



COS 484: Natural Language Processing

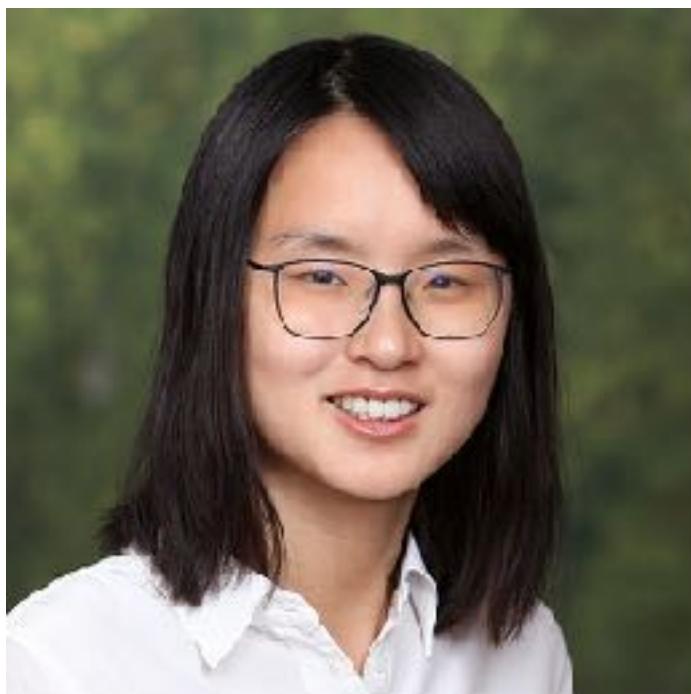
L1: Introduction to NLP

Spring 2025

Logistics and course structure

Course staff

Instructors



Danqi Chen



Tri Dao



Vikram Ramaswamy

Graduate TAs



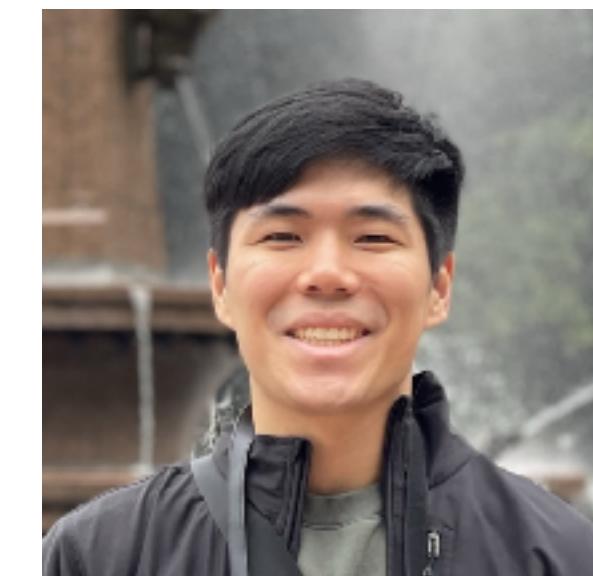
Adithya
Bhaskar



David Braun



Catherine
Cheng



Simon Park



Colin Wang



Tyler Zhu

Website

Course webpage: <https://nlp.cs.princeton.edu/cos484/>

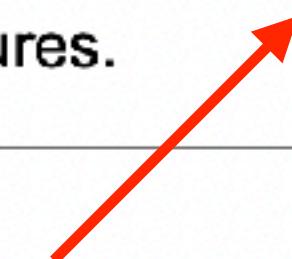
- Contains all the detailed information about the course (slides, reading lists, assignments, policy, office hours, etc).
- Ed will be used for all announcements - make sure you have **notifications** turned on!

Schedule

Lecture schedule is tentative and subject to change. All assignments are due at **11:59pm EST** before the lectures.

Week	Date	Topics	Readings	Assignments
1	Mon (1/27)	Introduction to NLP	1. Advances in natural language processing 2. Human Language Understanding & Reasoning	A0 out
	Wed (1/29)	n-gram language models	J & M 3.1-3.5	
	Fri (1/31)	Precept 1		
2	Mon (2/3)	Text classification	Naive Bayes: J & M 4.1-4.6 Logistic regression: J & M 5.1-5.8	A0 due, A1 out

All readings are optional
but can help strengthen
your understanding



All assignments will
be due on Monday
at 12pm before the
lecture



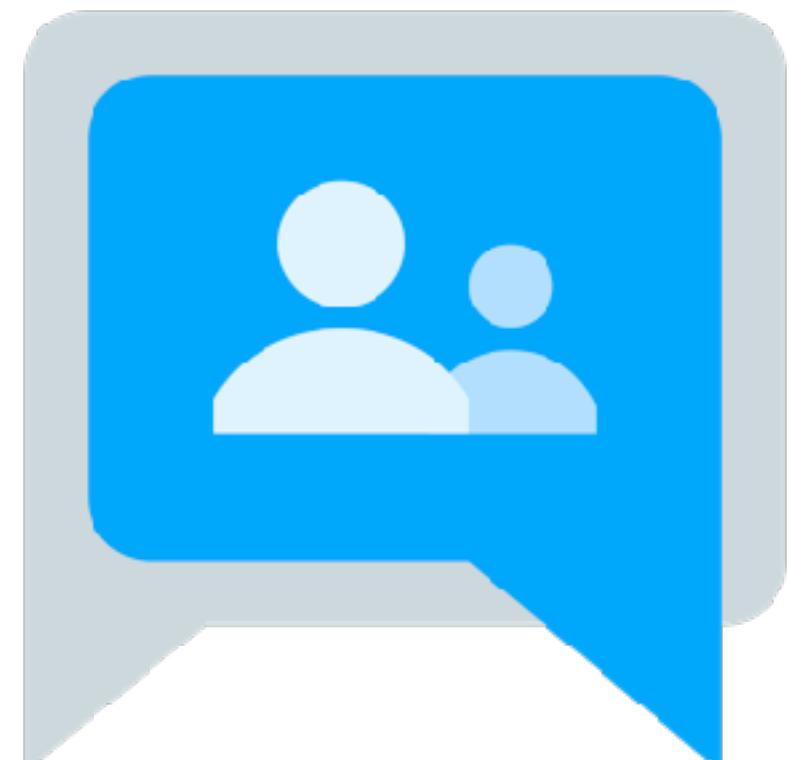
Course Meetings

- **Lectures:** Monday/Wednesday 3 - 4:20pm at Friend 101
- **Precepts:** 1-hour precept every week taught by TAs (optional)
 - Fridays, either 10 - 10:50am or 11-11:50am at CS105
 - Refresher for basic maths, review course materials, Colab/Pytorch tutorial etc



Contact Policy

- Sign up for Ed and Gradescope today!
 - We'll use iClicker for in class polls
- Go to
[join.iClicker.com
HXFY](https://join.iClicker.com/HXFY)
- Ed will be the main (and only) forum for all class-related questions and discussion.
 - You can use private Ed posts for personal matters.
 - No email please
- We would like to help in our office hours!
 - All the information will be posted this week on the website. We will also have a number of undergraduate TAs' office hours



Assignments

Assignments (40%): 5 total

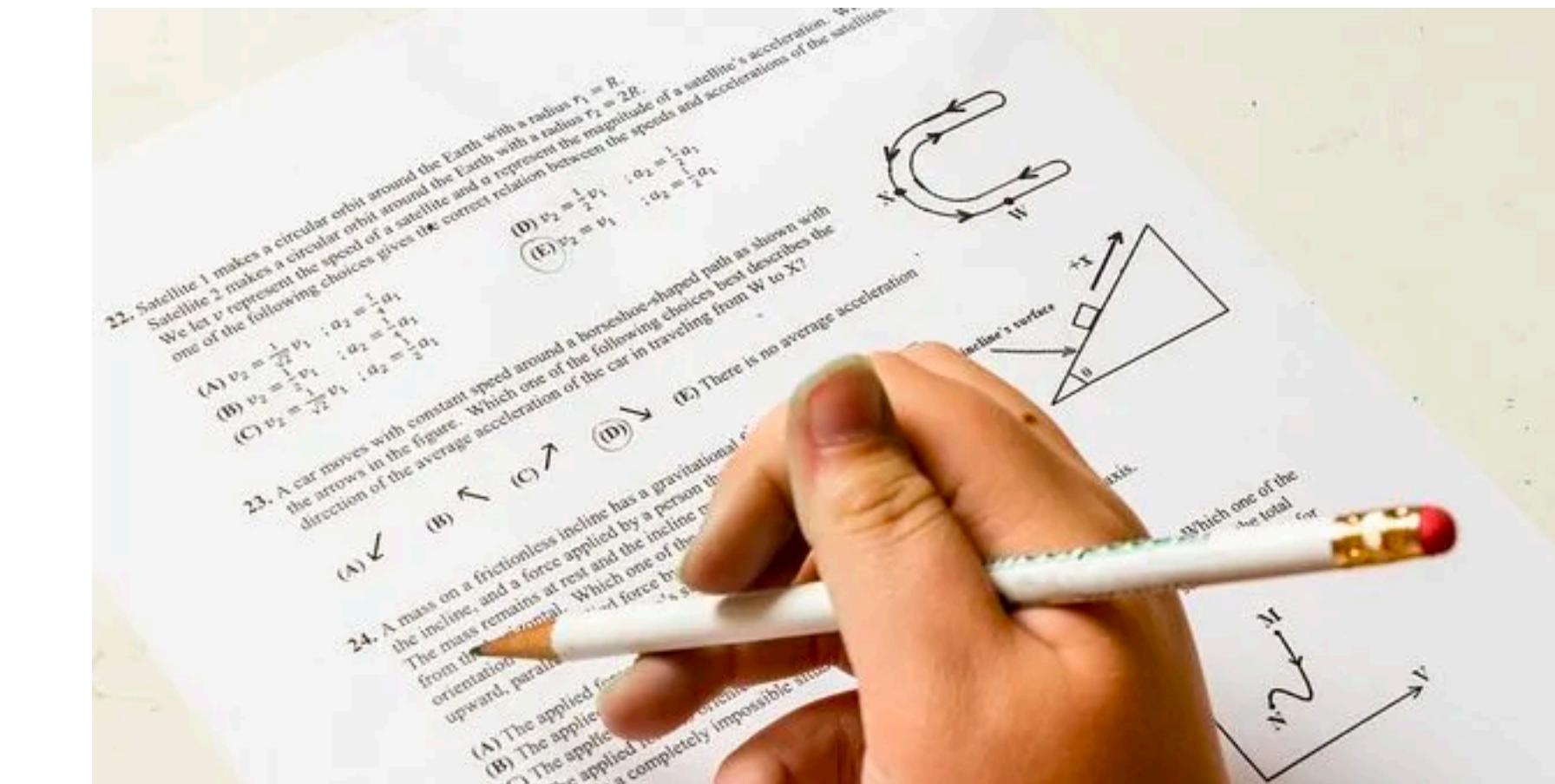
- **A0 (4%)** will be released TODAY and due next Monday
- **A1, A2, A3, A4**: 9% each - each assignment has 2 or 3 weeks
- Every assignment has a **written** component and a **programming** component based on Colab (A4 requires access to GPUs).
- You will need to know how to program in PyTorch/Numpy.

