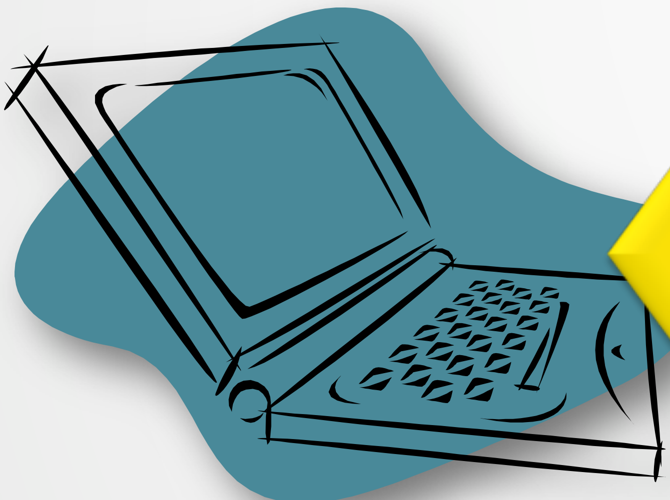
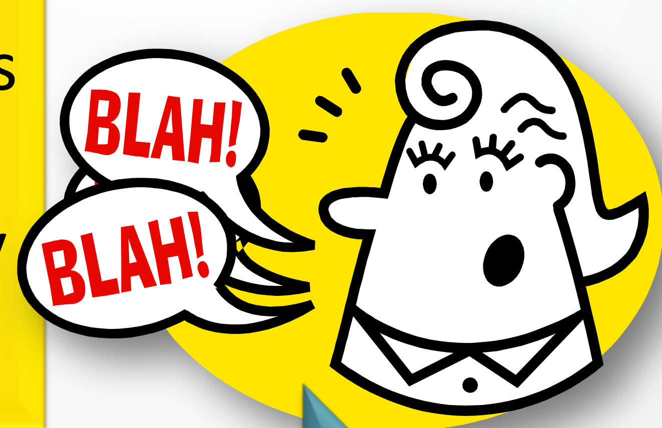

401
ONTARIO
NATURAL
LANGUAGE
COMPUTING

What is natural language computing?



Getting computers to understand everything we say and write.



In this class (and in the field generally), we are interested in learning the ***statistics of language***.

Increasingly, computers give insight into how humans process language, or generate language themselves.

Today

- Basic definitions in **natural language processing (NLP)**.

- Applications
  - Translating between languages
  - Speech recognition
  - Answering questions
  - Engaging in dialogue

  Examples

- Course logistics.

What can natural language do?

The ultimate in **human-computer interaction**.

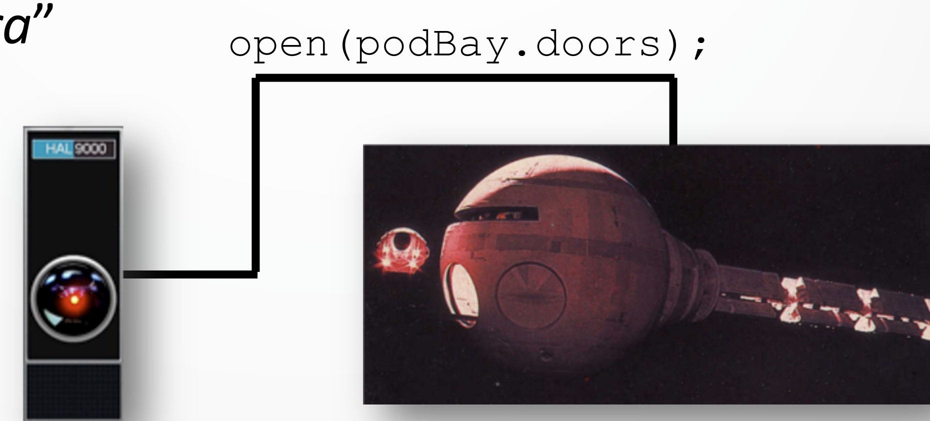
“translate *Also Sprach Zarathustra*”

“take a memo…”

“open the pod bay doors”

“how far until Jupiter?”

“Can you summarize *2001: A Space Odyssey?*”



We’re making progress, but why are these things *still* hard to do?

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A little deeper

- Language has ***hidden structures***, e.g.,
  - How are **sounds** and **text** related?
    - e.g., why is this:  not a '*ghoti*' (*enou**gh***, *w**o**men*, *na**ti**on*)?
  - How are words **combined** to make sentences?
    - e.g., what makes '*colourless green ideas sleep furiously*' **correct** in a way **unlike** '*furiously sleep ideas green colourless*'?
  - How are words and phrases used to produce **meaning**?
    - e.g., if someone asks *'do you know what time it is?'*, why is it **inappropriate** to answer *'yes'*?
- We need to organize the way we think about language…

Categories of linguistic knowledge

- **Phonology**: the study of patterns of speech sounds.
  e.g., “read” → */r iy d/*
- **Morphology**: how words can be changed by inflection or derivation.
  e.g., “read”, “reads”, “reader”, “reading”, …
- **Syntax**: the ordering and structure between words and phrases (i.e., grammar).
  e.g., *NounPhrase* → *article adjective noun*
- **Semantics**: the study of how meaning is created by words and phrases.
  e.g., “book” → 
- **Pragmatics**: the study of meaning in contexts.
  e.g., explanation span, refutation span

Ambiguity – Phonological

- Phonology: the study of patterns of speech sounds.

Problem for *speech synthesis*

"read"	→ */r iy d/*	as in *'I like to **read**'*
"read"	→ */r eh d/*	as in *'She **read** a book'*
"object"	→ */aa^1 b jh eh^0 k t /*	as in *'That is an **object**'*
"object"	→ */ah^0 b jh eh^1 k t /*	as in *'I **object**!'*

Problem for *speech recognition*

"too"	← /t uw/	as in *'**too** much'*
"two"	← /t uw/	as in *'**two** beers'*

- Ambiguities can often be **resolved** in context, but not always.
  - e.g., */h aw t uw r eh^1 k ah ?? n ay^2 z s (b|p) iy ch/*
    → *'how to recognize speech'*
    → *'how to wreck a nice beach'*

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Resolution with syntax

- If you hear the sequence of speech sounds

  /b ah f ae l ow b ah f ae l ow b ah f ae l ow b ah f ae l ow …
  b ah f ae l ow b ah f ae l ow b ah f ae l ow b ah f ae l ow/

  which word sequence is being spoken?

  → "Buff a low buff a lobe a fellow Buff a low buff a lobe a fellow…"
  → "Buffalo buff aloe buff aloe buff aloe buff aloe buff aloe …"
  → "Buff aloe buff all owe Buffalo buffalo buff a lobe …"
  → "Buff aloe buff all owe Buffalo buff aloe buff a lobe …"
  → **"Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo"**

- It's obvious (to us) that the last option is most likely because we have knowledge of **syntax**, i.e., grammar.

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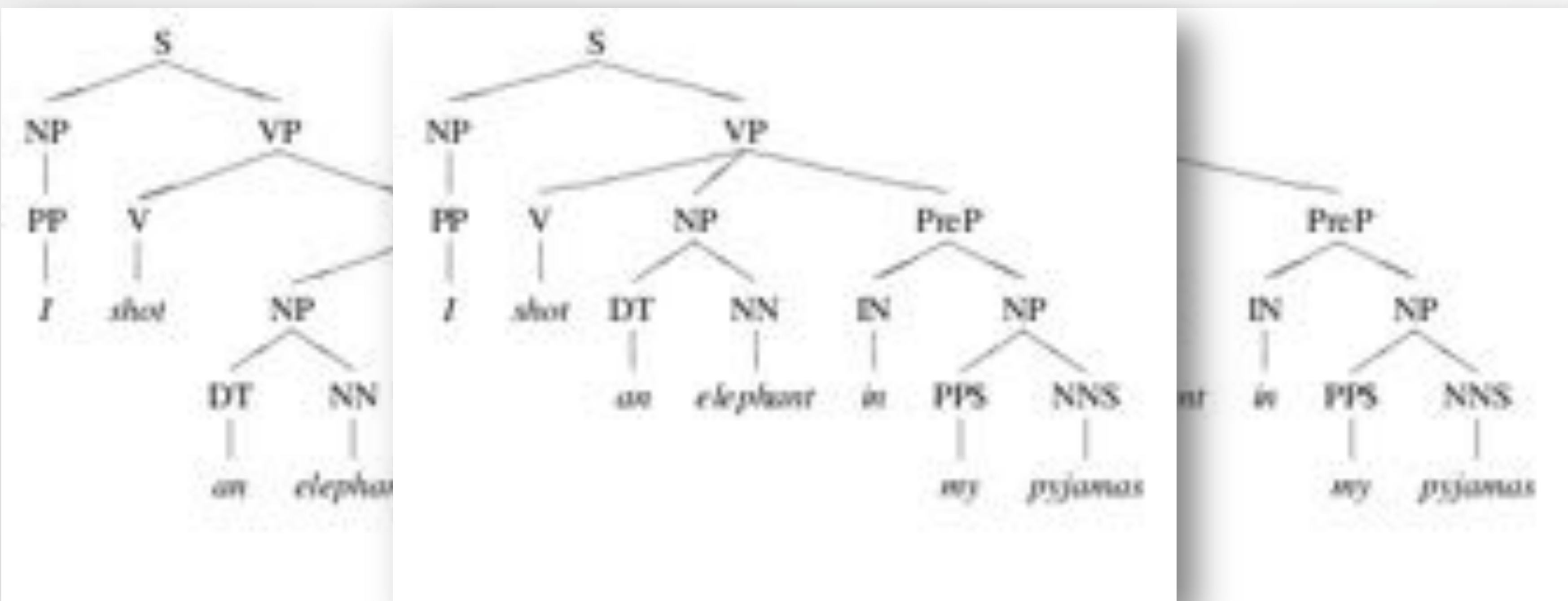
Ambiguity – Syntactic

