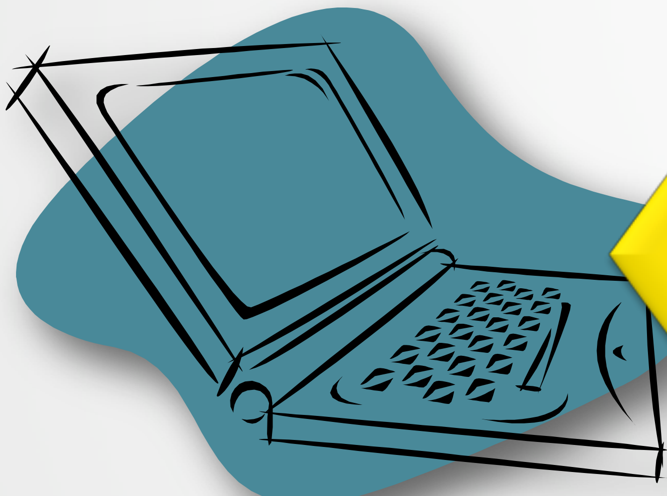
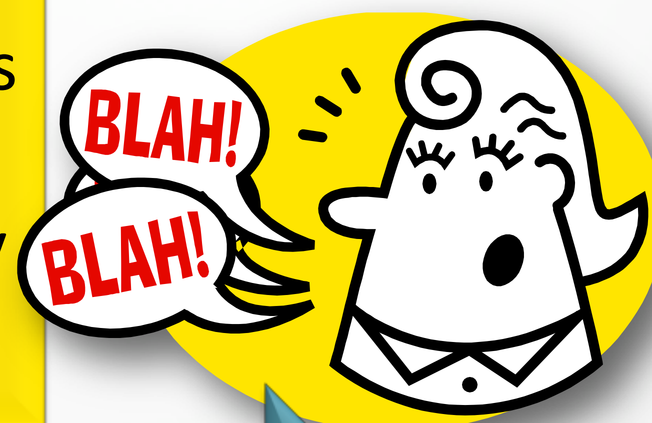

401
ONTARIO
NATURAL
LANGUAGE
COMPUTING

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 the ***statistics of language***.

(Occasionally, computer models give insight into how humans process language.)

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Today

- Common challenges with **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*”

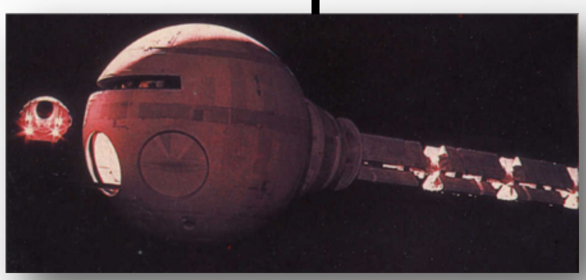
“take a memo…”

“open the pod bay doors”

“how far until Jupiter?”

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

`open(podBay.doors);`



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

A little deeper

- Language has ***hidden structures***, e.g.,
  - How are **sounds** and **text** related?
    - e.g., why is this:  not a '*ghoti*' (*enou**<u>gh</u>**, w**<u>o</u>**men, na**<u>ti</u>**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…

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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.

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"	→ */aa¹ b jh eh⁰ k t /*	as in *'That is an **object**'*
"object"	→ */ah⁰ b jh eh¹ 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 eh¹ k ah ?? n ay² z s (b|p) iy ch/*
    - → *'how to recognize speech'*
    - → *'how to wreck a nice beach'*

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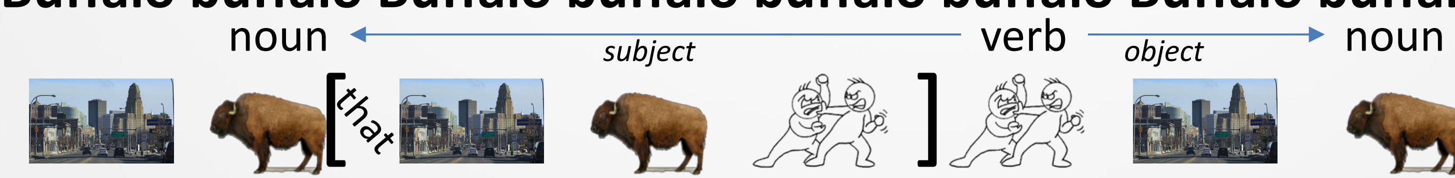
Resolution with syntax

- 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"**

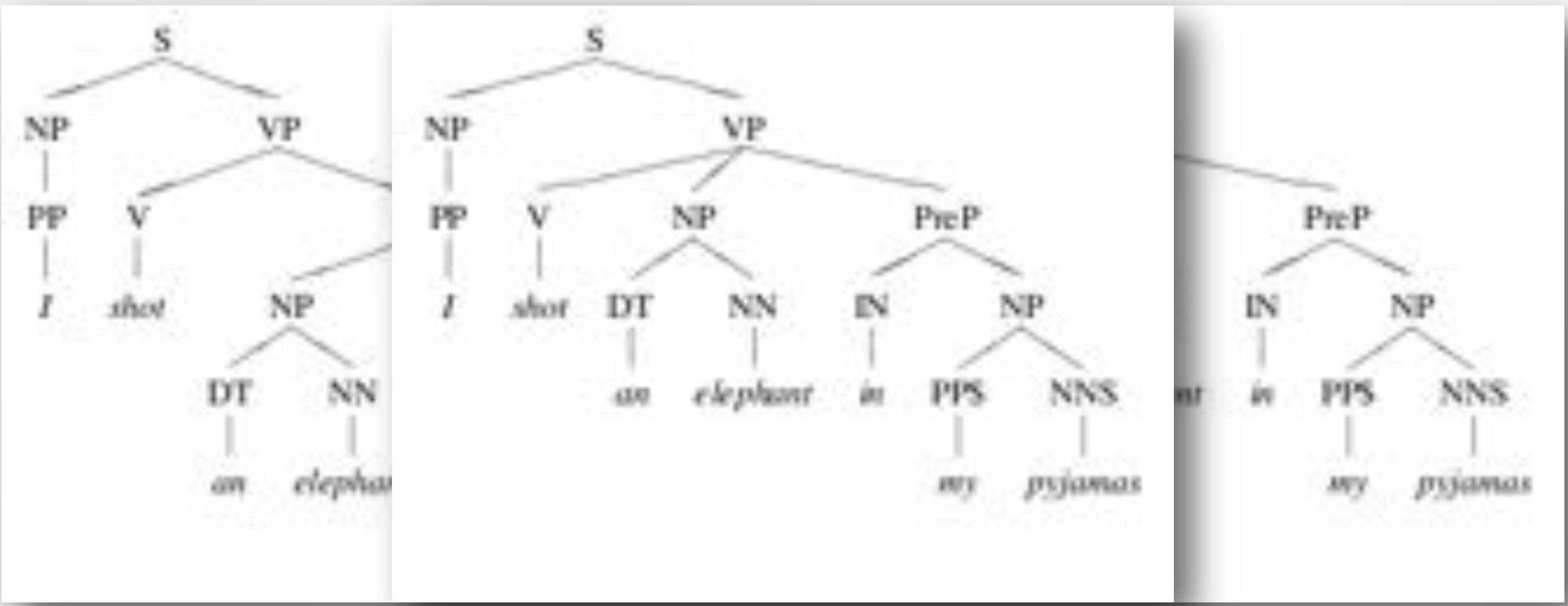


- It's obvious (to us) that the last option is most likely because we have knowledge of **syntax**, i.e., grammar.