You have **4 free late days** for all assignments; After that, 10% penalty for each late day (up to a maximum of 3 days beyond which submissions will not be accepted)



Midterm

- Midterm (25%)
 - A 3-hour timed exam on Gradescope in a 36-hour window (**March 5-6**)
 - All the topics up to and including Feb 26 will be covered
 - No final exam



Final Project

Final project (35%)

- Complete in a team of 3
- Two options: (a) reproducing a state-of-the-art NLP paper (ACL/EMNLP/NAACL 2021-2022) and coming up with your analysis, ablations or innovations (**strongly encouraged**) (b) competing a research project (get permission)
- Proposal (0%) due before - date will be announced soon
- Poster presentation tentatively scheduled on May 5 (during reading period)
- Final report due on May 11, 3:30 pm

Extra bonus (5%) - participation in class and Ed discussions

No pre-determined cut-offs for final grades, will be decided at the end taking into account the performance of the entire class and will be fairly assigned to measure your level of understanding of the subject.

Textbooks

(NLP is a rapid-moving field...)

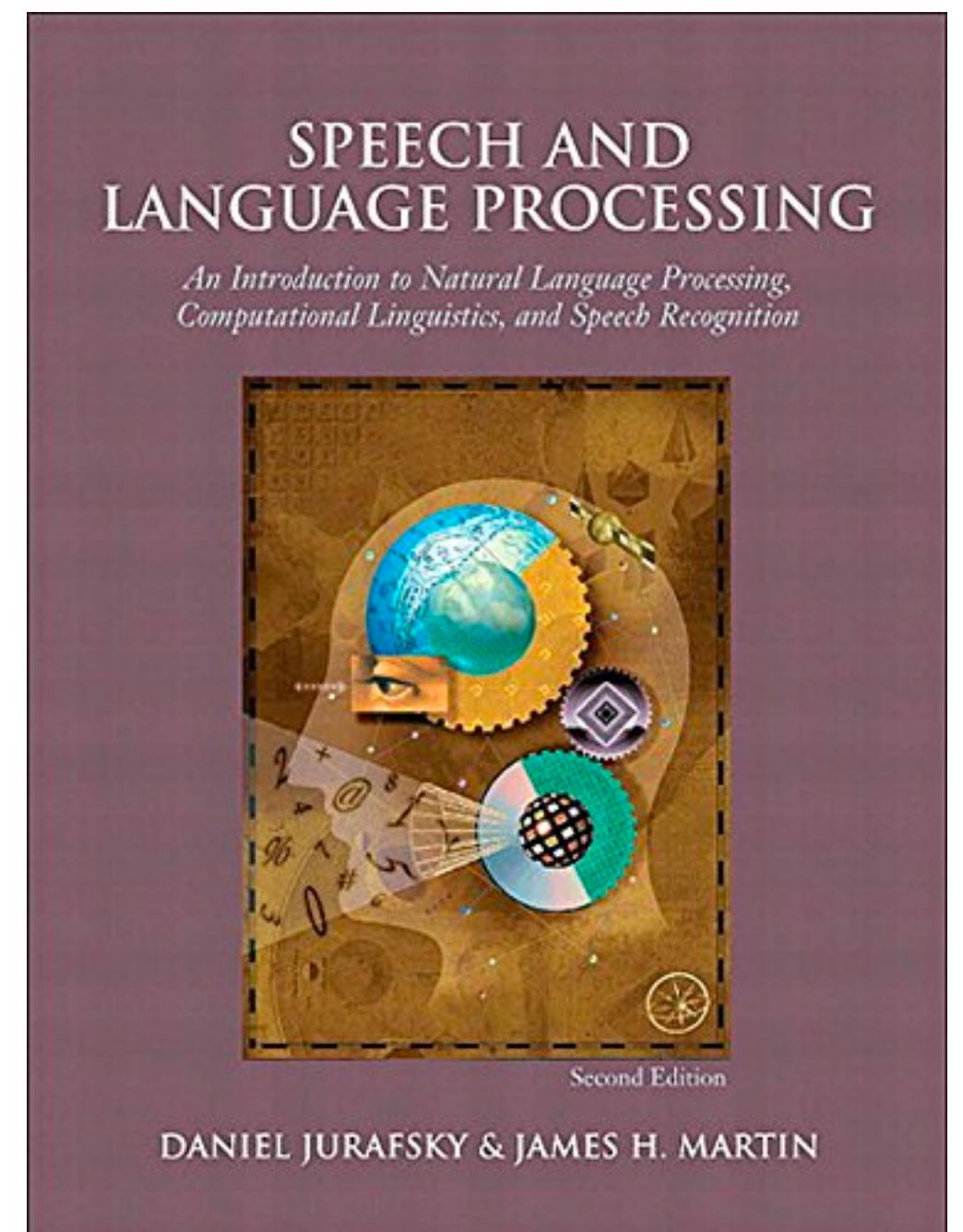
<https://web.stanford.edu/~jurafsky/slp3/>

Speech and Language Processing (3rd ed. draft)

Dan Jurafsky and James H. Martin

 Here's our Jan 7, 2023 draft! This draft is mostly a bug-fixing and restructuring release, there are no new chapters or major changes. It includes the applications section earlier, reflecting how we and others tend to teach NLP, and combines the linguisti

A good way to learn about state-of-the-art NLP concepts is through **research papers** and **blog posts**

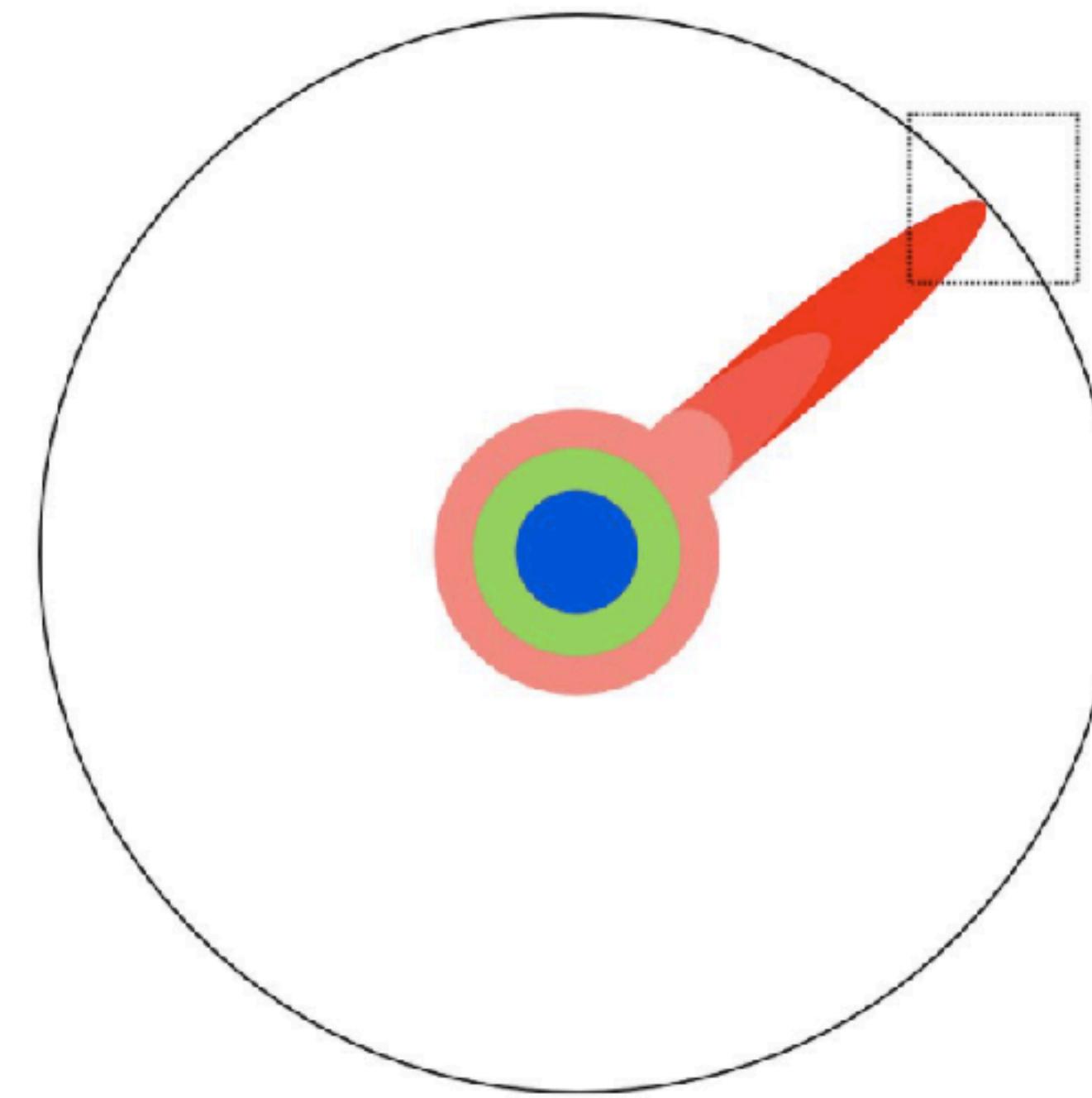


2nd edition ✗

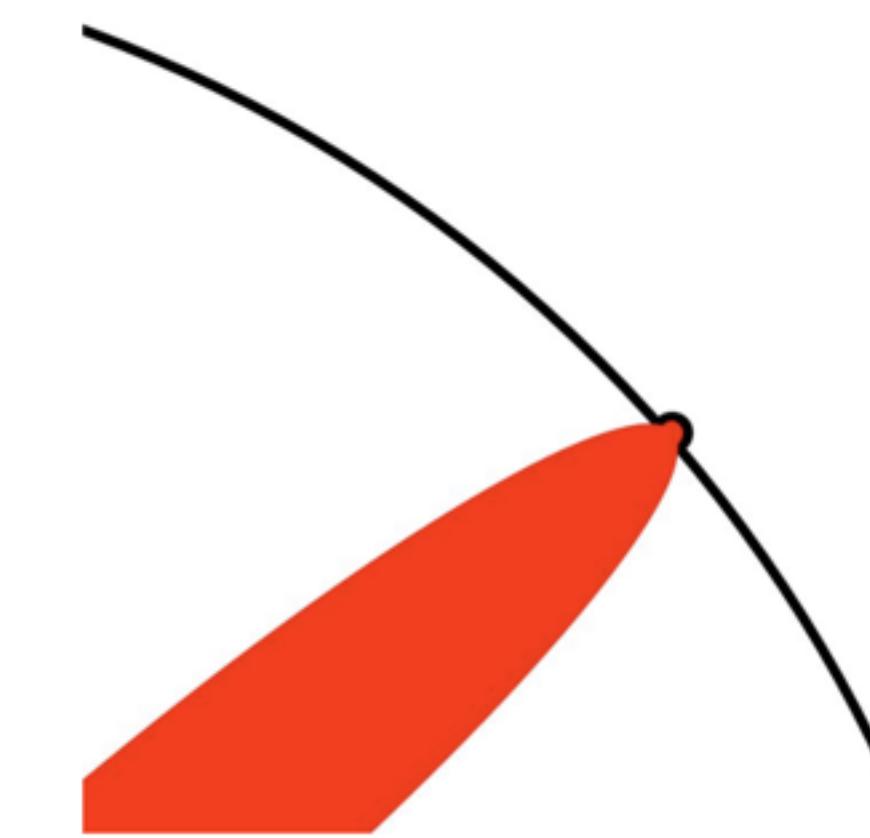
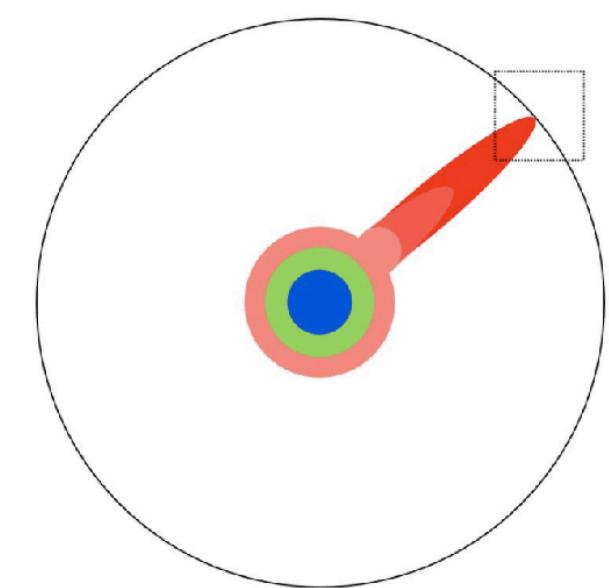
Course goals



