Course feedback

- Thank you all for sharing your thoughts and suggestions during discussion with Dr. Tershia Pinder-Grover!
- Re: adding more details in the homework
  - Yes, we have been adding more instructions; future offerings will add warm-up practices.
  - Yes, we will meet in the upcoming weeks.
- Re: smaller datasets
  - We have used datasets of varying sizes for different questions.
  - Lectures focus on the main topics and selectively zoom in; homework contains more hands-on practices.
- Re: collaborations among students
  - Let’s try in-class collaboration today!

What is Natural Language Dialogue?

- Communication involving
  - Multiple contributions
  - Coherent interaction
  - More than one participant
- Interaction modalities
  - Input: Speech, typing, writing, gesture
  - Output: Speech, text, graphical display, animated face/body (embodied virtual agent)

[Some slides are borrowed from Svetlana Stoyanchev and Dan Jurafsky]

What is involved in NL dialogue

- Understanding
  - What does a person say?
  - Identify words from speech signal
  - “Please close the window.”
- Managing interaction
  - What does the speech mean?
  - Identify semantic content
  - Request (subject: close; object: window)
- Can you deliver this action?
  - What were the speaker’s intentions?
  - E.g., speaker requests an action in a physical world
- Producing response
What is involved in NL dialogue

• Managing interaction
  • Knowledge for a domain
  • Weather: temperature, precipitation, wind, etc.
  • Identify new information
    • e.g. “which window?”, “the one on the left”
  • Identifying which action to perform given new information
    • “close the window”, “set a thermostat” → physical action
  • “what is the weather like outside?” → call the weather API
  • Determining a response
    • “Ok”, “I can’t do it”
    • Provide an answer
    • Ask a clarification question

• Access to information (Can you deliver this action?)
  • To process a request “Please close the window” you (or the system) needs to know:
    • There is a window
    • Window is currently opened
    • Window can/cannot be closed

What is involved in NL dialogue

• Producing response
  • Deciding when to speak
  • Deciding what to say
    • Choosing the appropriate meaning
  • Deciding how to present information
    • So partner understands it
    • So expression seems natural

• When hands-free interaction is needed
  • In-car interface
  • In-field assistant system
  • Command-and-control interface
  • Language tutoring
  • Immersive training

• When speaking is easier than typing
  • Voice search interface
  • Virtual assistant (Siri, Google Now)

• Replacing human agents (cutting cost for companies)
  • Call routing
  • Menu-based customer help
  • Voice interface for customer assistance

When is automatic dialogue system useful?

Visions of dialogue from science fiction

• Hal “2001: A Space Odyssey” (1968)
  • Naturally conversing computer
• Star Trek (original 1966)
  • Natural language command and control
• Her (2013)
  • A virtual partner with natural dialogue capabilities

Dialogue Agents

Phone-based Personal Assistants
  • Siri, Cortana, Google Now
Talking to your car
Communicating with robots
Clinical uses for mental health
Chatting for fun
Two classes of systems
1. (Goal-based) Dialogue agents
   - SIRI, interfaces to cars, robots
   - booking flights or restaurants
2. Chatbots

Examples of modern Virtual Assistant dialogue systems
- Apple Siri
  - Supports questions in a set of domains
  - Answers open-end questions
  - Cute “Easter egg” responses
Examples of modern Virtual Assistant dialogue systems

- Android Google Now (2013)
  - Predictive search assistant
- Windows Cortana (2014)
  - Works across different Windows devices
  - Aims to be able to "talk about anything"

Embedded devices with dialogue capabilities

- Amazon Echo (2014) – home assistant device
  - Plays music
  - With voice commands
  - Question answering
  - Get weather, news
  - More complex questions, like
    - "How many spoons are in a cup?"
  - Setting timer
  - Manages TODO lists

Outline

- Finite-state vs. Frame-based dialogue systems
- Dialogue system evaluation
- Beyond content: intentions
- Grounding and confirmation

Architectures for Practical Dialogue Systems

- Finite-State
  - Simple information: e.g., passwords or credit cards
- Frame-Based
  - All commercial and academic system (SIRI etc.)

Architectures for Practical Dialogue Systems

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Finite-State Dialog Management

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
Finite State Dialog Manager

Dialogue Initiative

- Systems that control conversation like this are called **single initiative**.
- **Initiative**: who has control of conversation
- In normal human-human dialogue, initiative shifts back and forth between participants.

System Initiative

- System completely controls the conversation
- Simple to build
- User always knows what they can say next
- System always knows what user can say next
  - Known words: Better performance from ASR
  - Known topic: Better performance from NLU (NL understanding)
- OK for VERY simple tasks (entering a credit card, or login name and password)
- Too limited

Problems with System Initiative

- Real dialogue involves give and take!
- In travel planning, users might want to say something that is not the direct answer to the question.
- For example answering more than one question in a sentence:

```
Hi, I'd like to fly from Seattle Tuesday morning
I want a flight from Milwaukee to Orlando one way leaving after 5 p.m. on Wednesday.
```
Architectures for Practical Dialogue Systems

• Finite-State
  Simple information: e.g., passwords or credit cards

⇒ Frame-Based
  All commercial and academic system (SIRI etc.)

