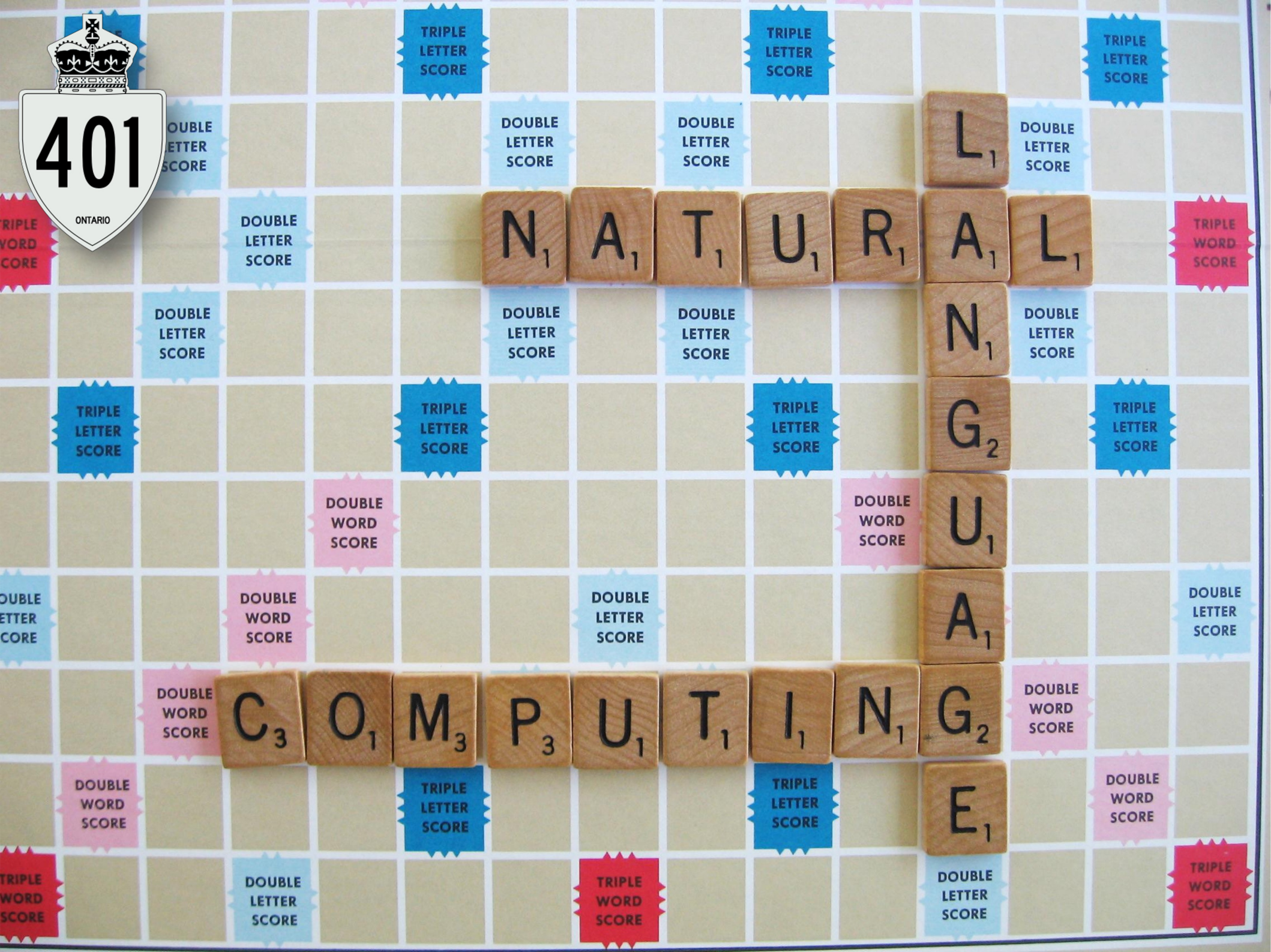
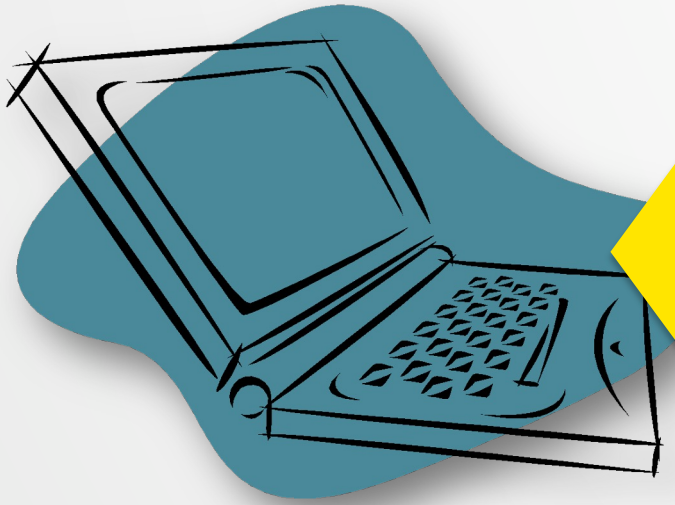
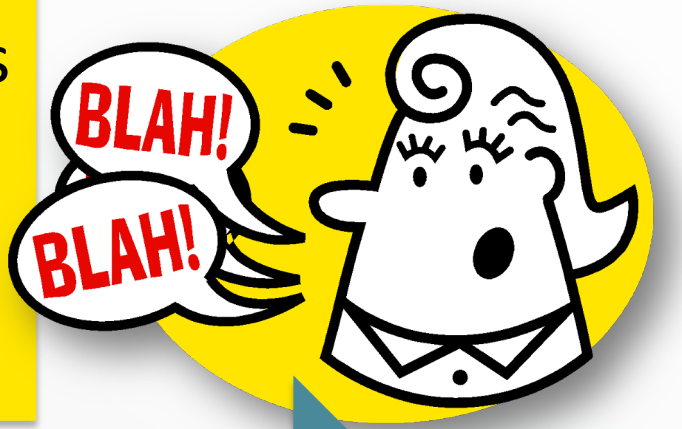