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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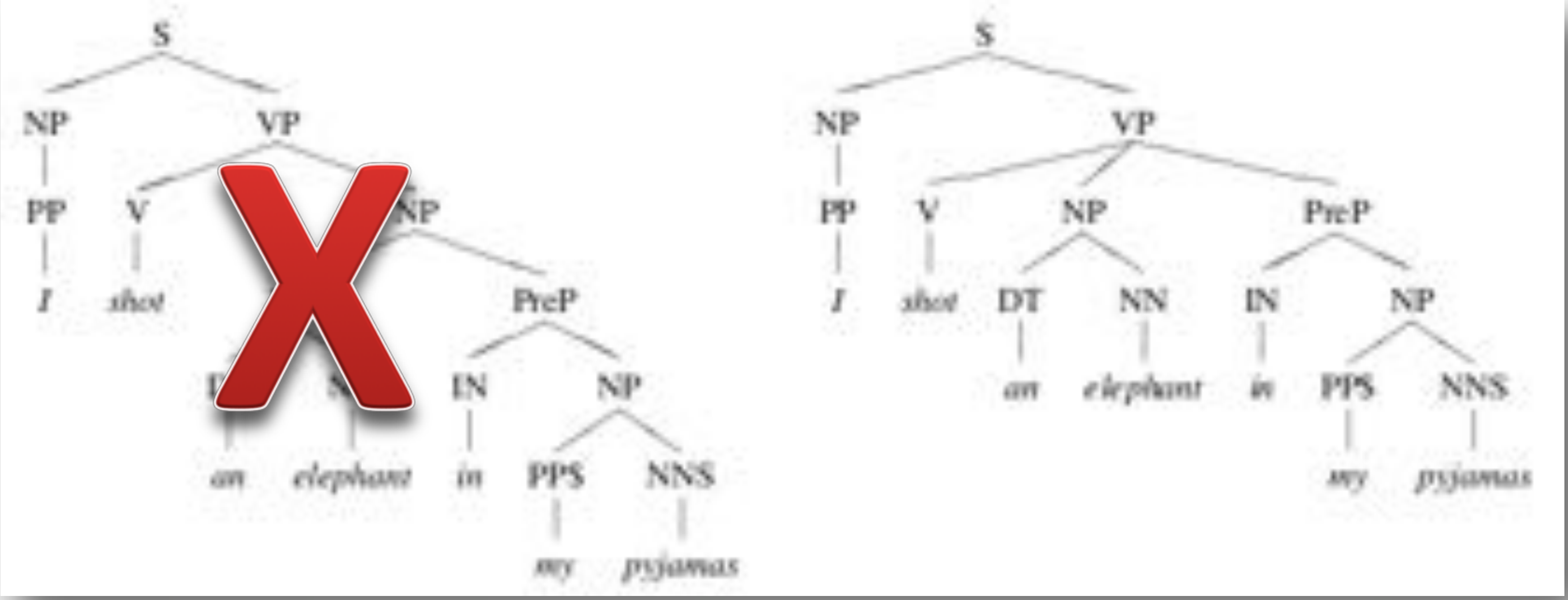
Resolution with semantics



- 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.

Ambiguity – Semantic

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

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

- "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"
  - $\rightarrow \forall x\ man(x) \exists y: \left(woman(y) \wedge loves(x, y)\right)$
  - $\cancel{\rightarrow \exists y: woman(y) \wedge \forall x\left(man(x) \rightarrow loves(x, y)\right)}$

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
…

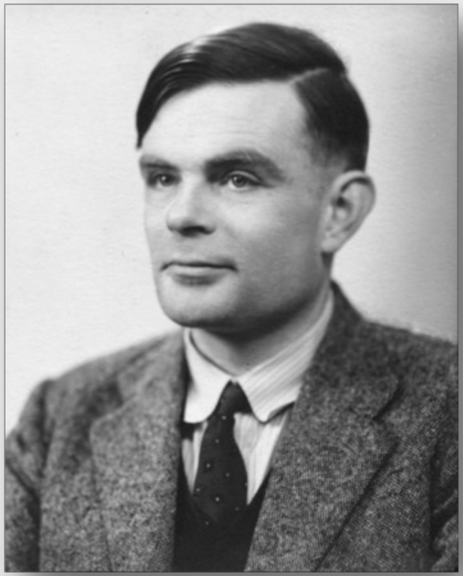
NLC as Artificial Intelligence

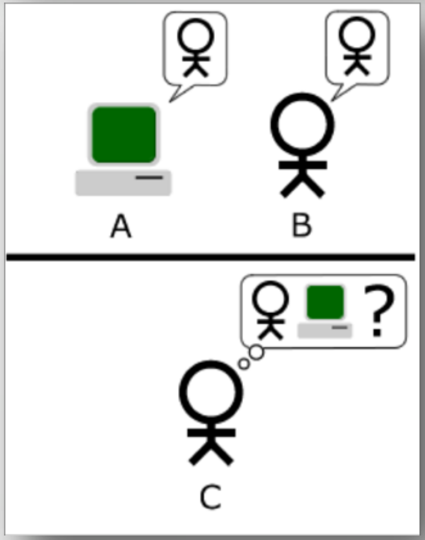
- NLC involves **resolving ambiguity** at all levels.
  - **Reasoning** with **world knowledge**.
    - In the early days knowledge was **explicitly encoded** in artificial **symbolic** systems (e.g., context-free grammars) by **experts**.

  - Now, algorithms learn using **probabilities** to distinguish subtly different competing hypotheses.
    - E.g., is *Google* a noun or a verb?
    - An example where $Google \in Nouns$ *("**Google** makes Android")*, does **not** mean that Google is never a verb ("*Go Google yourself*").

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

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.

Aside – Chatterbots

- 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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Course outline (approximate)

- Introduction, linguistic data, language models (3 lectures)
- Entropy and information theory (2 lectures) *
- Features and classification (2 lectures) *
- Hidden Markov models (3 lectures) *
- Statistical machine translation (4 lectures) **
- Neural language models (2 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 lecture) **
- Review (1 lecture)

* techniques ** applications

Preview: Machine translation

美国关岛国际机场及其办公室均接获一名自称沙地阿拉伯富商拉登等发出的电子邮件，威胁将会向机场等公众地方发动生化袭击後，关岛经保持高度戒备。 → The U.S. island of Guam is maintaining a high state of alert after the Guam airport and its offices both received an e-mail from someone calling himself the Saudi Arabian Osama bin Laden and threatening a biological/chemical attack against public places such as the airport .

- One of the most prized applications in NLC.
- Requires both **interpretation** and **generation**.
- Over $100B spent annually on human translation.

