NR Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

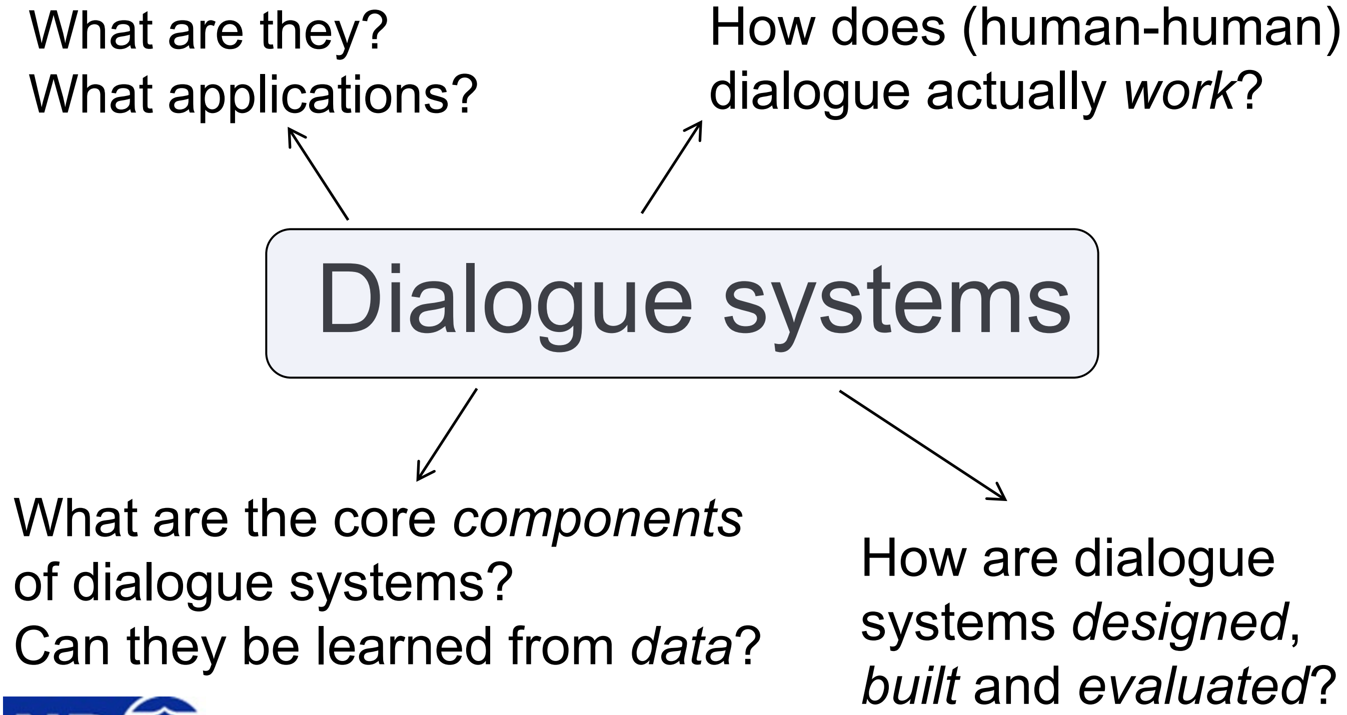
Dialogue systems & chatbots

Pierre Lison

IN4080: Natural Language Processing (Fall 2022)

13.10.2022

The next 3 weeks



Dialogue systems

What are they?
What applications?

How does (human-human) dialogue actually *work*?

What are the core *components* of dialogue systems?
Can they be learned from *data*?

How are dialogue systems *designed*, *built* and *evaluated*?

Plan

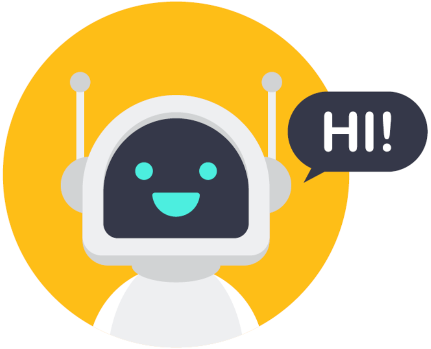
Lectures:

- October 13:
  - What is dialogue?
  - Basic chatbot models
- October 18 (⚠ Tuesday):
  - Chatbots (cont') & NLU
  - Short intro to ASR
- October 27
  - Dialogue management
  - System design & evaluation

Lab sessions:

- October 20:
  - Linguistic analysis
  - Basics of Numpy
- October 25 (⚠ Thursday):
  - Exercises on NLU & ASR
- November 1:
  - Exercises on dialogue management & RL
  - Help with assignment

Assignment



- Oblig 3 released soon
  - Deadline: november 11
- Three parts:
  - **Chatbots:** data-driven chatbot trained on movie and TV subtitles
  - **Speech processing**: implement a simple voice activity detector
  - **Dialogue management**: build a (simulated) talking elevator

Material

- The slides from the 3 lectures
- Chapter 24 of the upcoming version (v3) of Jurafsky & Martin's SLP book
  - & part of chapter 25 on phonetics
  - & dialog chapter from previous J&M edition
- + a few additional references listed in the weekly syllabus for the course