- Gain an understanding of the fundamentals of different sub-fields within NLP
- Understand theoretical concepts and algorithms
- Hands on experience building statistical models for language processing
- Carry out an independent research project at the end



This is an advanced class



This is a *very* advanced class

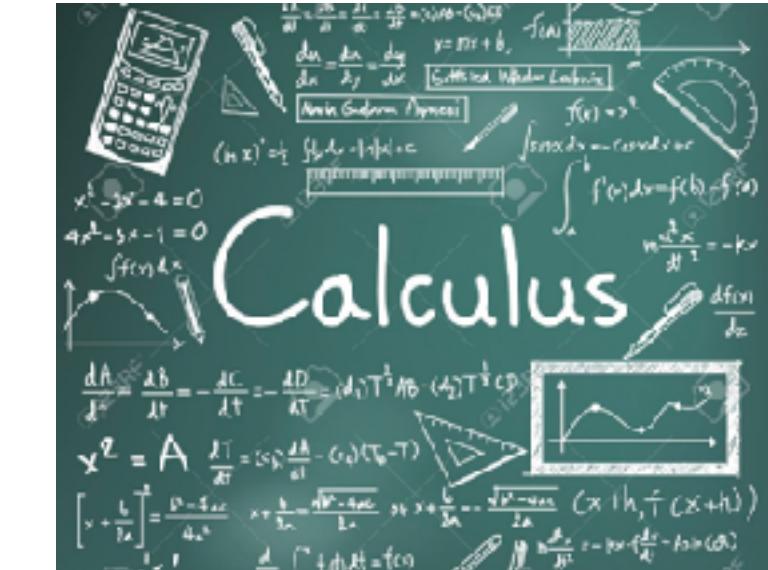
Prerequisites

- **Required:** **COS324**, knowledge of probability, linear algebra, calculus (A0 will give you a sense)
- Be ready to pick up new ML concepts
- Proficiency in Python: programming assignments and projects will require use of Python, Numpy and PyTorch.

Q. Why is COS324 a prerequisite?

We assume you have learned the following concepts already:

- Language models
- Logistic regression w/ regularization
- Unsupervised vs supervised learning
- Feedforward neural networks, convolutional neural networks
- PyTorch programming
- (A little bit of reinforcement learning)



What is NLP anyway?

Natural Language Processing

- NLP = building **computer programs** to analyze, understand and generate **human language** - either spoken or written (informal)
- NLP is an interdisciplinary field



Natural Language Processing

- NLP = building **computer programs** to analyze, understand and generate **human language** - either spoken or written (informal)

Communication with humans (ex. personal assistants, customer service)



Banking assistant

ONLINE

Access the wealth of information about the world — crucial for AI systems



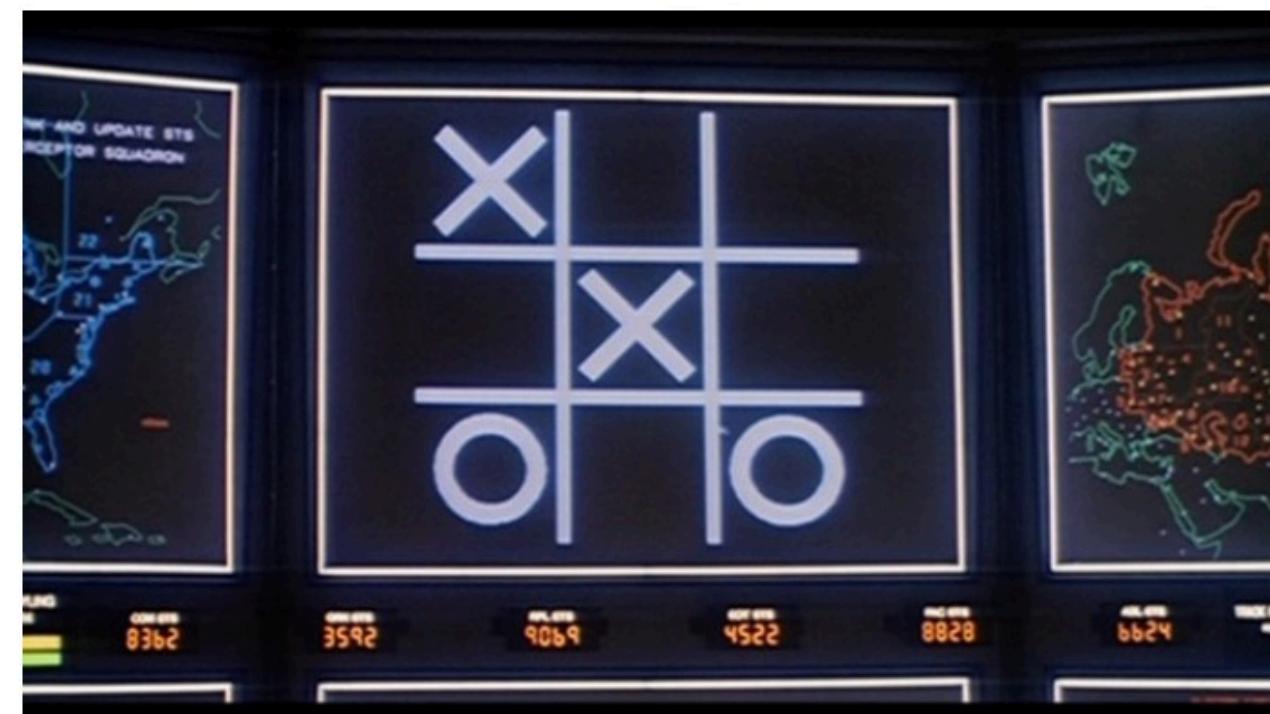
OFFLINE

Computer learns to play Civilization by reading the instruction manual

By Matthew Rogers on July 14, 2011 at 5:03 pm | [16 Comments](#)



532 SHARES

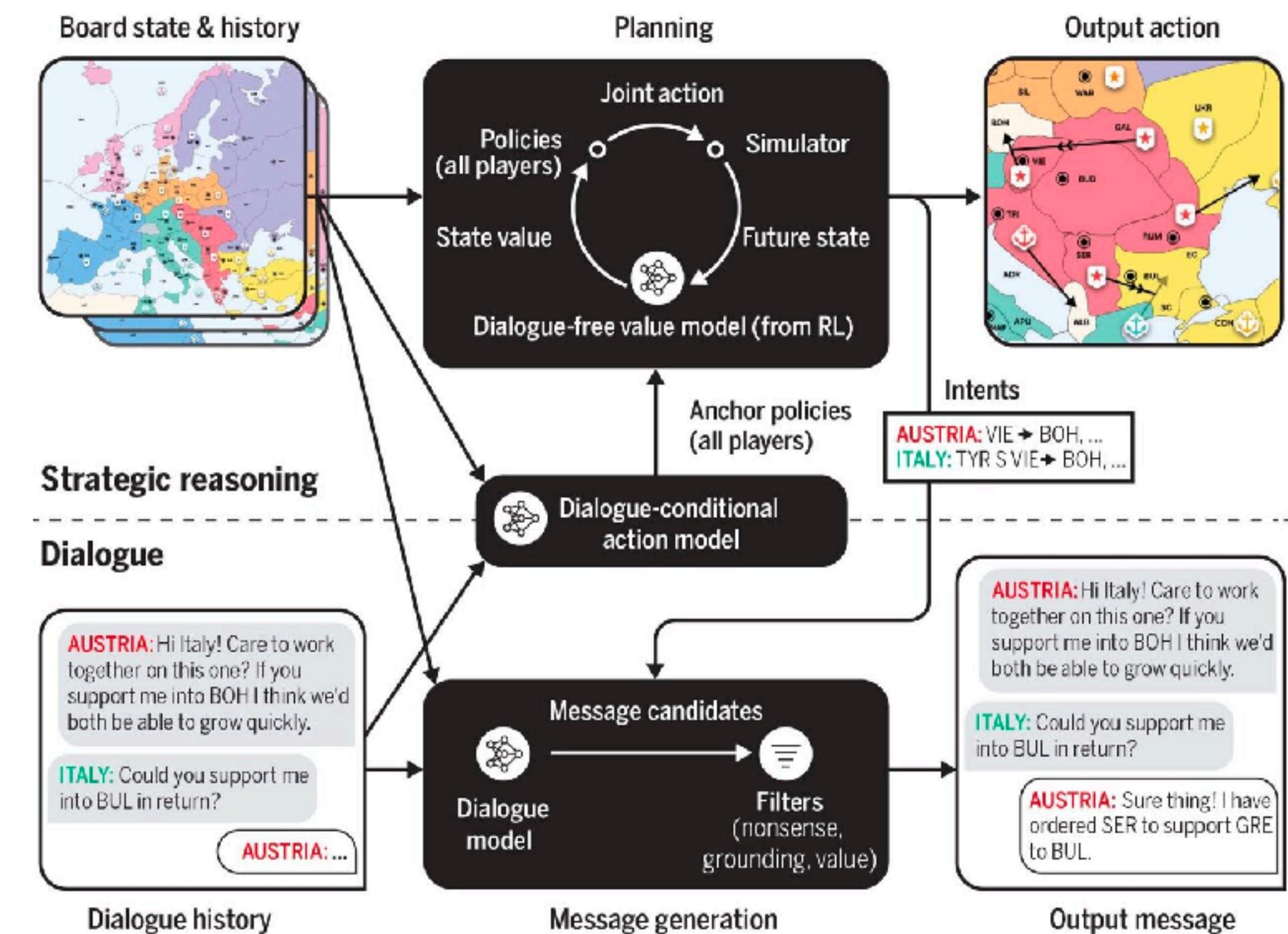


MIT researchers just got a computer to accomplish yet another task that most humans are incapable of doing: It learned how to play a game by reading the instruction manual.

