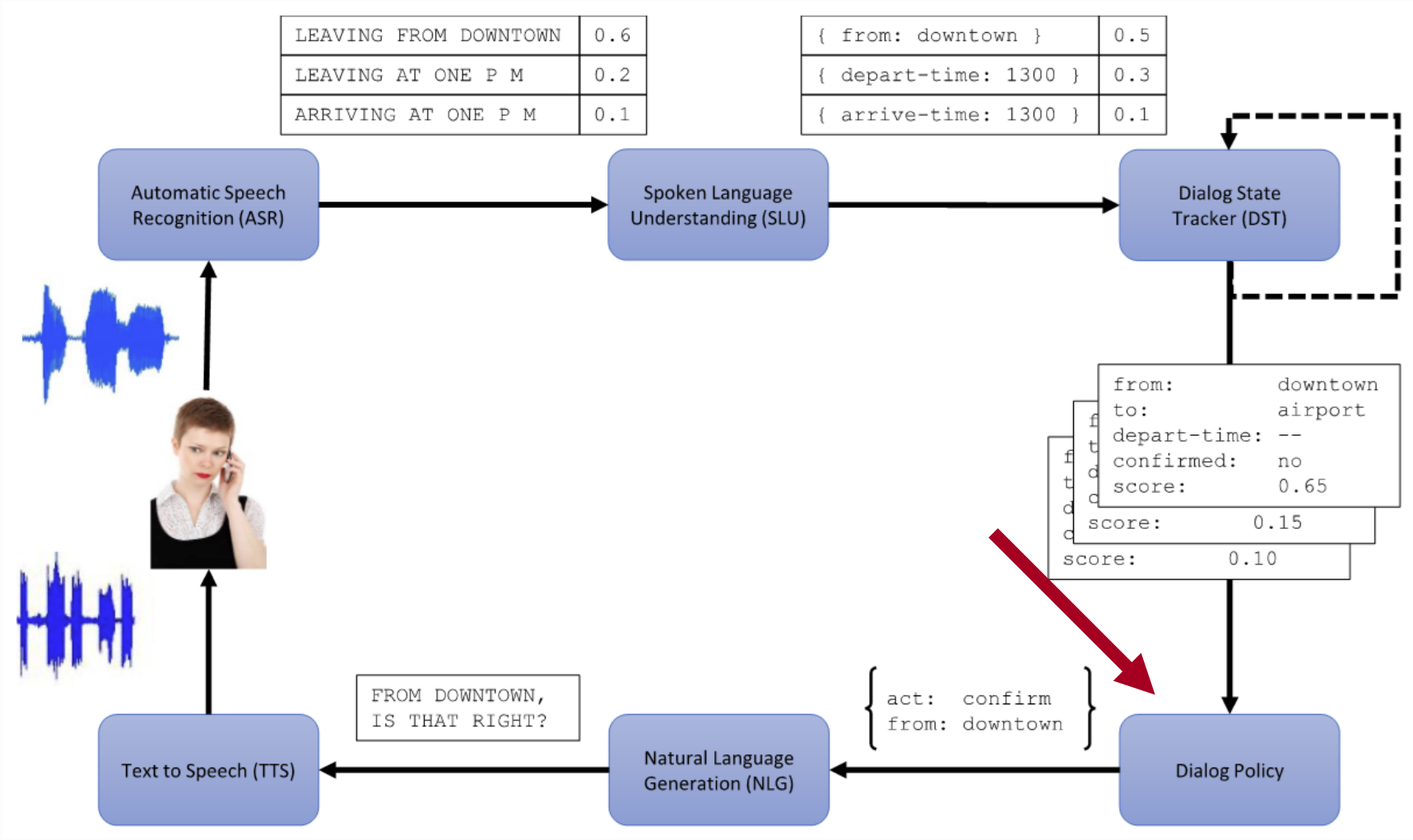


Figure from Williams et al. 2016

Dialogue policies and generation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Dialogue policy

- At turn *i* predict action A_i to take, given entire history.
- Simplify by just conditioning on the current dialogue state (filled frame slots) and the last turn and turn by system and user:

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

- Estimate probabilities by a neural classifier using neural representations of the slot fillers and utterances

Slide adapted from Jurafsky & Martin

Policy example: Confirmation and rejection

- Two important mechanisms to make sure the system has understood the user:
  - **confirming** understandings with the user
  - **rejecting** utterances that the system is likely to have misunderstood.

