Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

Dialogue systems & chatbots

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IN4080: Natural Language Processing (Fall 2020)

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The next 3 weeks

What are they?
What applications?

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

Dialogue systems

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

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

Plan

- **5/10 (today):**
  - What is dialogue?
  - Basic chatbot models
- **12/10 (next Monday)**:
  - Chatbots (cont') & NLU
  - Short intro to speech recognition
- **19/10 (in two weeks)**:
  - Dialogue management
  - System design & evaluation

Assignment

- Oblig 3 starting next week
  - Deadline: november 6
- Three parts:
  - **Chatbots:** build a 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 26 of the upcoming version (v3) of Jurafsky & Martin's SLP book
  - & part of chapter 27 on phonetics
  - & dialog chapter from previous J&M edition
- + a few additional references listed in the weekly syllabus for the course

Plan for today

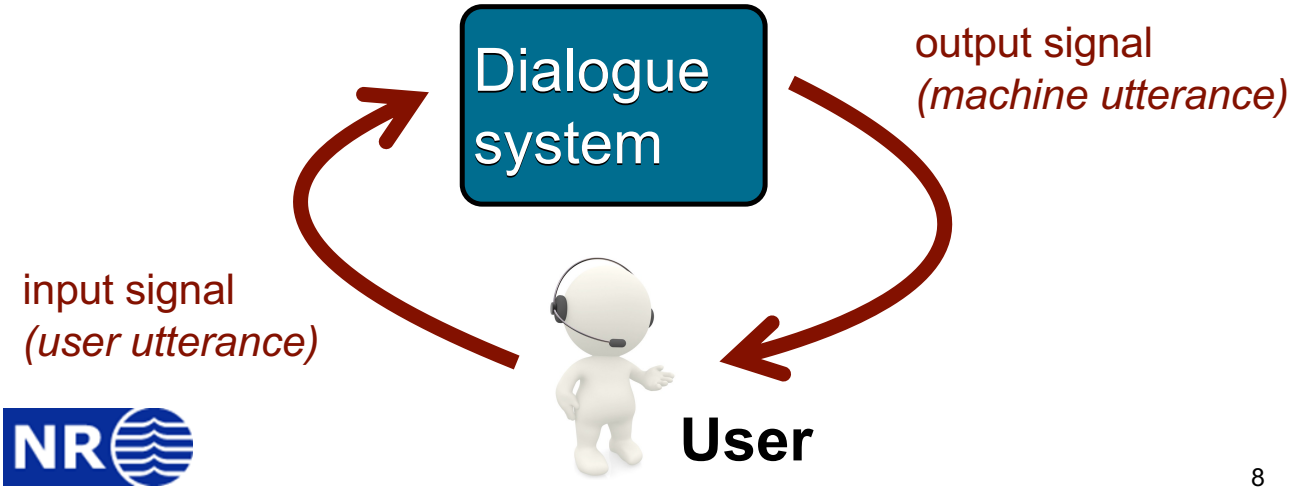
- A short intro to dialogue systems
- What is human dialogue?
- Basic chatbot models

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*

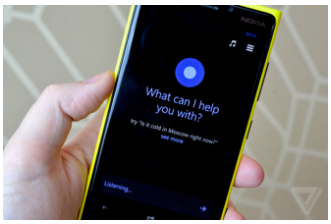


What for?

- **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.)