- Syntax: the ordering and structure between words. Words can be grouped into 'parse tree' structures given grammatical 'rules'.

e.g., *"I shot an elephant in my pyjamas"*



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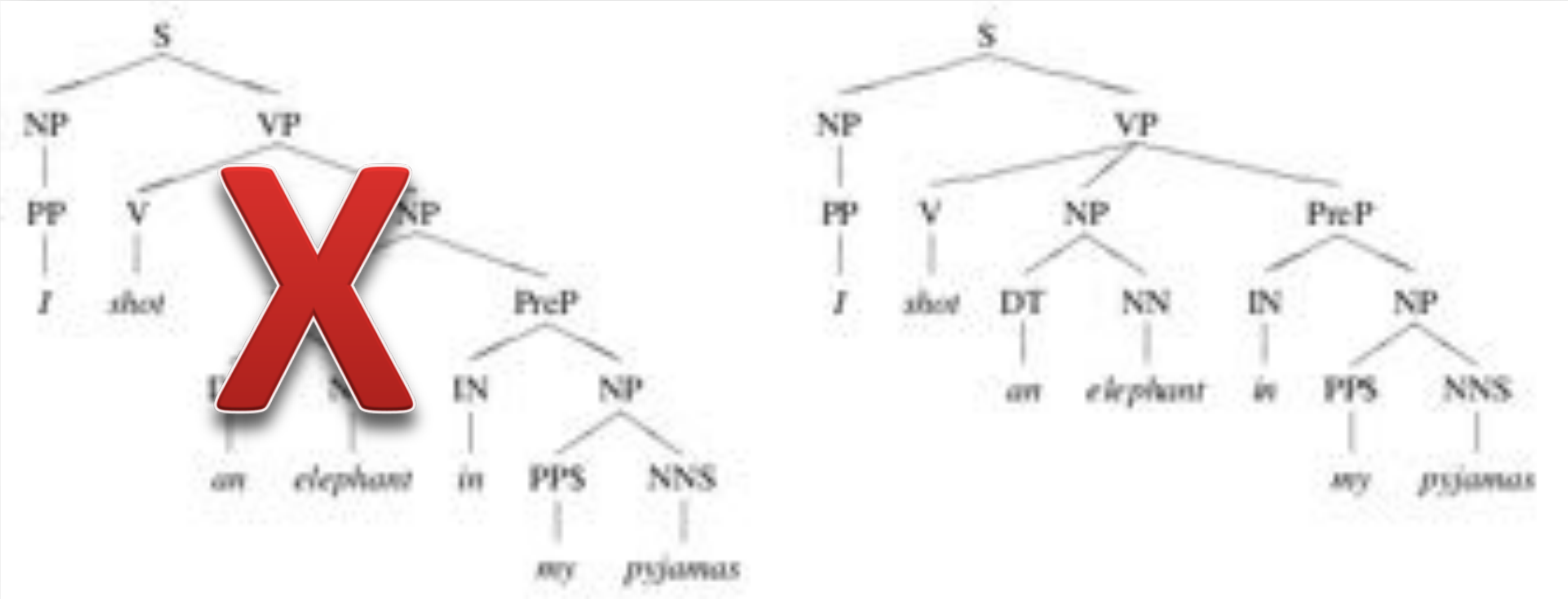
Resolution with semantics



- It’s obvious (to us) that the elephants don’t wear pyjamas, and we can discount one option because of our knowledge of **semantics**, i.e., meaning.

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Ambiguity – Semantic

- Semantics: the study of how meaning is created by the use of words and phrases.

  - "Every man loves a woman"
    → $\forall x\ man(x) \exists y: (woman(y)\ \wedge loves(x,y))$
    → $\exists y:\ woman(y) \wedge \forall x\big(man(x) \rightarrow loves(x,y)\big)$

  - "I made her duck"
    → I cooked waterfowl meat for her to eat.
    → I cooked waterfowl that belonged to her.
    → I carved the wooden duck that she owns.
    → I caused her to quickly lower her head.

  - "Give me the pot"
    → It's time to bake.
    → It's time to get baked.

Resolution with pragmatics

- It’s obvious (to us) which meaning is intended given **knowledge** of the **context** of the conversation or the **world** in which it takes place.

- “Every man loves a woman”
  - → $\forall x\ man(x) \exists y: \left(woman(y) \land loves(x,y)\right)$
  - ~~→ $\exists y: woman(y) \land \forall x\left(man(x) \rightarrow loves(x,y)\right)$~~

If you know that no one woman is so popular

- “I made her duck”
  - → I cooked waterfowl meat for her to eat.
  - ~~→ I cooked waterfowl that belonged to her.~~
  - ~~→ I carved the wooden duck that she owns.~~
  - ~~→ I caused her to quickly lower her head.~~

If the question was *“what type of food did you make for her?”*

- “Give me the pot”
  - ~~→ It’s time to bake.~~
  - → It’s time to get baked.

If the conversation is taking place in Canada

Ambiguity – miscellaneous

- Newspaper headlines (spurious or otherwise)

Kicking Baby Considered to be Healthy
...

Squad Helps Dog Bite Victim
...

Canadian Pushes Bottle Up Germans
...

Milk Drinkers are Turning to Powder
...

Grandmother of Eight Makes Hole in One
...

Kids Make Nutritious Snacks
...

Juvenile Court Tries Shooting Defendant
...

Local High School Dropouts Cut in Half
...

NLP as artificial intelligence

- NLP involves **resolving ambiguity** at all levels.
  - **Reasoning** with **world knowledge**.
    - In the early days knowledge was **explicitly encoded** in artificial **symbolic** systems (e.g., context-free grammars) by **experts**.

  - We tend to use **probabilities** (or pseudo-probabilities) to distinguish subtly different competing hypotheses.
    - E.g., is *Google* a noun or a verb?
    - Examples where $Google \in Nouns$ *("**Google** makes Android"),* does **not** mean that Google is never a verb ("*Go Google yourself*").

    - $P(Google \ \in Nouns) > P(Google \ \in Verbs) > 0$

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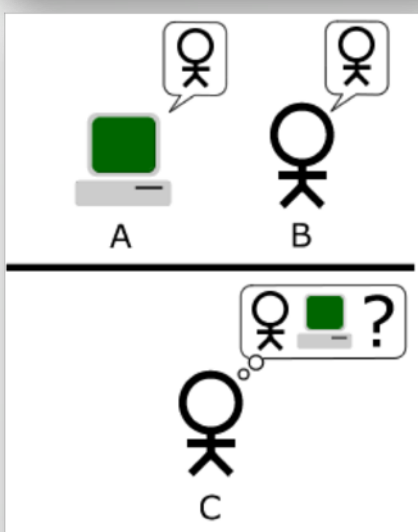
The Turing Test



- **First** and most **fundamental** test of machine intelligence.

- A machine (A) imitates a human using nothing but a text-based instant messenger.
  - If a human interrogator (C) cannot reliably differentiate a real human (B) from the machine, that machine is said to be 'intelligent'.

  - Turing, Alan M. (1950) Computing machinery and intelligence. *Mind*, **59**, pp. 433-460.

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Aside – Chatbots

- ELIZA (Weizenbaum, 1966): simple pattern matching to imitate a psychiatrist.
- Surprisingly effective despite **no linguistic knowledge**.
- e.g.,

```
User: Men are all alike.
ELIZA: In what way?
User: They're always bugging
us about something or other.
ELIZA: Can you think of a
specific example?
User: My boyfriend made me
come here.
ELIZA: Your boyfriend made you
come here.
```

(Jurafsky and Martin, 2009)