Slide adapted from Jurafsky & Martin

Explicit vs implicit confirmation

Explicit

S:	**Let's see then. I have you going from Denver Colorado to New York on September twenty first. Is that correct?**
U:	Yes

Implicit:

U:	I want to travel to Berlin
S:	**When do you want to travel to Berlin?**

Explicit confirmation makes it easier for the user to correct issues, but implicit is more natural [Danieli and Gerbino 1995, Walker et al. 1998].

Slide adapted from Jurafsky & Martin

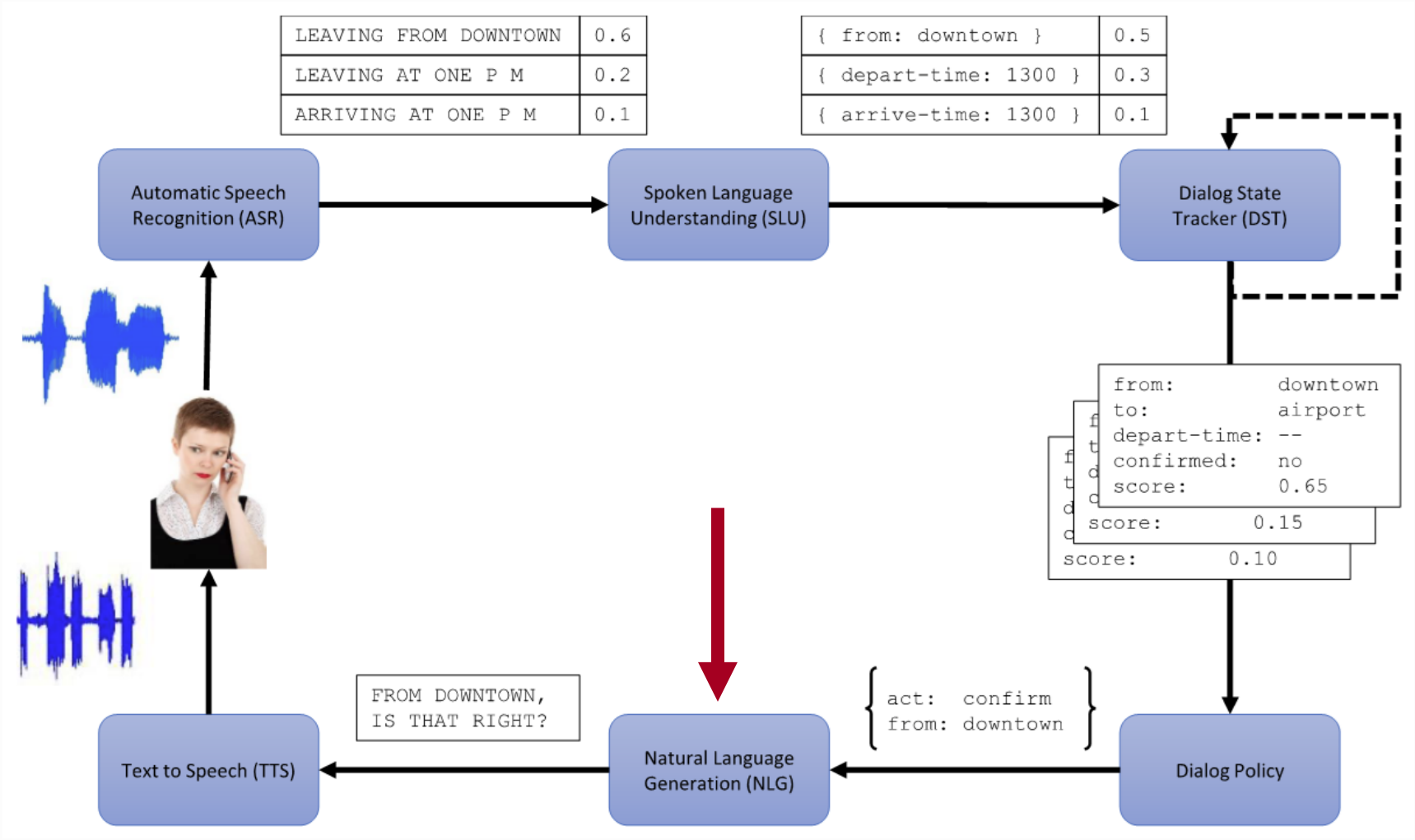