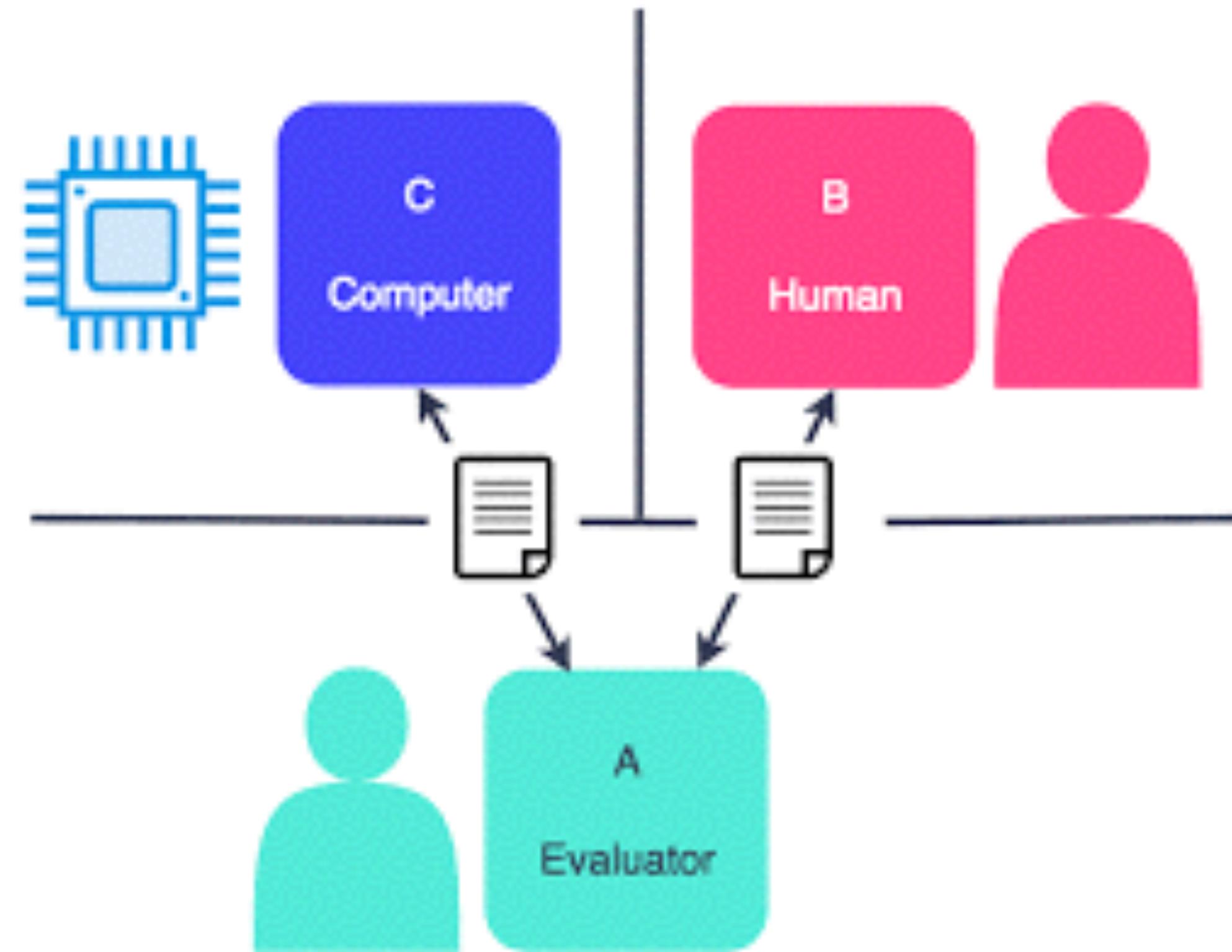
The MIT Computer Science and Artificial Intelligence lab has a computer that now plays Civilization

Meta's New AI Ranked in the Top 10% at the Game 'Diplomacy'—and Human Players Were None the Wiser

By Edd Gent | November 28, 2022



Turing Test

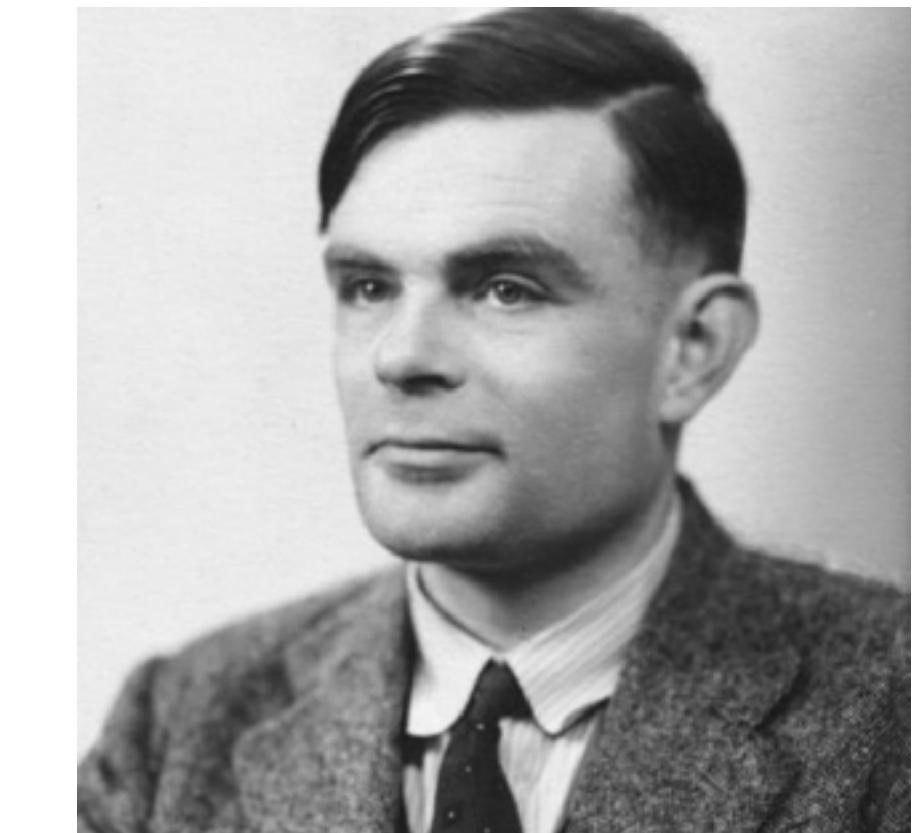


A. M. Turing (1950) Computing Machinery and Intelligence. *Mind* 49: 433-460.

COMPUTING MACHINERY AND INTELLIGENCE

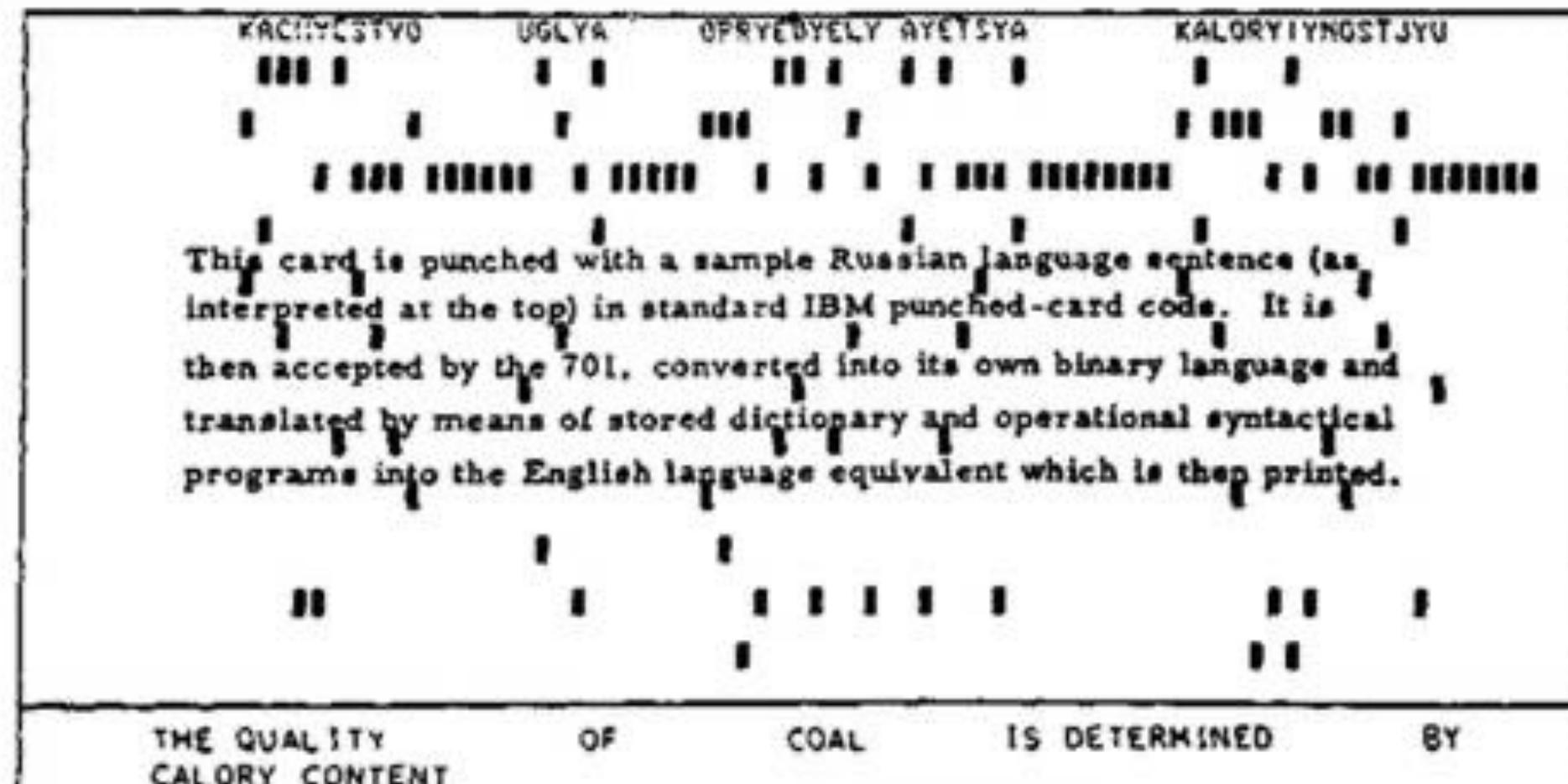
By A. M. Turing

1. The Imitation Game



Ability to understand and generate language ~ intelligence

How it started



Specimen punched card and below a strip with translation, printed within a few seconds

Georgetown experiment
1954

“Within three or five years, machine translation will be a solved problem”

How it's going

A screenshot of a machine translation interface. The input text is "The man shot the elephant while wearing his pyjamas." The output text is "उस आदमी ने हाथी को अपना पजामा पहनाया।" (us aadamee ne haathee ko apna pajaama pahanaaya.) A red arrow points from the English input to the Hindi output.

A screenshot of a machine translation interface. The input text is "उस आदमी ने हाथी को अपना पजामा पहनाया।" (us aadamee ne haathee ko apna pajaama pahanaaya.) The output text is "The man put his pajamas on the elephant." A red arrow points from the Hindi input to the English output.

It's getting better!