Frame-based dialogue

• Invented up the hill in 1977:

  GUS, A Frame-Driven Dialog System
  David G. Bobrow, Ronald M. Kaplin, Marvin Kay,
  Donald A. Norman, Henry Thompson and
  Terry Weingard
  Stanford Research Center, 350 Campus Dr. Road,
  Palo Alto, CA 94304 U.S.A.
  Artificial Intelligence Journal, 1977

• Still the state of the art (in real world systems)
  • SIRI based on GUS architecture

The Frame

• A set of slots, to be filled with specific information
  • Each associated with a question to the user

<table>
<thead>
<tr>
<th>Slot</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT CITY</td>
<td>What city are you leaving from?</td>
</tr>
<tr>
<td>DEST CITY</td>
<td>Where are you going?</td>
</tr>
<tr>
<td>DEPT DATE</td>
<td>What day would you like to leave?</td>
</tr>
<tr>
<td>DEPT TIME</td>
<td>What time would you like to leave?</td>
</tr>
<tr>
<td>AIRLINE</td>
<td>What is your preferred airline?</td>
</tr>
</tbody>
</table>

Frames are mixed-initiative

• System asks questions of user, filling any slots that
  user specifies
• When frame is filled, do database query
• If user answers 3 questions at once, system can fill 3
  slots and not ask these questions again!

Instead, the state of the art:
Frame-based dialogue

• A kind of mixed initiative
  • The conversational initiative shifts between system
    and user
  • The structure of the frame guides dialogue

The Natural Language Understanding Component

Show me morning flights from Boston to SF on Tuesday.

SHOW:

FLIGHTS:
  DEPT:
    CITY: Boston
  DATE: Tuesday
  TIME: morning
  DEST:
    CITY: San Francisco
Often called "dialogue state" detection

**Dialogue state**: representation of what the user wants at any point in a dialogue

- Which slots got filled in the last sentence?
- What is the current state of the frame?
- All the values of the filled slots
- What is the user’s last "dialogue act":
  - Did they ask me a question?
  - Inform me of something?

How to do Frame-based Natural Language Understanding?

- Rule-based models (precision is high)
- Statistical models (better generalizability)

Siri uses GUS architecture:
Condition-Action Rules

- Active Ontology: relational network of concepts
- **data structures**: a **meeting** has
  - a date (and time),
  - a location,
  - a topic
- a list of attendees
- **rule sets** that perform actions for concepts
  - the **date** concept turns string
    - **Monday at 2pm** into
      - object: **date(day, month, year, hours, minutes)**

Part of ontology for meeting task

- **command**: event
- verb has-a meeting
- **may-have-a**
  - date
  - person
  - location
  - topic
- name
- phone number
- email address

meeting concept: if you don't yet have a location, ask for a location

Statistical Natural Language Understanding

- Statistical classifiers to map words to semantic frame-fillers
- Given a set of labeled sentences
  - "I want to fly to San Francisco on Tuesday"
    - Destination: San Francisco
    - Depart-date: Tuesday
- Requirements: Lots of labeled data

Statistical Slot filling

- Given a sentence:
  - I want to go from Boston to SF
- Classifier predicts which slot the user wants to fill
  - Output: (ORIGIN, DESTINATION, DEPART-DATE, AIRLINE)
Statistical Slot filling

- Given a sentence: I want to go from Boston to SF
- Classifier predicts which slot the user wants to fill
  Output: (DEPARTURE, DESTINATION, DEPARTURE-DATE, AIRLINE)
- Features: Words, Named Entities
- Classifier or sequence model predicts the filler:

  DEPT : DEST
  I want to go from Boston to SF

Outline

- Finite-state vs. Frame-based dialogue systems
  - Dialogue system evaluation
- Beyond content: intentions
  - Grounding and confirmation

Evaluation

1. Slot Error Rate for a Sentence
   - # of inserted/deleted/substituted slots
   - # of total reference slots for sentence
2. End-to-end evaluation (Task Success)

Evaluation

"Make an appointment with David at 11:30 in Rm 101"

<table>
<thead>
<tr>
<th>Slot</th>
<th>Filler</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERSON</td>
<td>David</td>
</tr>
<tr>
<td>TIME</td>
<td>11:30 p.m.</td>
</tr>
<tr>
<td>ROOM</td>
<td>Rm 101</td>
</tr>
</tbody>
</table>