Plan for today

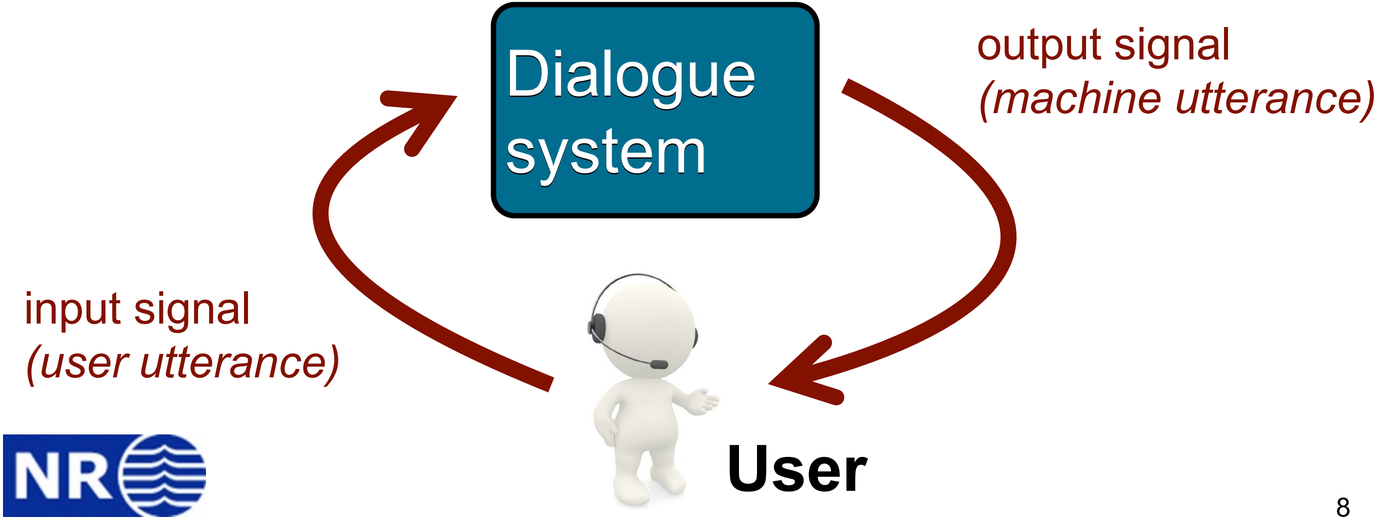
- A short intro to dialogue systems
- What is human dialogue?
- Basic chatbot models

Plan for today

- ► **A short intro to dialogue systems**
- ► What is human dialogue?
- ► Basic chatbot models

Dialogue systems?

A dialogue system is an artificial agent designed to interact with humans using *(spoken or text-based) natural language*

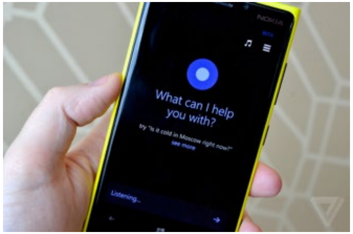


What for?

- **Highly intuitive**: no need for training or expertise: all you need is to talk/write!
- Touch-based interfaces may be inadequate, cumbersome or dangerous (car driving)
- Language is the ideal medium to express complex ideas in a flexible and efficient way

Applications

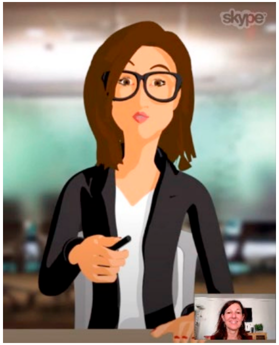
Mobile virtual assistants (Siri, Cortana, etc.)



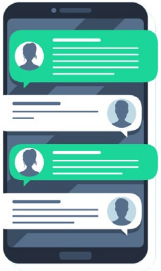
Smart home environments

In-car navigation & control

Tutoring systems



Chatbots



Service robots

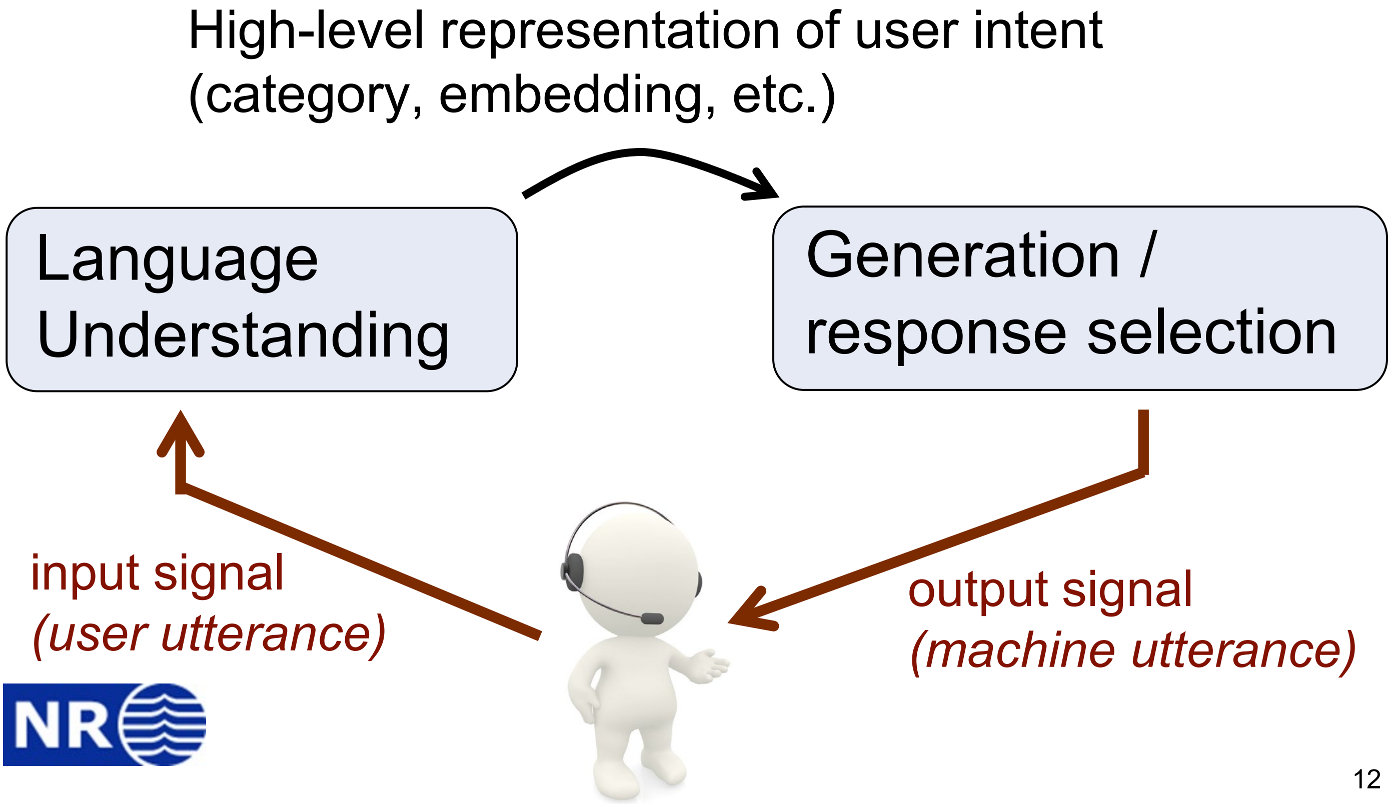
Why is it interesting?