401
ONTARIO
NATURAL
LANGUAGE
COMPUTING

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.

What is Natural Language Computing?

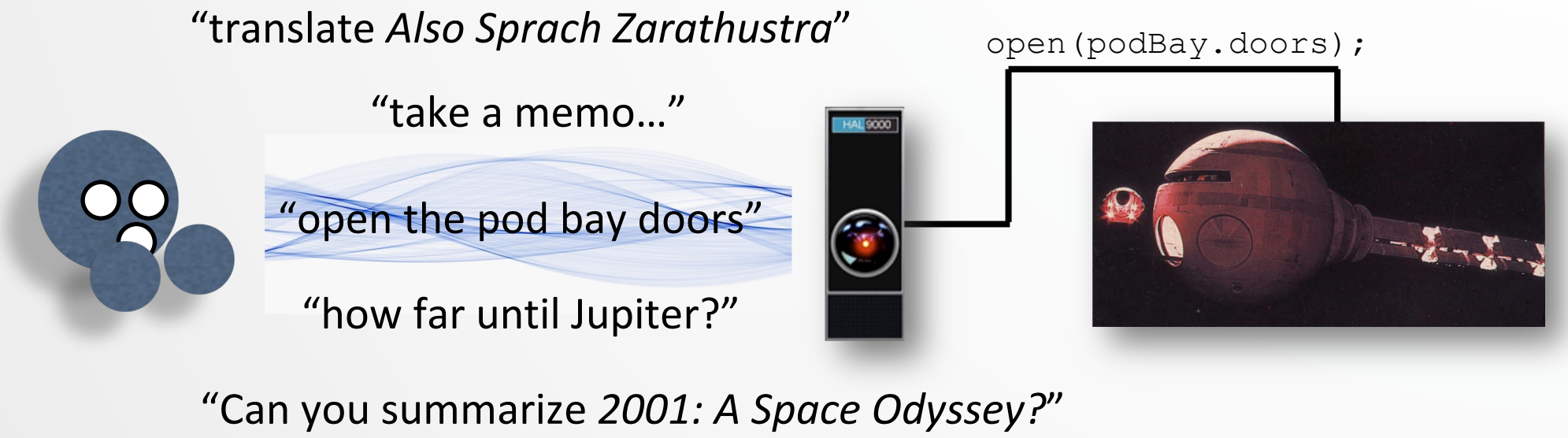
- The computer science (and statistics) behind **natural language processing (NLP)**, also known as **computational linguistics (CL)**.