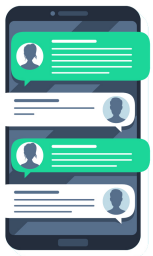


Smart home environments

In-car navigation & control

Tutoring systems

Chatbots



Service robots

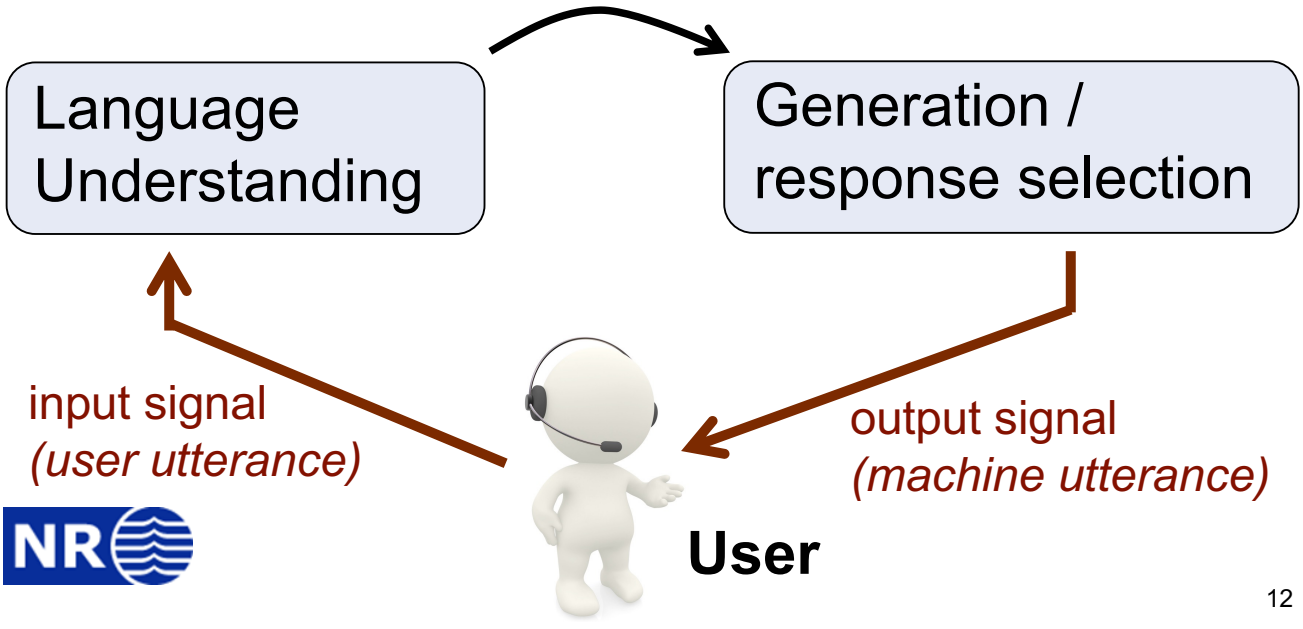
Why is it interesting?

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

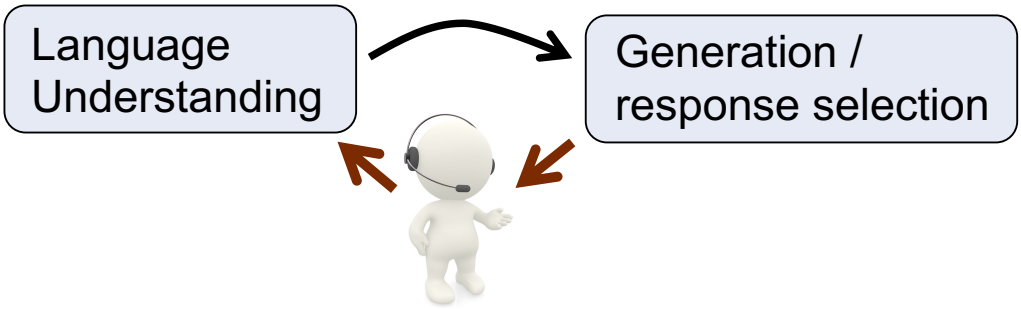
- Study language «as a whole», as it is used in real interactions
- Playground for key AI problems:
  - *Sense*, *reason* and *act* under uncertainty
  - Capture the *context* & *other agents*