- Major application area for NLP (with large R&D investments)

- Study language «as a whole», as it is used in real interactions

- Playground for key AI problems:
  - *Sense*, *reason* and *act* under uncertainty
  - Capture the *context* & *other agents*

Basic architecture



High-level representation of user intent (category, embedding, etc.)

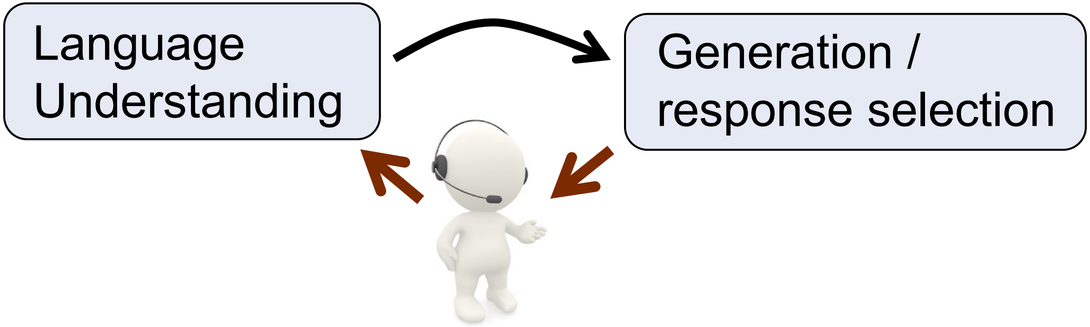
Language Understanding

Generation / response selection

input signal *(user utterance)*

output signal *(machine utterance)*

Basic architecture

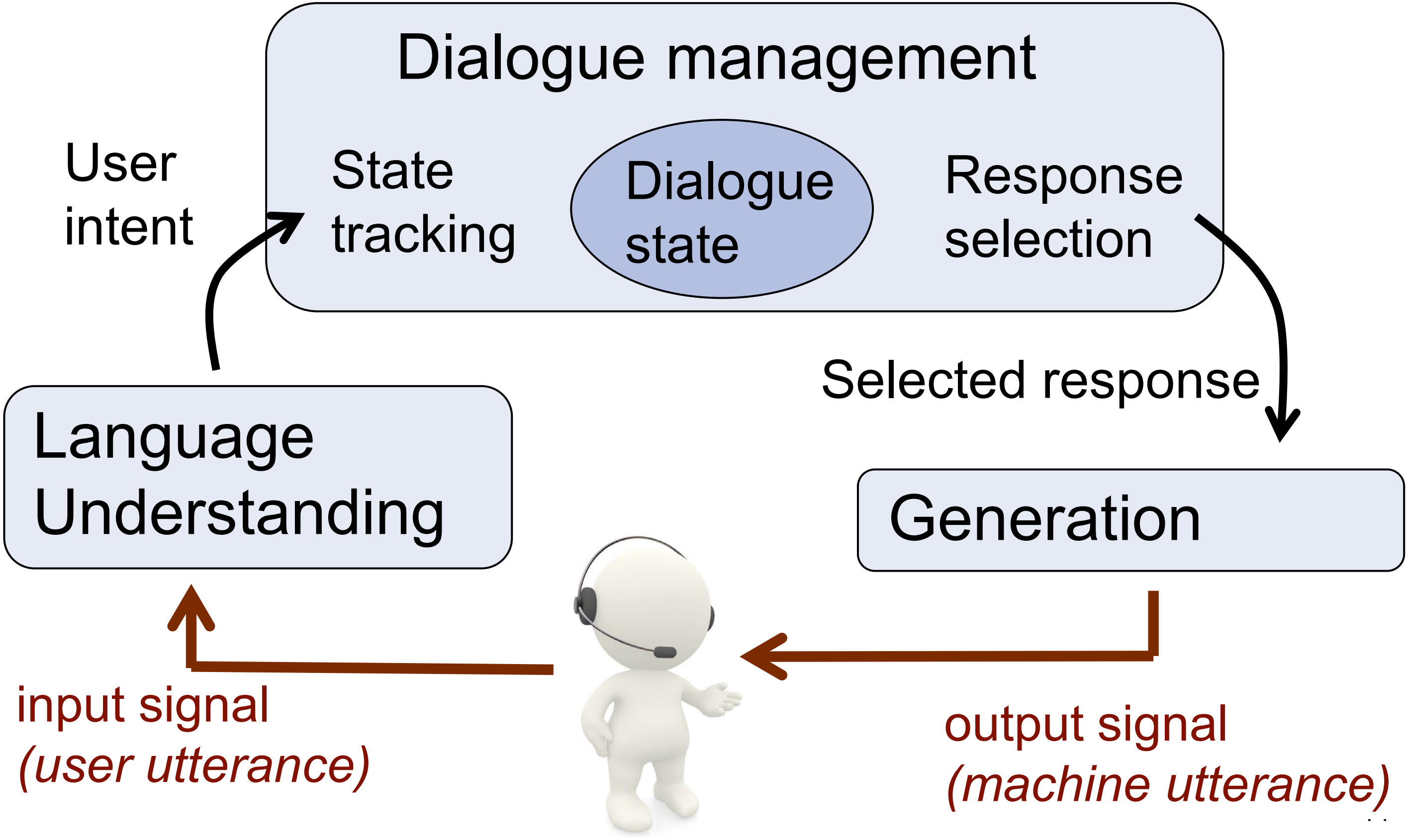

Language Understanding

Generation / response selection

This pipeline is often used for chatbots

- **Main limitation**: no management of the dialogue itself (beyond current utterance)
- Most appropriate for short interactions

Basic architecture



Dialogue management

State tracking

Dialogue state

Response selection

User intent

Selected response

Language Understanding

Generation

input signal
(user utterance)

output signal
(machine utterance)

Outline

- In two weeks, we'll look at dialogue management in more details
  - How to integrate the external «context»?
  - How to handle multiple (i.e. non-verbal) modalities?
  - How to design, build and evaluate dialogue systems?

- *But let's first have a look at how human conversation actually works*

Plan for today

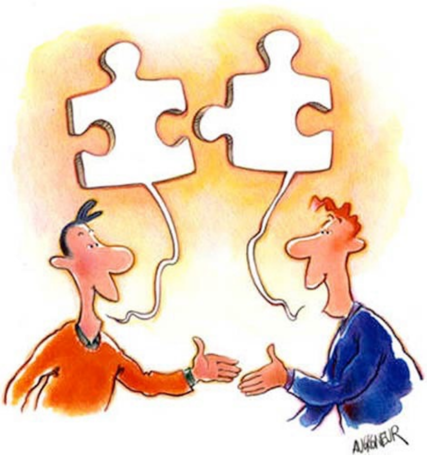
- A short intro to dialogue systems
- **What is human dialogue?**

What is dialogue?