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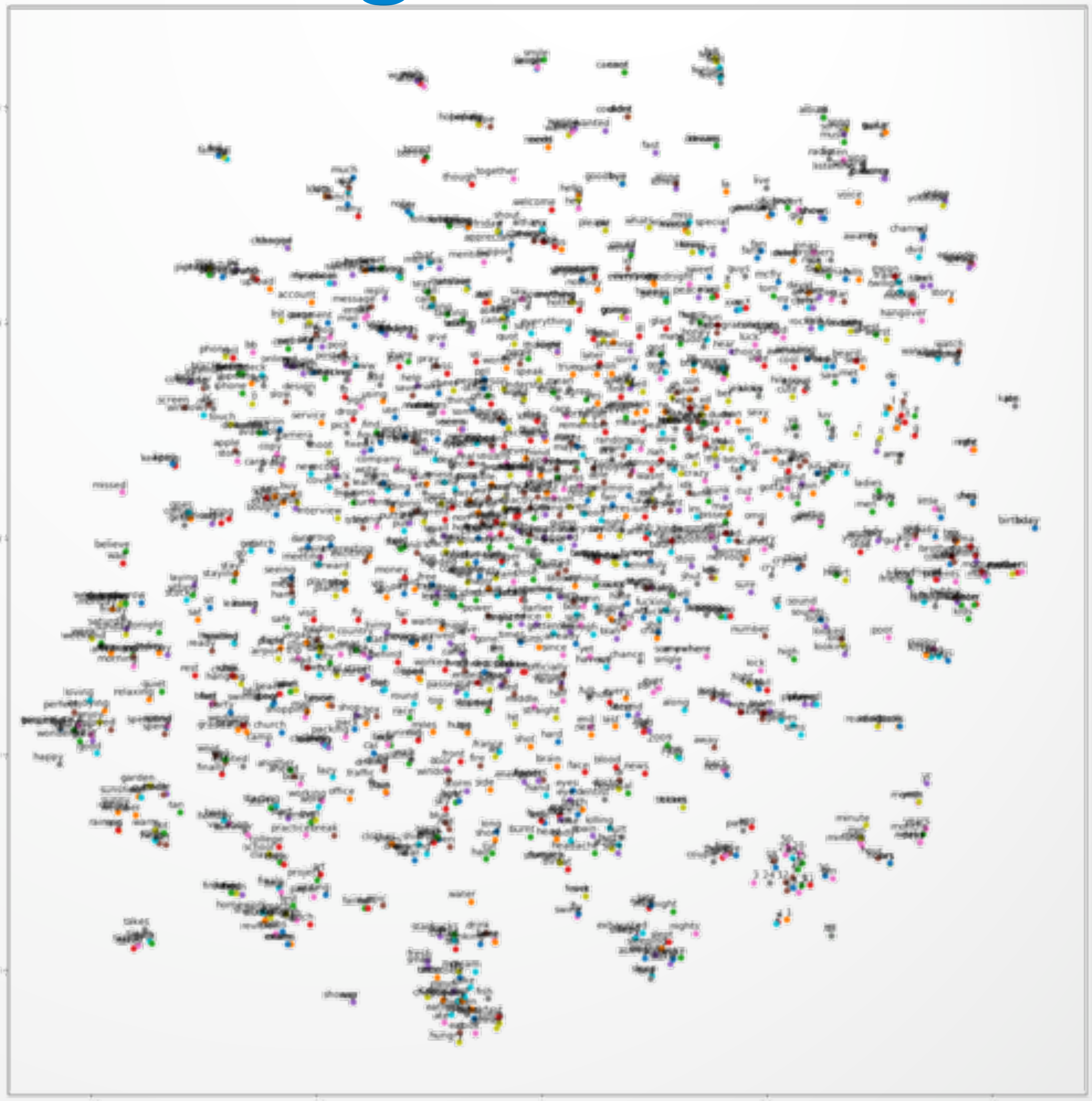
NLP as machine learning

- Modern NLP increasingly ignores linguistic theory in order to obtain models directly from data (visualized here)
- We still use linguistic theory to interrogate (or 'probe') the resulting models.



Course outline (approximate)

- Introduction, linguistic data, language models (3 lectures)
- Features and classification (1 lecture) *
- Entropy and information theory (2 lectures) *
- Neural language models (2 lectures) *
- Machine translation (3 lectures) **
- Hidden Markov models (3 lectures) *
- Articulatory and acoustic phonetics (2 lectures) *
- Automatic speech recognition (2 lectures) **
- Speech synthesis (1 lecture) **
- Information retrieval (1 or 2 lectures) **
- Dialogue and chatbots (1 or 2 lectures) **
- Review (1 lecture)

* techniques ** applications

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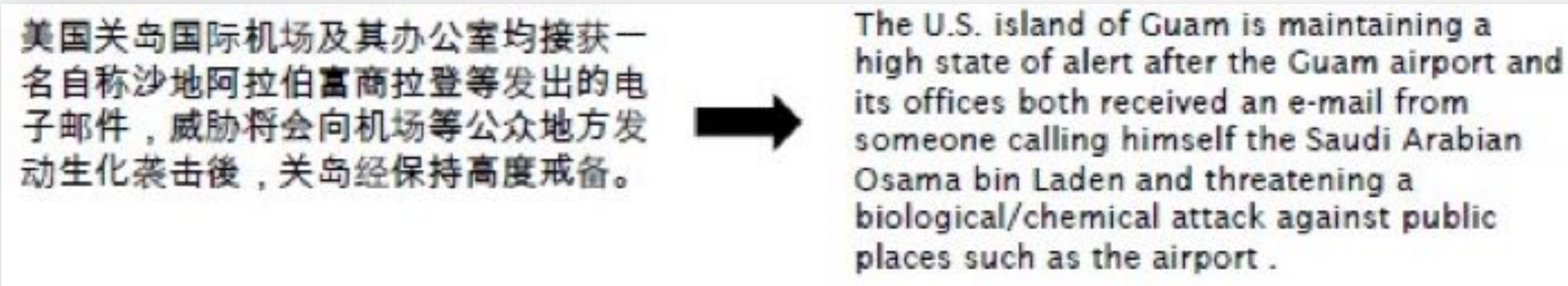
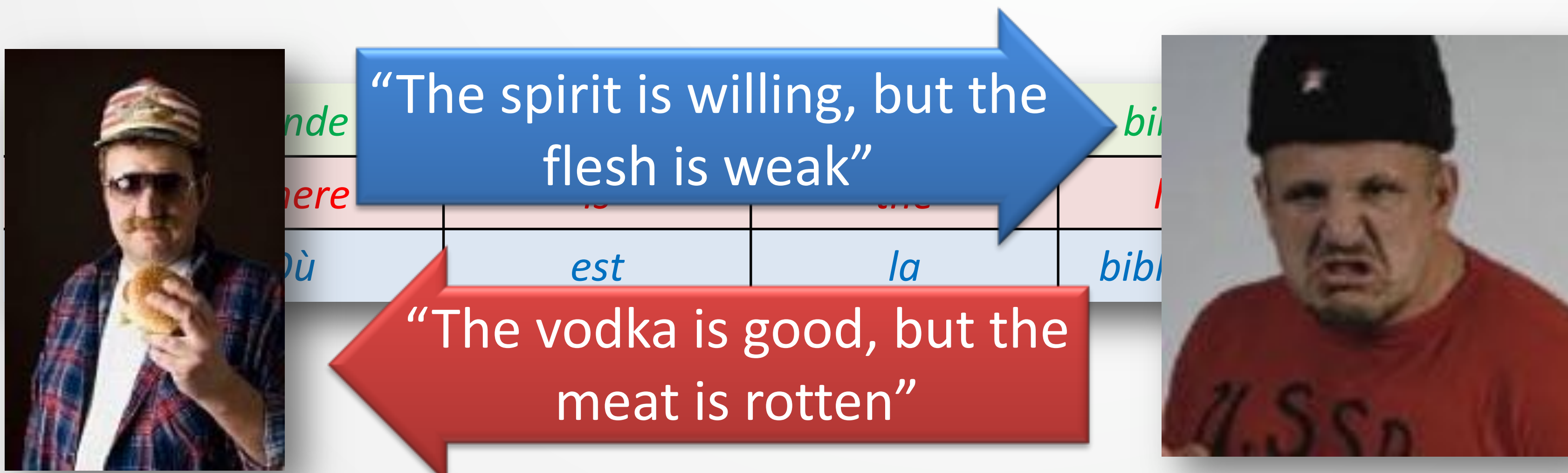
Preview: Machine translation



- One of the most prized applications in NLP.
- Requires both **interpretation** and **generation**.

Preview: Machine translation

- Initially, direct **word-for-word** replacement was popular.
  - Due to semantic and **syntactic ambiguities** and **differences** in source languages, results were mixed.



US English

Russian

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Preview: Machine translation

- One problem is disparity of meanings in languages.

nation *n.* a large body of people, associated with a particular **territory**, that is sufficiently conscious of its **unity** to seek or to possess a **government** of its own

nation *n.* an aggregation of persons of the same **ethnic family**, often speaking the same **language** or cognate **languages**

Stephen Harper

Former Prime Minister of Canada

Pauline Marois

Former Première Ministre du Québec

Preview: Machine translation

- Solution: automatically learn statistics on parallel texts

… citizen of Canada has the right to vote in an election of members of the House of Commons or of a legislative assembly and to be qualified for membership …

… citoyen canadien a le droit de vote et est éligible aux élections législatives fédérales ou provinciales …

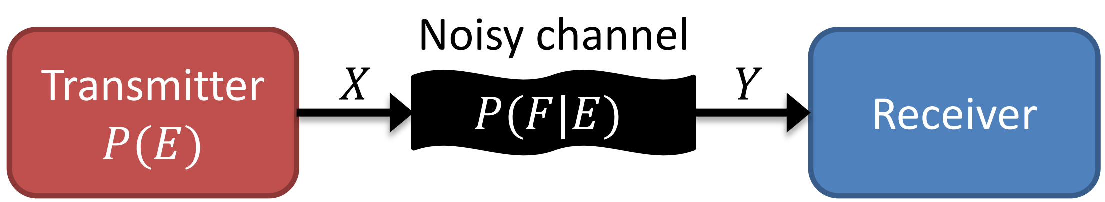
e.g., the *Canadian Hansards*:
bilingual Parliamentary proceedings

Statistical machine translation

- Much of modern statistical machine translation is based on the following perspective…