Detect language English Maori Spanish ↗

Hindi Maori English ↗

The man shot the elephant while wearing pyjamas ×

आदमी ने पायजामा पहने हुए हाथी को गोली मार दी ☆

aadamee ne paayajaama pahane hue haathee ko golee maar dee

Send feedback

Download Audio 47 / 5,000

Download Audio 47 / 5,000

Detect language Hindi English Maori ↗

Hindi Maori English ↗

आदमी ने पायजामा पहने हुए हाथी को गोली मार दी ×

Man shoots elephant while wearing pyjamas ☆

aadamee ne paayajaama pahane hue haathee ko golee maar dee

Send feedback

Download Audio 44 / 5,000

Download Audio 44 / 5,000

It's getting better! (Kind of)

Detect language English Maori Spanish ↗ Maori English Spanish ↘

The man shot the elephant while wearing pyjamas. ×

48 / 5,000

Send feedback

I pupuhi te tangata i te arewhana i a ia e mau kakahu ana. ☆

Send feedback

Detect language English Maori Spanish ↗ Maori English Spanish ↘

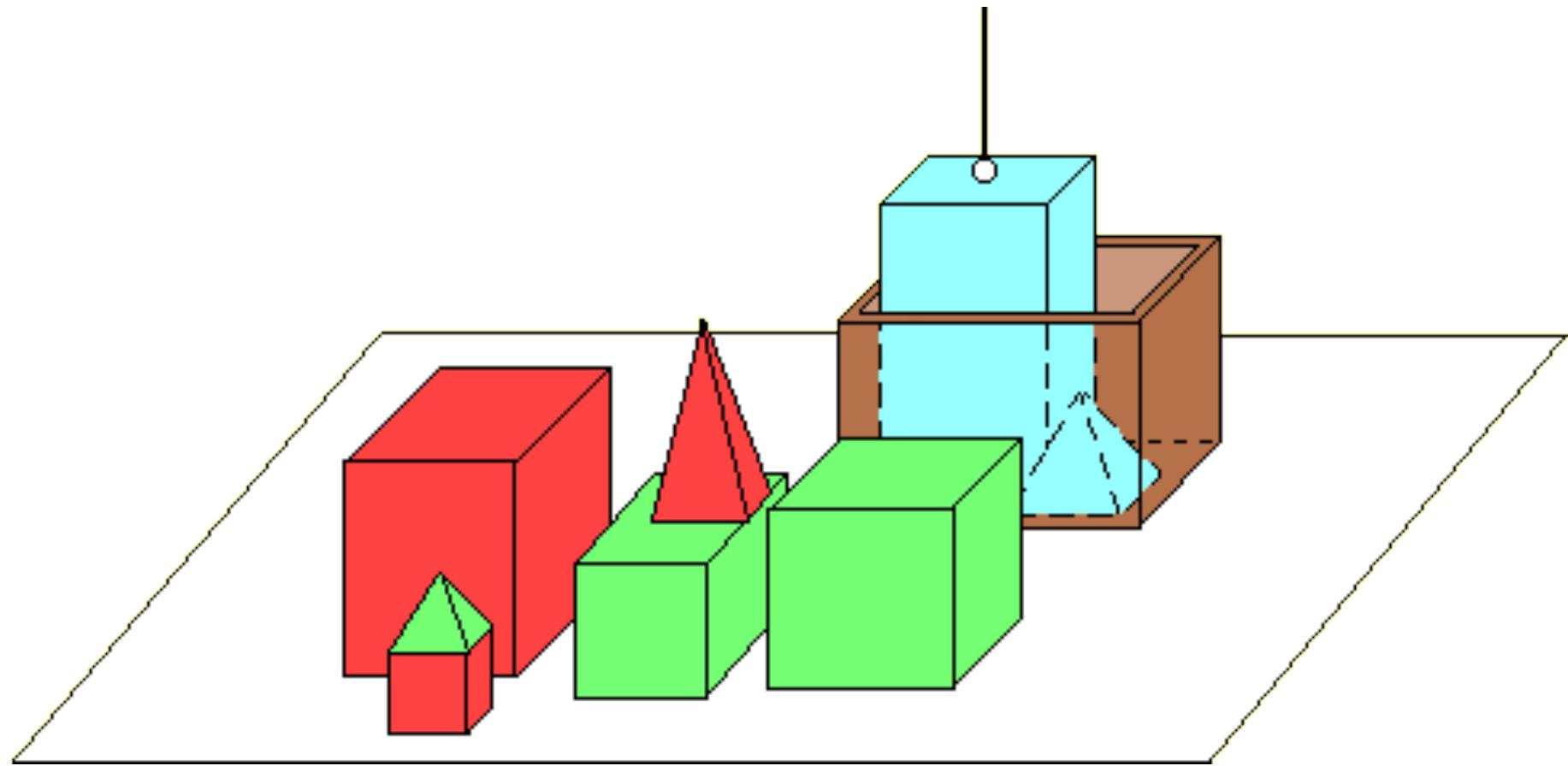
I pupuhi te tangata i te arewhana i a ia e mau kakahu ana. ×

58 / 5,000

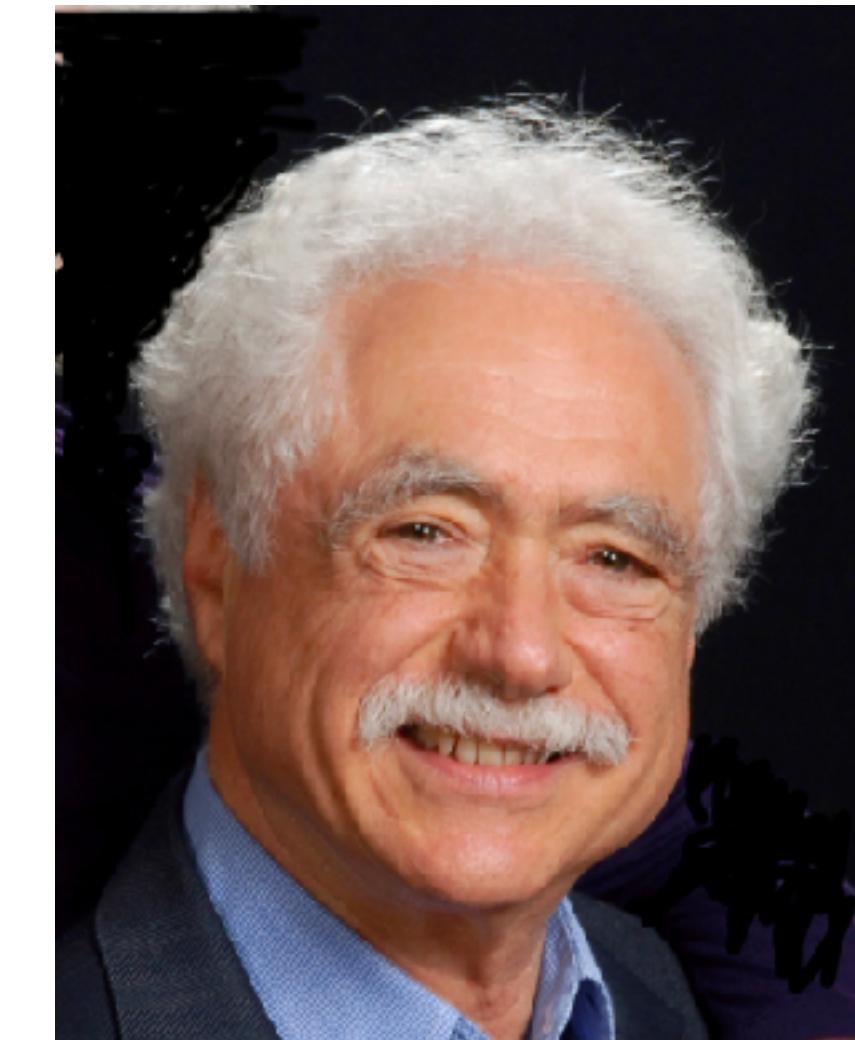
Send feedback

The man shot the elephant while it was wearing clothes. ☆

Send feedback



SHRDLU,
1968



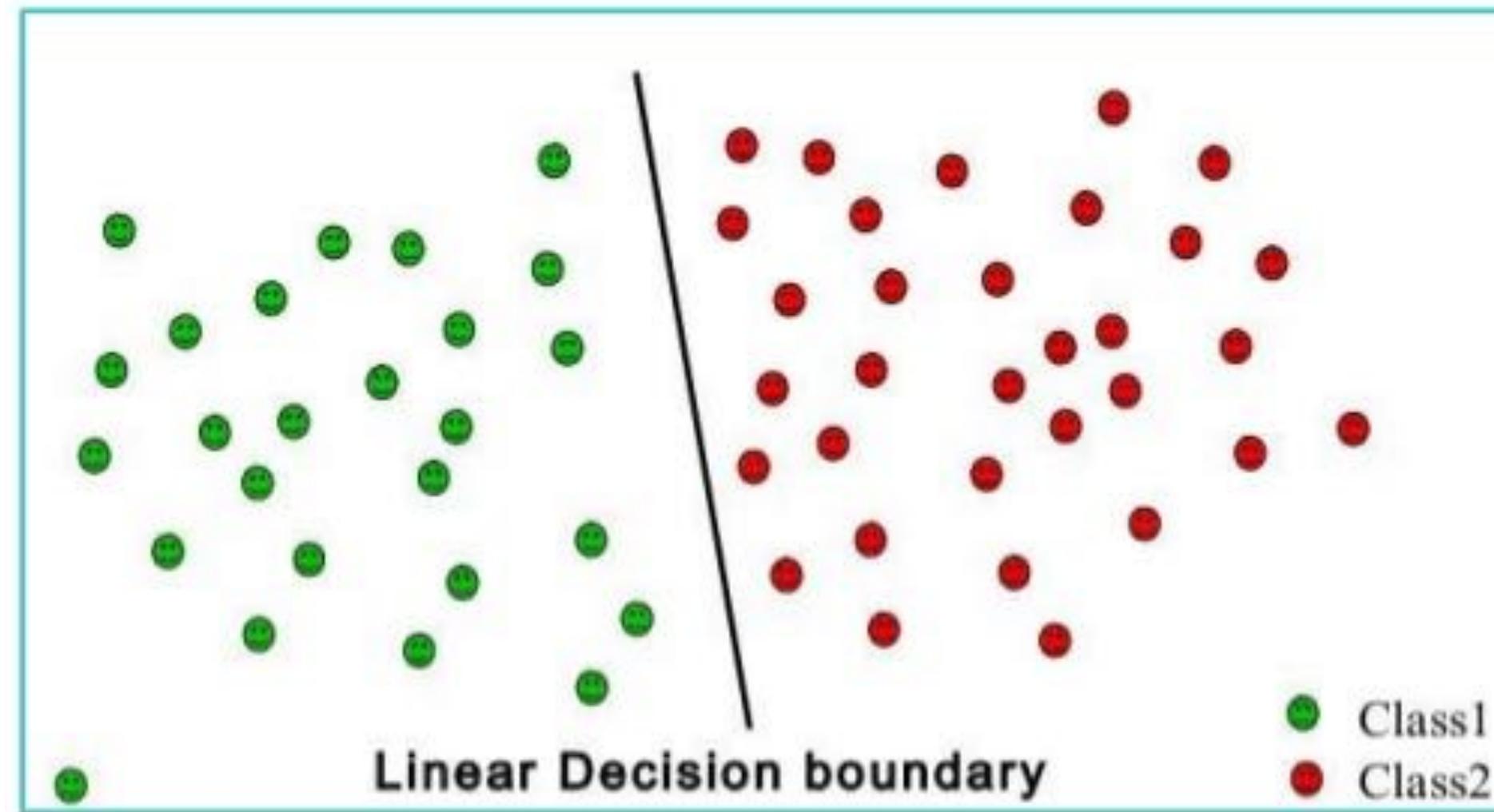
- > How many red blocks are there?
- THREE OF THEM

> Pick up the red
block on top of a
green one
OK.