- Spoken (“verbal”) + possibly non-verbal interaction between two or more participants

- Dialogue is a joint, social *activity*, serving one or several purposes for the participants

- What does it mean to view dialogue as a **joint activity**?



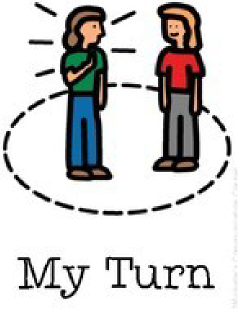
Turn-taking

- Dialogue participants take *turns*
  - Turn = continuous contribution from one speaker
  - Turn-taking is a *resource allocation problem*
- Surprisingly fluid in normal conversations:
  - Minimise both gaps (no speaker) and overlaps (more than one speaker)
  - Interval between speakers is around 250 ms

[Duncan (1972): «Some Signals and Rules for Taking Speaking Turns in Conversations», in *Journal of Personality and Social Psychology*]

Turn-taking

- How are turns taken or released?
- Markers for turn boundaries:
  - Complete syntactic/semantic unit?
  - Dialogue structure (greetings → greetings, question → answer)
  - Intonation (falling intonation signals that speaker if finished)
  - Non-verbal cues (eye gaze, gestures)
  - Silence & hesitation markers (unfilled pauses ≠ filled pauses)
  - Social conventions

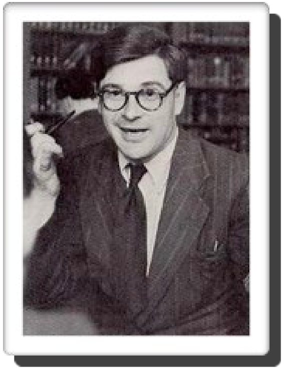


Example of turn-taking

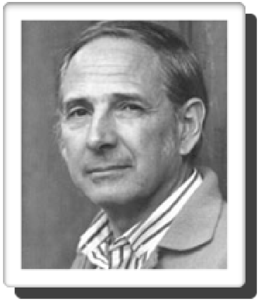
Speaker 1:	han vil bo i skogen ?
Speaker 2:	# altså hvis jeg hadde kommet og sagt " skal vi flytte i skogen ? " så hadde han sagt ja
Speaker 1:	mm
Speaker 2:	men jeg vil ikke bo i skogen
Speaker 1:	nei det skjønner jeg
Speaker 2:	så vi må jo finne et sted som er mellomting og det jeg vil ikke bo utpå landet # i hvilken som helst (uforståelig) ...
Speaker 1:	* men det kommer jo an på hvor i skogen da

Dialogue acts

- Each utterance is an *action* performed by the speaker
  - The speaker has a specific **goal** (which might be only to establish or maintain *rapport* with the listeners)
  - The utterance produces specific **effects** upon the listeners, or the world at large
  - «*Language as action*» perspective

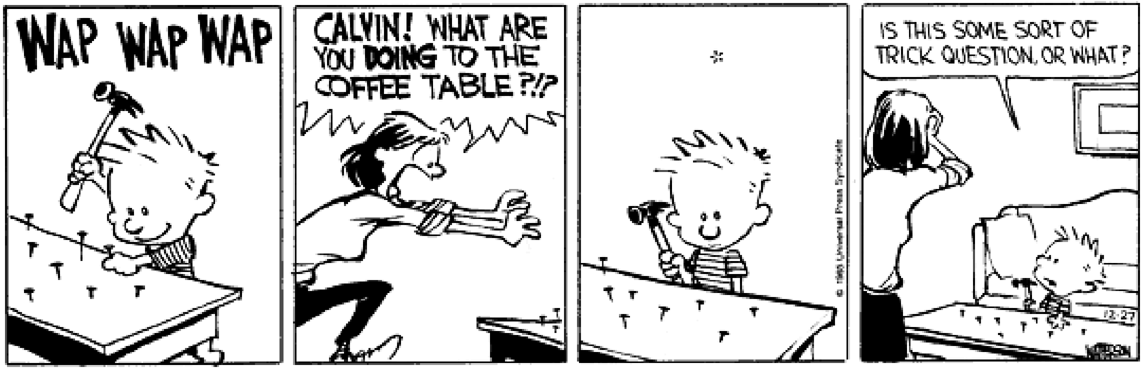


J.L. Austin (1911-1960)
philosopher of language



J. Searle (1932, -)
philosopher of language

Dialogue acts


WAP WAP WAP
CALVIN! WHAT ARE YOU DOING TO THE COFFEE TABLE?!?
IS THIS SOME SORT OF TRICK QUESTION, OR WHAT?
© 1985 Universal Press Syndicate
12-27
WATTERSON

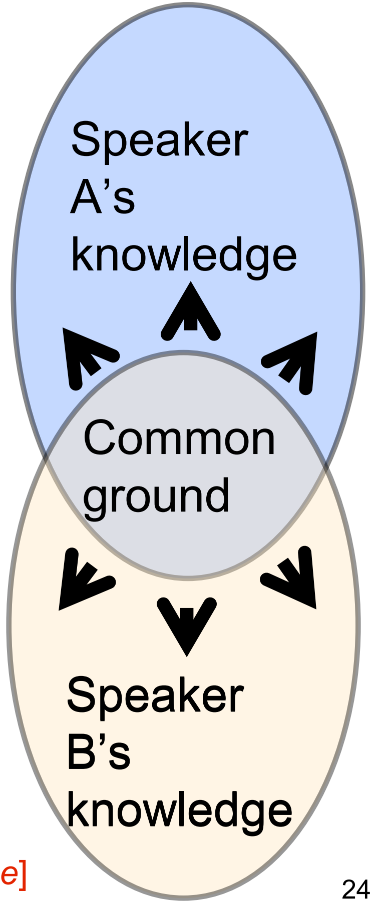
- The mother reaction has a specific **purpose**
  - Communicating her suprise/anger, and stop Calvin
- Her question will trigger some **effects**:
  - A psychological reaction from Calvin (e.g. surprise)
  - Possibly a real-world effect as well (Calvin stopping his action)

