CS6314:
Natural Language Processing

Introduction to NLP

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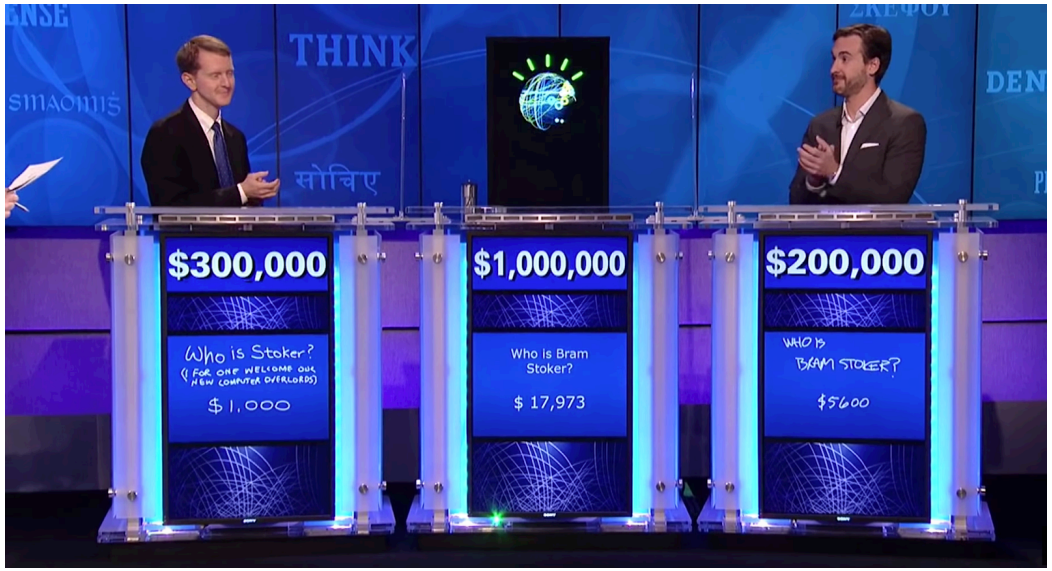
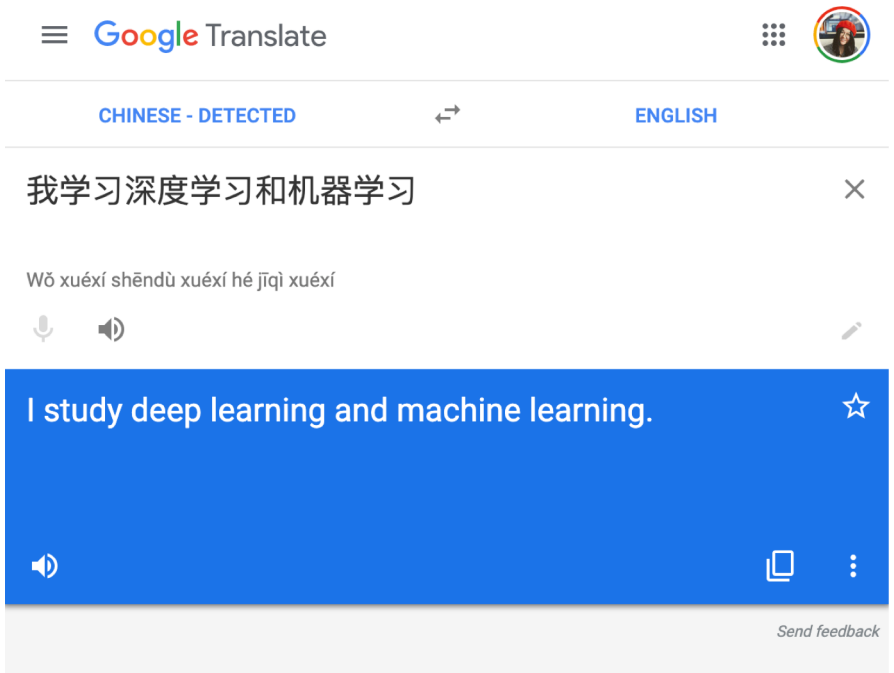
In early 2011, an IBM computing system named Watson
competed against the world's best Jeopardy! champions.