Slot error rate: 1/3
Task success: At end, was the correct meeting added to the calendar?
Intentsions

• After understanding "what is said"...
  • Dialogue Act
  • Grounding and Confirmation
  • Rejection

Type of Dialogue Acts (Speech Acts)

<table>
<thead>
<tr>
<th>Constatives: committing the speaker to something’s being the case</th>
</tr>
</thead>
<tbody>
<tr>
<td>(answering, claiming, confirming, denying, disagreeing, stating)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Directives: attempts by the speaker to get the addressee to do</th>
</tr>
</thead>
<tbody>
<tr>
<td>something (advising, asking, forbidding, inviting, ordering, requesting)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commissives: committing the speaker to some future course of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>(promising, planning, vowing, betting, opposing)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acknowledgments: express the speaker’s attitude regarding the hearer</th>
</tr>
</thead>
<tbody>
<tr>
<td>with respect to some social action (apologizing, greeting, thanking, accepting an acknowledgment)</td>
</tr>
</tbody>
</table>

Type of Dialogue Acts (Speech Acts)

• “Turn up the music!”
  DIRECTIVE

• “What day in May do you want to travel?”
  DIRECTIVE

• “I need to travel in May”
  CONSTATIVE

• Thanks
  ACKNOWLEDGEMENT

Dialogue Act Detection

• Common categories in task-oriented dialogue systems:
  • Question
  • Command
  • Suggestion
  • Statement

• Given a user’s sentence:
  • Context: David wants to eat Italian food.
  • He asked: How many Italian restaurants are in walking distance?
  • Was that a question?

• Similarly, what looks like a STATEMENT can be QUESTION
  • I was wanting to make some arrangements for a trip that I’m going to be taking uh to LA uh beginning of the week after next...
DA interpretation as statistical classification

• Lots of clues in each sentence that can tell us which DA it is:
  • Words and Collocations
    • Please or would you: good cue for REQUEST
    • Are you: good cue for INFO-REQUEST
  • Prosody
    • Rising pitch is a good cue for INFO-REQUEST
    • Loudness/stress can help distinguish yeah/AGREEMENT from yeah/BACKCHANNEL
  • Conversational Structure
    • Yeah following a proposal is probably AGREEMENT; yeah following an INFORM probably a BACKCHANNEL

Another example of dialogue act detection: Correction Detection

• If system misrecognizes an utterance, and either
  • Rejects
  • Via confirmation, displays its misunderstanding
• Then user has a chance to make a correction
  • Repeat themselves
  • Rephrasing
  • Saying “no” to the confirmation question.

Corrections

• Unfortunately, corrections are harder to recognize than normal sentences!
  • Swerts et al (2000): corrections misrecognized twice as often as non-corrections!!!
  • Why?
    • Prosody seems to be largest factor: hyperarticulation
  • Liz Shriberg example:
    • “NO, I am DE-PAR-TING from Jacksonville”

Machine learning to detect user corrections: features

• Lexical information (no, correction, I don’t, swear words)
• Prosodic indicators of hyperarticulation
  • pause duration, word duration
• Length
• LM probability
• Repetition of content

Outline

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Finally...

Should I do a “Confirmation” dialog act?

Given that I’m confirming, what exactly should I say?
Grounding

- Why do elevator buttons light up?
  Principle of closure. Agents performing an action require evidence, sufficient for current purposes, that they have succeeded in performing it
- What is the linguistic correlate of this?

Grounding and Confirmation

- We need to know whether an action succeeded or failed
- Talking is an action!
- I need to know if my action succeeded
  - i.e. the hearer understood my turn!

How do speakers ground?
Clark and Schaefer

- Continued attention:
  - B continues attending to A
- Relevant next contribution:
  - B starts in on next relevant contribution
- Acknowledgement:
  - B nods or says continuers (uh-huh) or assessment (great!)
- Demonstration:
  - B demonstrates understanding A by reformulating A's contribution, or by collaboratively completing A's utterance
- Display:
  - B repeats verbatim all or part of A's presentation

A human-human conversation

| C | ...I need to travel in May. |
| A | And, what day in May did you want to travel? |
| C | OK, oh I need to be there for a meeting that's from the 12th to the 15th. |
| A | And you're flying into what city? |
| C | Seattle. |
| A | And what time would you like to leave Pittsburgh? |
| C | Uh-huh, I don't think there's many options for non-stop. |
| A | Right. There's three non-stops today. |
| C | What are they? |
| A | 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 8:00pm. And the last flight departs PGH at 8:35pm arrives Seattle at 10:29pm. |
| C | OK, I'll take the 5th flight on the eight before on the 13th. |
| A | On the 13th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115. |
| C | OK. |

Grounding examples

Display:
- C: I need to travel in May
  - A: And, what day in May did you want to travel?
- Acknowledgement
  - C: He wants to fly from Boston
  - A: mmm-hmmm
  - C: to Baltimore Washington International

Grounding examples (2)

- Acknowledgement + next relevant contribution
  And, what day in May did you want to travel?
  And you're flying into what city?
  And what time would you like to leave?
- The and indicates to the client that agent has successfully understood answer to the last question.
Grounding negative responses
From Cohen et al. (2004)

• System: Did you want to review some more of your personal profile?
• Caller: No.
• System: Okay, what’s next?
• System: Did you want to review some more of your personal profile?
• Caller: No.
• System: What’s next?