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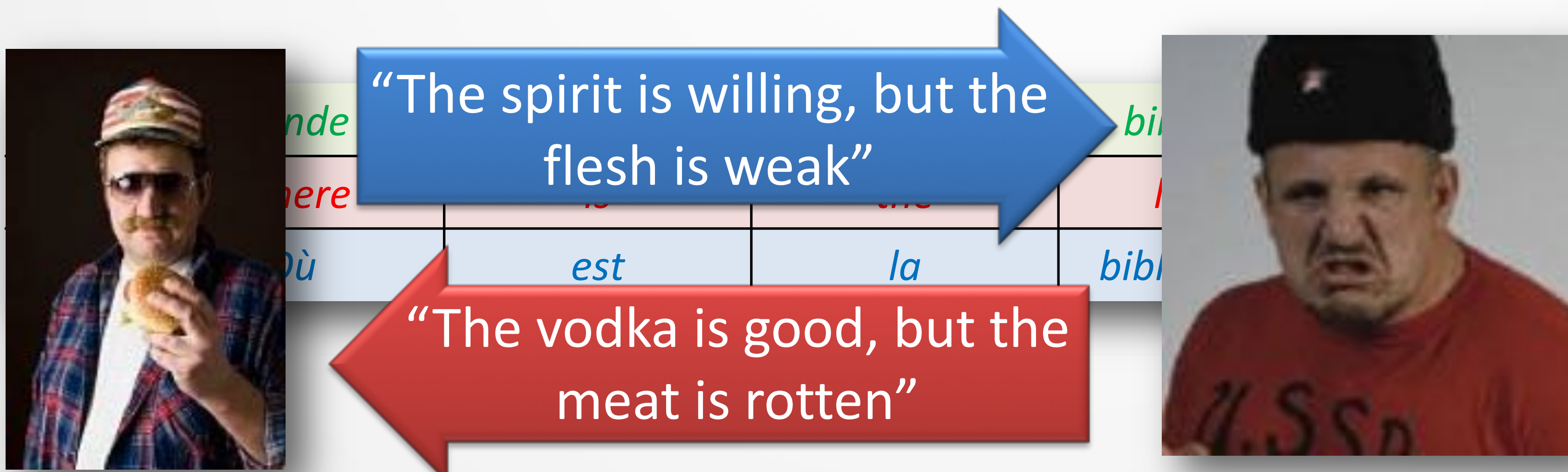
Preview: Machine translation

对外经济贸易合作部今天提供的数据表明，今年至十一月中国实际利用外资四百六十九点五九亿美元，其中包括外商直接投资四百点零七亿美元。

Human	According to the data provided today by the Ministry of Foreign Trade and Economic Cooperation, as of November this year, China has actually utilized 46.959B US dollars of foreign capital, including 40.007B US dollars of direct investment from foreign businessmen.
IBM4	The Ministry of Foreign Trade and Economic Cooperation, including foreign direct investment 40.007B US dollars today provide data include that year to November China actually using foreign 46.959B US dollars and
Yamada/Knight	Today's available data of the Ministry of Foreign Trade and Economic Cooperation shows that China's actual utilization of November this year will include 40.007B US dollars for the foreign direct investment among 46.959B US dollars in foreign capital.

Preview: Machine translation

- In the 1950s and 1960s 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.

Stephen
Harper

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**

Pauline
Marois

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 …

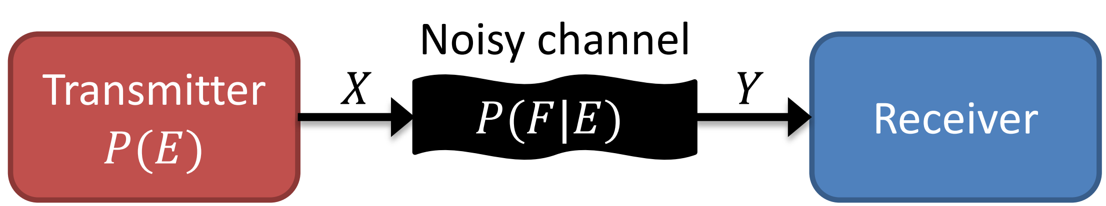
e.g., the *Canadian Hansards*:
bilingual Parliamentary proceedings

Statistical machine translation

- 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

Aside – Machine translation

- http://www.translationparty.com uses Google Translate to go back and forth between English and Japanese until we get two consecutive identical English phrases.

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Preview: Machine translation

Start with an English phrase:

that's one small step for a man, one giant leap for mankind

find equilibrium

that's one small step for a man, one giant leap for mankind

let's go!

それは人間にとっては小さな一歩だが、
一歩

It is but one small step for man, o
mankind

それは人間にとっては小さな一歩一歩、
しいが、さ

It is step by small step for man, b
humanity, the

人類にとっては小さな一歩ステップは、男性にとって理想的なホテルです

back into Japanese

Step One small step for mankind, this hotel is ideal for men

back into English

人類にとっては小さな一歩ステップ、このホテルは、男性にとって理想的なホテルです

back into Japanese

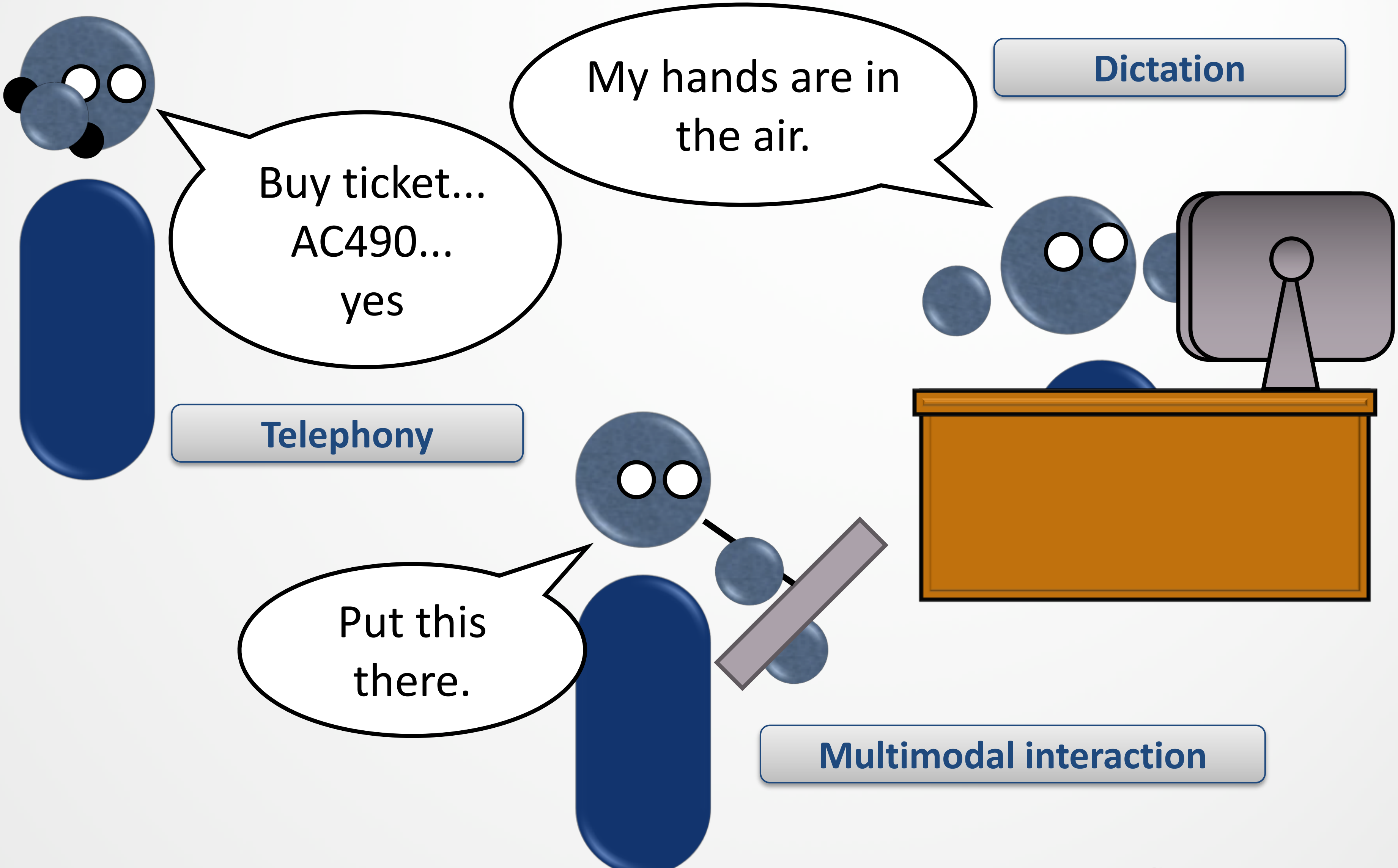
Step One small step for mankind, this hotel is ideal for men

back into English

Equilibrium found!