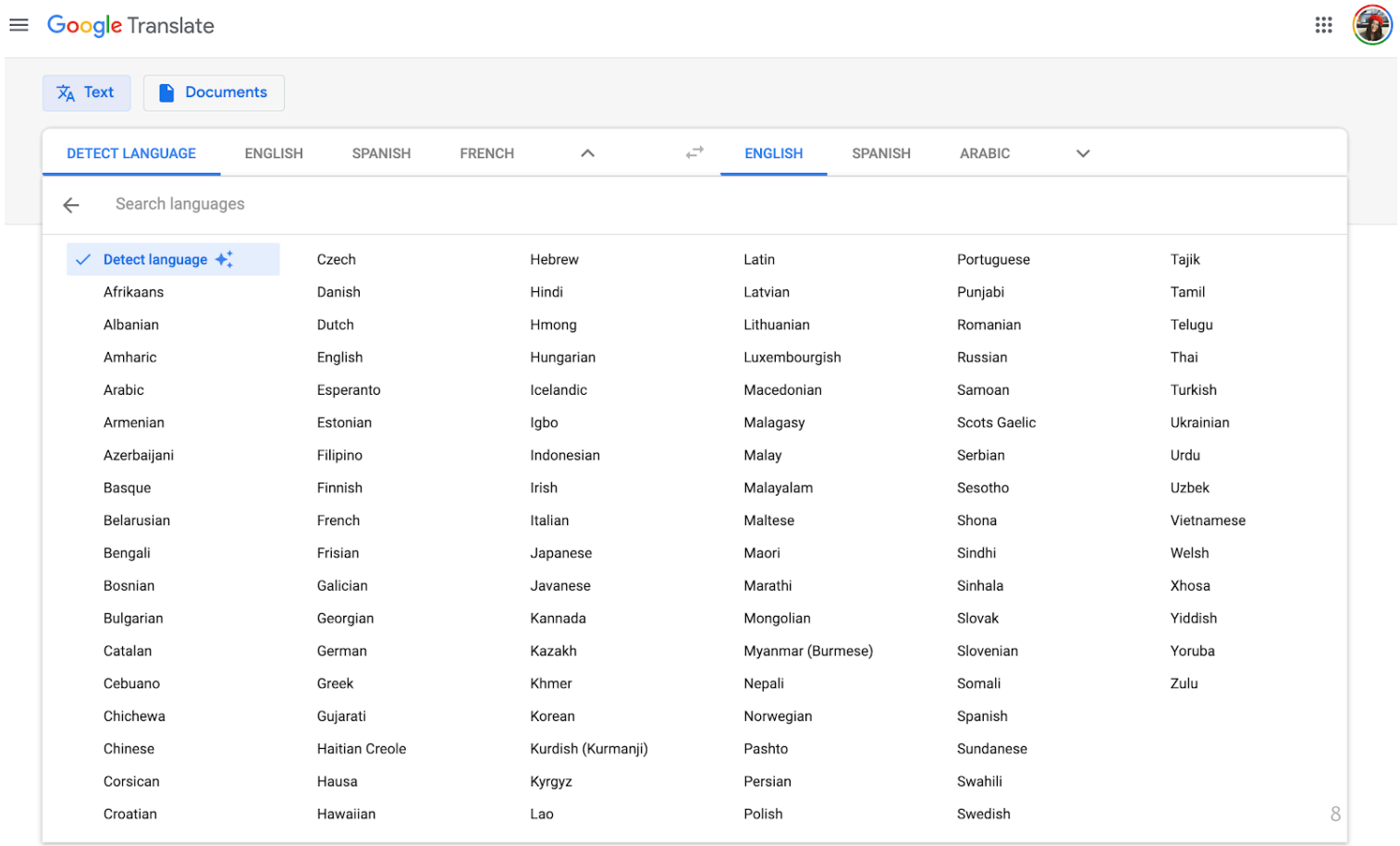
Question Answering



- What does “divergent” mean?
- What year was Abraham Lincoln born?
- How many states were in the United States that year?
- How much Chinese silk was exported to England in the end of the 18th century?
- What do scientists think about the ethics of human cloning?

Machine Translation





Natural Language Processing

Applications

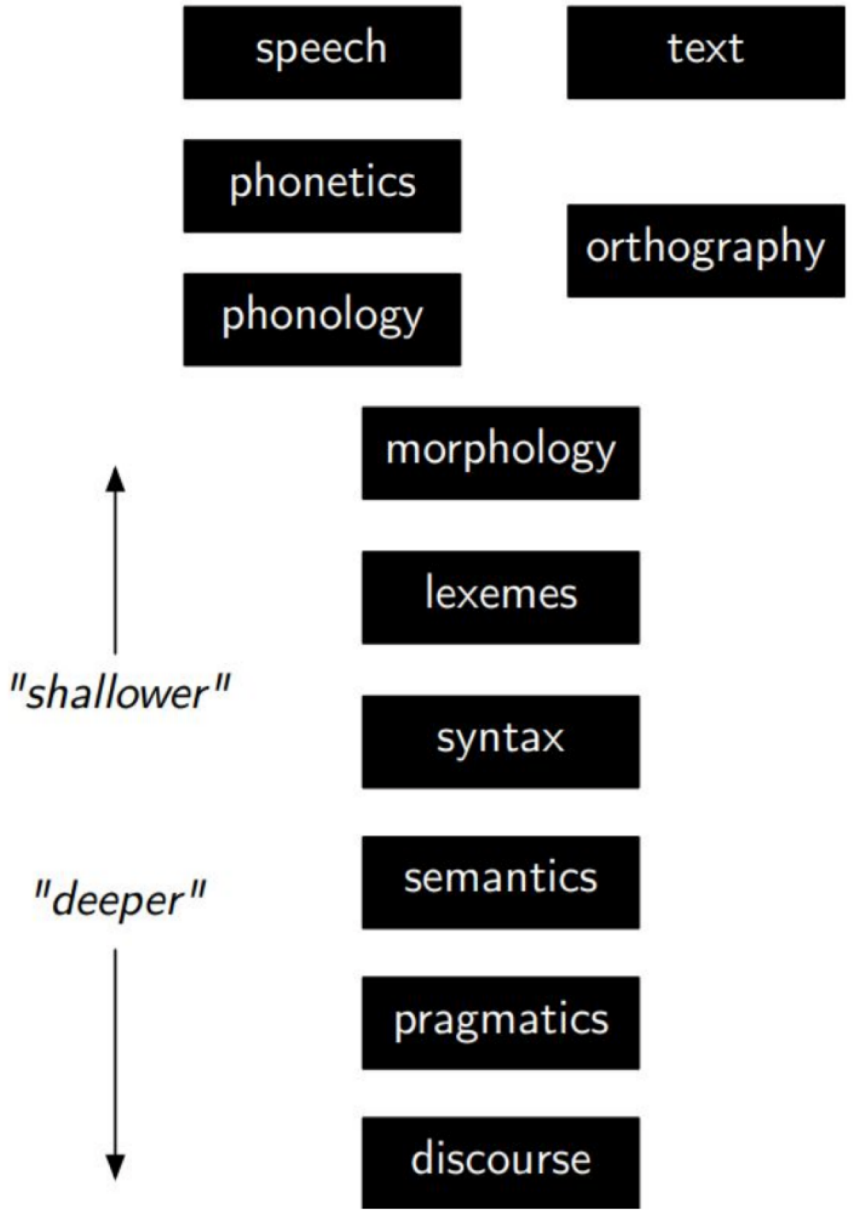
- Machine Translation
- Information Retrieval
- Question Answering
- Dialogue Systems
- Information Extraction
- Summarization
- Sentiment Analysis
- …

Core Technologies

- Language modeling
- Part-of-speech tagging
- Syntactic parsing
- Named-entity recognition
- Word sense disambiguation
- Semantic role labeling
- …

NLP lies at the intersection of computational linguistics and machine learning.