Basic architecture

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



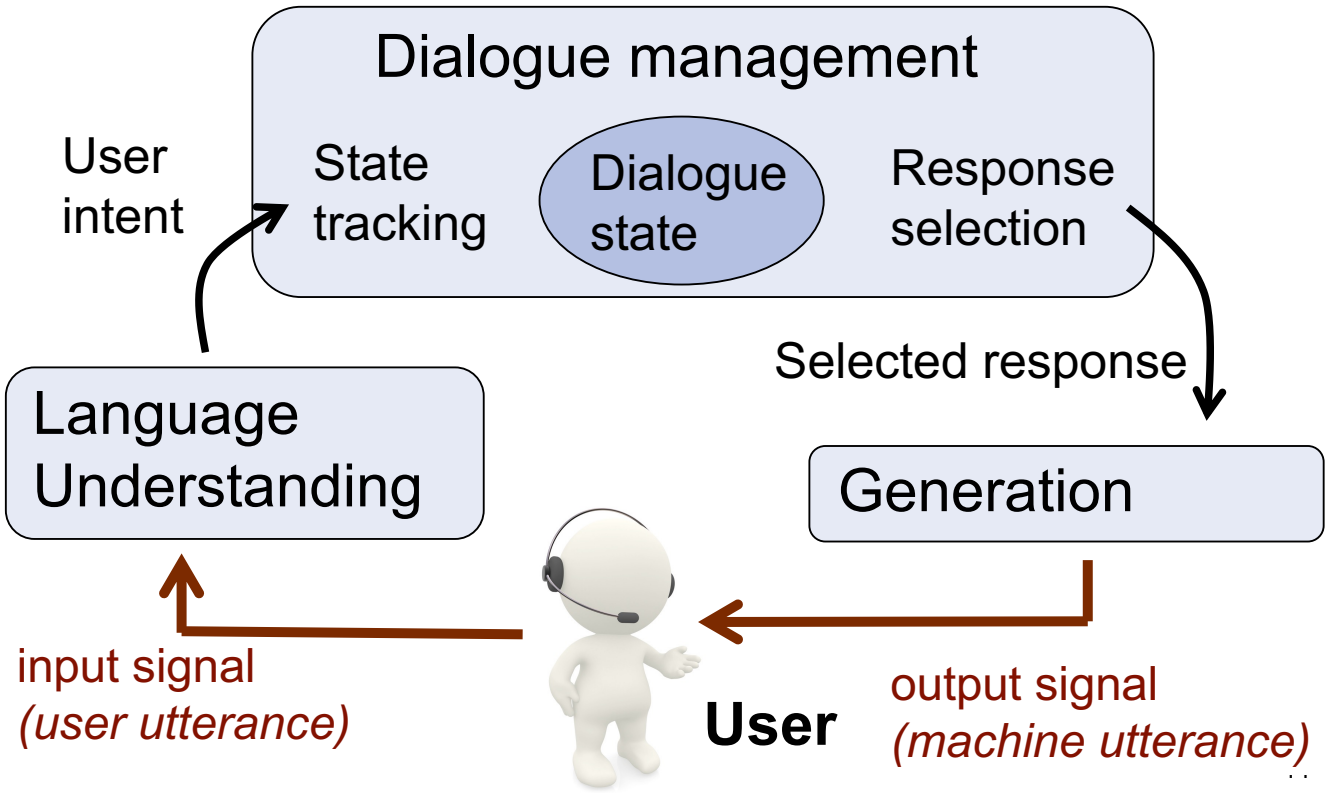
Basic architecture



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



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**?

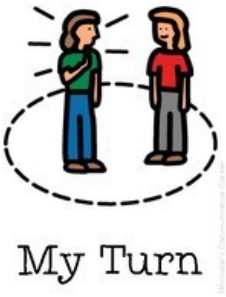
Turn-taking

- 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



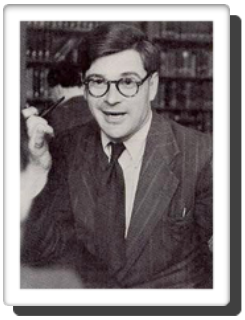
Example of turn-taking

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

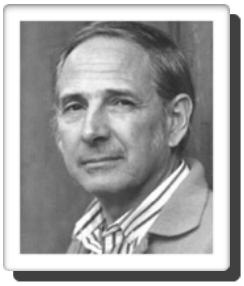
[«*Norske talespråkskorpus - Oslo delen*» (NoTa), collected and annotated by the Tekstlaboratoriet]

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

[J. L. Austin (1955), *How to do things with words*.]

Dialogue acts

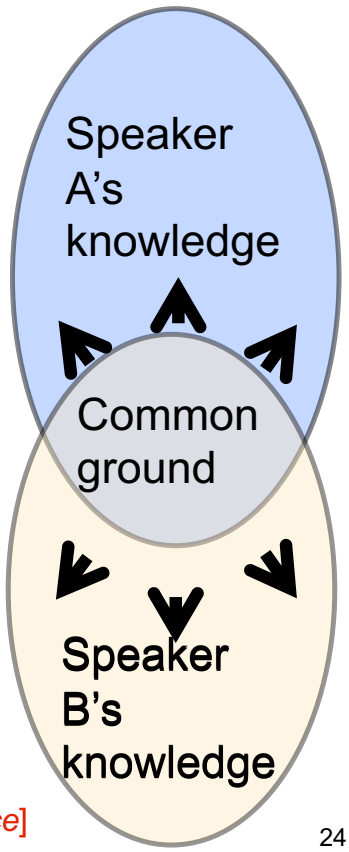
- The mother reaction has a specific **purpose**
  - Communicating her suprise/anger, and stop Calvin
- Her question will trigger some **effects**:
  - A psychological reaction from Calvin (e.g. surprise)
  - Possibly a real-world effect as well (Calvin stopping his action)