Okay, I get it, you like Translation Party.

Preview: Speech recognition



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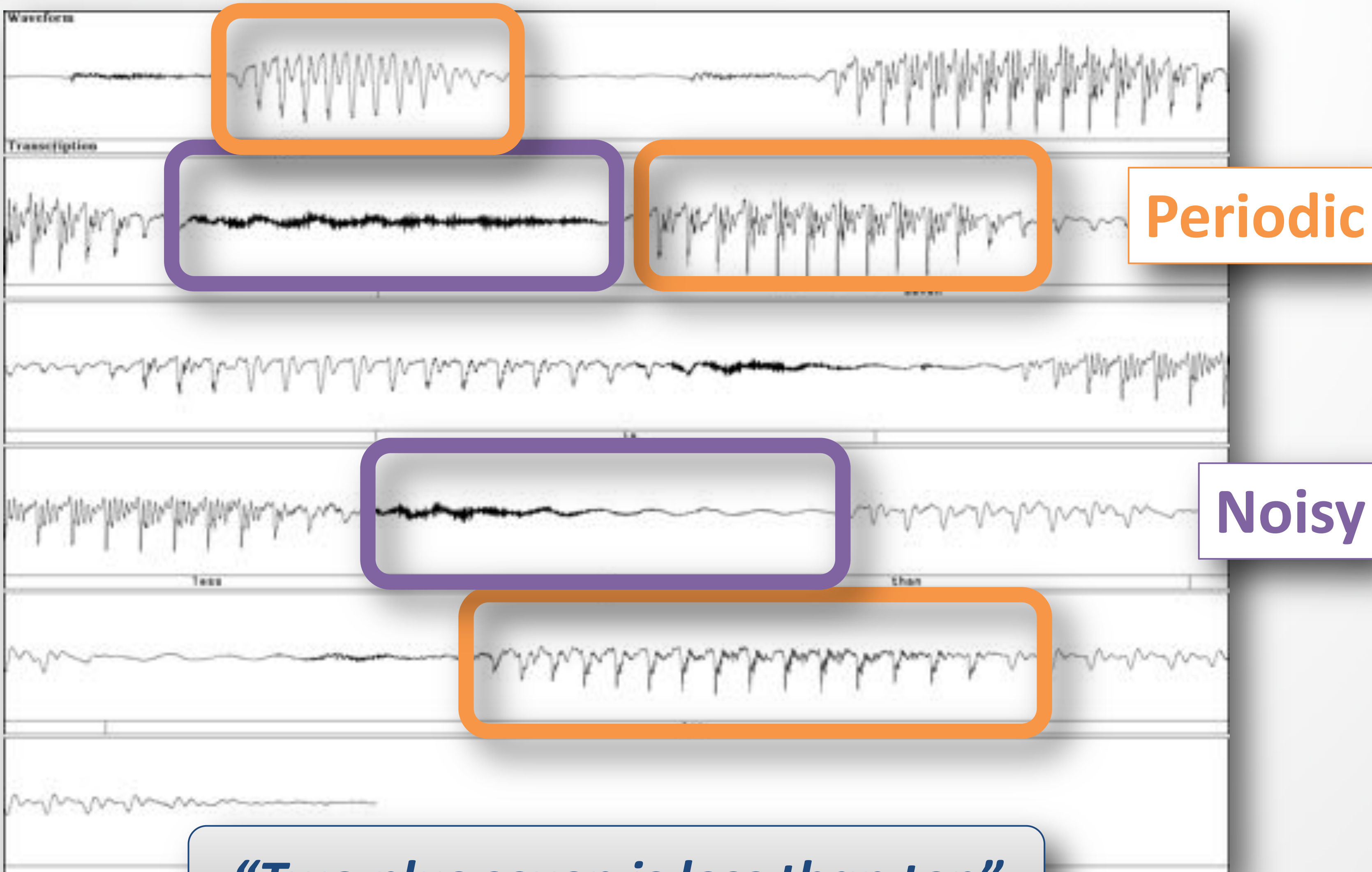
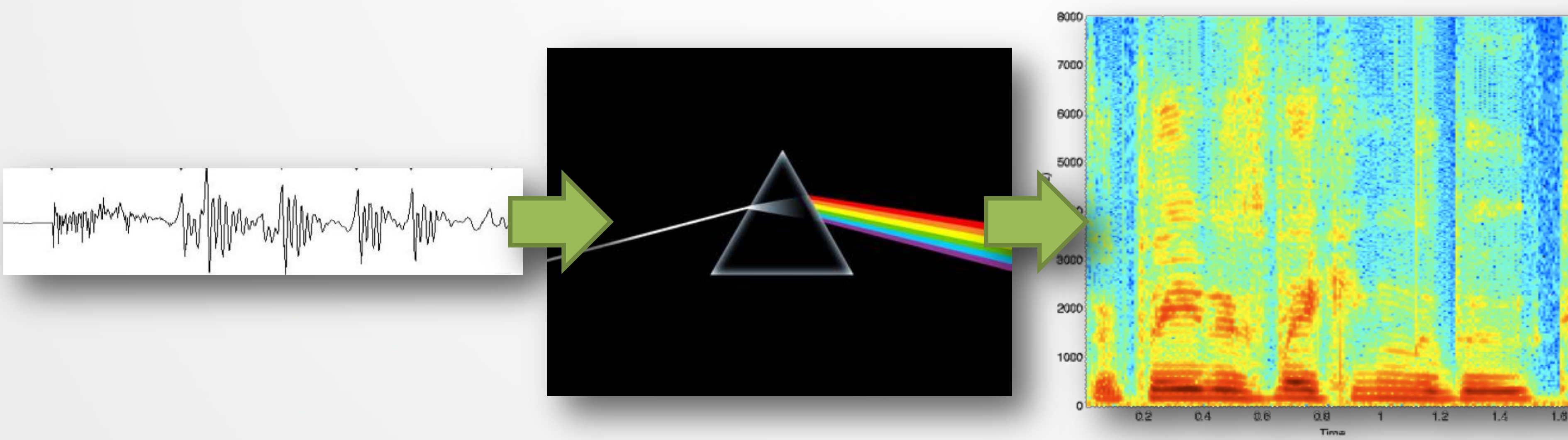
Speech waveforms



"Two plus seven is less than ten"