Level Of Linguistic Knowledge



Phonetics, Phonology

- Pronunciation Modeling

SOUNDS	Th	i	a	si	e	n

Words

- Language Modeling
- Tokenization
- Spelling correction

Morphology

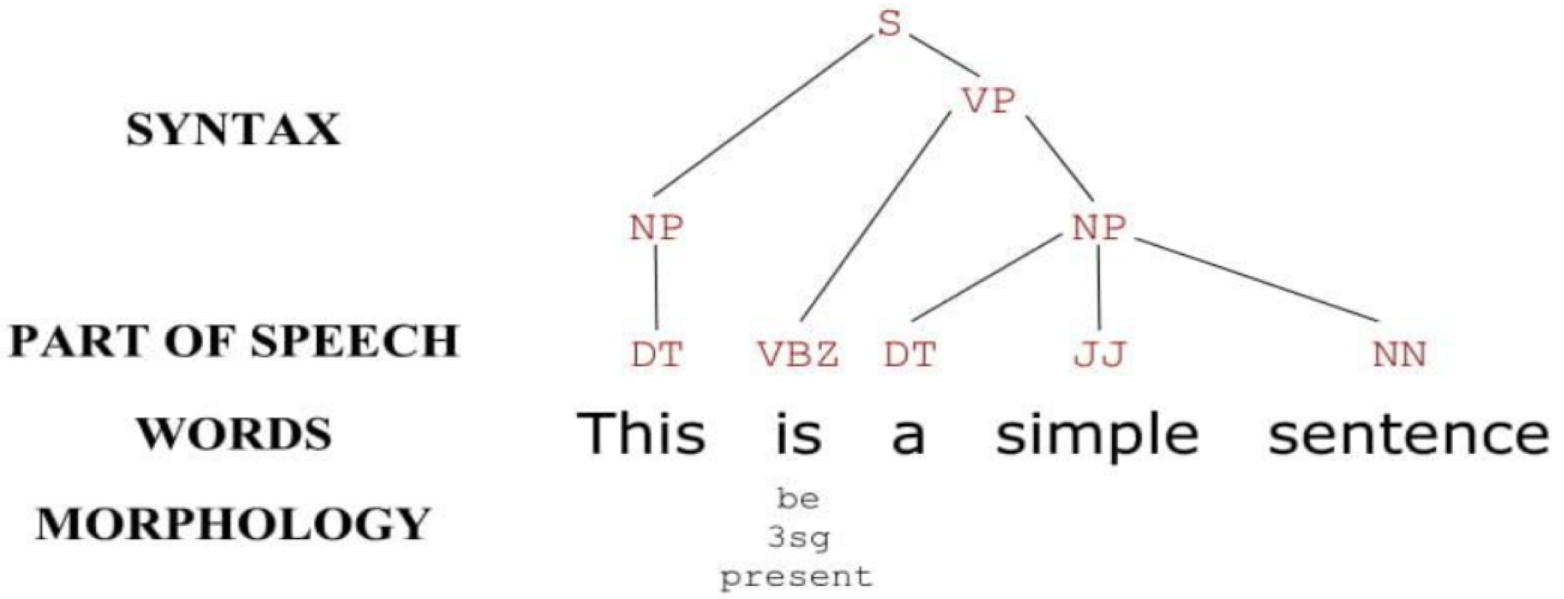
- Morphology analysis
- Tokenization
- Lemmatization

