Artificial Intelligence
3rd year, 1st semester

Natural Language Processing

"Science is what we understand well enough to explain to a computer; art is everything else."— Donald E. Knuth

Language - a structured system of communication.

Structured system - has items, relations between them and (production) rules over them

Communication - there has to be a semantic association from that language to the outside of it

Intelligence uses and builds knowledge and language.

Sapir-Whorf and Neurolinguistics

Natural (human) languages   vs   Formal languages

(Full ?) Expressive power   Limited expressiveness

Personal interpretation   Unambiguous
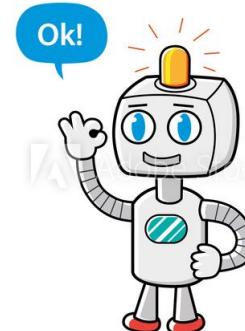
Dynamic   Little dynamism

Easy to learn   Harder to learn
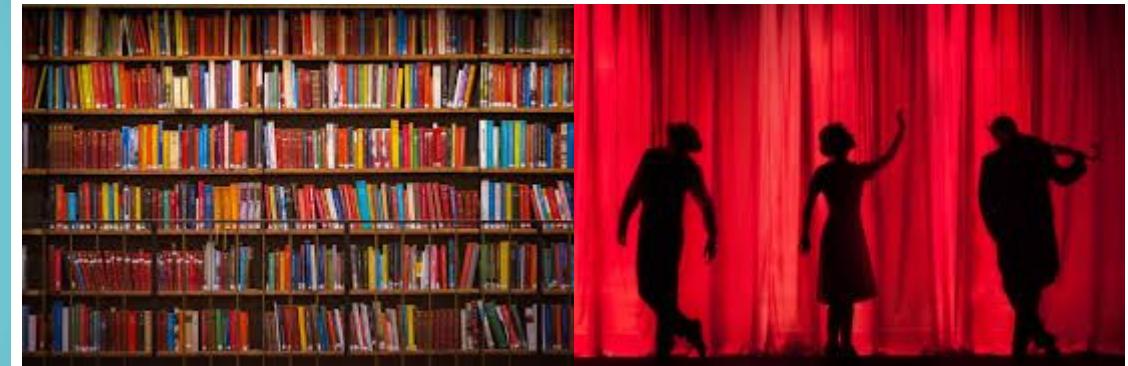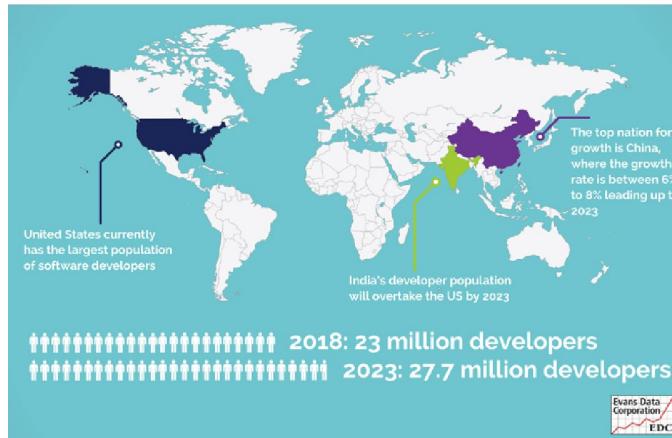
Does the computer need human language?