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
(1947,-)
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)

[«*Norske talespråkskorpus - Oslo delen*» (NoTa), collected and annotated by the Tekstlaboratoriet]

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

[«*Norske talespråkskorpus - Oslo delen*» (NoTa), collected and annotated by the Tekstlaboratoriet]

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 :

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

Conversational implicatures

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

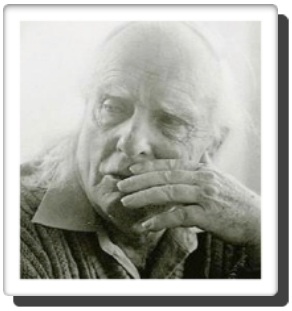
  A: «Is William working today?»

  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

[Paul Grice (1975), *Logic and Conversation*.]

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

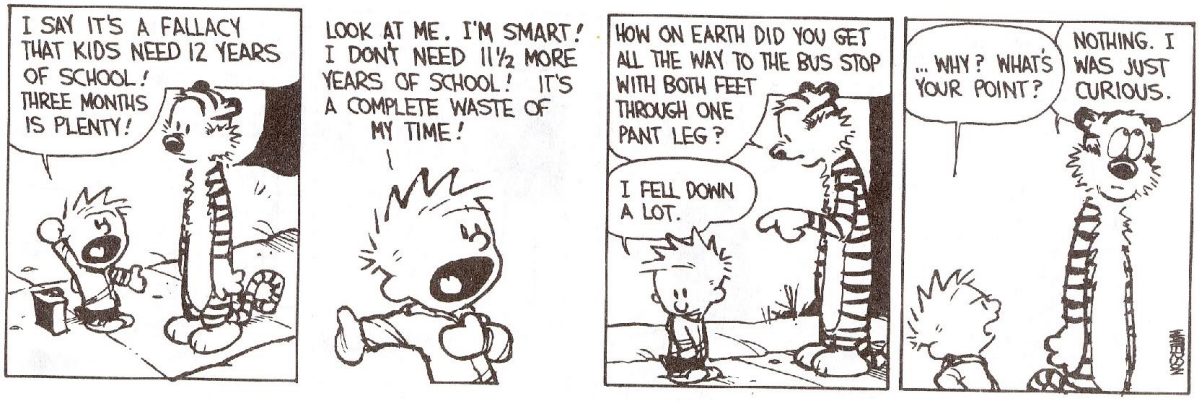
Conversational implicatures

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



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:

Which maxim is violated here?

Social interactions

- 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 (1999), *The cultural origins of human cognition*.]

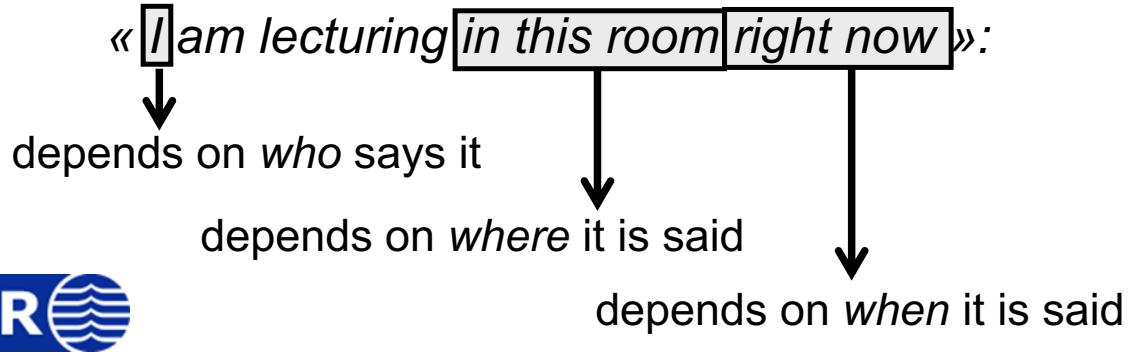
Alignment

- 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*]