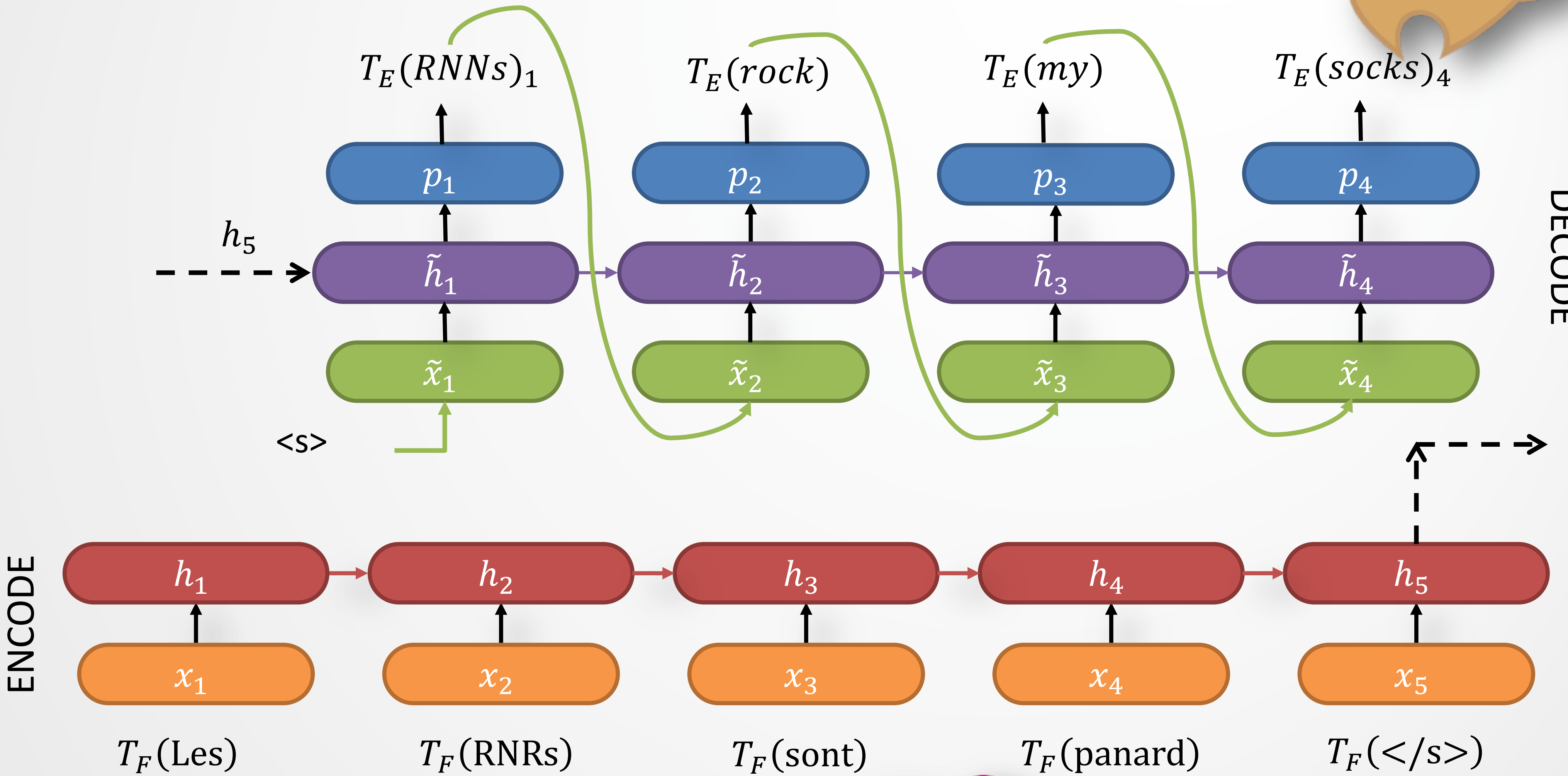
When I look at an article in Russian, I say: 'This is really written in English, but it has been **coded** in some strange symbols. I will now proceed to **decode**.'