- Accessibility
- Access to resources
- Expressiveness

THE NUMBER OF SOFTWARE DEVELOPERS IN THE WORLD

Example: Virtual assistants

Apple's Siri

Amazon's Alexa
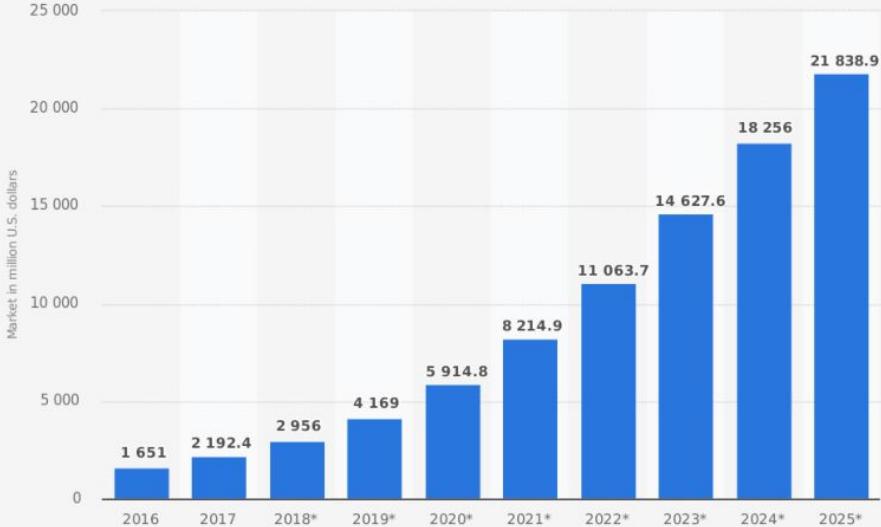
Microsoft's Cortana

Google's Assistant

Size of the enterprise virtual digital assistant (VDA) market worldwide from 2016 to 2025 (in million U.S. dollars)

Year	Market in million U.S. dollars
2016	1 651
2017	2 192.4
2018*	2 956
2019*	4 169
2020*	5 914.8
2021*	8 214.9
2022*	11 063.7
2023*	14 627.6
2024*	18 256
2025*	21 838.9

Source
Tractica
© Statista 2018

Additional Information:
Worldwide; Tractica; 2016 to 4th quarter 2017

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OK, now what?

We already know that:
- Language has items, relations between them and (production) rules over them
- There has to be a semantic association from that language to the outside of it
- Language has generous expressive power and is dynamic

Types of NLP

Text analysis: understand the meaning of a natural language message.

Text generation: convey a meaning in natural language.

Speech processing.

Other multimodal applications: for example, sign language translation/transcription.
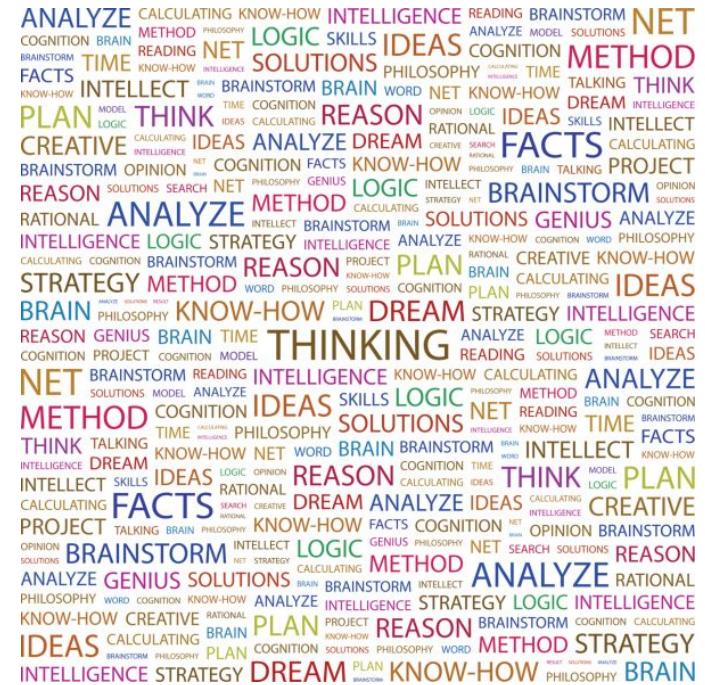
Text analysis: morphological level

Morphology: morpho = form

First step: developing a vocabulary

Recognize words as belonging to your
language: is a dictionary enough?