Searle’s taxonomy

- **Assertives**: committing the speaker to the truth of a proposition. E.g.: *«The exam will take place on November 25»*
- **Directives**: attempts by the speaker to get the addressee to do something. E.g. : *«could you please clean up your room?»*
- **Commissives**: committing the speaker to some future course of action. E.g.: *«I promise I’ll clean up my room»*.
- **Expressives**: expressing the psychological state of the speaker. E.g.: *«thanks for cleaning up your room».*
- **Declaratives**: bringing about a different state of the world by the utterance. E.g.: *«You’re fired».*

Grounding

- Dialogue is a *joint, collaborative process* between the participants
  - Need to ensure mutual understanding
- Gradual expansion and refinement of **common ground**
  - Common ground = shared knowledge

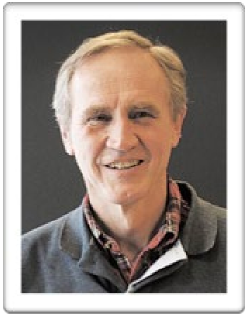


[H. H. Clark and E. F. Schaefer (1989), «Contributing to discourse», in *Cognitive Science*]

Grounding

- Grounding is the process of gradually augmenting the common ground during the interaction
  - Variety of signals and strategies
- Multiple levels:
  - Contact (attention to interlocutor)
  - Perception (detection of utterance)
  - Understanding (comprehension of utterance)
  - Attitudinal reactions

Herbert H. Clark
psycholinguist



Jens Allwood
linguist

[Jens Allwood (1992), «On discourse cohesion», in *Gothenburg papers in Theoretical Linguistics*.]

Grounding acts

- Backchannels: «*uh-uh*», «*mm*», «*yeah*»
- Explicit feedback: «*ja det skjønner jeg*»
- Implicit feedback: A: «*I want to fly to Rome*» → B: «*there are two flights to Rome on Wednesday: ...* »
- Clarification strategies: «*Did you mean to Rome or to Goa?*», «*could you confirm that ...*»
- Repair strategies: «*OK, you're not going to Goa. Where do you want to go then?*»

Examples of grounding

Speaker 1:	vi vasker den hver dag vi # vi har mopp
Speaker 2:	**mm** ## **ja** det er fort og faren til M27 legger nytt teppe han # det er gjort på to timer ## så det er fort gjort
Speaker 1:	**ja** ## da er ikke noe sak
Speaker 2:	vi har skifta teppe tre ganger allerede han gjør det gratis
Speaker 1:	**hæ ?**
Speaker 2:	vi har skifta teppe tre ganger og # han han ...
Speaker 1:	* **jeg skjønner ikke** hvorfor dere har teppe
Speaker 2:	jeg syns det var rart jeg **òg** # men e # (sibilant)

Examples of grounding

Speaker 1:	e # **nei** det er ikke mange
Speaker 2:	**ja * nei**
Speaker 1:	men heldigvis så var ikke Petter Rudi tatt ut denne gangen da
Speaker 2:	**ja** # jeg skjønner ikke hva han skal på landslaget å gjøre
Speaker 1:	*** nei han har ingen ting på landslaget**
Speaker 2:	**nei** # definitivt
Speaker 1:	å gjøre # han er ubrukelig
Speaker 2:	* moldensere
Speaker 1:	**hm?**
Speaker 2:	ja disse moldenserne
Speaker 1:	**en gang til?**
Speaker 2:	disse moldenserne
Speaker 1:	* **å ja** (fremre klikkelyd) # unnskyld # jeg hørte ikke hva du sa

implicit feedback (repetition of *landslaget*)

clarification requests

Grounding

- Common ground is more than «knowledge that happens to be shared by all participants»
  - The participants must also know that it is shared (i.e. know that the others know it as well)
- Given two speakers A and B, the common ground CG can be defined as :

$$
\begin{aligned}
\forall x,\ CG(x) \rightarrow\ & knows(A,x) \\
\wedge\ & knows(B,x) \\
\wedge\ & knows(A,knows(B,x)) \\
\wedge\ & knows(B,knows(A,x)) \\
\wedge\ & knows(A,knows(B,knows(A,x))) \\
\wedge\ & \ldots
\end{aligned}
$$

Conversational implicatures

- Very often, part of the meaning of utterance is not explicitly stated, but only implied

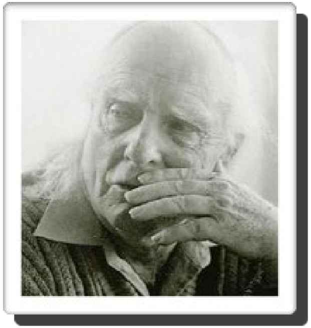
  A: «Is William working today?»

  B: «He has a cold»

- How can we retrieve this «suggested» meaning, and go beyond literal interpretations?
  - Need to make some assumptions about the speaker to help us infer the hidden part

Conversational implicatures

- Same idea again: dialogue as a *collaborative process*
- Grice’s *Cooperative Principle*:
  - Maxim of Quality: «be truthful»
  - Maxim of Quantity: «be exactly as informative as required»
  - Maxim of Relation: «be relevant»
  - Maxim of Manner: «be clear»



Paul Grice (1913-1988)
philosopher of language

Conversational implicatures

- Based on the cooperative principle, one can draw conversational implicatures
  - All participants are assumed to adhere to the maxims
  - If an utterance initially seems to deliberately violate a maxim, the listener will then infer additional hypotheses required to make sense of the utterance