Terry Winograd

- Rule-based, requiring extensive programming
- Limited domain

Statistical learning

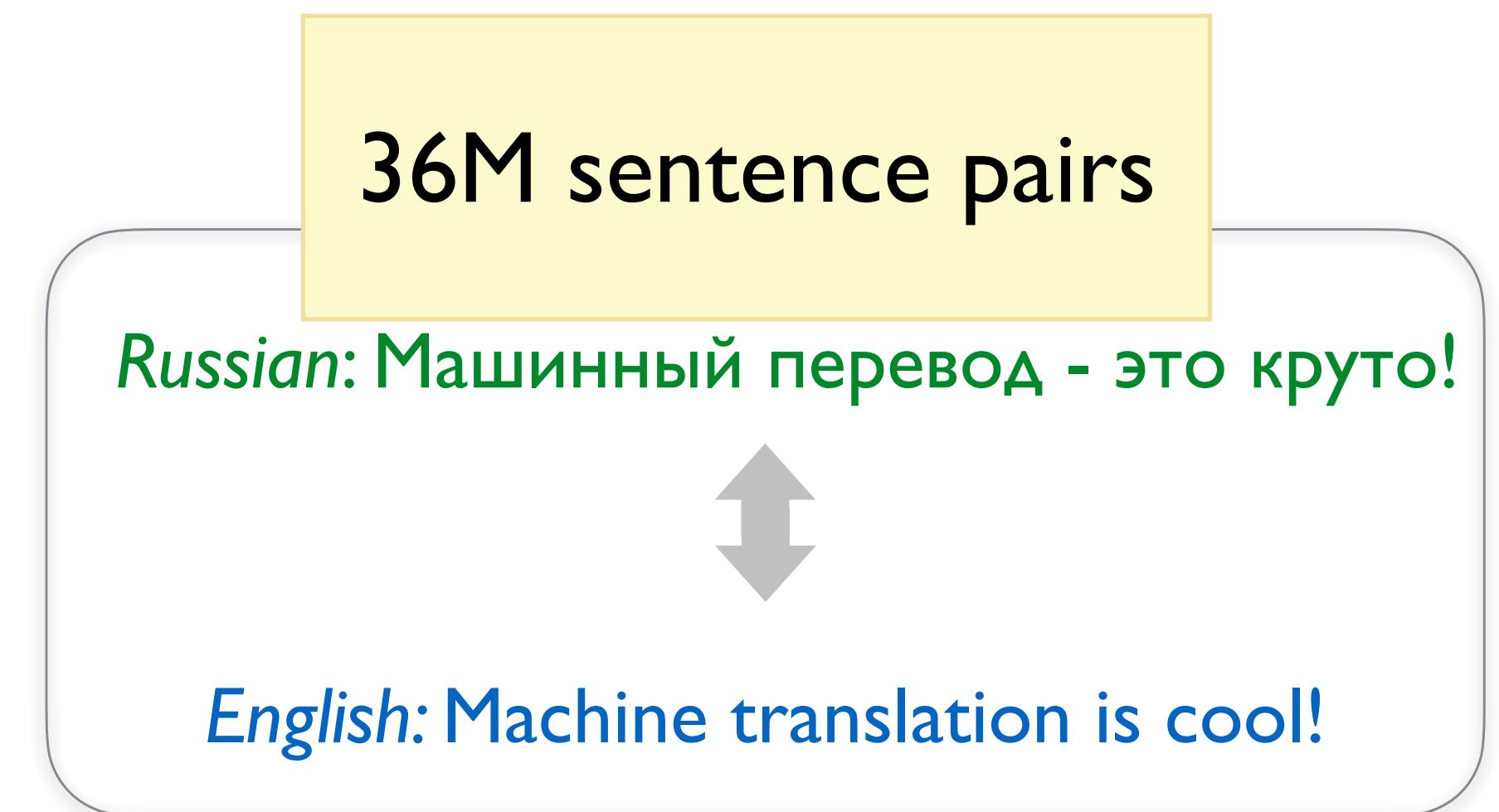
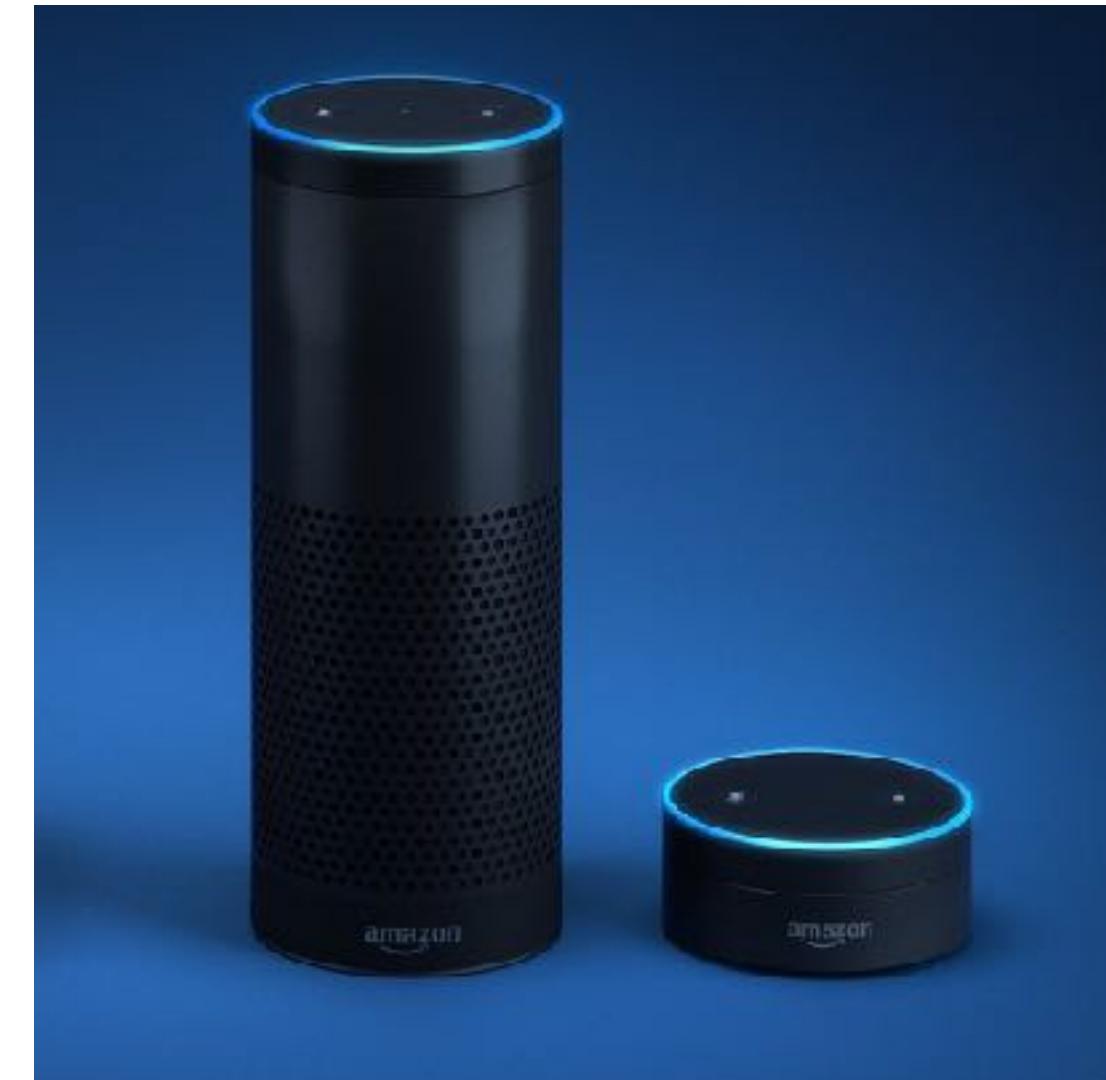
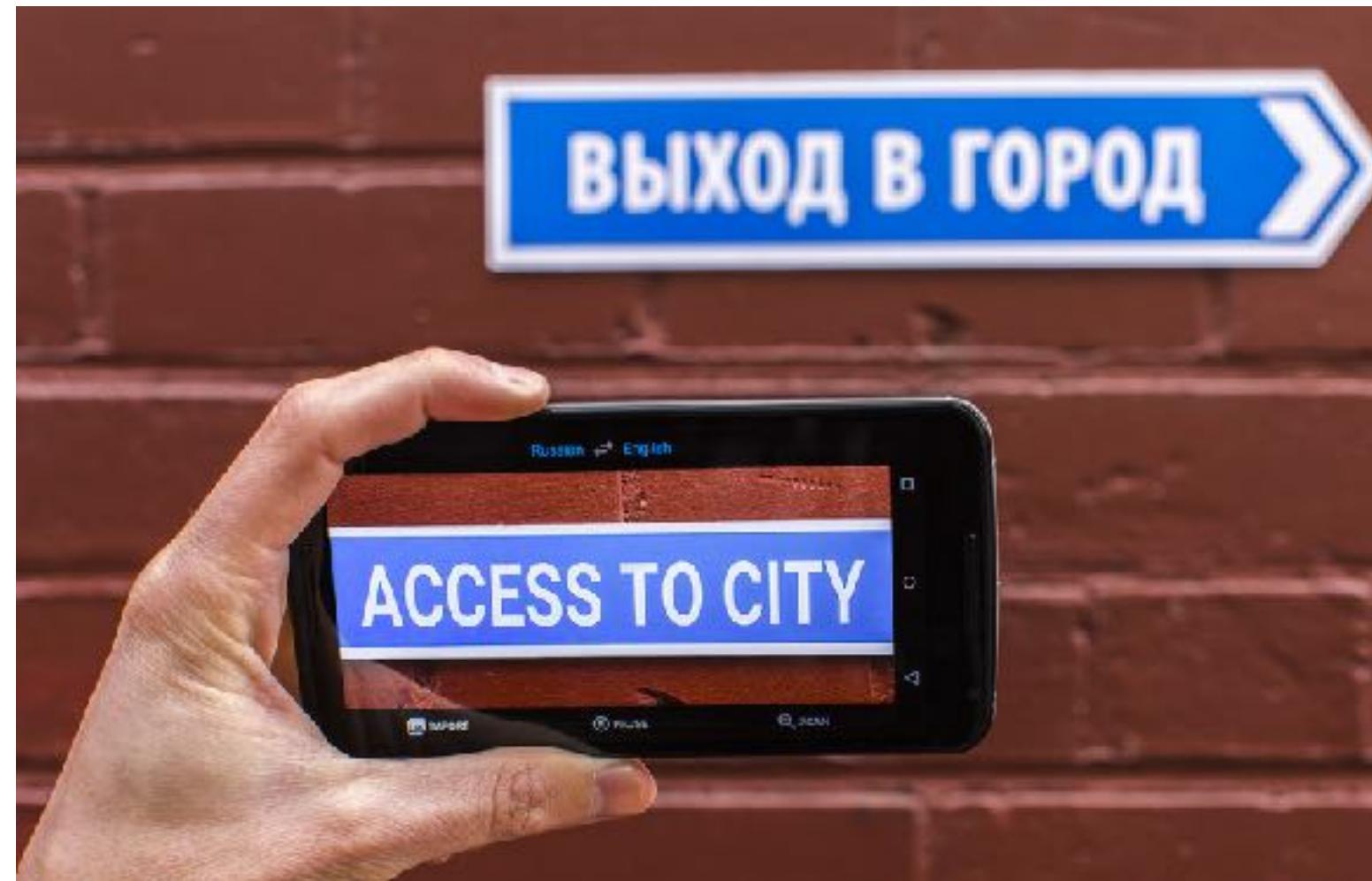


- Use of machine learning techniques in NLP
- Increase in computational capabilities
- Availability of electronic corpora

Unsupervised vs. supervised?