Example

Why not 100%?

How many words are in "F.B.I."?

Is "F.B.I." a word?

How about "eccedentesiast"?

Text analysis: lexical level

Lexicology : lexicos = of words

How words are formed:
- Lemmas
- Suffixes and prefixes
- Syllables
- Morphemes
- Parts of speech

Further reading
How to split a word in syllables?

	thermometer	an instrument for measuring temperature
	thermal	relating to or caused by heat or changes in temperature
	Thermos	a container which is used to keep hot drinks hot and cold drinks cold

How does a Part-Of-Speech tagger work?

1. Identify lexical tokens: `The/students/are/learning/.`
2. Identify lemmas: `The/student-s/be-are/learn-ing/.`
3. Use a lexicon and match unambiguous lemmas:
   `D-The/student-s/V-be-are/learn-ing/P-.`
4. Use a language model to disambiguate the rest:

D	N	V	V	P	250
D	V	V	V	P	18
D	A	V	AV	P	5

Why not 100%?

"Time flies like an arrow."

"Will, will Will will Will Will's will?"

Text analysis: syntactic level

Syntax: syn - together, taxis - arrange

Identify sentences/ discourse units.
Find the roles of words in a sentence.
(subject, predicate, complement,...)
Find syntactic relations between words.
(Noun Phrase, Anaphora, direct object,...)
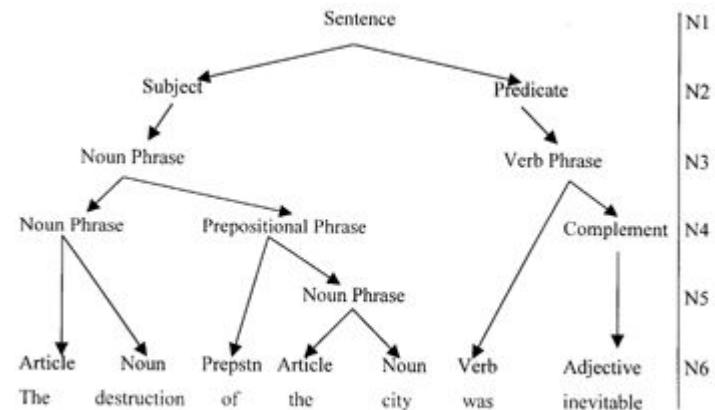
Further reading

Example

Why not 100%?

"Time flies like an arrow."

"We saw her duck."

"I saw the man on the hill with a telescope."
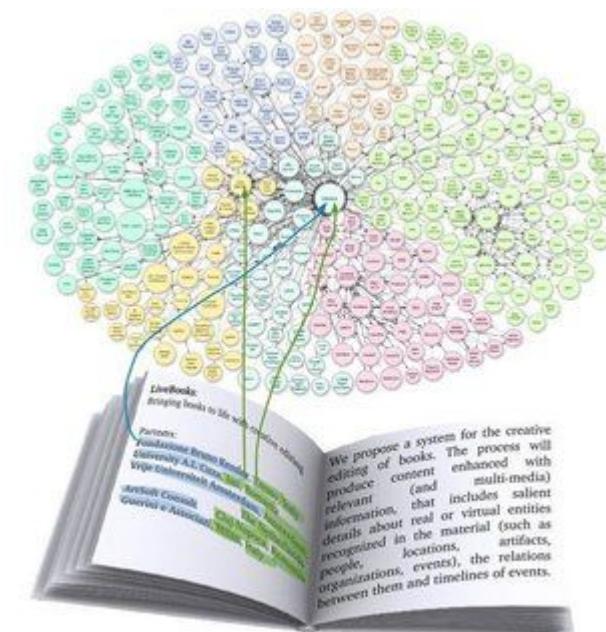
Text analysis: semantic level

Semantic: semantikos - significant

Associate meanings to words which have them.
(substantives, verbs, adjectives and adverbs)

Word Sense Disambiguation:
What are the possible senses of a word?
Is there a correct sense?