Warren Weaver March, 1947

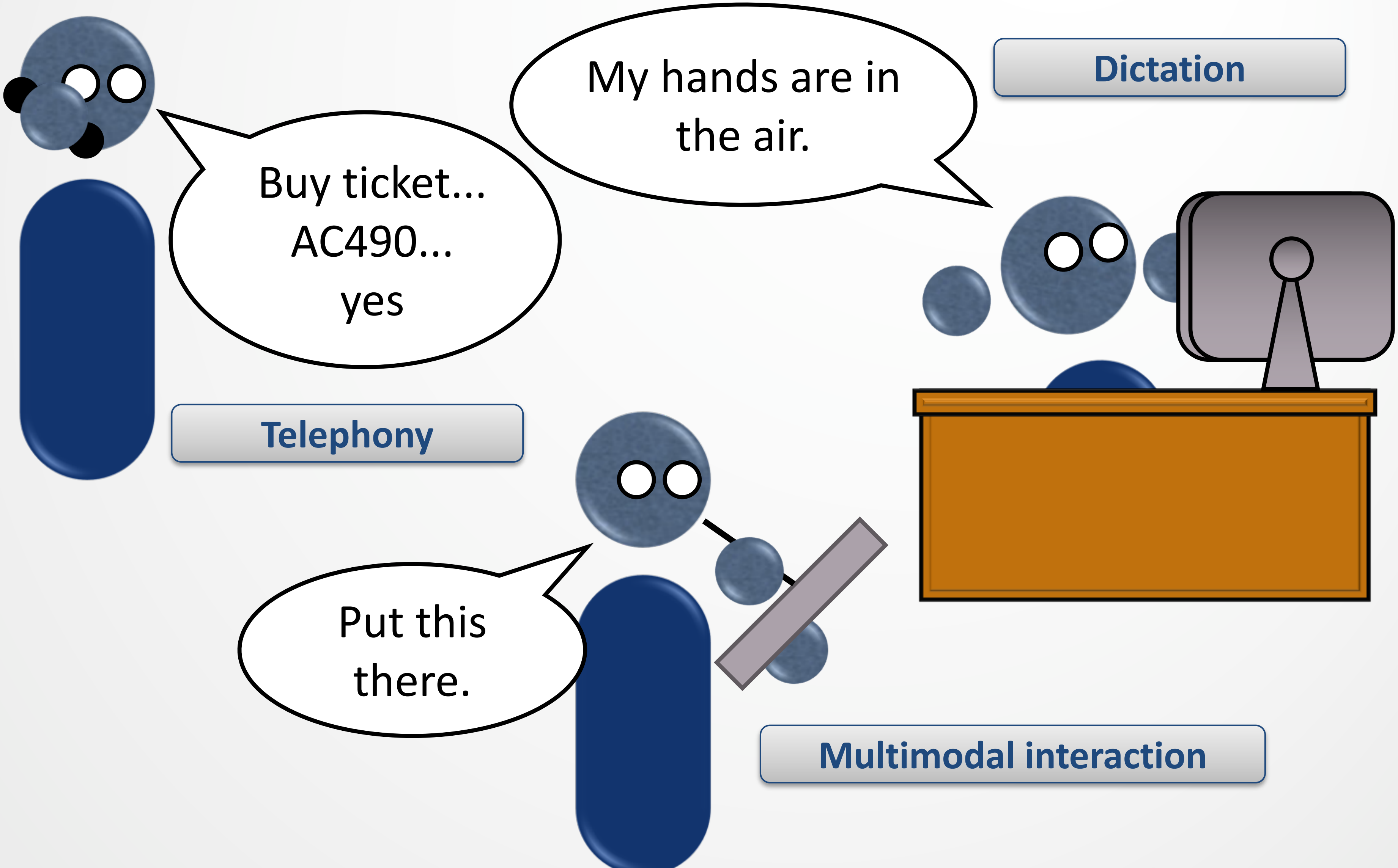


Claude Shannon July, 1948

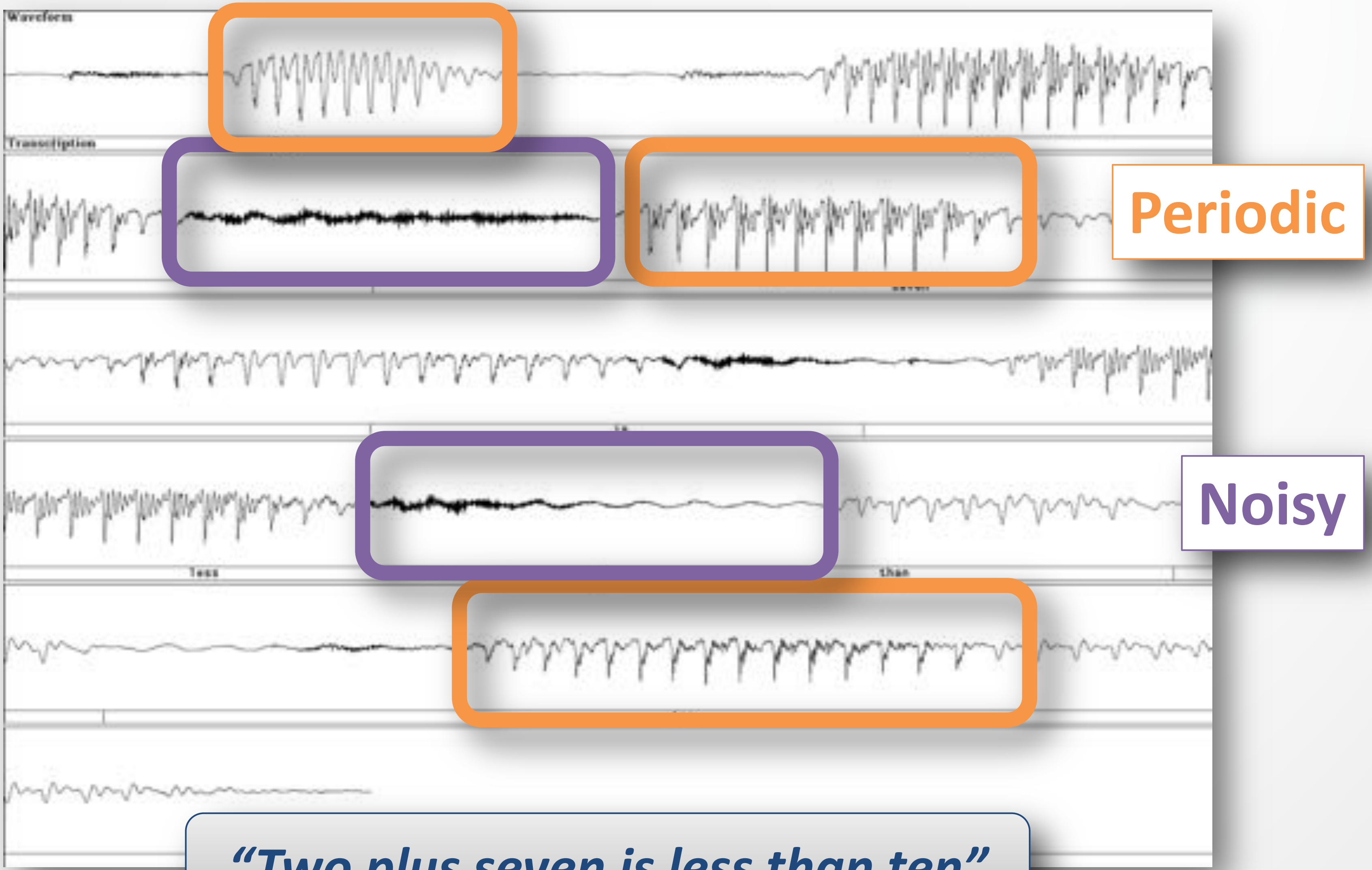
Neural machine translation



Preview: Speech recognition



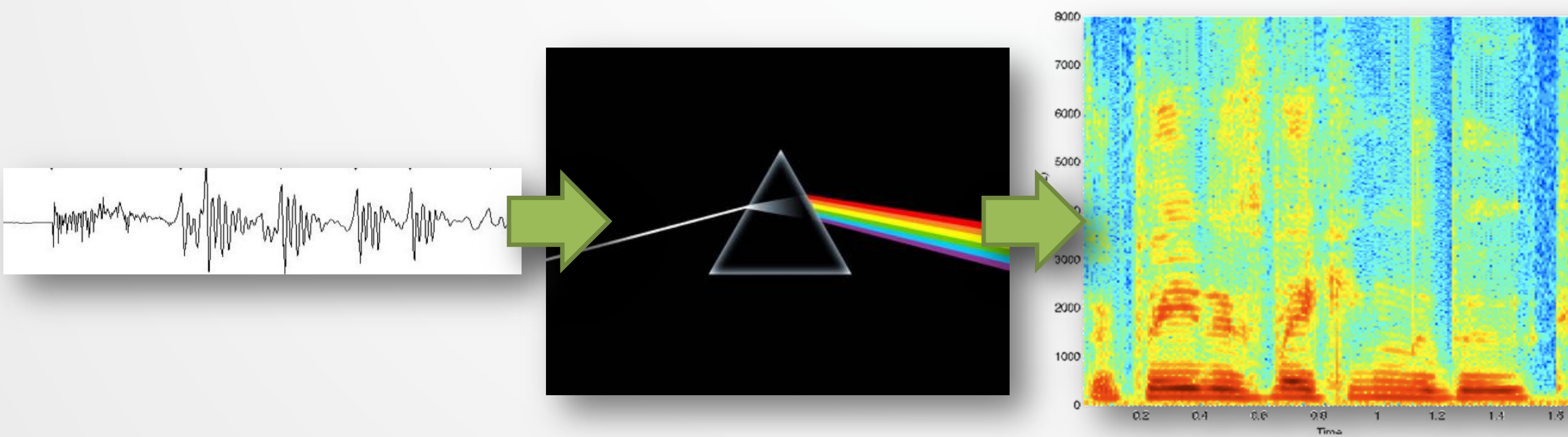
Speech waveforms



“Two plus seven is less than ten”

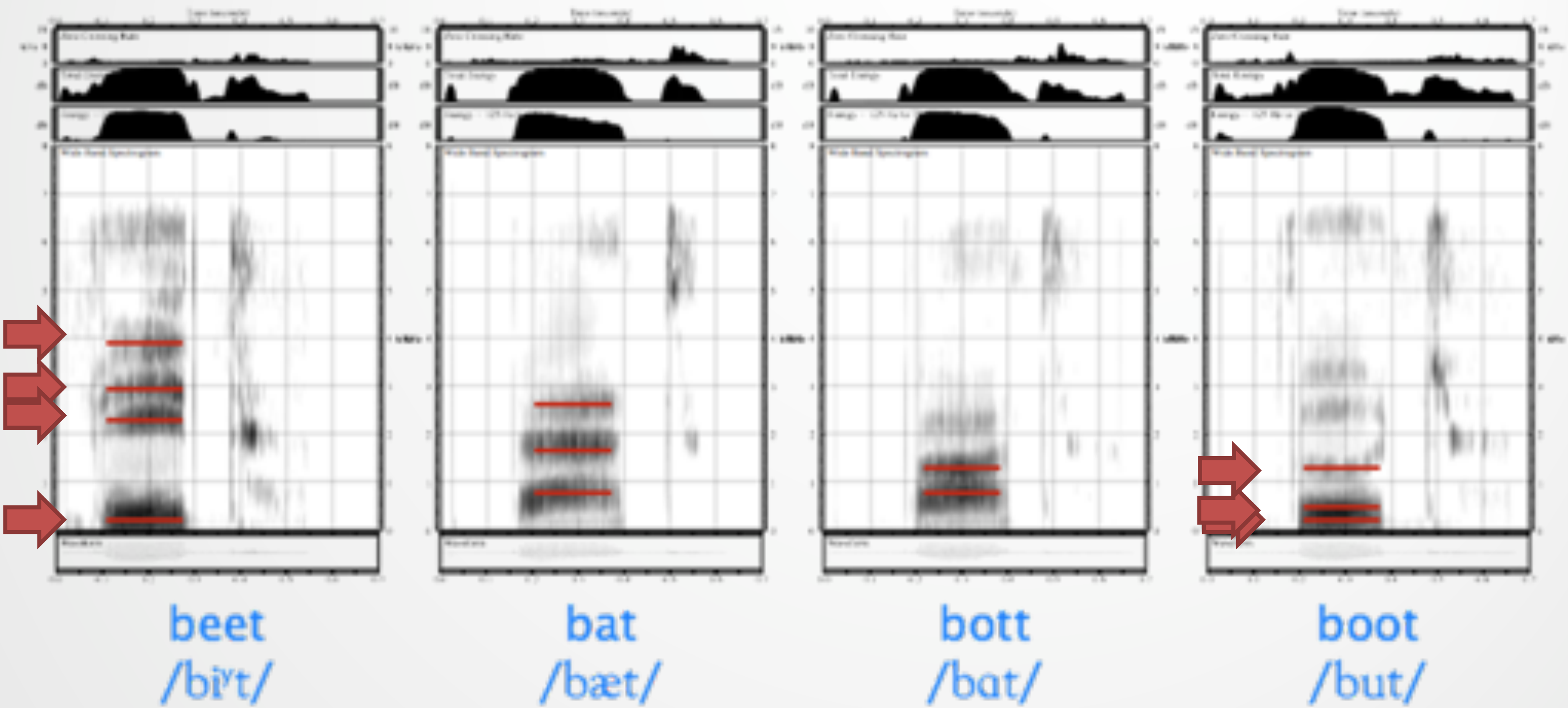
Spectrograms

- Speech sounds can be thought of as overlapping **sine waves**.
  - Speech is **split apart** into a 3D graph called a ‘**spectrogram**’.
  - Spectrograms allow machines to extract **statistical features** that differentiate between different kinds of sounds.