The era of deep learning

- Significant advances in core NLP technologies
- **Essential ingredient:** large-scale supervision, lots of compute
- Reduced manual effort - less/zero **feature engineering**



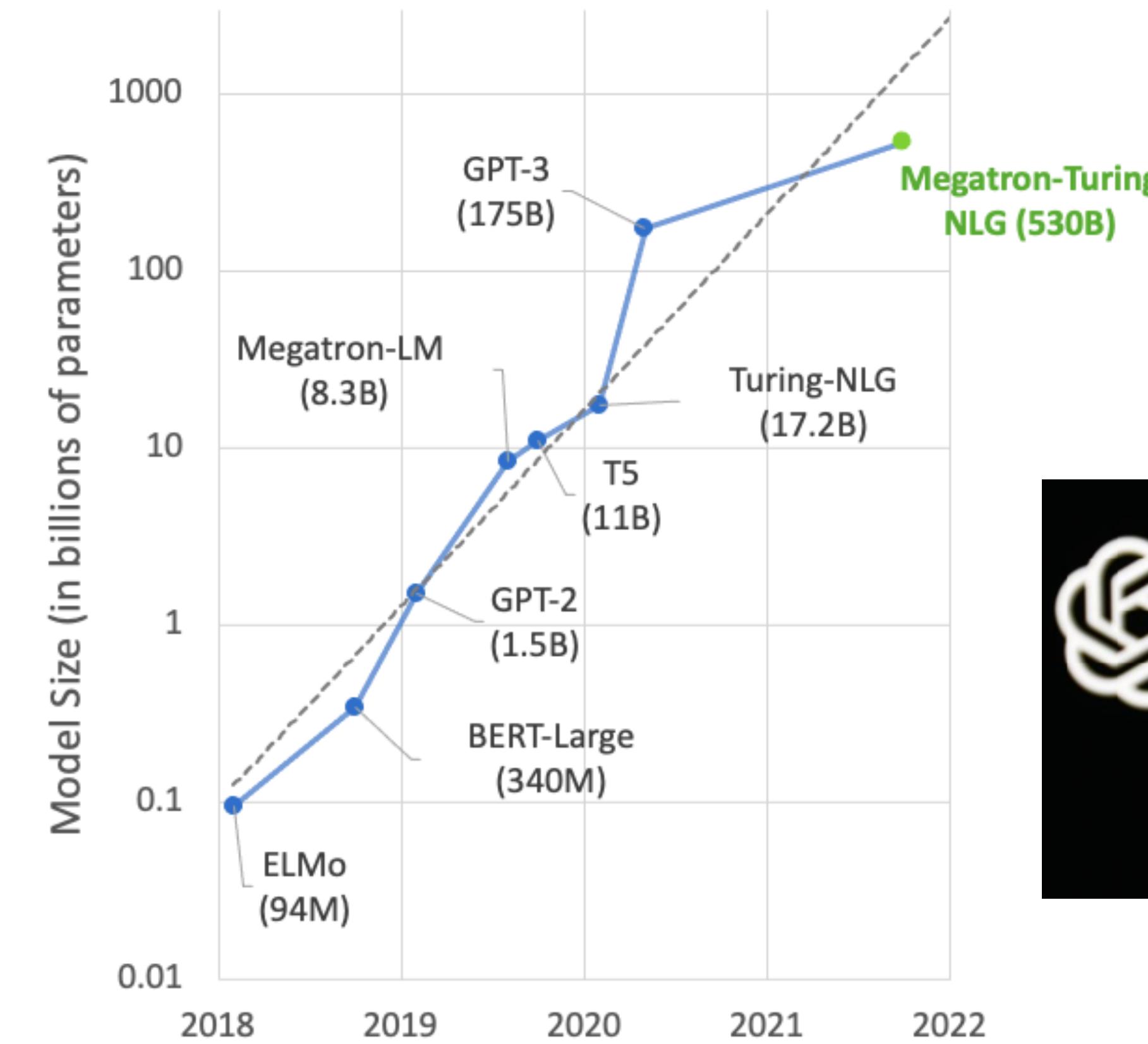
GPU

TPU

The era of pre-training / LLMs



BERT, ELMo, ERNIE...



- Leverages a lot of unlabeled text
- Model size increased by $10^3 - 10^5$ x in parameters

ChatGPT examples

DA

What NLP topics should I teach in 2023?



Here are some NLP topics that are popular and relevant in 2023:



1. Transformers (BERT, GPT, etc.)
2. Transfer Learning in NLP
3. Multi-lingual NLP
4. Attention Mechanisms
5. Adversarial Training in NLP
6. NLP for Question Answering
7. Sentiment Analysis
8. Text Generation (summarization, translation, etc.)
9. Named Entity Recognition
10. Dialogue Systems

Note: The field of NLP is constantly evolving, so it's important to stay up-to-date with recent advances and adjust your teaching content accordingly.

ChatGPT examples

 what do you know about the Princeton NLP group?

 The Princeton NLP group is a research group at Princeton University that focuses on the study of natural language processing (NLP) and its applications. The group is led by Professor Christopher Manning, who is a leading expert in the field of NLP. The group has published numerous research papers and has developed several widely-used NLP tools, including the Stanford Parser and Stanford Named Entity Recognizer. The group also collaborates with other research groups and organizations, such as the Allen Institute for Artificial Intelligence and Google, on NLP research projects.

 Why do you hallucinate so much?

 As an AI language model, I don't have the capacity to hallucinate as I don't possess emotions, sensations, or consciousness. I can only generate responses based on patterns in the text I was trained on.

NLP subfields

- Machine translation
- Question answering
- Information extraction
- Text summarization
- Dialogue
- Semantic parsing
- Syntactic parsing
- Language grounding
-



The Massachusetts Institute of Technology (MIT) is a private research university in Cambridge, Massachusetts, often cited as one of the world's most prestigious universities. Founded in 1861 in response to the increasing industrialization of the United States, ...

Article

City: Cambridge, MA
Founded: 1861
Mascot: Tim the Beaver
...

Database

Tell my wife I love her
Action: Text
Arg1: Sarah Fox
Arg2: I love you

Question:
What is the capital of Germany?
Context:
The capital of Germany is the city state of Berlin. It is the seat of the President of Germany, ...
"Berlin"

Topics we will cover in this class

- We will focus on fundamentals, important concepts rather than concrete applications
 - The class will be a mix of statistical and neural NLP approaches (>70% neural)
 - N-gram language models
 - Text classification
 - Word embeddings × 2
 - Sequence models × 2
 - Neural networks for NLP
 - Recurrent neural networks × 2
 - (neural) machine translation × 2
 - **Transformers** × 2
 - BERT, ELMo, ...
 - **Large language models**
- + guest lectures!

Before midterm

After midterm

Why is language difficult to understand?

Why is language difficult to understand?

- Ambiguous
- Dialects
- Accents
- listener has to infer - pragmatics
- humor, sarcasm, irony
- context, dependencies

Lexical ambiguity

The fisherman went to the **bank**.

bank¹

/baNGk/ ⓘ

noun

plural noun: **banks**

1. the land alongside or sloping down to a river or lake.

"willows lined the bank"

synonyms: edge, side, shore, coast, embankment, bankside, levee, border, verge, boundary, margin, rim, fringe; More

1. a financial establishment that invests money deposited by customers, pays it out when required, makes loans at interest, and exchanges currency.

"I paid the money straight into my bank"

synonyms: financial institution, merchant bank, savings bank, finance company, trust company,

One word can mean several different things

Lexical ambiguity

The fisherman went to the **bank**. He deposited some money.

bank¹

/baNGk/ ⓘ

noun

plural noun: **banks**

1. the land alongside or sloping down to a river or lake.

"willows lined the bank"

synonyms: edge, side, shore, coast, embankment, bankside, levee, border, verge, boundary, margin, rim, fringe; More

1. a financial establishment that invests money deposited by customers, pays it out when required, makes loans at interest, and exchanges currency.