- Applications
  - Text Classification
  - Automatic translation between languages
  - Automatic speech transcription
  - Spoken language understanding
  - Information Retrieval
  - Text/speech Summarization

Examples

What can natural language do?

A key component of **human-computer interaction**.



We've made 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**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'*

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.

NLP as artificial intelligence

NLP involves **resolving ambiguity** at all levels.

- Reasoning with **linguistic** knowledge
- Reasoning with **world** knowledge
- We sometimes represent the former with *grammars*

We tend to use numerical parameters (probabilities?) to distinguish competing hypotheses.

- E.g., is Google a noun or a verb?
- Examples where Google is a noun ("Google makes Android") does not mean Google is never a verb ("Google his name").
- P(noun|Google) > P(verb|Google) > 0.

Aside – Chatbots

- ELIZA (Weizenbaum, 1966): simple pattern matching to imitate a psychiatrist.
- Surprisingly effective despite **unsophisticated methods**.
- 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)

Course outline (approximate)

- Introduction, lexical distributions, language modelling, lexical embeddings (3 lectures)
- Features and classification (2 lecture) *
- Entropy and information theory (2 lectures) *
- Neural language models (2 lectures) *
- Machine translation (3 lectures) **
- Large language models (3 lectures) *
- Acoustics and signal processing (3 lectures) *
- Automatic speech recognition (2 lectures) **
- Speech Synthesis (1 lecture) **
- Information retrieval (1 lecture) **
- Summarization (1 lecture) **
- Ethics for NLP (2 lectures)

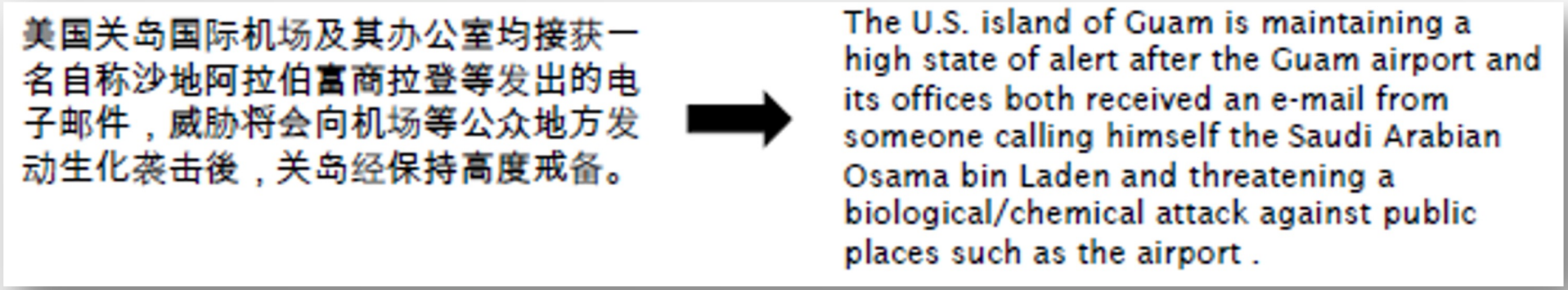
* techniques ** applications

What we will not cover

- Interpretability of language models…*
- Advanced lexical semantics*
- Question answering (including ChatGPT 😭)*
- Information extraction*
- Parsing/generation of natural language*%
- Advanced speech recognition and synthesis¶
- Cognitively based methods§^
- Semantic inference,% semantic change/drift^
- Understanding dialogues and conversations¶
- Advanced ethics for NLP$

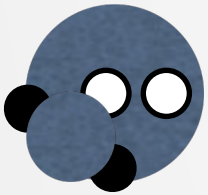
* csc 485 / 2501. % csc 2517. ¶ csc 2518. § csc 2540. ^ csc 2611. $csc 2528.