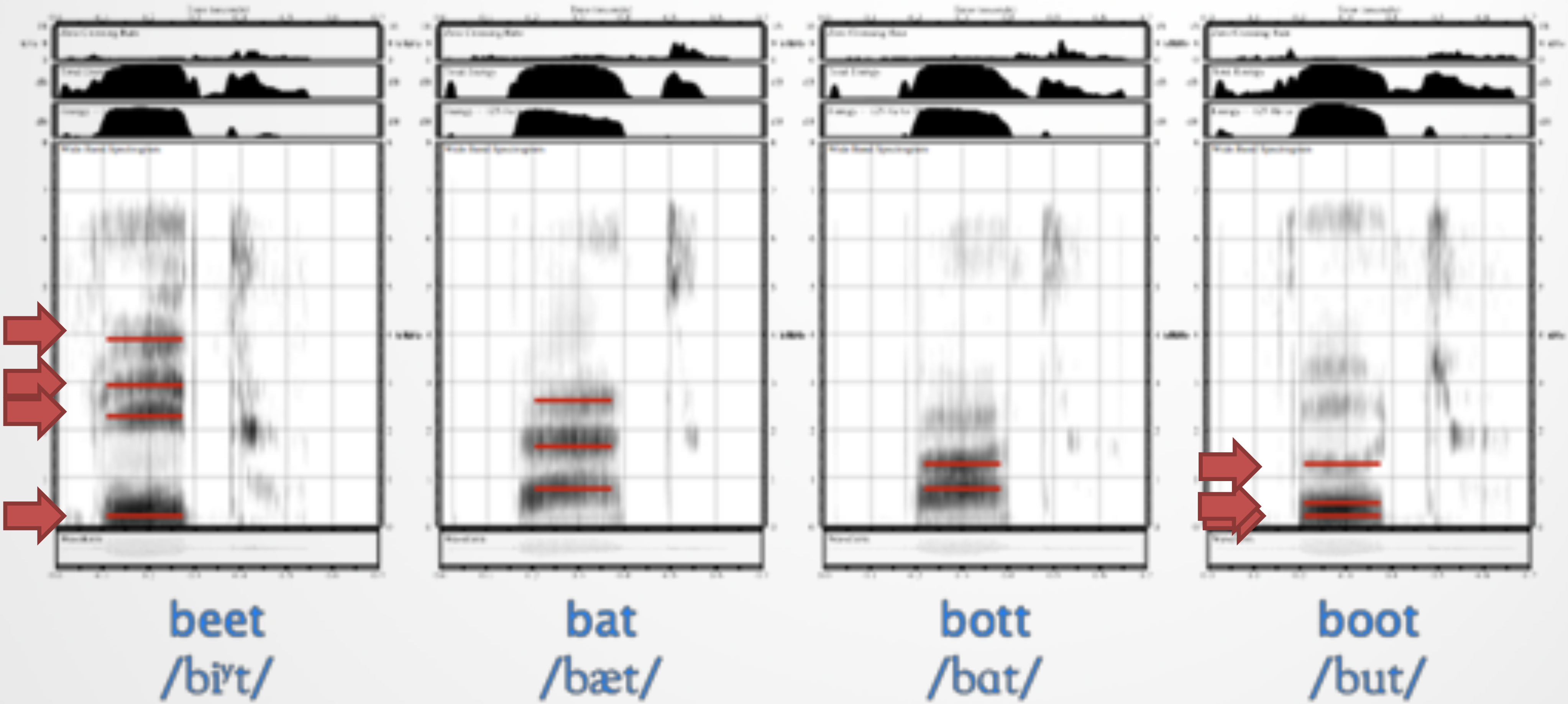
Spectrograms

- 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.