Speech waveform | Fourier transform | Spectrogram

Speech recognition



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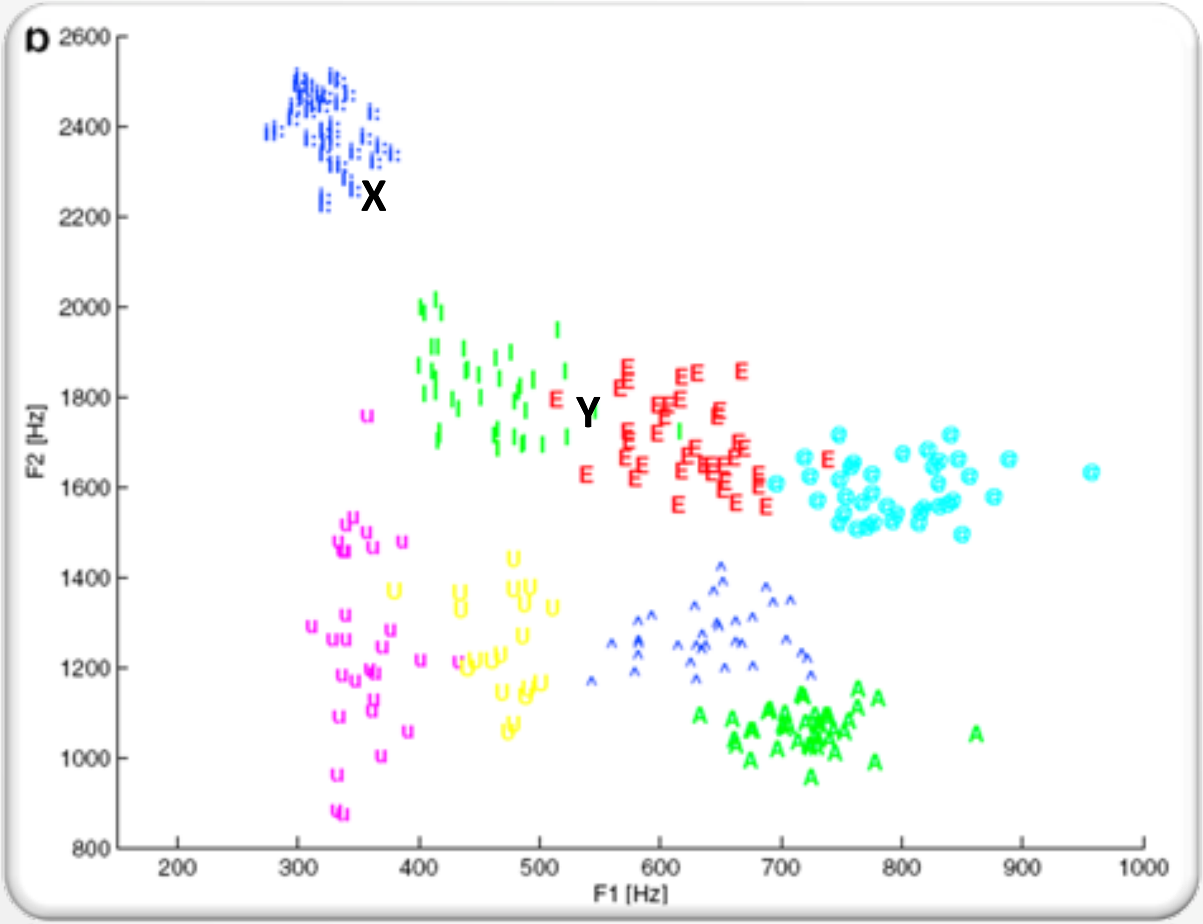
Preview: Speech recognition



What is **Y**?

- In order to classify an unknown observation (e.g., **X**), we need a **statistical** model of the distribution of sounds

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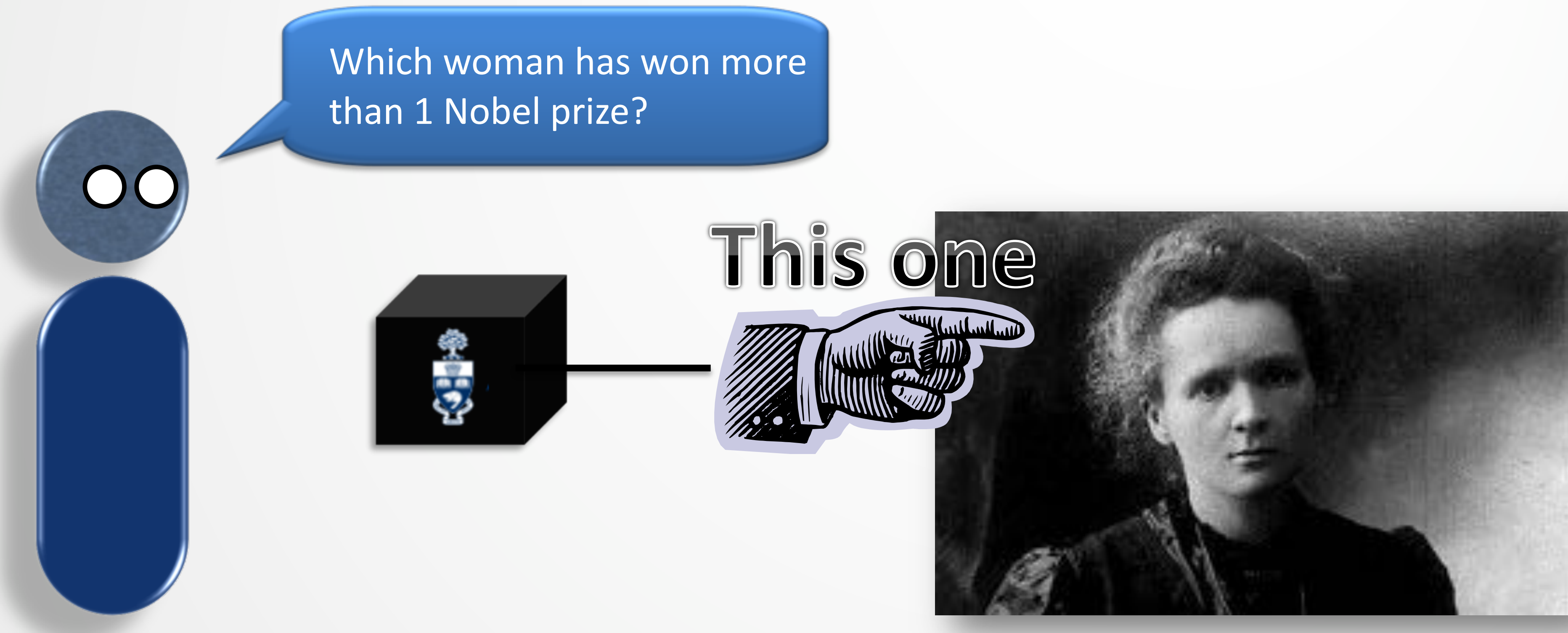
Preview: Questions and answers



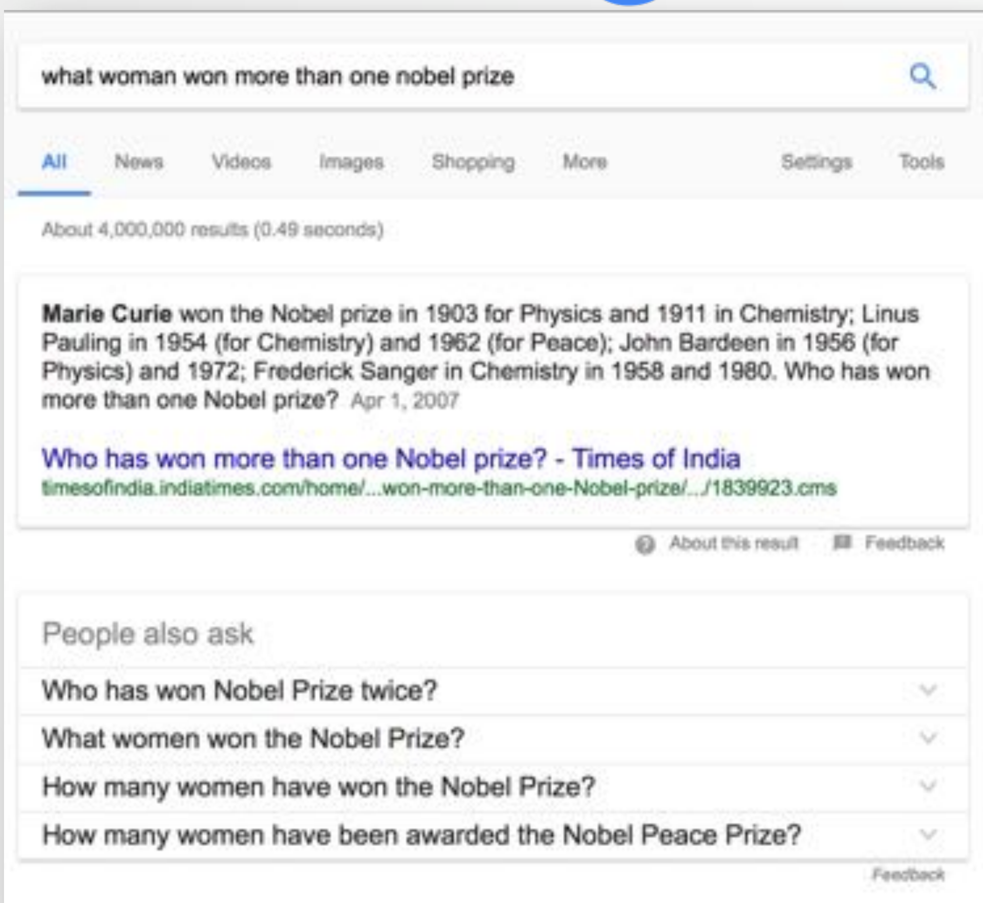
(Marie Curie)