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)



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

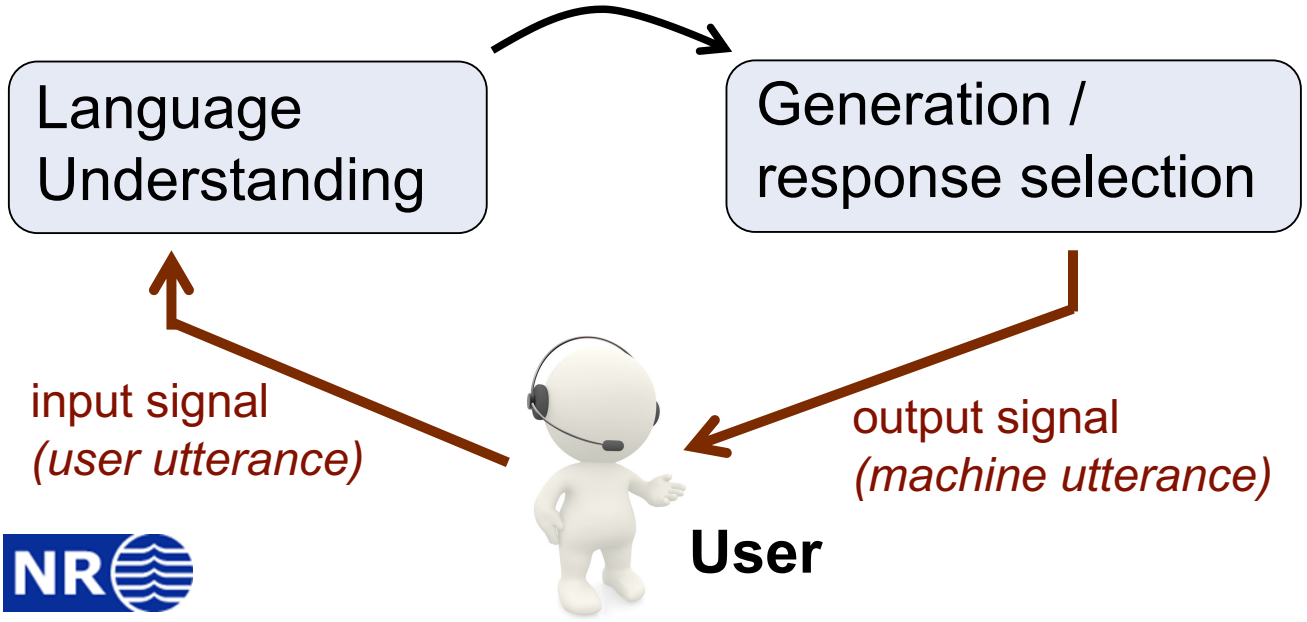
- Deictics can refer to virtually anything:
  - Objects: «take that mug»
  - Events: «don't do that», «this car accident was awful»
  - Persons: «You're being an idiot»
  - Abstract entities: «This methodology is flawed»
- Perspective is important:

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.)



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

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

- 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								

Example

$\log(6) \approx 0.78$

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

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

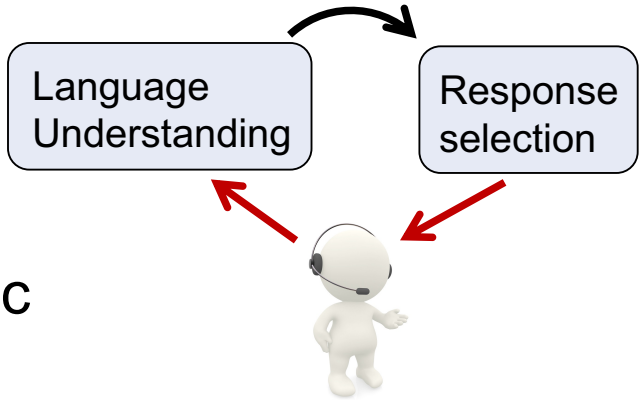
- A short intro to dialogue systems
- What is human dialogue?
- Basic chatbot models
- **Wrap up**

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!