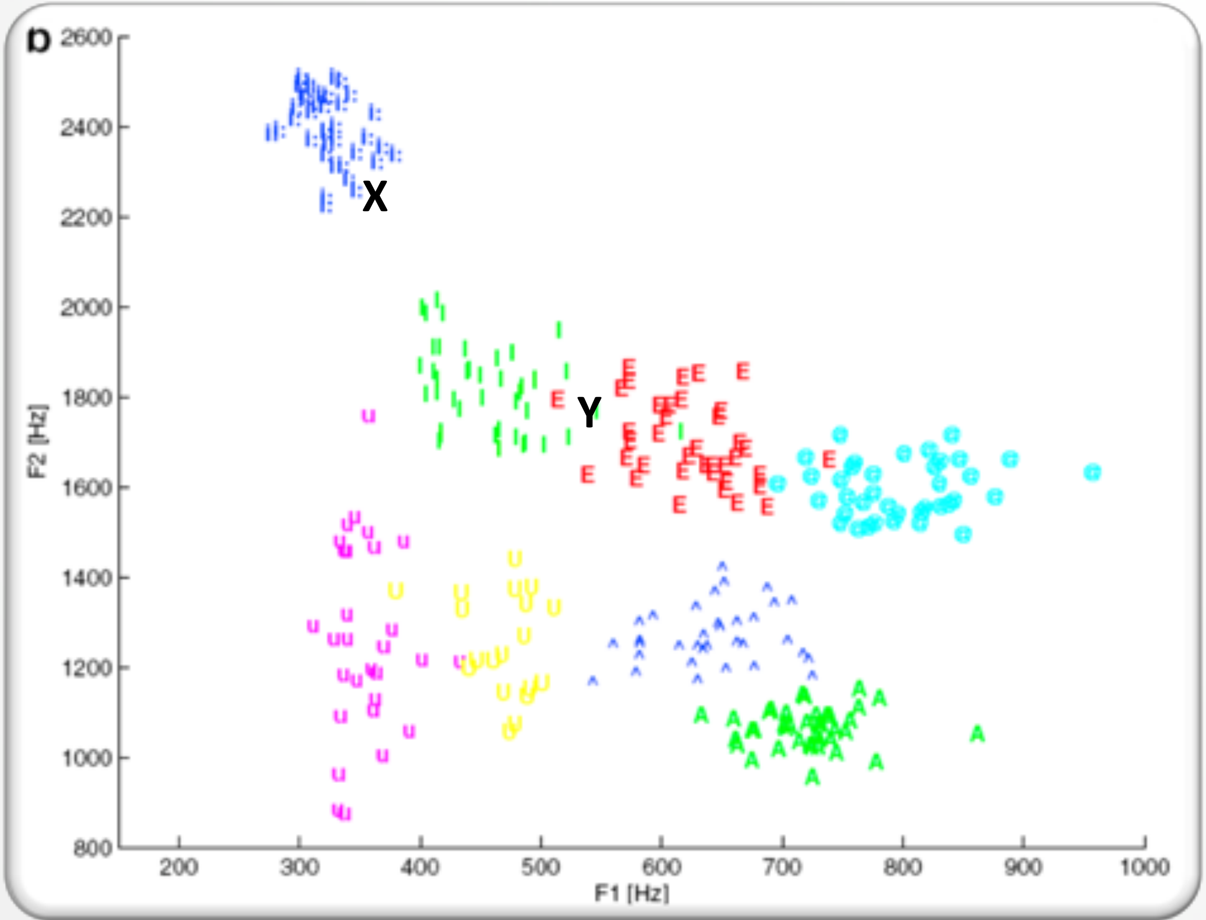


Speech waveform | Fourier transform | Spectrogram

Speech recognition



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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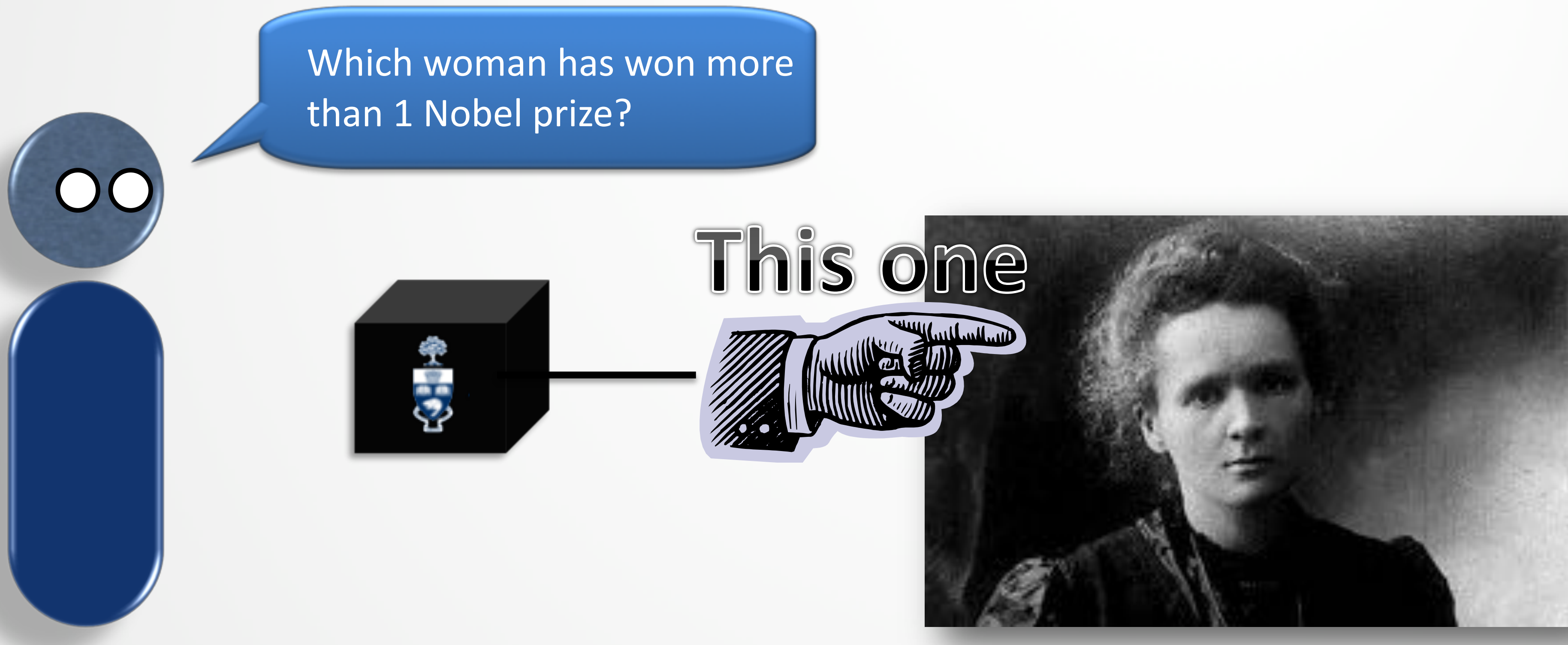
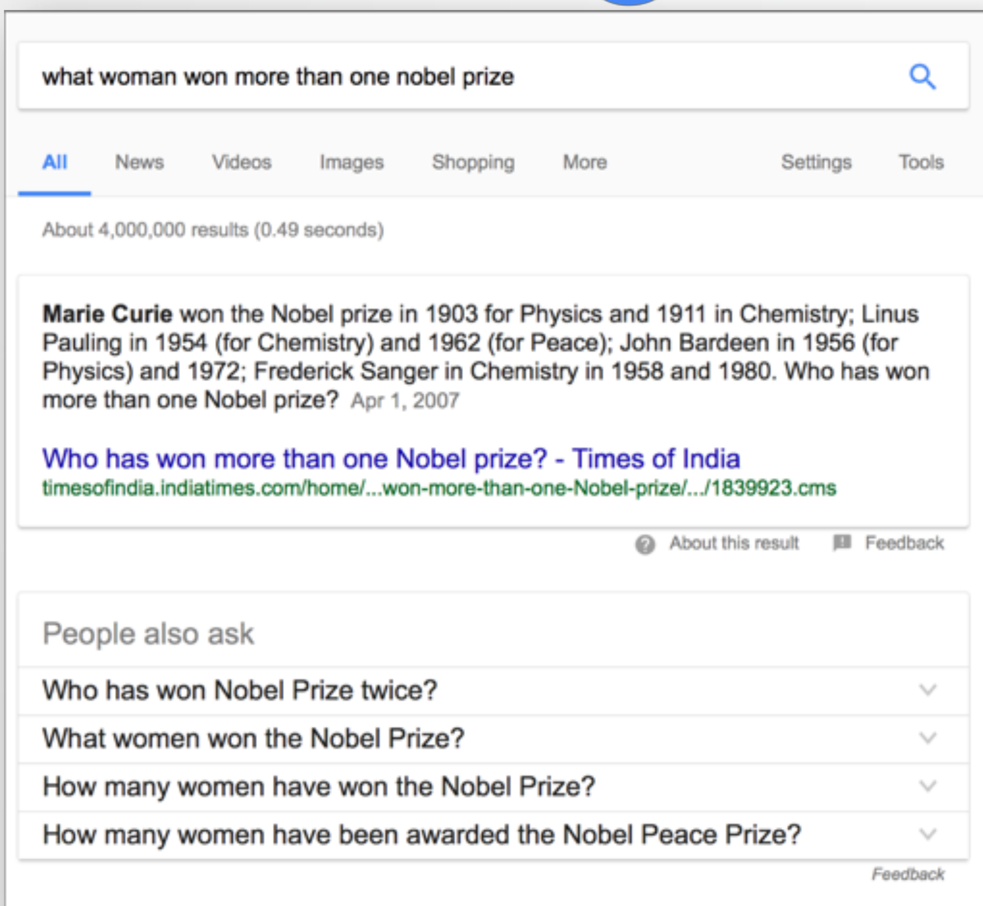
Preview: Questions and answers