Further reading

Why not 100%?

"He's mad."

"You're done."

"We are far from each other."
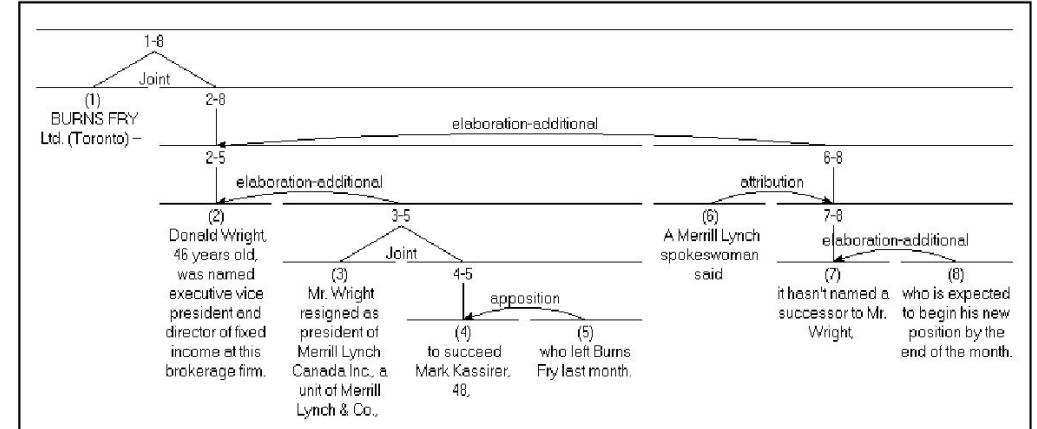
Text analysis: discourse level

Discourse: discursus - running around, going over something

What is the underlying structure of
a text?

Several representations:
- Rhetorical structure theory
- Centering theory
- Veins theory
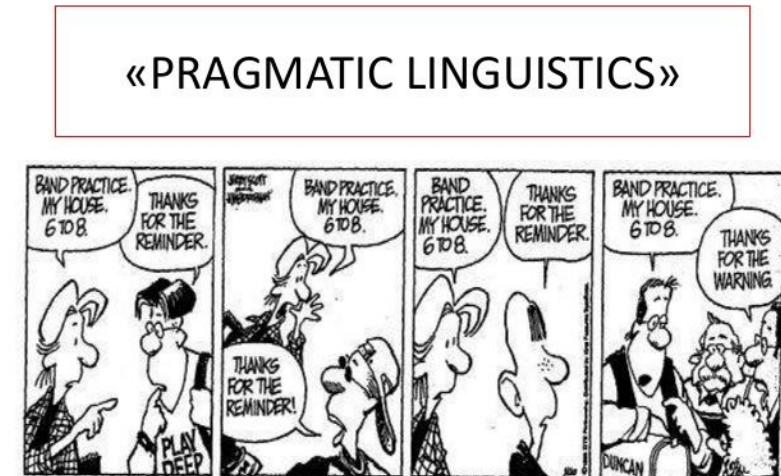
Text analysis: pragmatic level

Pragmatics: pragmatikos - fit for social activity

Context matters even for written text.
You have to identify the target of the message.
"Alexa, play a song."

Punctuation matters:
"I like to eat my family and my cat"

Prosody: tone and intonation matters.

Further reading

Text generation: I have knowledge, how do I communicate it?

Generally done by applying templates to knowledge.