Preview: Machine translation



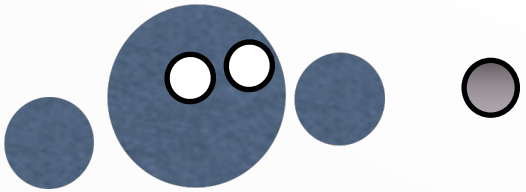
- For years, the holy grail of NLP.
- Requires both **interpretation** and **generation**.
- Over $60B spent annually on human translation in 2022 – projected to reach $96B by 2032
- Machine translation: $1.1B. $3B by 2027.
- 1 in every 4M words of content is translated into at least one other language.

Preview: Speech recognition

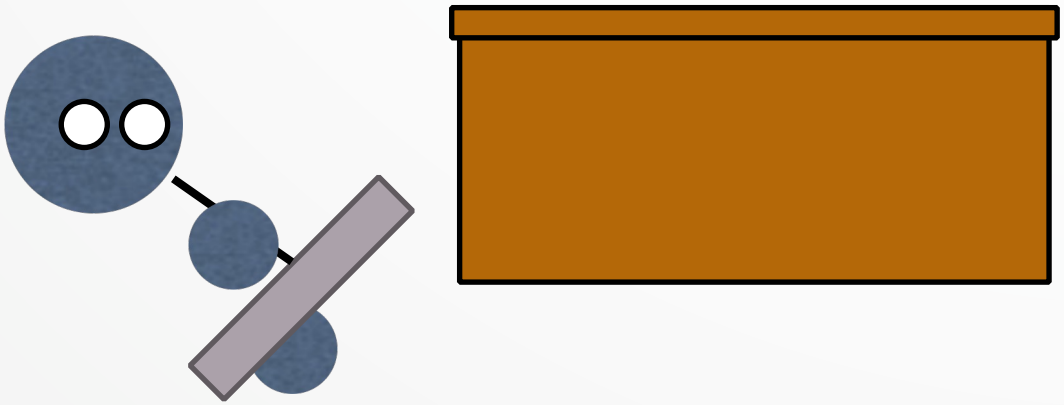


Dictation

Buy ticket...
AC490...
yes



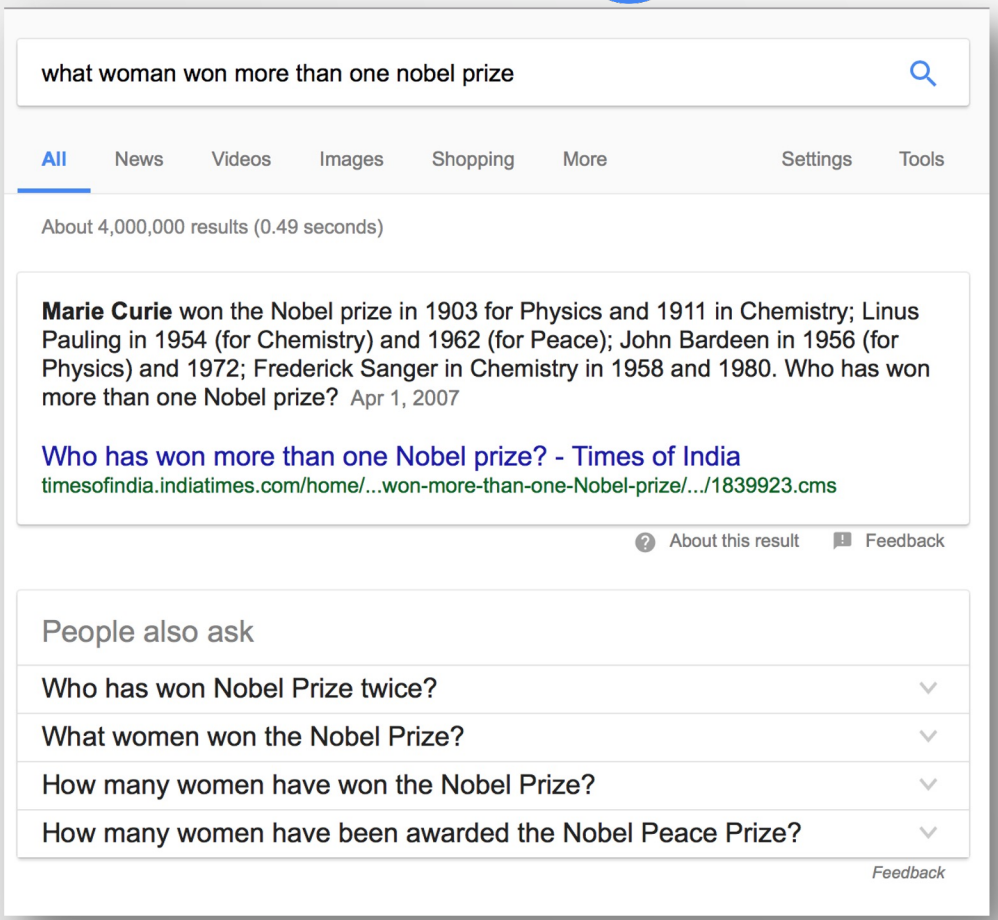
Telephony



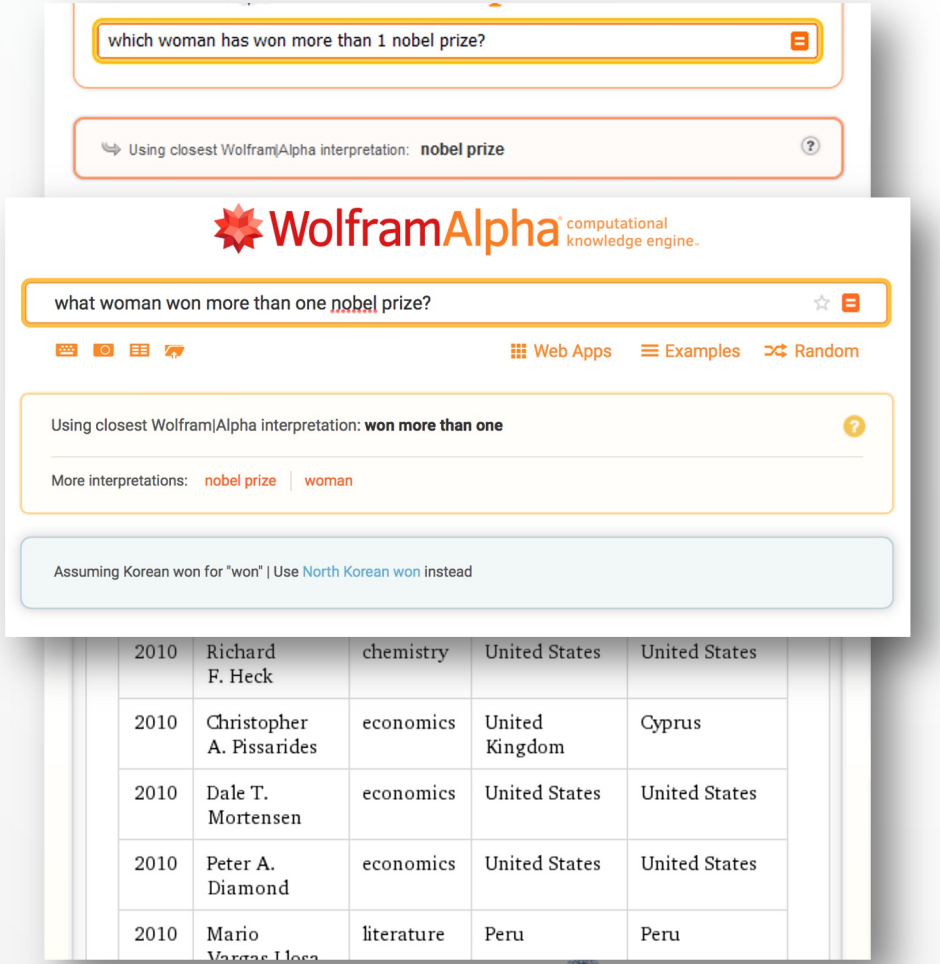
Multimodal interaction

Preview: Information retrieval

Google



WolframAlpha computational knowledge engine



2010	Richard F. Heck	chemistry	United States	United States
2010	Christopher A. Pissarides	economics	United Kingdom	Cyprus
2010	Dale T. Mortensen	economics	United States	United States
2010	Peter A. Diamond	economics	United States	United States
2010	Mario Vargas Llosa	literature	Peru	Peru

Aside – Spoken Information Retrieval

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

Natural language computing

- **Instructors**: Gerald Penn, Sean Robertson, Raeid Saqur (csc401-2024-01@cs)
- **Meetings**: MW (lecture), F (tutorial) at 10h and 11h
- **Languages**: English, Python.
- **Website**: Quercus, www.cs.toronto.edu/~raeidsaqur/csc401/
- **You**: Understand basic **probability**, can **program**, or (grads) can pick these up as we go.
- **Syllabus**: Key **theory** and **methods** in statistical natural language computing.
  Focus will be on ***neural models***, ***language models***, and their ***applications***.

Office hours

Name	Time	Location
Gerald Penn	F 12-2	PT 283
Sean Robertson	TBA	TBA
Raeid Saqur	TBA	TBA