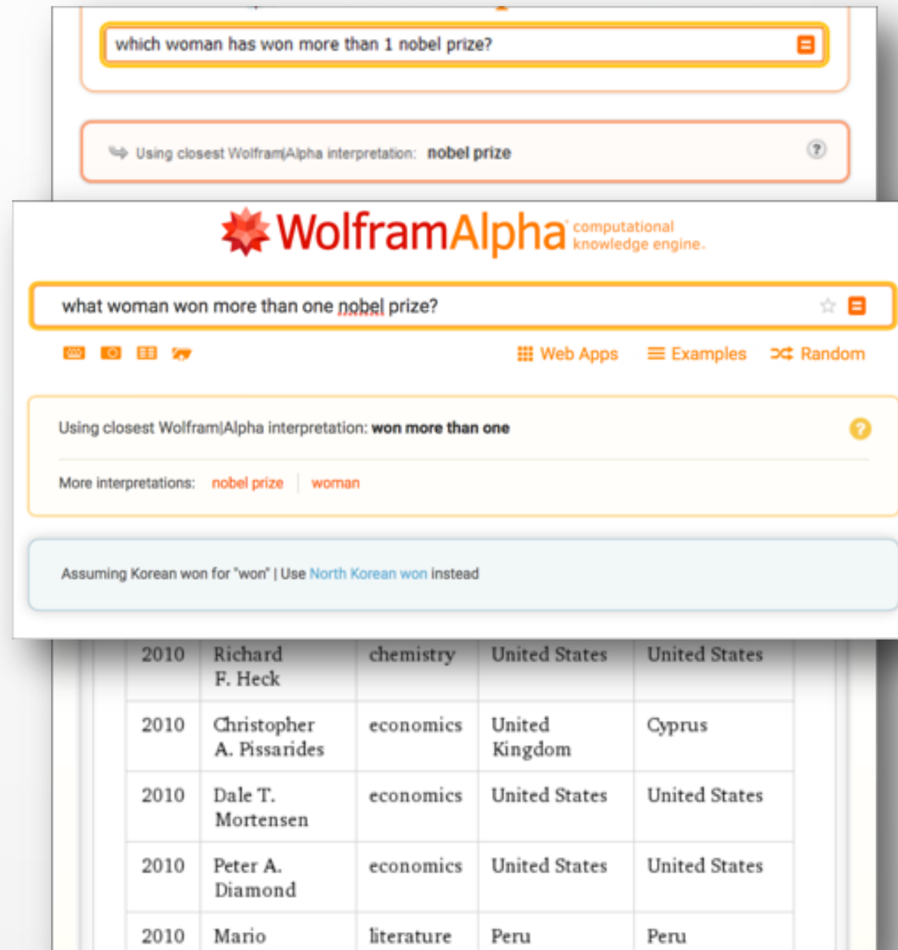


(Marie Curie)

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

Preview: Information retrieval





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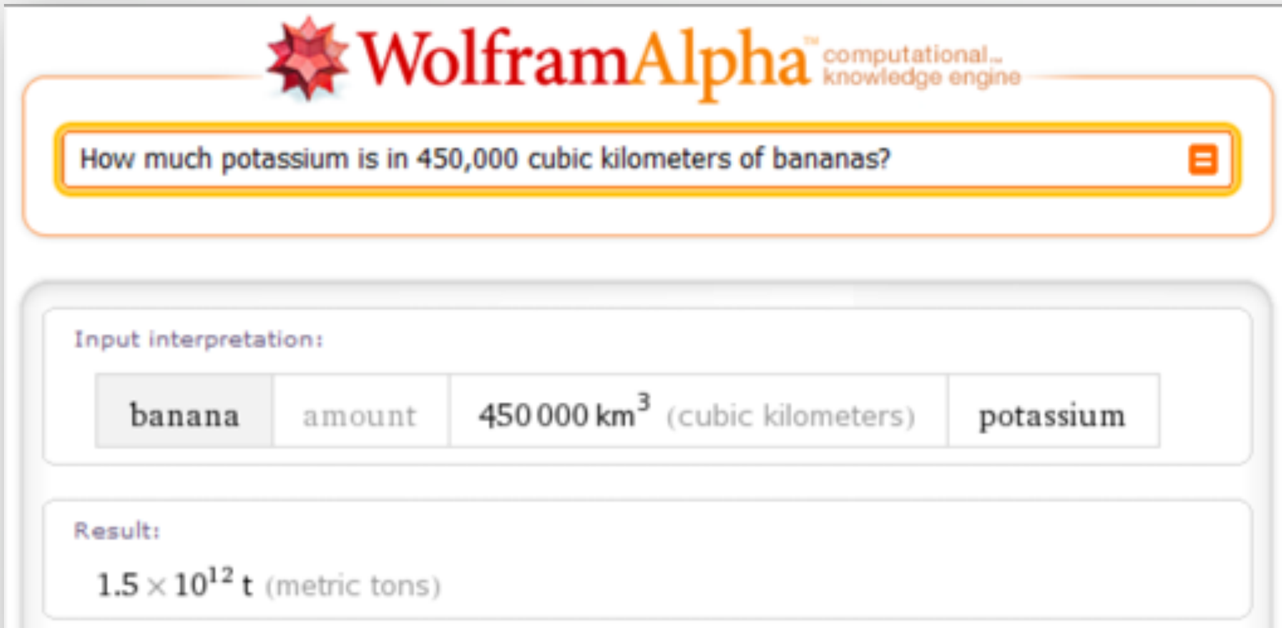
Aside – Question answering



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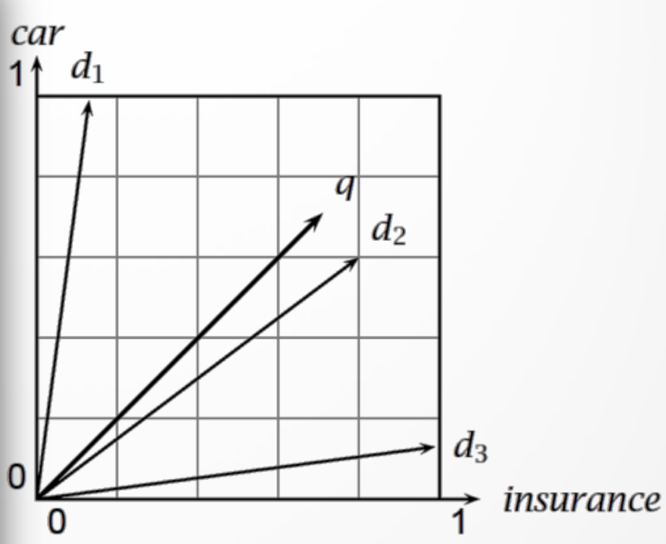
Answer questioning?



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

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

Overview: NLC

- Is natural language computing (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…

NLC 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
NUANCE
IBM
PEARSO
Knowledge Technologies
amazon
J.D. POWER AND ASSOCIATES
THOMSON REUTERS
HUAWEI
at&t
WolframAlpha computational knowledge engine

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Natural language computing

- **Instructor**: Frank Rudzicz and Chloé Pou-Prom (csc401.2019@gmail)
- **TAs**: Zhewei Sun, Maryam Fallah, Mohamed Abdalla, TBD, Amanjit Kainth, Jianan Chen
- **Meetings**: MF (lecture, PB250), W (tutorial, MB128) at 10h-11h
- **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***.

Office hours

- **Time**:
  - Mondays, 11h30-12h30
- **Location**:
  - The Vector Institute (MaRS West, Suite 710)
  - The streets

Theme – NLC 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 gives us **tools** to combat this scourge.

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Evaluation policies

- **General**: Three assignments : **15%, 20%, 25%** (ranked by your mark)
  Final exam : **40%**
- **Lateness**: **10%** deduction applied to electronic submissions that are 1 minute late.
  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.

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Assignments

- Assignment 1: Corpus statistics, sentiment analysis

  task: bias analysis on Reddit

  learn: statistical techniques, features, and classification.

- Assignment 2: Statistical machine translation

  task *: translate between political extremes

  learn: statistical *n*-grams, smoothing, and multilingual word alignment.

- Assignment 3: Automatic speech recognition

  task: detect lies in speech

  learn: signal processing, phonetics, and hidden Markov models.

* Hopefully

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.
    You might even get a **publication**!