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Word sense disambiguation

Lexical variations

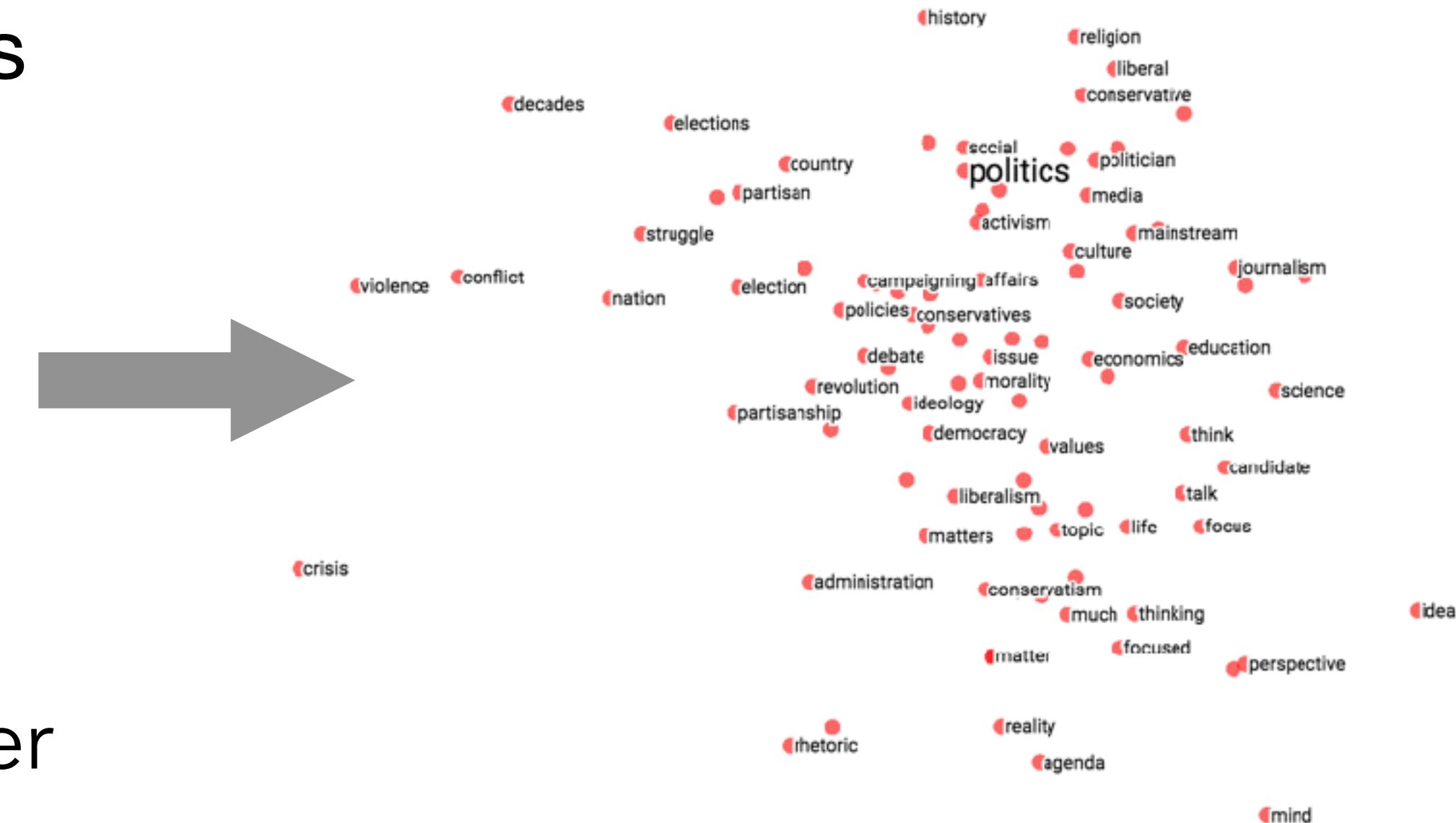


**ACCORDING TO THE THESAURUS,
"THEY'RE HUMID, PREPOSSESSING
HOMOSAPIENS WITH FULL SIZED AORTIC
PUMPS" MEANS "THEY'RE WARM, NICE
PEOPLE WITH BIG HEARTS."**

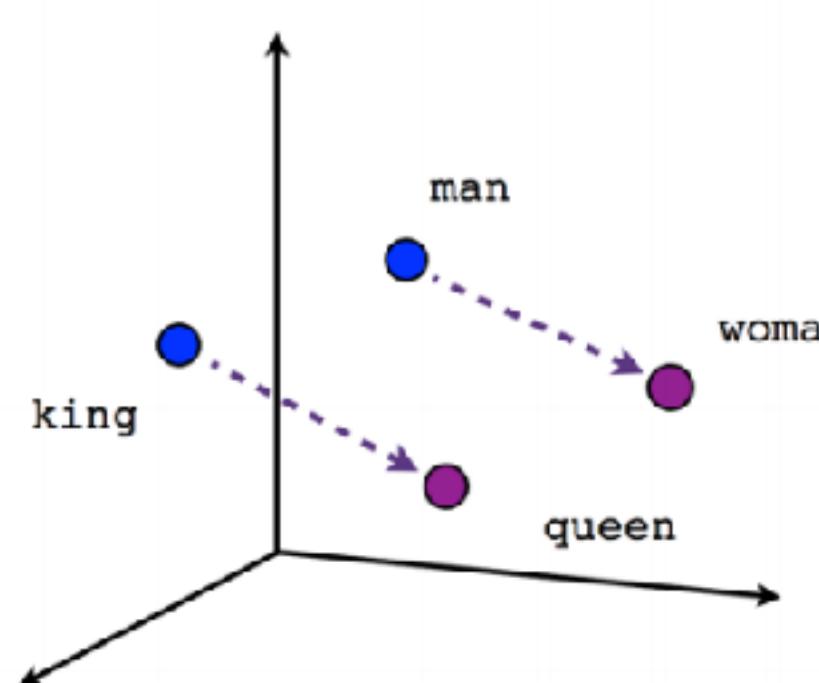
Several words can mean the same thing!

Distributed representations

Project words onto a continuous vector space



Similar words closer to each other



Male-Female



Verb tense

$$v(\text{king}) - v(\text{man}) + v(\text{woman}) = v(\text{queen})$$

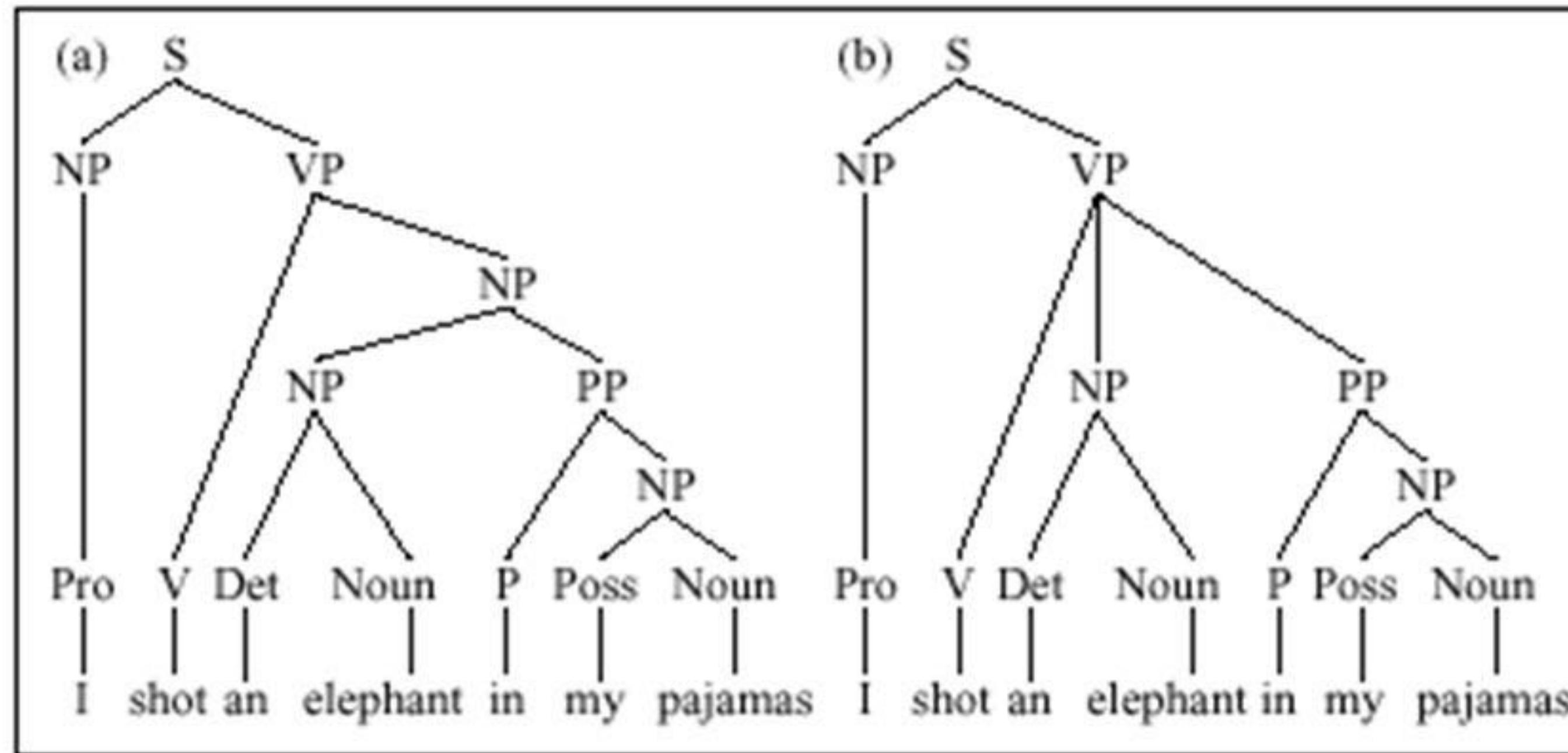
Comprehending word sequences

- My brother went to the park near my sister's house
 - Implicit structure in all languages
- Park my went house near to sister's my brother the
 - Coarse-to-fine levels (recursive)
- “My brother went park near sister’s house”?
- The old man the boat
 - What are some good data structures to represent this?
- The cotton clothing is made of grows in Mississippi

Garden Path sentence

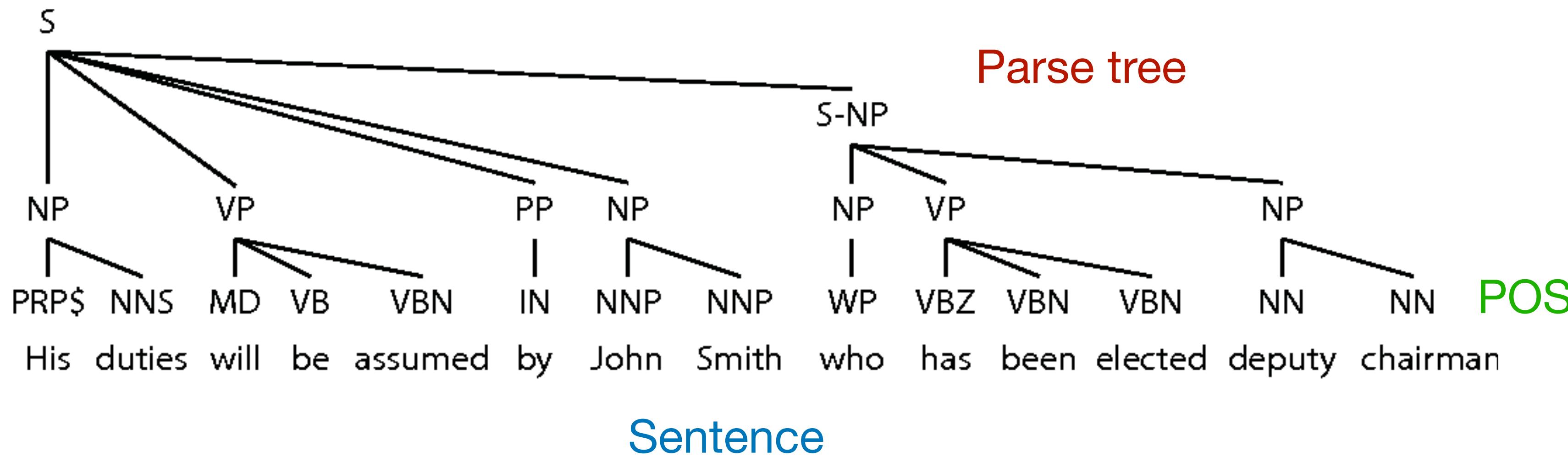
Syntactic ambiguity

I shot an elephant in my pajamas



Human language is full of such examples!

Syntactic parsing



Online tools: <http://nlp.stanford.edu:8080/corenlp/>

Discourse ambiguity

- The man couldn't lift his son because **he** was so **heavy**.
- The man couldn't lift his son because **he** was so **weak**.

What does “he” refer to?

- The city councilmen refused the demonstrators a permit because **they feared** violence.
- The city councilmen refused the demonstrators a permit because **they advocated** violence.

What does “they” refer to?

Anaphora resolution

Next: n-gram language models