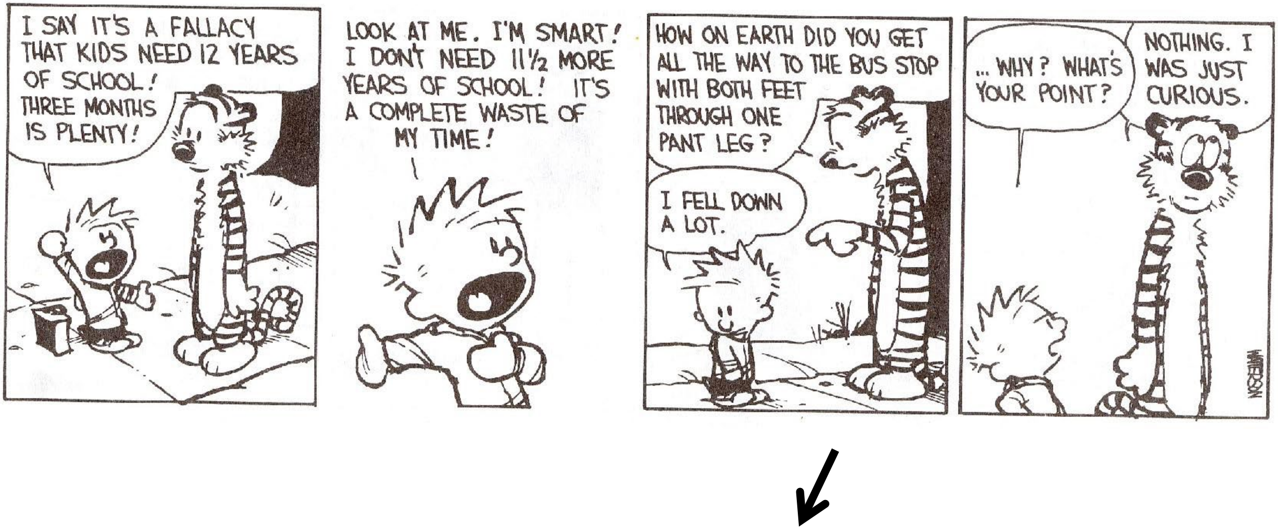
Conversational implicatures

A: «Is William working today?»

B: «He has a cold»

- At first glance, B seems to violate the maxim of relevance - he does not directly answer A’s question
- But looking at the utterance more closely, we can read it as implying that (due to his cold) he is probably at home, and thus not working today
- This is because we assume that B is cooperative and wouldn’t have uttered «he has a cold» if it didn’t help answering A’s question

Conversational implicatures

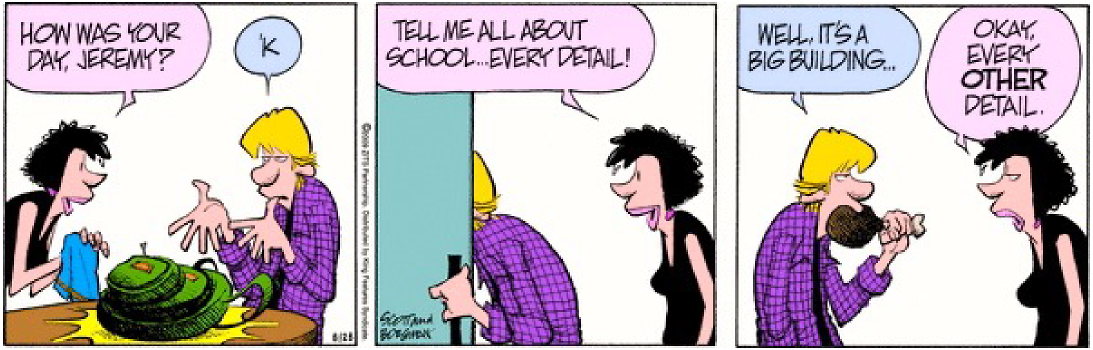

I SAY IT'S A FALLACY THAT KIDS NEED 12 YEARS OF SCHOOL! THREE MONTHS IS PLENTY!
LOOK AT ME. I'M SMART! I DON'T NEED 11½ MORE YEARS OF SCHOOL! IT'S A COMPLETE WASTE OF MY TIME!
HOW ON EARTH DID YOU GET ALL THE WAY TO THE BUS STOP WITH BOTH FEET THROUGH ONE PANT LEG?
I FELL DOWN A LOT.
... WHY? WHAT'S YOUR POINT?
NOTHING. I WAS JUST CURIOUS.
WATTERSON

Hobbes' question is *suggesting* something about Calvin's need for schooling, without stating it explicitly

We can understand it because we assume that Hobbes' contribution is cooperative and thus relevant to the discussion

Conversational implicatures

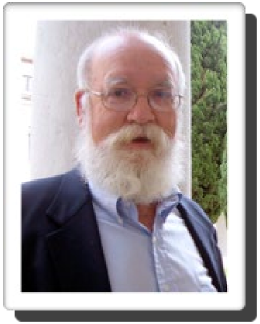
- When the cooperative maxims are violated, we can quickly notice it:


HOW WAS YOUR DAY, JEREMY?
'K
TELL ME ALL ABOUT SCHOOL...EVERY DETAIL!
WELL, IT'S A BIG BUILDING...
OKAY, EVERY OTHER DETAIL.
SCOTT and BORGMAN

Which maxim is violated here?

Shared intentionality

- ▶ Humans naturally view each other as goal-directed, *intentional agents*
  - ▪ Understand other agents in terms of belief, desires and intentions (*theory of mind*)
- ▶ But there's more: humans can *jointly attend* to external entities and establish *shared intentions*



Daniel Benett (1942, -)
philosopher of mind

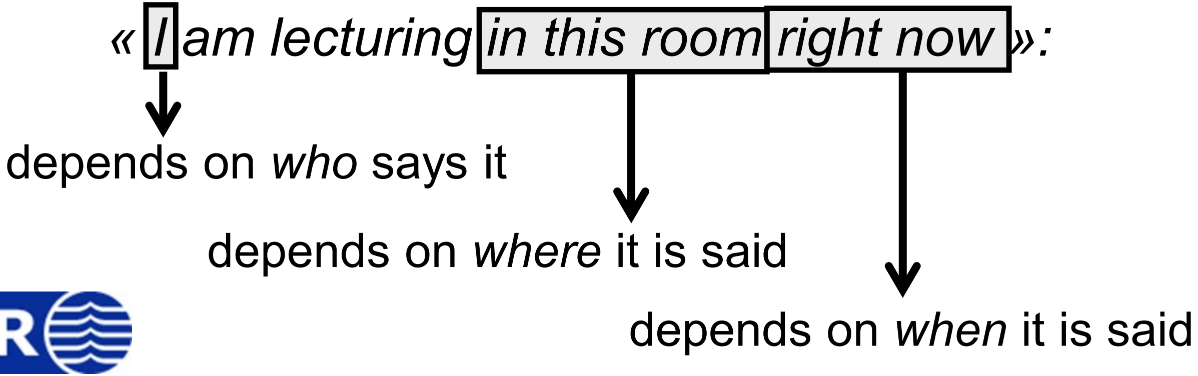
Michael Tomasello (1950, -)
developmental psychologist

[Dennett, D (1996), *The intentional stance*.]