- 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

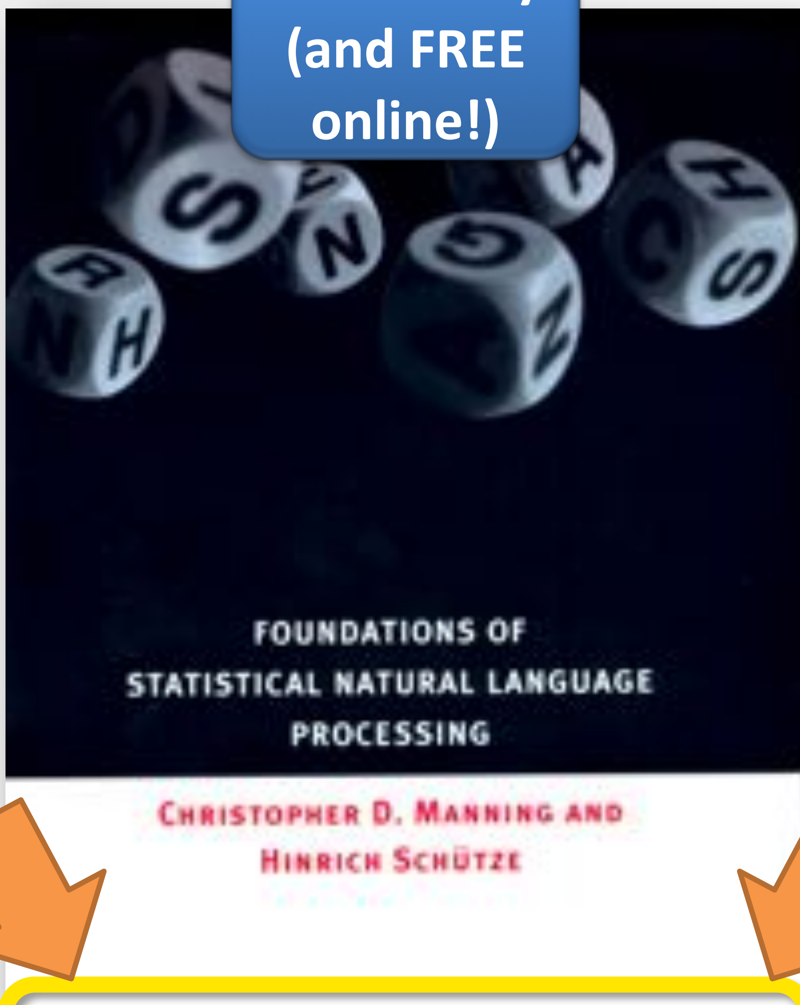
- Some possible ideas for projects include:
  - A deception filter for news media online.
  - A novel method of using data in language A to train a classification system in language B for $A \neq B$.

- 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!

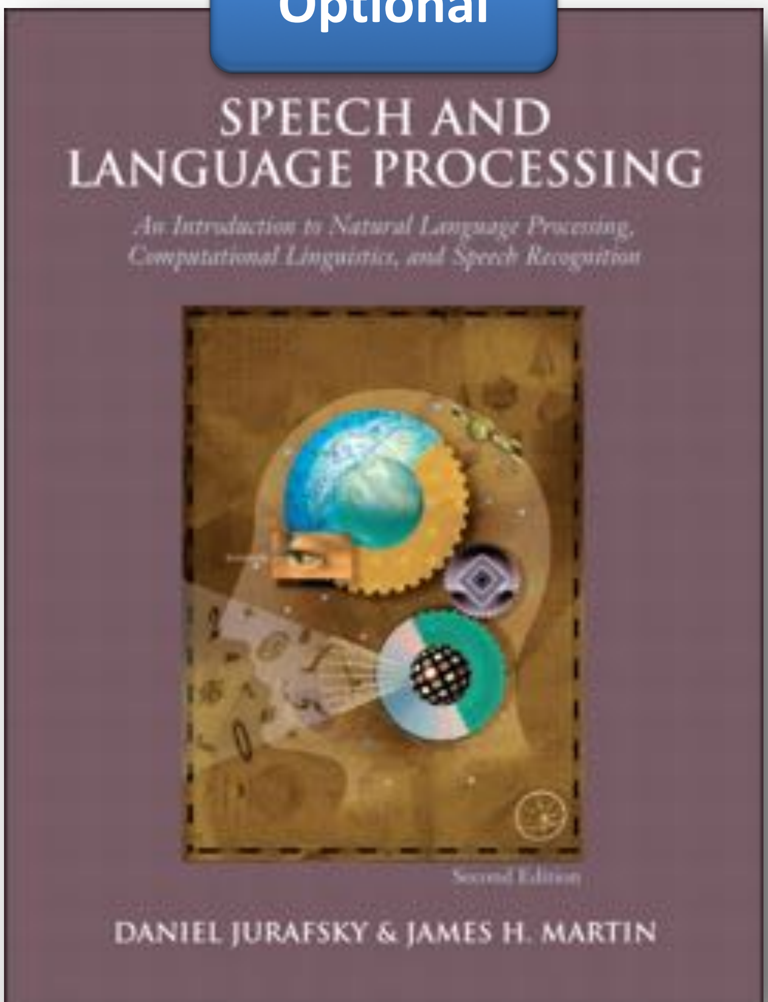
Reading

Mandatory (and FREE online!)



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

Optional



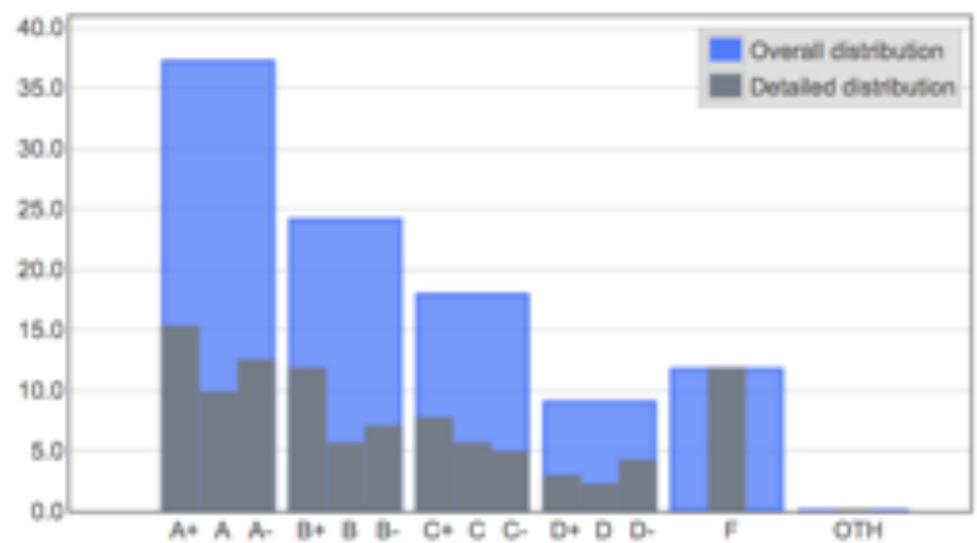
Stats from 2017

The average overall grade among **undergraduates** was 63.0% ($\sigma=26.7$).
The average overall grade among **graduates** was 74.4% ($\sigma=31.7$).

The grade *range* breakdown among undergraduates was:

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%



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Assignment 1 and reading

- **Assignment 1** available (on course webpage)!
  - Due 11 February
  - TAs: Zhewei Sun (zheweisun@cs);
    Maryam Fallah (mary.fallah@mail.utoronto).

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

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