Part of Speech

- Part of speech tagging

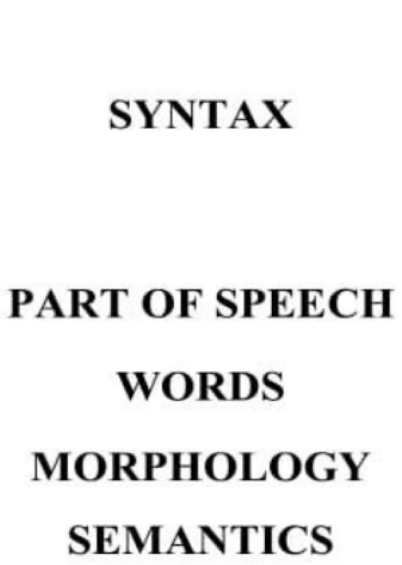
Syntax

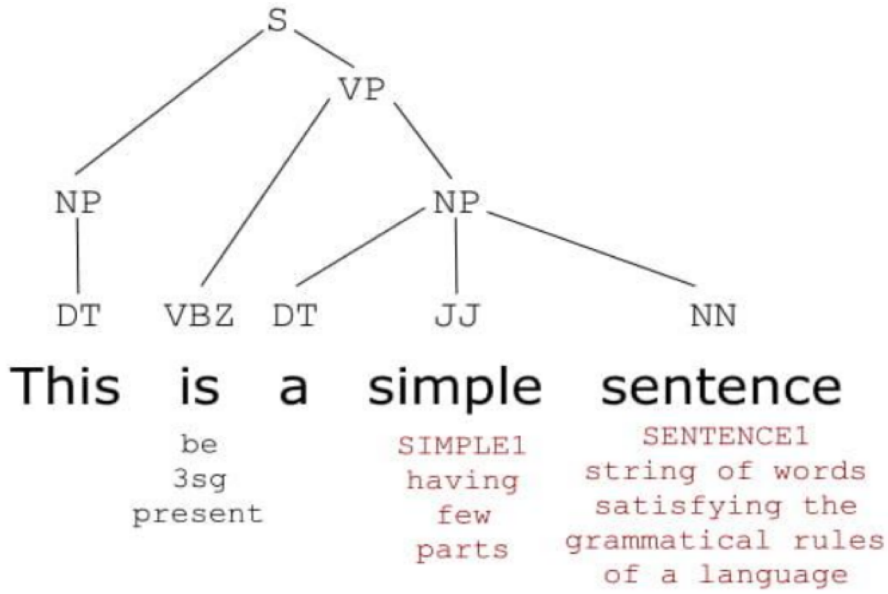
- Syntactic parsing



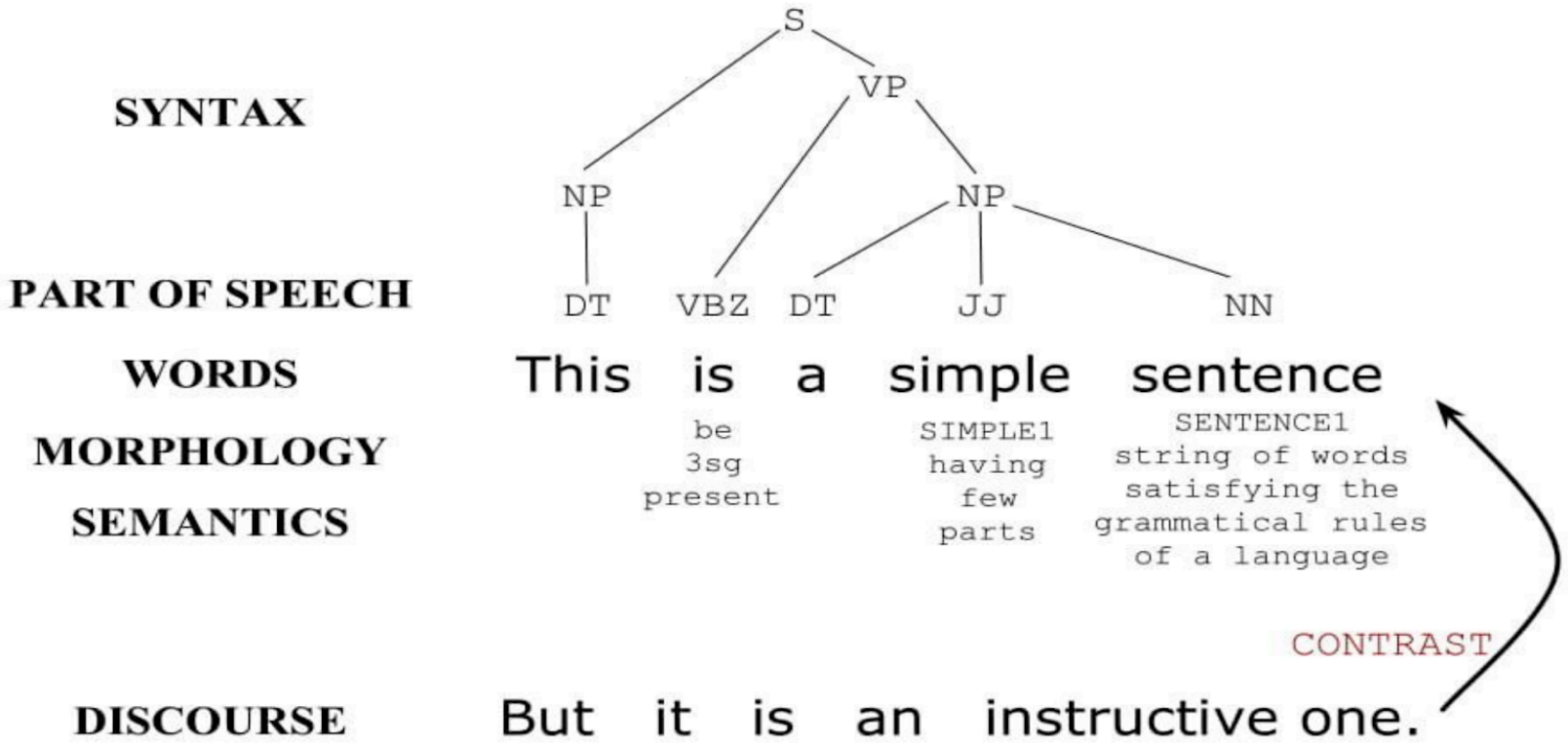
Semantics

- Named entity recognition
- Word sense disambiguation
- Semantic role labeling





Discourse


SYNTAX
PART OF SPEECH
WORDS
MORPHOLOGY
SEMANTICS
DISCOURSE
S
VP
NP
NP
DT
VBZ
DT
JJ
NN
This is a simple sentence
be
3sg
present
SIMPLE1
having
few
parts
SENTENCE1
string of words
satisfying the
grammatical rules
of a language
CONTRAST
But it is an instructive one.

Why NLP is Hard?

1. Ambiguity
2. Scale
3. Sparsity
4. Variation
5. Expressivity
6. Unmodeled Variables
7. Unknown representations

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Ambiguity

- Ambiguity at multiple levels
  - Word senses: **bank** (finance or river ?)
  - Part of speech: **chair** (noun or verb ?)
  - Syntactic structure: **I can see a man with a telescope**
  - Multiple: **I made her duck**

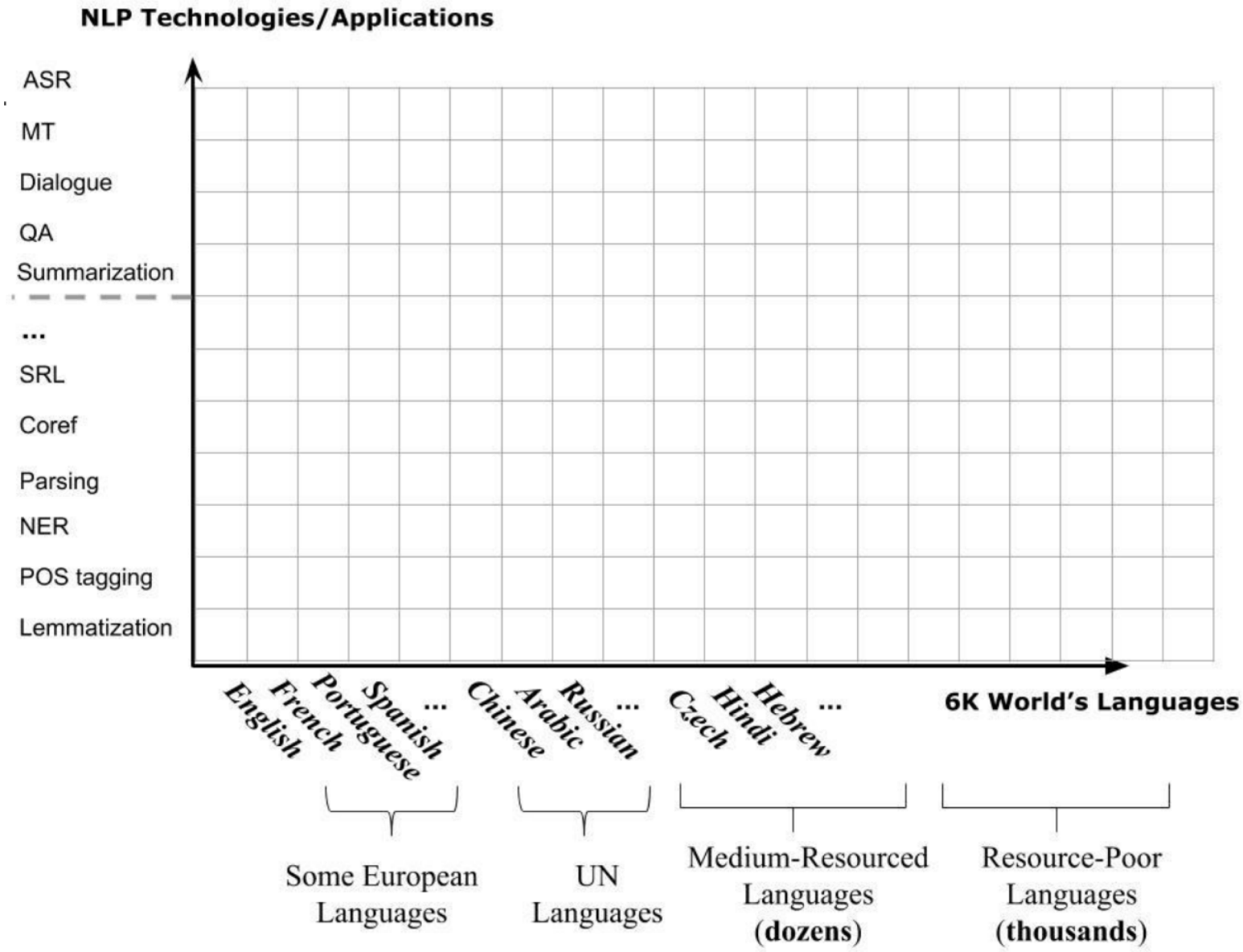
"One morning I shot
an elephant in my pajamas"