[Tomasello, M (2018), *Becoming Human: A Theory of Ontogeny*]

Deixis

- Dialogue often *referential* to a spatio-temporal context
- Such references are called deictics
  - Related concepts: indexicals, anaphora
- The meaning of a deictic depends on the context in which it is uttered (including the speaker perspective)



«I am lecturing in this room right now»:

depends on *who* says it

depends on *where* it is said

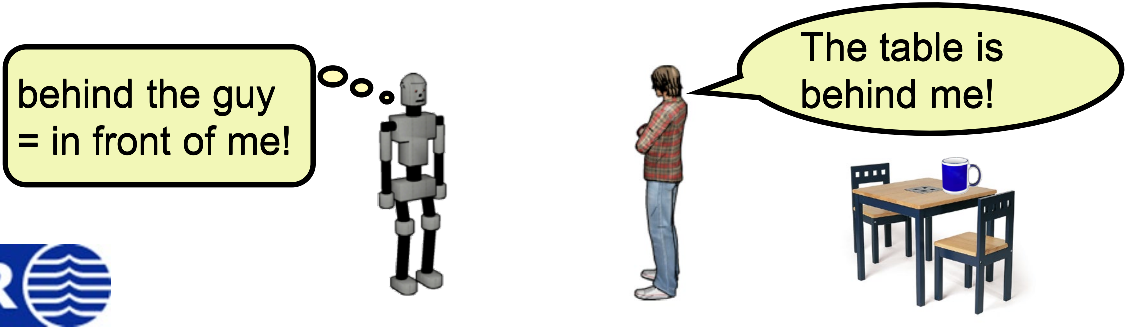
depends on *when* it is said

Deictic markers

- *Pronouns*: «I», «you», «my», «yours»
- *Adverbs of time and place*: «now», «yesterday», «here», «there»
- *Demonstratives*: «this», «that»
- *Tense markers*: «he just left»
- *Others*: «the mug to your right», «go away!», «the other one»
- *Non-verbal signs*, based on gestures, gaze, etc.

Deixis

- Deictics can refer to virtually anything:
  - Objects: «take that mug»
  - Events: «don't do that», «this car accident was awful»
  - Persons: «You're being an idiot»
  - Abstract entities: «This methodology is flawed»
- Perspective is important:



Alignment

- Participants in a dialogue continuously **align** their mental representations
  - Notion of common ground discussed earlier
- But dialogue participants also align at a deeper level, by unconsciously *imitating* each other
- As the interaction unfolds, the participants automatically align their *wording*, *pronunciation*, *speech rate*, and *gestures*

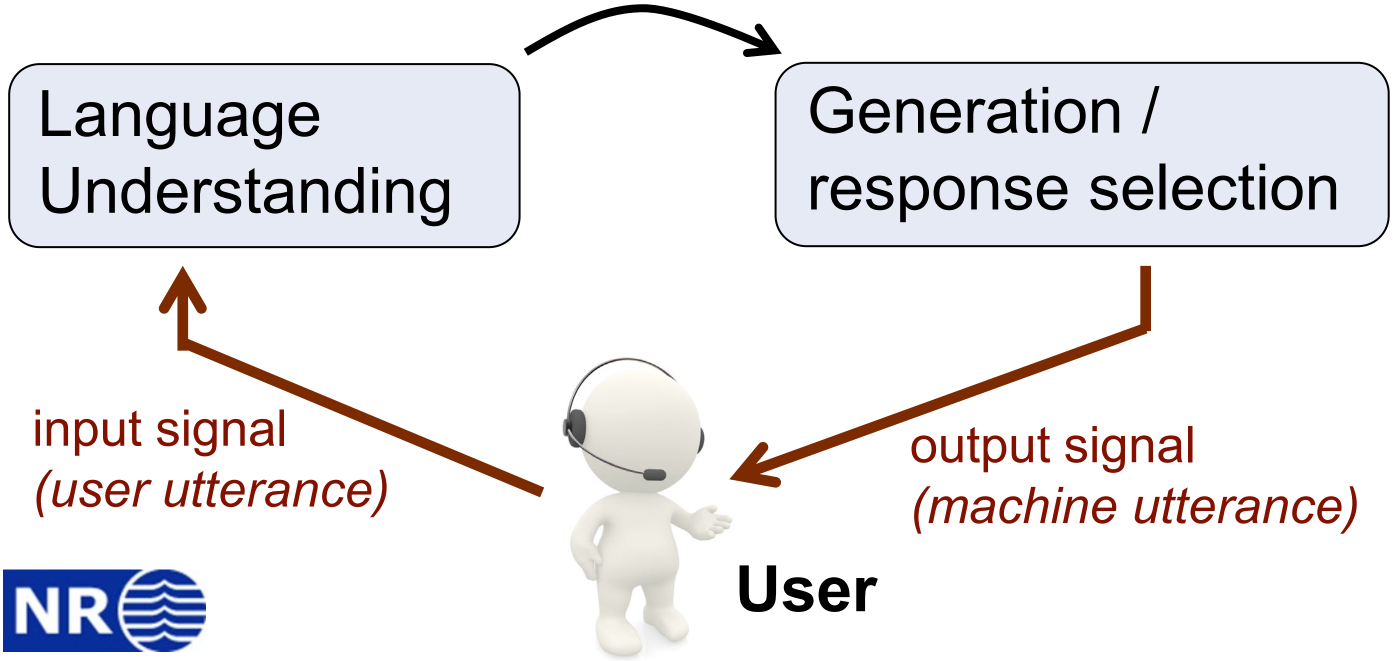
[Garrod, S., & Pickering, M. J. (2009). Joint action, interactive alignment, and dialog. *Topics in Cognitive Science*]

Plan for today

- A short intro to dialogue systems
- What is human dialogue?
- **Basic chatbot models**

Chatbots

High-level representation of user intent
(category, embedding, etc.)