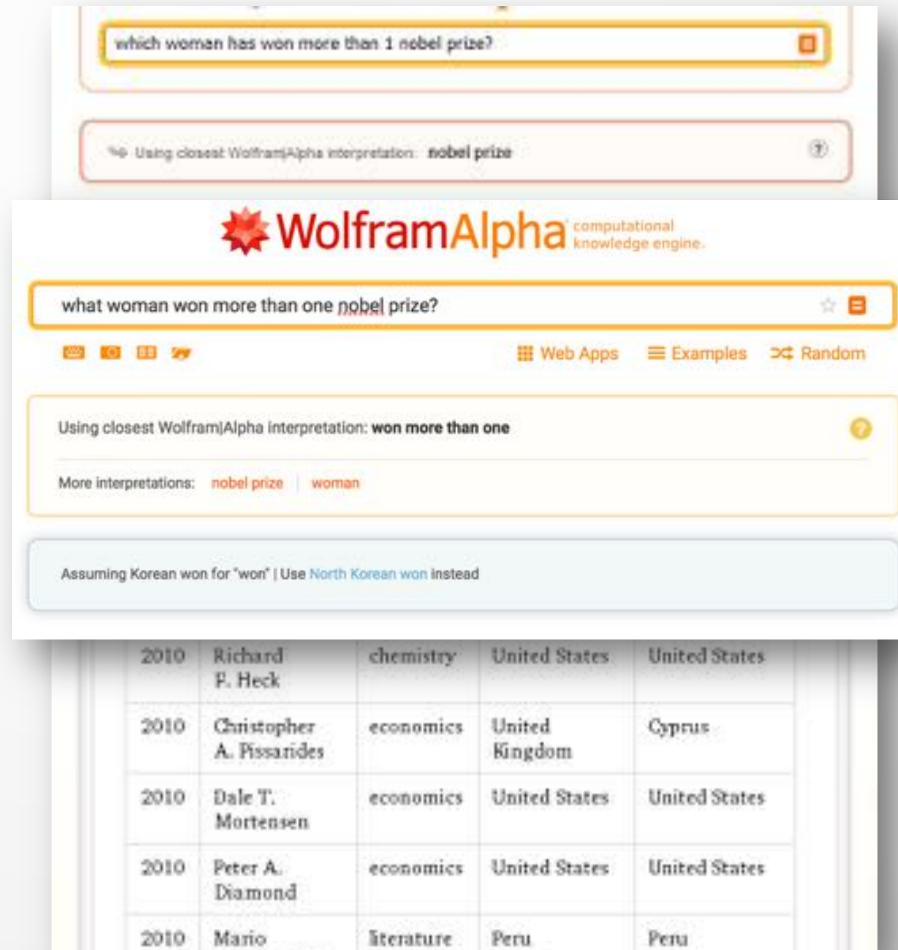
- **Question Answering** (QA) and **Information Retrieval** (IR) involve many of the same principles.

Preview: Information retrieval

Google

WolframAlpha computational knowledge engine





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Aside – Question answering

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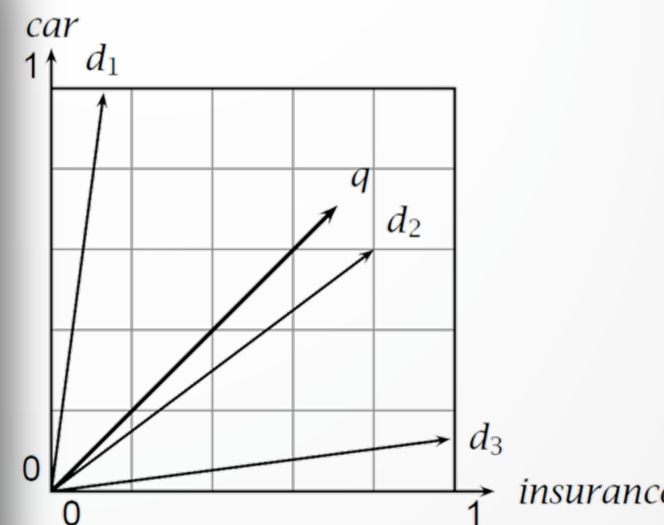
Answer questioning?



$$\cos(\vec{q},\vec{d}) = \frac{\sum_{i=1}^{n} q_i d_i}{\sqrt{\sum_{i=1}^{n} q_i^2}\sqrt{\sum_{i=1}^{n} d_i^2}}$$

- **Retrieving information** can be a **clever combination** of many very **simple concepts** and algorithms.

Overview: NLP

- Is natural language processing (the discipline) hard?
  - **Yes**, because **natural language**
    - is highly ambiguous at all levels,
    - is complex and subtle,
    - is fuzzy and probabilistic,
    - involves real-world reasoning.
  - **No**, because **computer science**
    - gives us many powerful statistical techniques,
    - allows us to break the challenges down into more manageable features.
- Is Natural Language Computing (the course) hard?
  - More on this soon…

NLP in industry

wattpad
Maluuba
A Microsoft company
cymfony
harnessing influence 2.0™
Google
Receptiviti
Nielsen
BuzzMetrics
yelp
umbria
BETA
hakia
search for meaning
OPEN TEXT
The Content Exp
collective intellect
YAHOO!
Microsoft
SST SURGICAL SAFETY TECHNOLOGIES
WINTERLIGHT LABS
NUANCE
IBM
PEARSON
Knowledge Technologies
amazon
J.D. POWER AND ASSOCIATES
HUAWEI
THOMSON REUTERS
at&t
WolframAlpha computational knowledge engine
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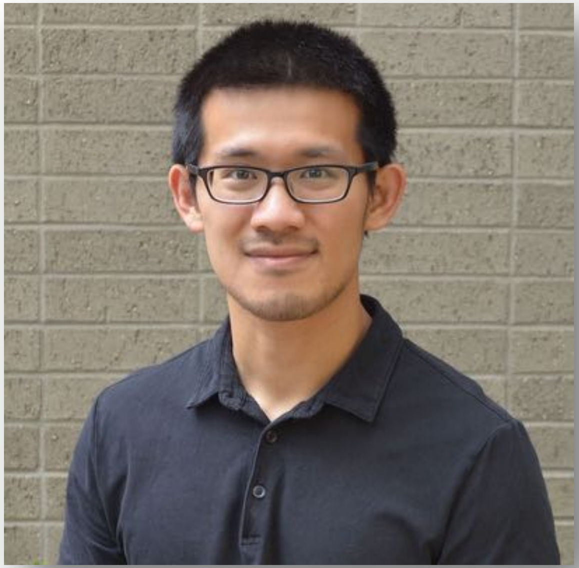
Natural language computing

- **Instructor**: Frank Rudzicz, Raeid Saqur, Zining Zhu (csc401-2022-01@cs)
- **Meetings**: MW (lecture), F (tutorial) at 10h or 11h (check your section)
- **Languages**: English, Python.
- **Website**: http://www.cs.toronto.edu/~frank/csc401/
- **You**: Understand basic **probability**, can **program**, or can pick these up as we go.
- **Syllabus**: Key **theory** and **methods** in statistical natural language computing.
  Focus will be on ***Markov and neural models***, ***machine translation***, *and* ***speech recognition***.

Natural language computing

Frank

Raeid



Zining

Evaluation policies

- **General**: Three assignments : **15%, 20%, 25%** (ranked by your mark)
  Final 'assessment' : **40%**
- **Lateness**: **10%** deduction applied to late submissions. Additional **10%** applied every 24 hours up to 72 hours total, at which point grade is **zero**.
- **Final**: If you **fail** the final exam, then you **fail** the course.
- **Ethics**: Plagiarism and unauthorized collaboration can result in a grade of **zero** on the homework, **failure** of the course, or **suspension** from the University.
  See the course website.

Theme – NLP in a post-truth society

- The **truth** is the most important thing in the Universe.
  - At the very least, the truth allows us to rationally **optimize** legal, political, and personal decisions.

- The truth can sometimes be obscured deliberately via **deception**, or inadvertently through **bias**, **fallacy**, or intellectual **laziness**.
  - Nowhere is this perhaps more obvious than on **social media** or in **pseudo-journalism**.

- Natural language processing *may* give us **tools** to combat this scourge.

Assignments

- Assignment 1: Corpus statistics, sentiment analysis
  - task: analyze bias on Reddit
  - learn: statistical techniques, features, and classification.
- Assignment 2: Neural machine translation
  - task: translate between languages
  - learn: neural seq2seq and language models.
- Assignment 3: Automatic speech recognition
  - task: detect lies in speech
  - learn: signal processing, phonetics, and speech recognition.

* Probably

Assignment 1 – Bias in social media

- Involves:
  - Working with social media data (i.e., gathering statistics on some data from Reddit),
  - Part-of-speech tagging (more on this later),
  - Classification.
- **Announcements**: Piazza forum, email.
- You should get an early start.

Projects – graduate students only

- Graduate students can **optionally** undertake a full-term **project** worth **60%** of their grade **instead** of the assignments.
  - Good for those, e.g., who prefer to work in teams.

- Teams must consist of 1 or 2 humans (no more, no fewer).
- Projects must contain a significant **programming** and **scientific** component.
- Projects must be **relevant** to the course.