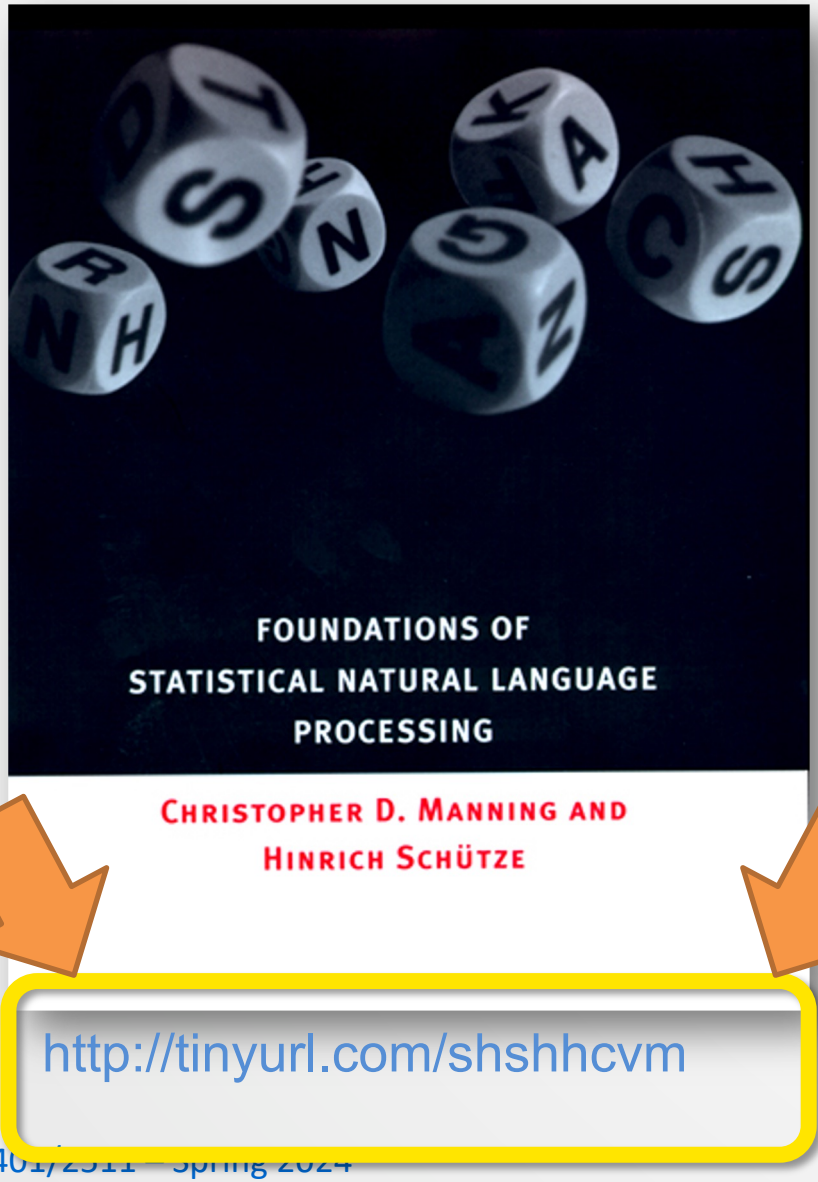
Evaluation policies

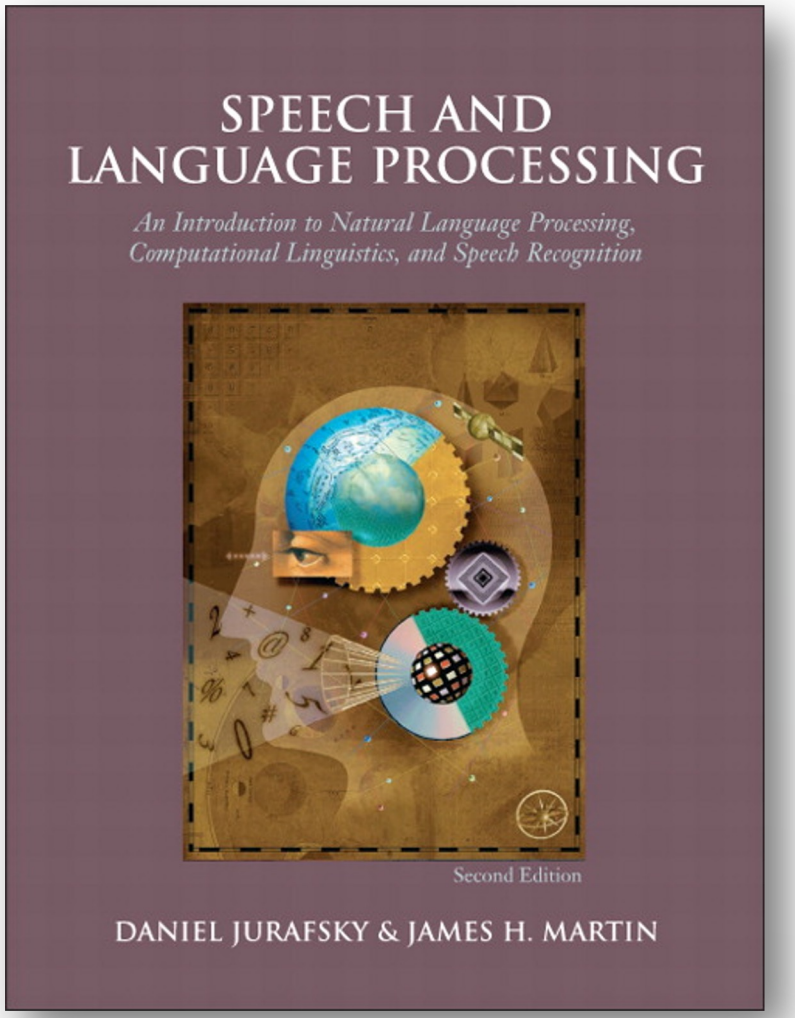
- **General**: Three assignments : **20%** (each)
  Final 'assessment' : **39%**
  Two ethics surveys **: 0.5%** (each)
- **Lateness**: **10%** deduction applied to electronic submissions that are 1 minute late.
  Additional **10%** applied every 24 hours up to 72 hours total, at which point grade is **zero**.
- **Final**: If you **fail** the final 'assessment', 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.

Assignments

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

Reading





http://tinyurl.com/shshhcvm

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.
- Start early.

Assignment 1 and reading

- **Assignment 1** available soon (on course webpage)!
  - Due 9 February
  - TA:

    Mahya Mirbagheri <mahya.mirbagheri@mail.utoronto.ca>

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