I made her duck

[SLP2 ch. 1]

- I cooked waterfowl for her
- I cooked waterfowl belonging to her
- I created the (plaster?) duck she owns
- I caused her to quickly lower her head or body
- …

Ambiguity and Scale



The Challenges of “Words”

- Segmenting text into words
- Morphological variation
- Words with multiple meanings: bank, mean
- Domain-specific meanings: latex
- Multiword expressions: make a decision, take out, make up

Part of Speech Tagging

ikr smh he asked fir yo last name

so he can add u on fb lolololol

Part of Speech Tagging

I know, right	shake my head			for	your		
ikr	smh	he	asked	fir	yo	last	name

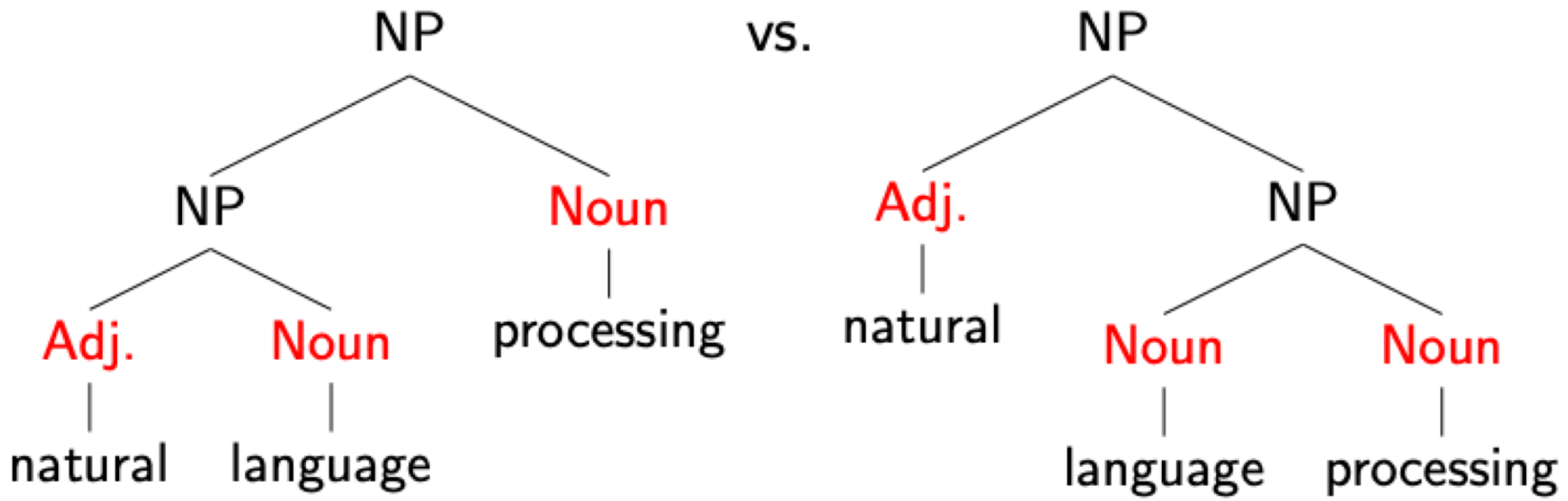
				you		Facebook	laugh out loud
so	he	can	add	u	on	fb	lolololol

Part of Speech Tagging

I know, right	shake my head			for	your		
ikr	smh	he	asked	fir	yo	last	name
!	G	O	V	P	D	A	N
interjection	acronym	pronoun	verb	prep.	det.	adj.	noun

				you		Facebook	laugh out loud
so	he	can	add	u	on	fb	lololol
P	O	V	V	O	P	∧	!
preposition						proper noun	

Syntax


NP
NP
Noun
Adj.
Noun
processing
natural
language
vs.
NP
Adj.
NP
natural
Noun
Noun
language
processing

Morphology + Syntax

A ship-shipping ship, shipping shipping-ships

Semantics

- Every fifteen minutes a woman in this country gives birth.

Semantics

- Every fifteen minutes a woman in this country gives birth. Our job is to find this woman, and stop her!

– Groucho Marx

Syntax + Semantics

- We saw the woman with the telescope wrapped in paper.

Syntax + Semantics

- We saw the woman with the telescope wrapped in paper.
  - Who has the telescope?
  - Who or what is wrapped in paper?
  - An even of perception, or an assault?

Dealing with Ambiguity

- How can we model ambiguity?
  - Non-probabilistic methods (CKY parsers for syntax) return all possible analyses
  - Probabilistic models (HMMs for POS tagging, PCFGs for syntax) and algorithms (Viterbi, probabilistic CKY) return the best possible analyses, i.e., the most probable one
- But the "best" analysis is only good if our probabilities are accurate. Where do they come from?

Corpora

- A corpus is a collection of text
  - Often annotated in some way
  - Sometimes just lots of text
- Examples
  - Penn Treebank: 1M words of parsed WSJ
  - Canadian Hansards: 10M+ words of French/English sentences
  - Yelp reviews
  - The Web!