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Projects – graduate students only

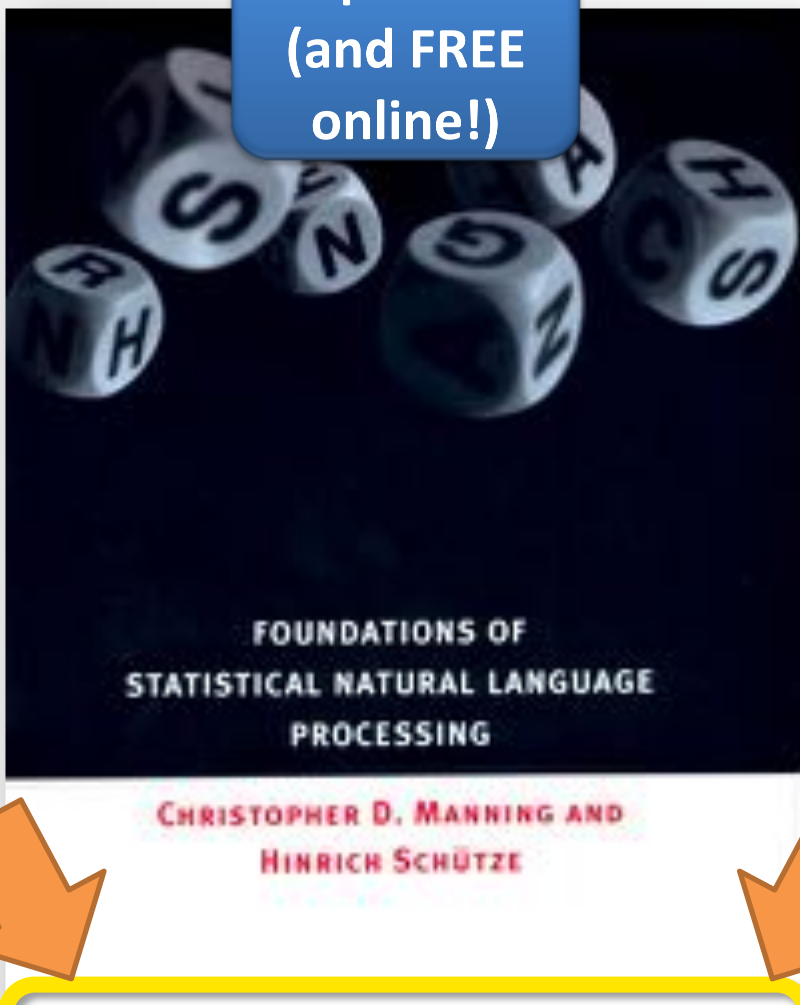
- Some possible ideas for projects include:
  - A deception filter for news media online.
  - A novel method of using data in language A to train a classification system in language B for $A \neq B$.

- If you decide to take this option, you have to notify us by email about your team by **18 January**!

- You will need to periodically submit **checkpoints** that build on their antecedents.
  - See course webpage for detailed requirements!

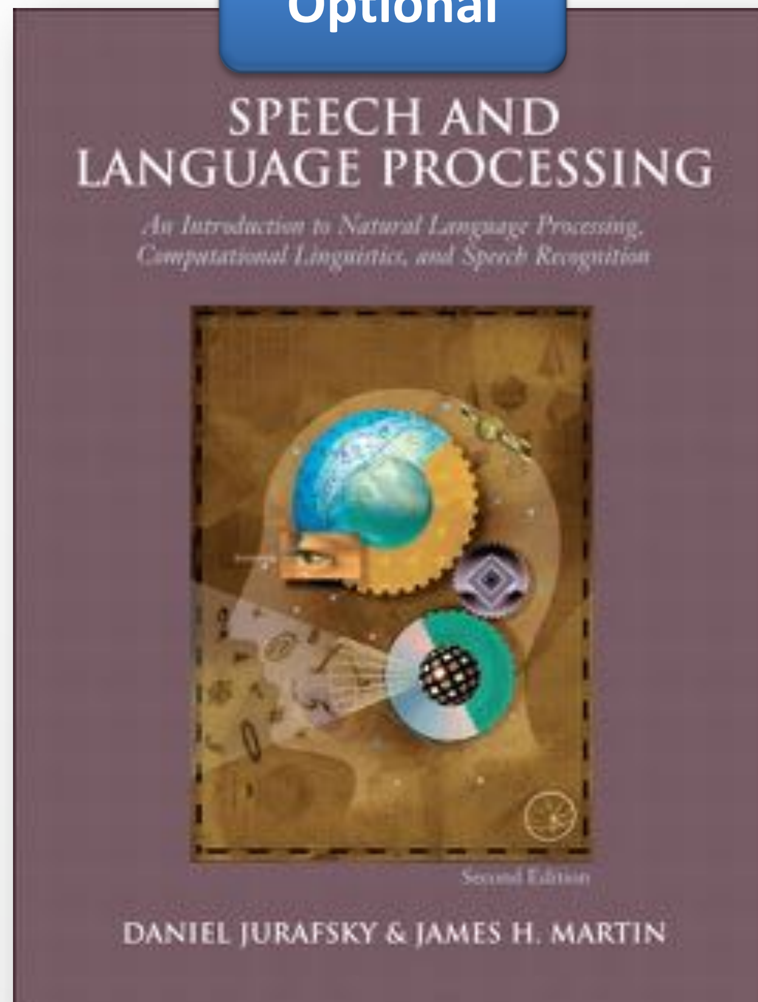
Reading

Optional (and FREE online!)



https://search.library.utoronto.ca/details?10552907

Optional



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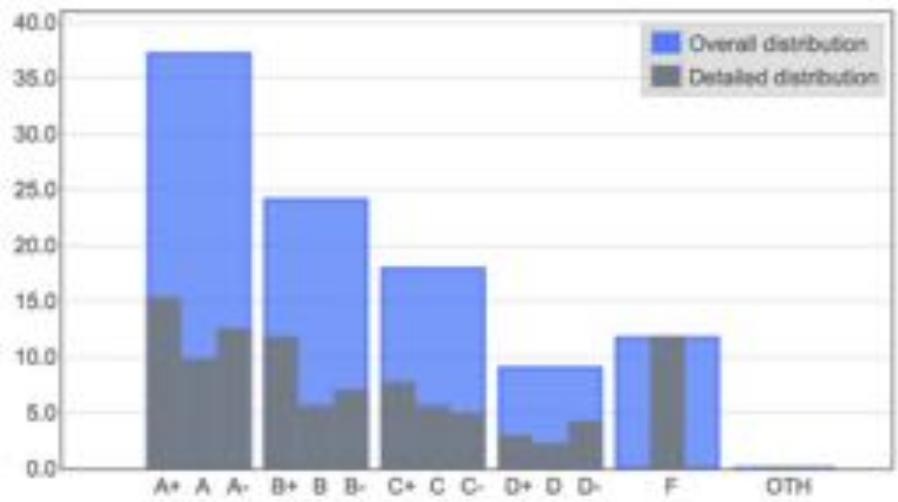
Stats from 2017-2019

2017

A	37.2%	B	24.1%	C	17.9%	D	9%
A+	15.2%	B+	11.7%	C+	7.6%	D+	2.8%
A	9.7%	B	5.5%	C	5.5%	D	2.1%
A-	12.4%	B-	6.9%	C-	4.8%	D-	4.1%
F	11.7%	OTH	0%	Average		Median	
F	11.7%	OTH	0%	70.01 %		76 %	

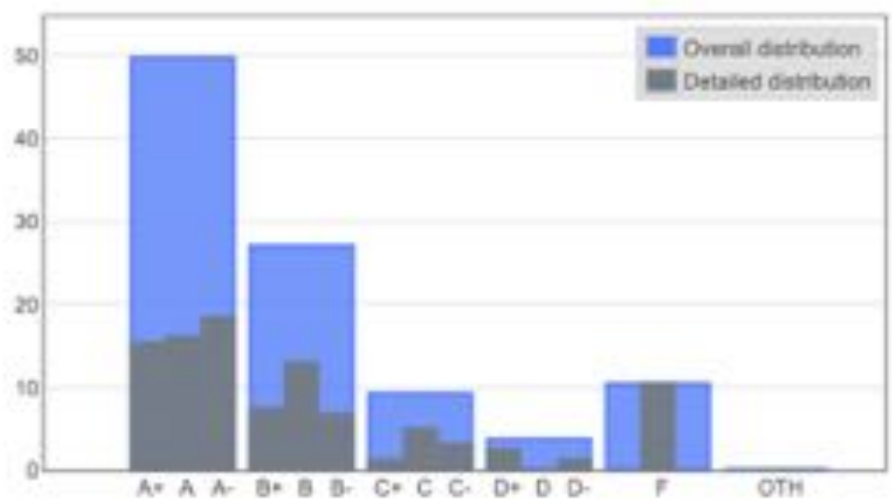
Class average excluding exam no shows: 75.20%
Fails excluding exam no shows: 3.79%



2019

A	49.7%	B	27%	C	9.2%	D	3.7%
A+	15.3%	B+	7.4%	C+	1.2%	D+	2.5%
A	16%	B	12.9%	C	4.9%	D	0%
A-	18.4%	B-	6.7%	C-	3.1%	D-	1.2%
F	10.4%	OTH	0%	Average		Median	
F	10.4%	OTH	0%	73.54 %		79 %	

Class average excluding exam no shows: 77.52%
Fails excluding exam no shows: 4.58%



Consider the waitlist!

Assignment 1 and reading

- **Assignment 1** available by Friday (on course webpage)!
  - Due 11 February
  - TAs: B Eyre;
    KP Vishnubhotla.

- **Reading**:
  - Manning & Schütze: Sections 1.3—1.4.2,
    Sections 6.0—6.2.1.