Language Understanding

Generation / response selection

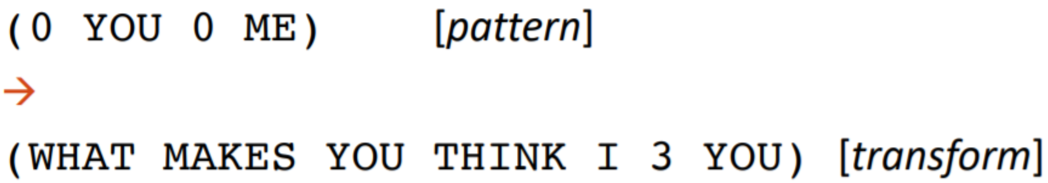
input signal
(user utterance)

output signal
(machine utterance)

User

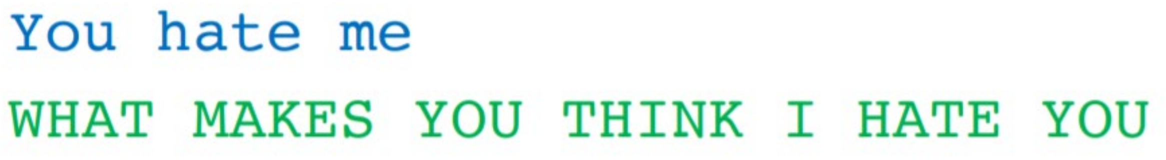
Rule-based models

- Pattern-action rules



```
(0 YOU 0 ME)        [pattern]
→
(WHAT MAKES YOU THINK I 3 YOU) [transform]
```

- For instance:



```
You hate me
WHAT MAKES YOU THINK I HATE YOU
```

[example from D. Jurafsky]

IR models

- Alternatively, one can adopt a data-driven approach and learn how to respond to the user based on a *dialogue corpus*
- Key idea:
  - Given a user input **q**, find the utterance **t** in the dialogue corpus that is most similar to **q**
  - Then return as response the utterance **r** following **t** in the corpus

IR models

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

- How to determine which utterance is «most similar» to the actual user utterance?
  - Cosine similarity over some vectors
  - The vectors can be TF-IDF weighted words
  - Or utterance-level embeddings

Example

Corpus:

1. hei !
2. hei ! har du det bra ?
3. ja , hva med deg ?
4. bare bra
5. har du spist ?
6. ja

TF vectors:

bare	bra	deg	det	du	ja	har	hei	hva	med	spist	,	!	?
							1					1	
	1		1	1		1	1					1	1
		1			1			1	1		1		1
1	1												
				1		1				1			
					1								

$$\log(6) \approx 0.78$$

$$\log\left(\frac{6}{2}\right) \approx 0.48$$

Example

Corpus:

1. hei !
2. hei ! har du det bra ?
3. ja , hva med deg ?
4. bare bra
5. har du spist ?
6. ja

TF-IDF vectors:

bare	bra	deg	det	du	ja	har	hei	hva	med	spist	,	!	?
							.48					.48	
	.48		.78	.48		.48	.48					.48	.48
		.78			.48			.78	.78		.78		.48
.78	.48												
				.48		.48				.78			
					.48								

New user utterance *q*: "går det bra med deg?"

TF-IDF vector:

	.48	.78	.78						.78				.48

Example

	bare	bra	deg	det	du	ja	har	hei	hva	med	spist	,	!	?	$q^T t$	$\frac{q^T t}{\|q\|\|t\|}$
1.								.48					.48		0	0
2.		.48		.78	.48		.48	.48					.48	.48	1.07	0.50
3.			.78			.48			.78	.78		.78		.48	1.45	0.56
4.	.78	.48													0.23	0.17
5.					.48		.48				.78				0	0
6.						.48									0	0
		.48	.78	.78						.78				.48		

Example

$$\frac{q^T t}{||q||\,||t||}$$

Corpus:

1.	hei !	0
2.	hei ! har du det bra ?	0.50
3.	ja , hva med deg ?	0.56
4.	bare bra	0.17
5.	har du spist ?	0
6.	ja	0

→ The utterance closest to *q* in our corpus is utterance 3: "ja, hva med deg?"

→ the system should choose as response utterance 4

New user utterance *q*: "går det bra med deg?"

→ **System response**: "bare bra"

Plan for today

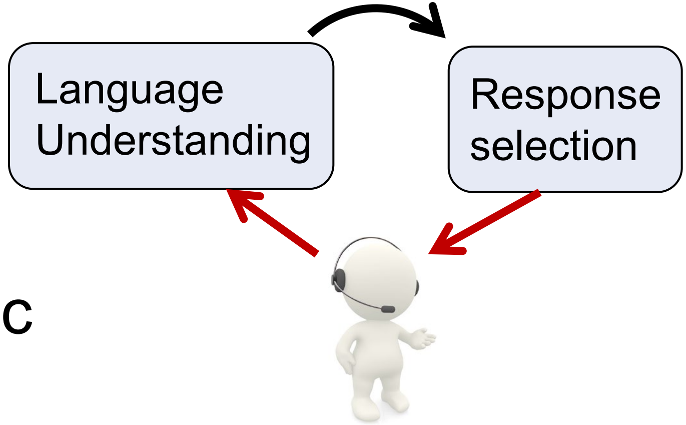
- ► A short intro to dialogue systems
- ► What is human dialogue?
- ► Basic chatbot models
- ► **Wrap up**

Summary (1)

Dialogue = **joint social activity**

- Dialogue participants take *turns*
- Each turn is composed of one or several *dialogue acts*
- Cooperation to ensure mutual understanding (gradual expansion of *common ground*)
- Cooperative interpretation of each other’s utterances (*conversational implicatures*)
- Takes place in a *context* which is crucial for making sense of the interaction (cf. *deictics*)

Summary (2)

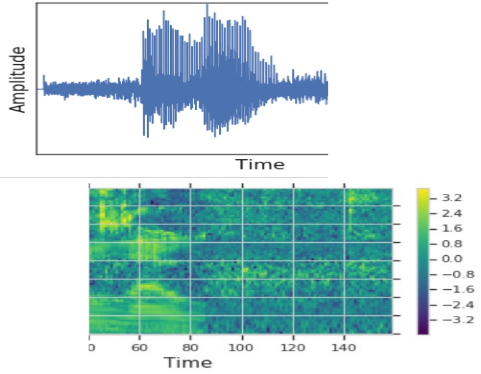


We also looked at basic models for chatbots:

- **Rule-based systems**, which map *conditions* (e.g. surface patterns on the user utterance) to *responses*
- **IR-based systems** searching for the most similar utterance in a dialogue corpus, and then selecting the utterance after it

Next week

- In the next lecture, we'll look at more advanced chatbot models
  - Other corpus-based approaches: dual encoders, sequence-to-sequence
  - NLU-based approaches (intent & slot recognition)
- + short intro to phonetics & speech recognition!


Amplitude
Time
Time