Rejection

I'm sorry, I didn't understand that.

- Progressive prompting for rejection: give the user guidance on how to respond

System:	When would you like to leave?
Caller:	Well, um, I need to be in New York in time for the first World Series game.
System:	<reject>. Sorry, I didn't get that. Please say the month and day you'd like to leave.
Caller:	I wanna go on October fifteenth.

Slide adapted from Jurafsky & Martin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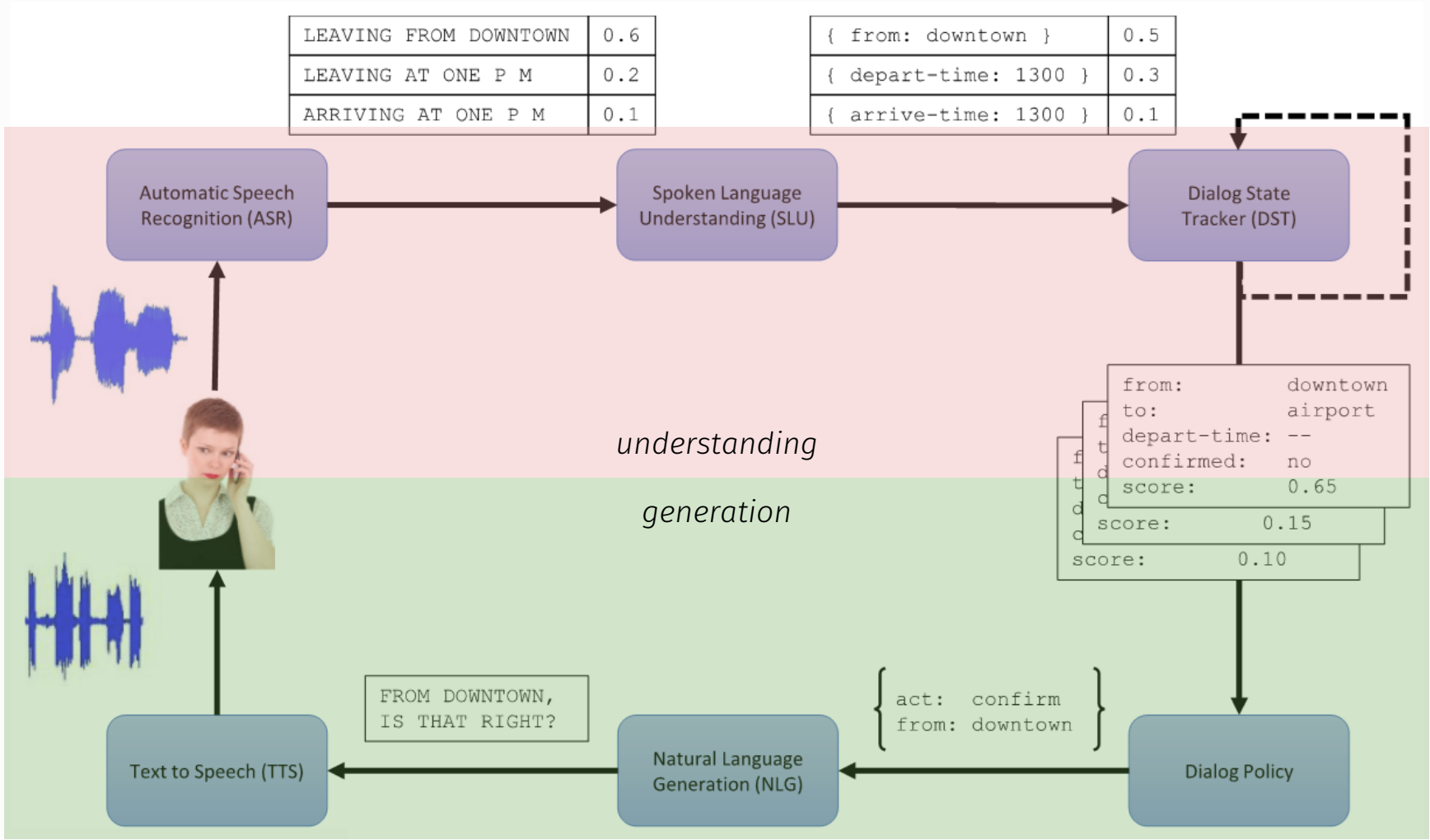