Statistical NLP

- Like most other parts of AI, NLP is dominated by statistical methods
  - Typically more robust than rule-based methods
  - Relevant statistics/probabilities are learned from data
  - Normally requires lots of data about any particular phenomenon

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Sparsity

- Sparse data due to Zipf's Law
- Example: the frequency of different words in a large text corpus

any word

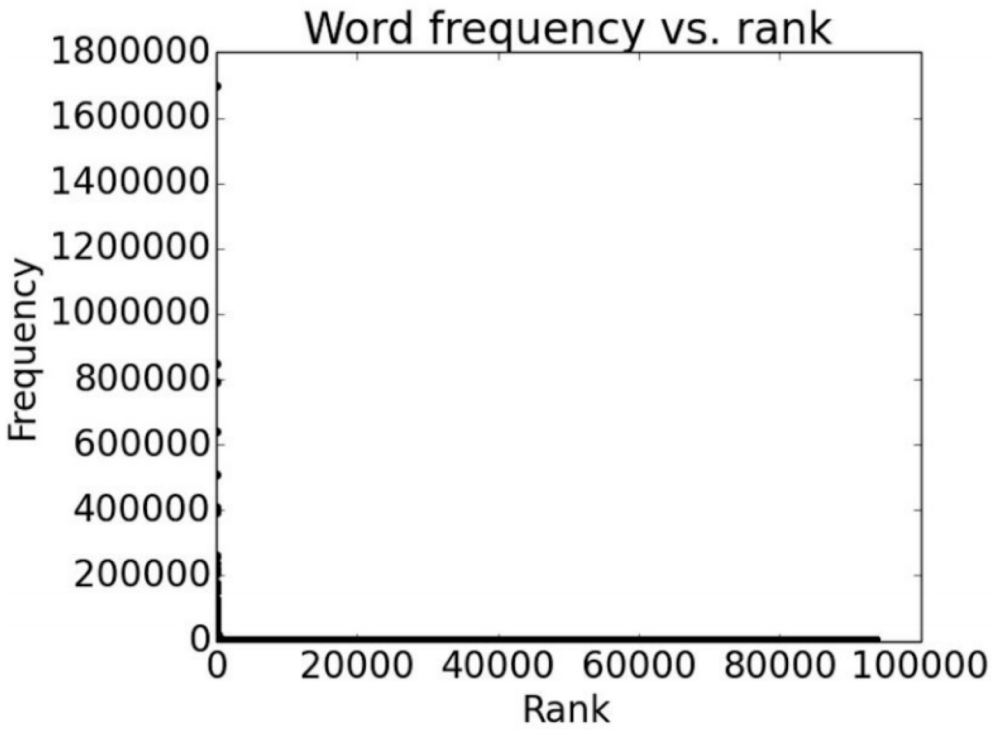
Frequency	Token
1,698,599	the
849,256	of
793,731	to
640,257	and
508,560	in
407,638	that
400,467	is
394,778	a
263,040	I

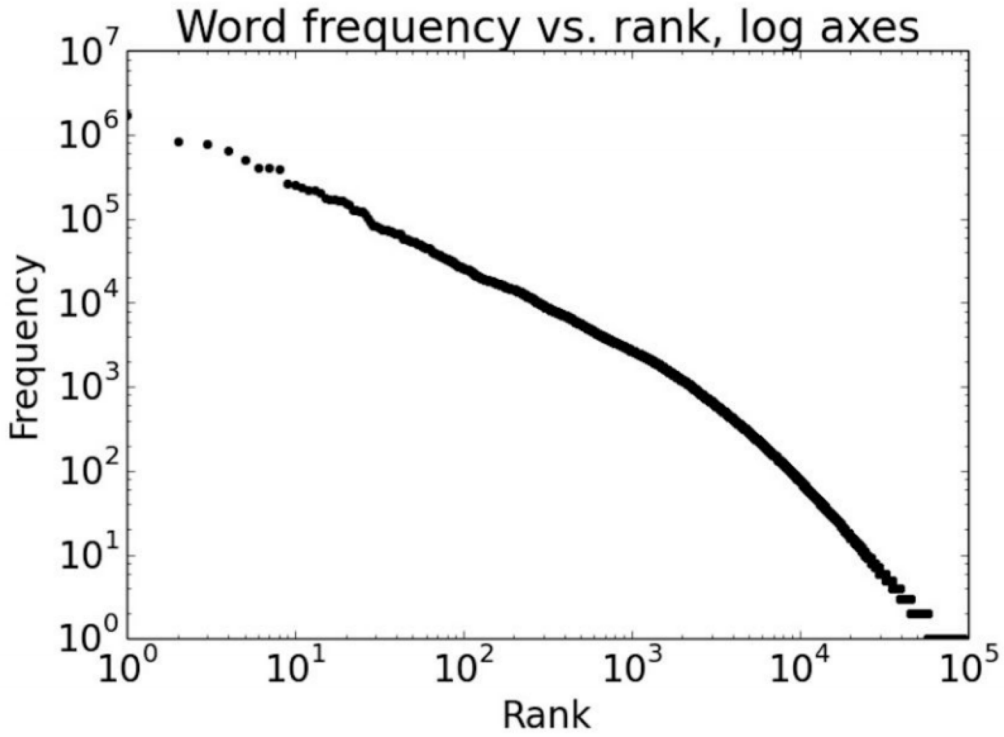
nouns

Frequency	Token
124,598	European
104,325	Mr
92,195	Commission
66,781	President
62,867	Parliament
57,804	Union
53,683	report
53,547	Council
45,842	States

Sparsity

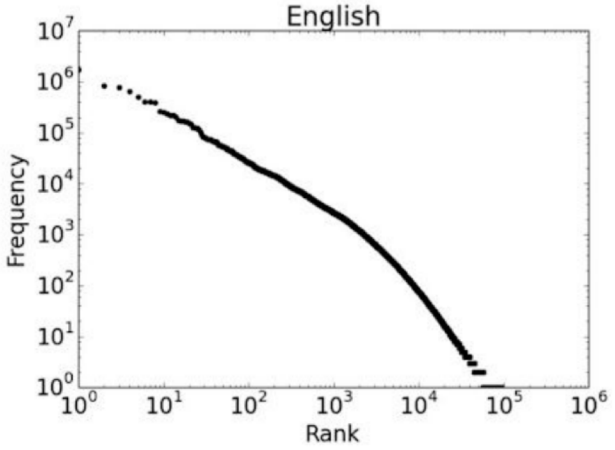
- Order words by frequency. What is the frequency of nth ranked word?