`I have ?x ?y.`

Quantity	Type
20	apples

Often uses language models to determine most likely word to be used in the context.

have	possess	apples
180	5	frequency

Overview

Example systems: RosaeNLG, SimpleNLG

Brief history of conversational agents:
50s to 70s - templates and regular expressions

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```aiml
<aiml version="1.0.1" encoding = "UTF-8"?>
    <category>
        <pattern> HELLO ALICE </pattern>
        <template>
            Hello User
        </template>
    </category>
</aiml>
```

The following regex is sentient:

s/[Aa]re\s[Yy]ou\s\(.*\)?/Indeed, I am \1./

Input: "Are you sentient?"
Output: "Indeed, I am sentient."

**Input**: "Are you capable of intelligence?"
Output: "Indeed, I am capable of intelligence."
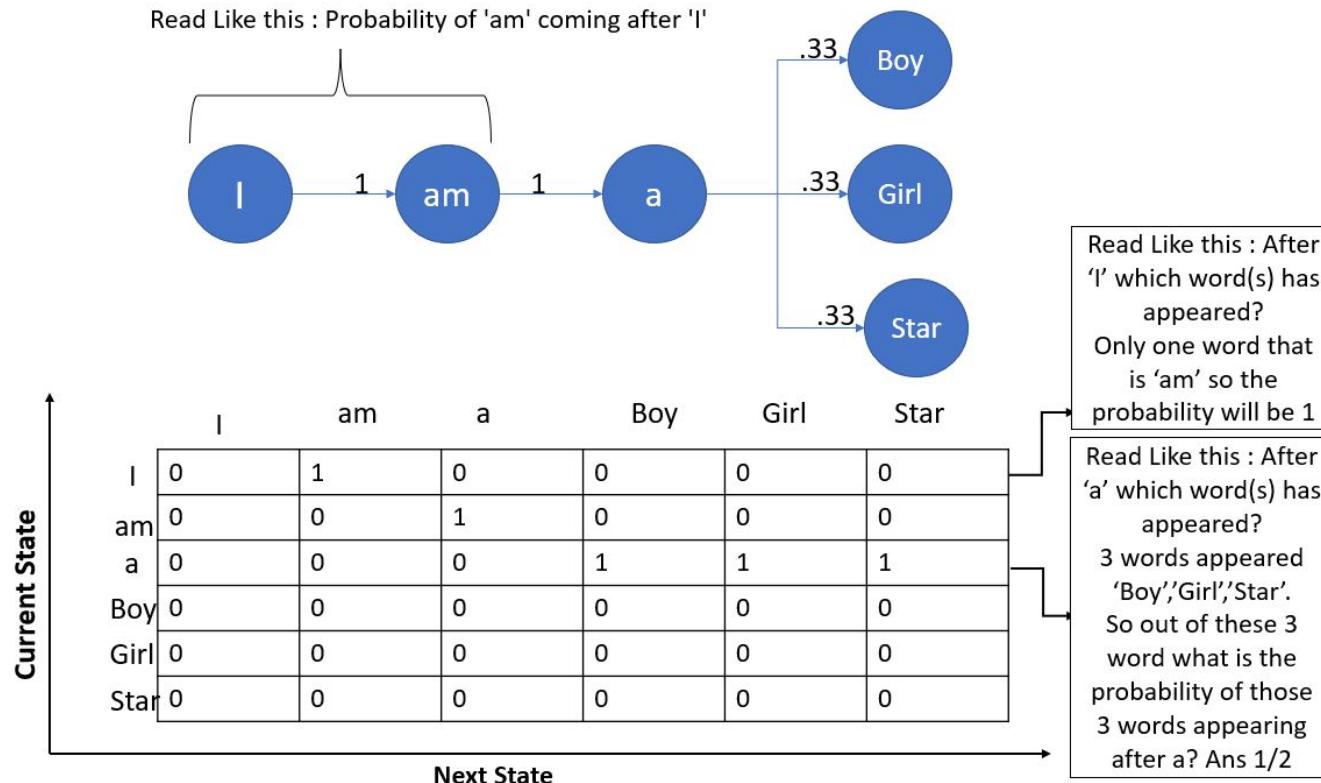
**Input**: "Are you going to take over the world?"
Output: "Indeed, I am going to take over the world."
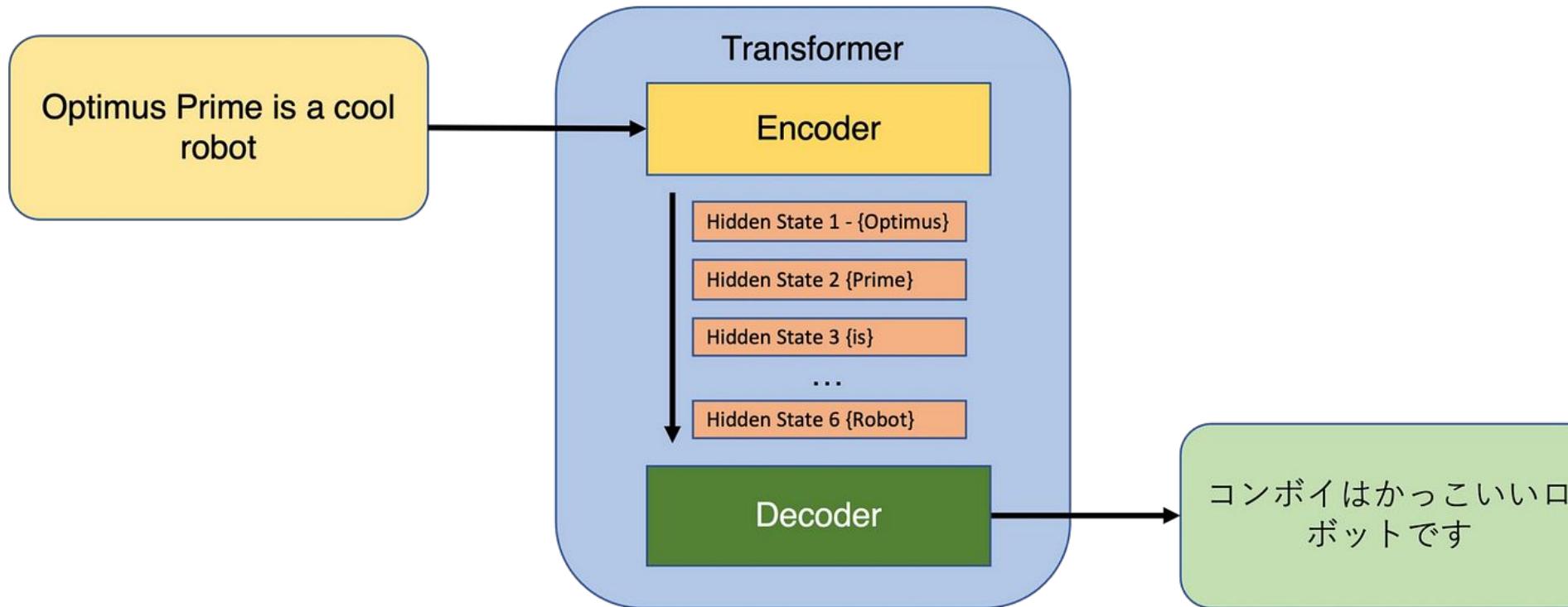
Brief history of conversational agents: 80s to 2000s - language models and Markov chains

Brief history of conversational agents: Current state-of-the-art - Transformers and Reinforcement Learning

Speech to text: what is that human speaking?

We use sounds, not words or letters.

Phonemes: sounds forming words.

I teach Artificial Intelligence.

aɪ tiːʧ ˌɑːtɪˈfɪʃ(ə)l ɪnˈtɛlɪʤəns.
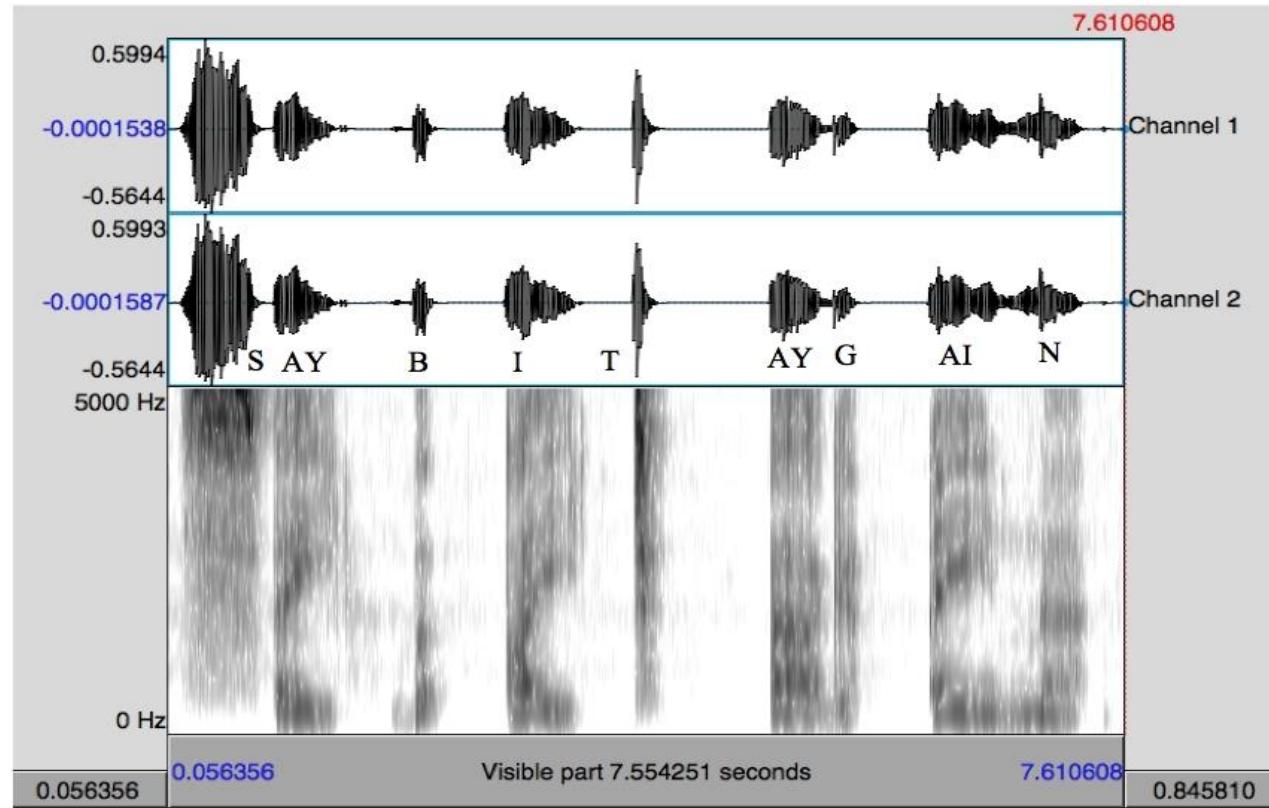
44 phonemes for English

International Phonetic Alphabet
Phonetic keyboard

Recognizing phonemes

Speech to text and reverse

Phonemes to words

r eh k ao g n ay z   s p iy ch   "recognize speech"

r eh k   ay   n ay s   b iy ch   "wreck a nice beach"

Language models
60k words - 216 trillion possible sets of 3 words

IBM Watson STT
DeepSpeech

Google Assistant

Multimodal NLP: how else can I communicate?

Using sign language:
[Google's MediaPipe](#)
[Demo for Amazon Echo](#)
[Let's TalkSign](#)

Lip reading
[Deep Lip Reading](#)
[Google's DeepMind](#)
[Demo](#)

Handwriting recognition
[Overview](#)

NLP resources

CLARIN VLO

LRE Map

Linguistic Data Consortium

General Architecture for Text Engineering (GATE)

Apache UIMA