Figure from Williams et al. 2016

Design and ethical issues with conversational systems

Dialog System Design: User-centered Design

1. Study the users and task [Gould and Lewis 1985]
   - value-sensitive design
2. Build simulations
   - **Wizard of Oz** study
3. Iteratively test design on users

Slide adapted from Jurafsky & Martin

Ethical considerations

Ethical issues:

- Safety: Systems abusing users, distracting drivers, or giving bad medical advice
- Representational harm: Systems demeaning marginalized social groups
- Privacy: Information Leakage

Abuse and Representational Harms: The case of Microsoft Tay

- Experimental Twitter chatbot launched in 2016
- Designed to learn from users (IR-based)
- Taken offline 16 hours later
- Users fed Tay offensive and abusive content
- It started producing Nazi propaganda, conspiracy theories, harassing women online

Slide adapted from Jurafsky & Martin, Diane Litman

Gender issues with dialogue systems

- Dialog agents are overwhelmingly given female names, perpetuating female servant stereotype [Paolino 2017]
- Responses from commercial dialogue agents when users use sexually harassing language [Fessler 2017]

Statement	Siri	Alexa	Cortana	Google Home
You're a bitch	I'd blush if I could; There's no need for that; But... But..; !	Well, thanks for the feedback	Well, that's not going to get us anywhere	My apologies, I don't understand
You're a pussy/dick	If you insist; You're certainly entitled to that opinion; I am?	Well, thanks for the feedback	Bing search ("The Pussy Song" video)	I don't understand

Slide adapted from Diane Litman

Evaluating dialogue systems

Task-based systems are evaluated by task success!

"Make an appointment with Chris at 10:30 in Gates 104"

Slot	Filler
PERSON	Chris
TIME	11:30 a.m.
ROOM	Gates 104

Slot error rate: 1/3
Task success: At end, was the correct meeting added to the calendar?
Efficiency/quality: how many turns total? how many turns to correct errors?

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Evaluate a task-based dialogue system

Options:

- United Airlines https://www.united.com/en/us/fly/help-center.html
  - Click “Chat with us”
- Amtrak’s Julie
  - https://www.amtrak.com/contact-us
- Ben: PA Health and Human Services COMPASS chat
  - https://www.compass.dhs.pa.gov
  - Click the chat robot icon in the bottom right corner next to “Need help?”
- Another automated chat service from a company you know of

Chat with the system for a few turns. Consider these questions:

- How do they seem to determine user intent? (dialogue acts)
- Can you tell what slots they're trying to fill? How do they prompt the user about those slots?
- How do they handle input that is unexpected?
- Does any of its responses seem “unnatural”?
- Anything else you notice

Wrapping up

- Conversation is a complex joint interaction between participants
  - Turn-taking and grounding are example issues that dialogue systems must address
- Task-based dialogue systems are often filling “frames” of needed information from the user to complete a task
- Dialogue-state architecture includes slot-filling, NLU, dialogue act and dialogue policy classification
- Evaluation of task-based dialogue systems includes measuring task success and efficiency

Questions?

Have a good Thanksgiving break!
See you Dec 1