Conversational Implicature

• A: And, what day in May did you want to travel?
• C: OK, uh, I need to be there for a meeting that’s from the 12th to the 15th.

• Note that client did not answer question
• Meaning of client’s sentence
  • Meeting: Start-of-meeting: 12th; End-of-meeting: 15th
  • Doesn’t say anything about flying!
• What dates do the client plan to travel?

Conversational Implicature

• A: … there’s 3 non-stops today.
• This would still be true if 7 (or 8 or 9) non-stops today.
• But no, the agent means: 3 and only 3.
• How can client infer that agent means?
  • only 3

• Pragmatics: the study of how language is used to accomplish goals; beyond literal meaning. The interpretation of utterance relies on more than just the literal meaning of the sentences.
• Conversational Implicature means a particular class of inferences (that the speaker expects the hearer to draw)
• Grice’s maxims (1975) for conversation explain what enables hearers draw such inferences.
• Cooperative Principle
  • This is a tacit agreement by speakers and listeners to cooperate in communication

Four Gricean Maxims

• Relevance: Be relevant
• Quantity: Do not make your contribution more or less informative than required
• Quality: try to make your contribution one that is true (don’t say things that are false or for which you lack adequate evidence)
• Manner: Avoid ambiguity and obscurity; be brief and orderly

Relevance

• A: Is Regina here?
• B: Her car is outside.
Relevance

• A: Is Regina here?
• B: Her car is outside.

• Implication: yes
• Hearer thinks:
  • Why mention the car?
  • It must be relevant.
  • How could it be relevant?
  • It could since if her car is here she is probably here.

Relevance

• Client: I need to be there for a meeting that’s from the 12th to the 15th

• Hearer thinks:
  • Speaker is following maxims, would only have mentioned meeting if it was relevant. How could meeting be relevant?
  • If client meant me to understand that they had to depart in time for the meeting

Quantity and Quality

• A: How much money do you have on you?
• B: I have 5 dollars

• Implication: not 6 dollars

• Similarly, 3 non stops can’t mean 7 non-stops
  • Hearer thinks:
    • If speaker meant 7 non-stops she would have said 7 non-stops

Quantity and Quality

• A: Did you do the reading for today’s class?
• B: I intended to

• Implication: No
• B’s answer would be true if B intended to do the reading AND did the reading, but would then violate maxim

Confirmation

• Errors: Speech is a pretty errorful channel
  • Humans use grounding to confirm that they heard correctly
  • Automatic speech recognition (ASR) is way worse than humans!
  • Dialogue systems need to do even more grounding and confirmation than humans
    • Users are confused when system doesn't give explicit acknowledgement signal.

Stifelman et al. (1993), Yankelovich et al. (1995)
Explicit confirmation

S: Which city do you want to leave from?
U: Baltimore
S: Do you want to leave from Baltimore?
U: Yes

Explicit confirmation

U: I'd like to fly from Denver Colorado to New York City on September 21st in the morning on United Airlines
S: Let's see then. I have you going from Denver Colorado to New York on September 21st. Is that correct?
U: Yes

Implicit confirmation: display

U: I'd like to travel to Berlin
S: When do you want to travel to Berlin?
U: Hi I'd like to fly to Seattle Tuesday morning
S: Traveling to Seattle on Tuesday, August eleventh in the morning. Your name?

Implicit vs. Explicit

• Complementary strengths
• Explicit is easier for users to correct systems’s mistakes (can just say "no")
• But explicit is cumbersome and long
• Implicit is much more natural, quicker, simpler (if system guesses right).

Implicit and Explicit

• Early systems: all-implicit or all-explicit
• Modern systems: adaptive, switching between the two
• How to decide?
  • ASR system can give confidence metric.
  • This expresses how convinced system is of its transcription of the speech
  • If high confidence, use implicit confirmation
  • If low confidence, use explicit confirmation

Should also consider cost of an error: Explicit confirmation before moving money or booking flights
Rejection

- "I'm sorry, I didn't understand that."
- Reject when:
  - ASR confidence is low
  - Best interpretation is semantically ill-formed
- Might have four-tiered level of confidence:
  - Below confidence threshold, reject
  - Above threshold, explicit confirmation
  - If even higher, implicit confirmation
  - Even higher, no confirmation