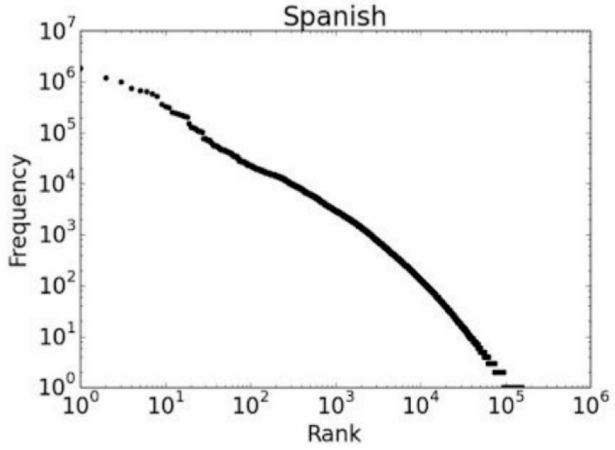


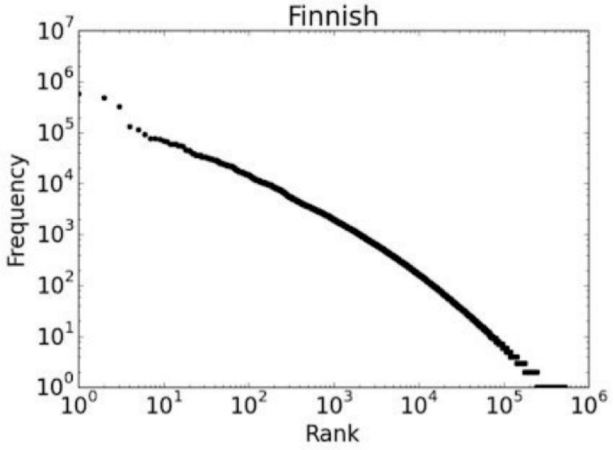


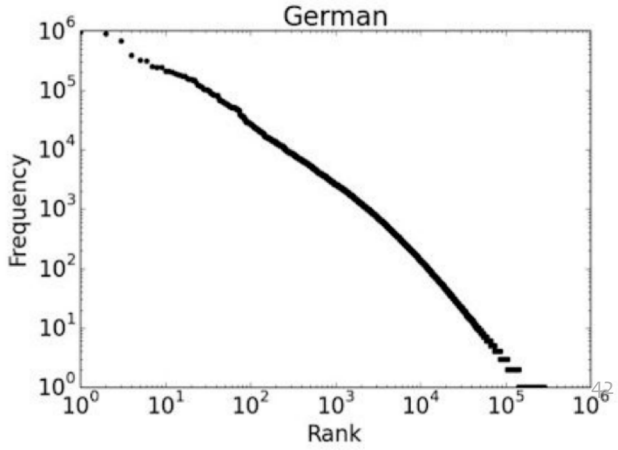
Sparsity

- Regardless of how large our corpus is, there will be a lot of infrequent words
- This means we need to find clever ways to estimate probabilities for things we have rarely or never seen









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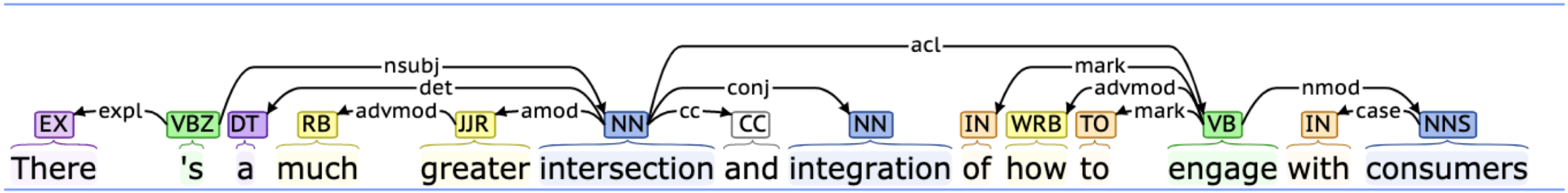
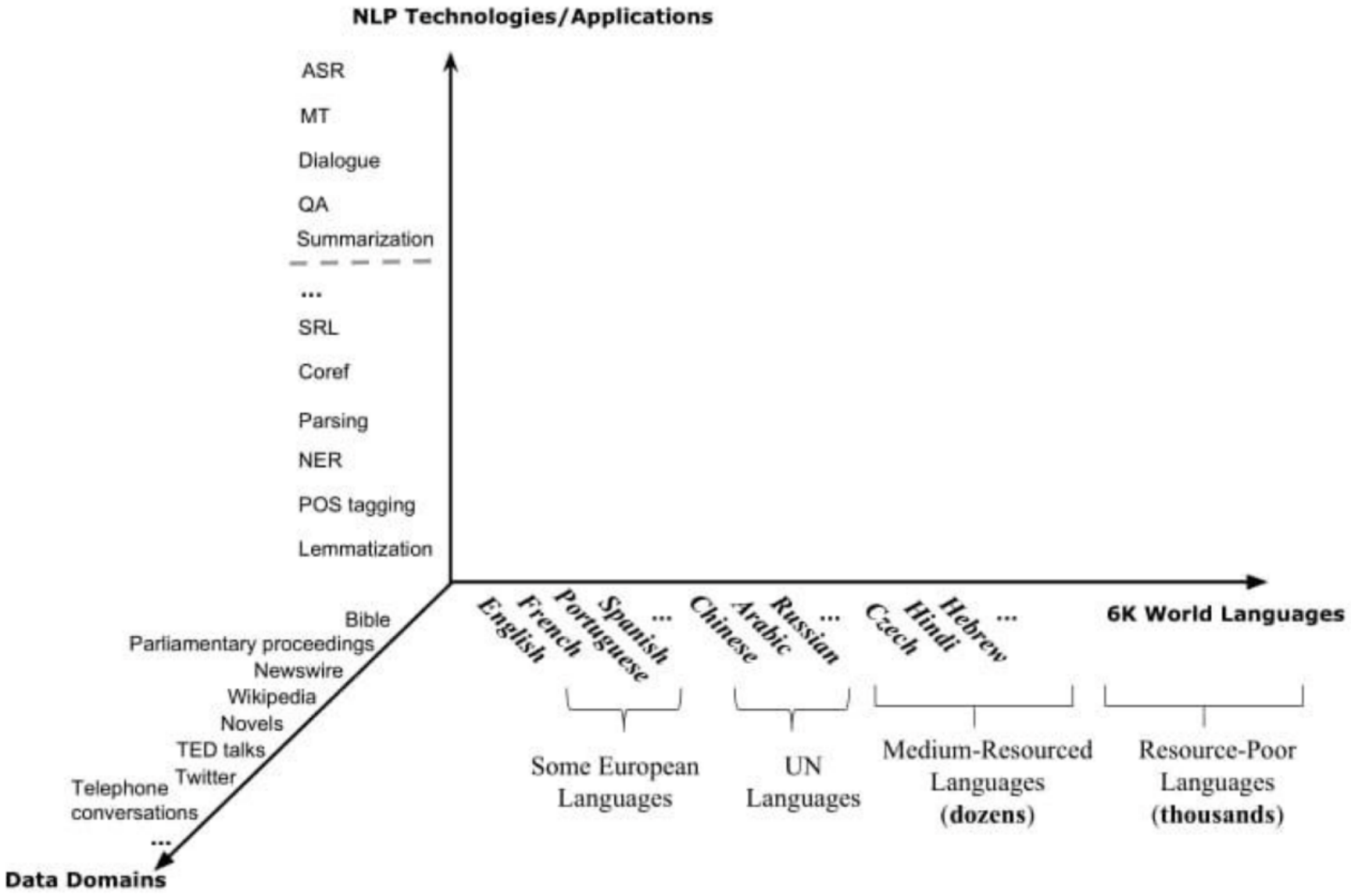
Variation

- Suppose we train a part of speech tagger or a parser on the Wall Street Journal



- What will happen if we try to use this tagger/parser for social media?
  - *"ikr smh he asked fir yo last name so he can add u on fb lolololol"*

Variation


NLP Technologies/Applications
ASR
MT
Dialogue
QA
Summarization
...
SRL
Coref
Parsing
NER
POS tagging
Lemmatization
English
French
Portuguese
Spanish
...
Chinese
Arabic
Russian
...
Czech
Hindi
Hebrew
...
6K World Languages
Some European Languages
UN Languages
Medium-Resourced Languages (dozens)
Resource-Poor Languages (thousands)
Bible
Parliamentary proceedings
Newswire
Wikipedia
Novels
TED talks
Twitter
Telephone conversations
...
Data Domains

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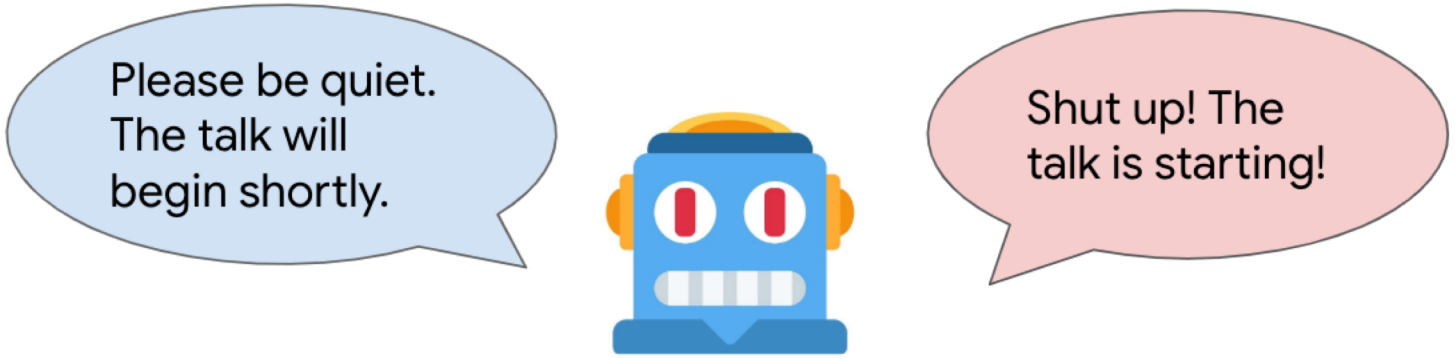
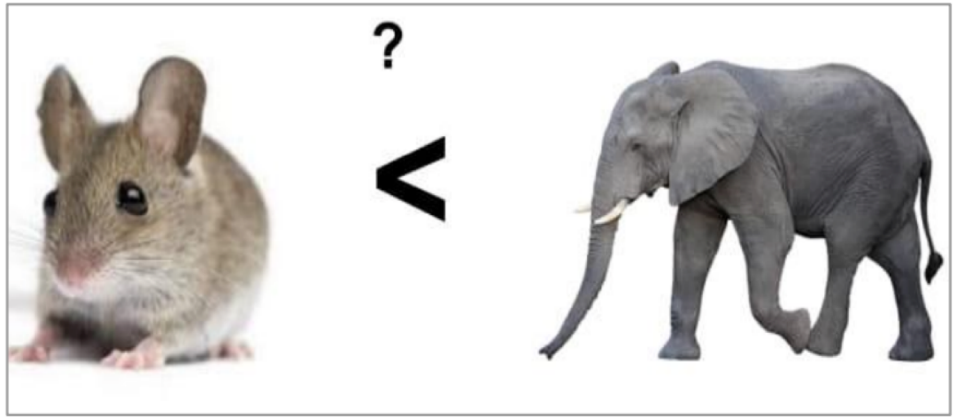
Expressivity

- Not only can one form have different meanings (ambiguity) but the same meaning can be expressed with different forms:
  - *She gave the book to Tom* vs. *She gave Tom the book*
  - *Some kids popped by* vs. *A few children visited*
  - *Is that window still open?* vs. *Please close the window*



Unmodeled Variables

"Drink this milk"



World knowledge

I dropped the glass on the floor and it broke

I dropped the hammer on the glass and it broke

Unmodeled Representation

Very difficult to capture what is $\mathcal{R}$, since we don't even know how to represent the knowledge a human has/needs:

- What is the "meaning" of a word or sentence?
- How to model context?
- Other general knowledge?

NLP vs. Linguistics

- NLP must contend with NL data as found in the world
- NLP ≈ computational linguistics
- Linguistics has begun to use tools originating in NLP!

Fields with Connections to NLP

- Machine learning
- Linguistics (including psycho-, socio-, descriptive, and theoretical)
- Cognitive science
- Information theory
- Logic
- Data science
- Political science
- Psychology
- Economics
- Education

Today's Applications

- Conversational agents
- Information extraction and question answering
- Machine translation
- Opinion and sentiment analysis
- Social media analysis
- Visual understanding
- Essay evaluation
- Mining legal, medical, or scholarly literature

Factors Changing NLP Landscape

1. Increases in computing power
2. The rise of the web, then the social web
3. Advances in machine learning
4. Advances in understanding of language in social context

Logistics

Outline of Topics

- Words and Sequences
  - Text classifications
  - Probabilistic language models
  - Vector semantics and word embeddings
  - Sequence labeling: POS tagging, NER
  - HMMs, Speech recognition
- Parsers
- Semantics
- Applications
  - Machine translation, Question Answering, Dialog Systems

Readings

- Books:
  - Primary text: Jurafsky and Martin, Speech and Language Processing, 2nd or 3 rd Edition
    - https://web.stanford.edu/~jurafsky/slp3/
  - Also: Eisenstein, Natural Language Processing
    - https://github.com/jacobeisenstein/gt-nlp-class/blob/master/notes/eisenstein-nlp-notes.pdf