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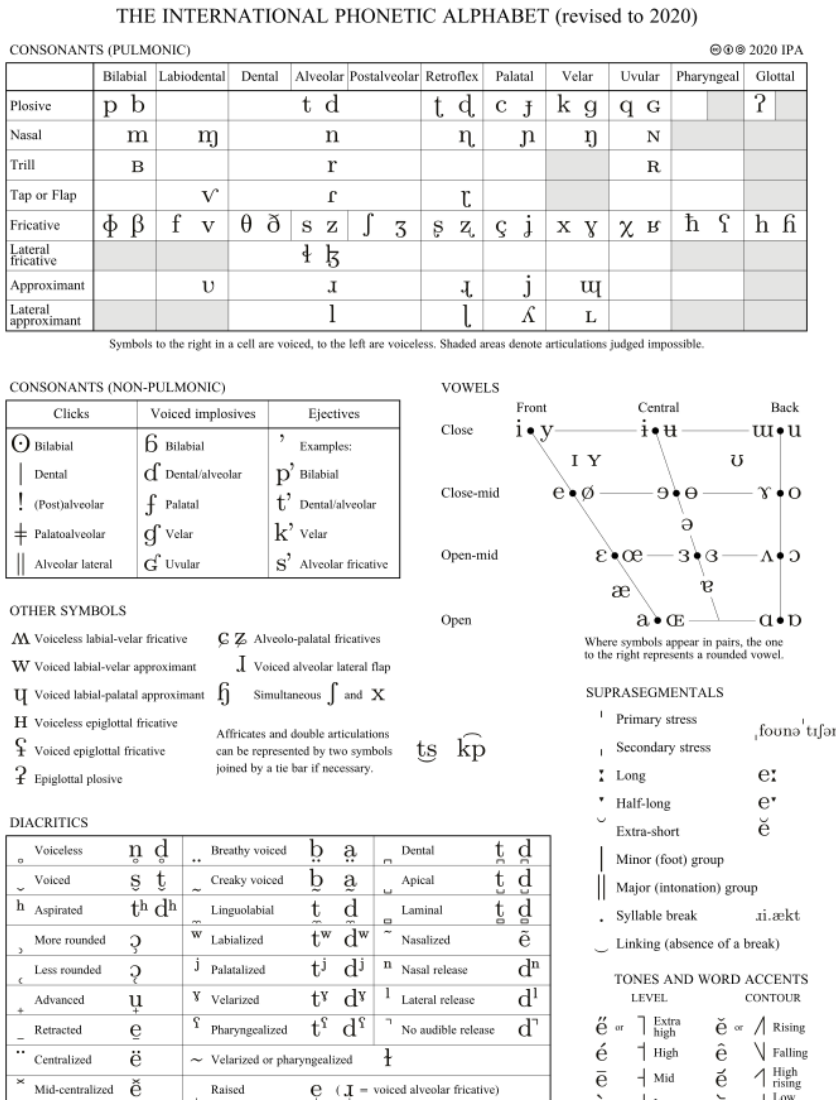
Introduction to Machine Learning for Language Processing

LIAD MAGEN

həˈloʊ, wɜrld



THE INTERNATIONAL PHONETIC ALPHABET (revised to 2020)

CONSONANTS (PULMONIC) ©℗® 2020 IPA

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k g	q ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	ɴ		
Trill	ʙ			r					ʀ		
Tap or Flap		ⱱ		ɾ		ɽ					
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Lateral fricative				ɬ ɮ							
Approximant		ʋ		ɹ		ɻ	j	ɰ			
Lateral approximant				l		ɭ	ʎ	ʟ			

Symbols to the right in a cell are voiced, to the left are voiceless. Shaded areas denote articulations judged impossible.

CONSONANTS (NON-PULMONIC)

Clicks	Voiced implosives	Ejectives
ʘ Bilabial	ɓ Bilabial	ʼ Examples:
ǀ Dental	ɗ Dental/alveolar	pʼ Bilabial
ǃ (Post)alveolar	ʄ Palatal	tʼ Dental/alveolar
ǂ Palatoalveolar	ɠ Velar	kʼ Velar
ǁ Alveolar lateral	ʛ Uvular	sʼ Alveolar fricative

OTHER SYMBOLS

ʍ Voiceless labial-velar fricative
ɕ ʑ Alveolo-palatal fricatives
w Voiced labial-velar approximant
ɺ Voiced alveolar lateral flap
ɥ Voiced labial-palatal approximant
ʢ Simultaneous ʃ and x
ʜ Voiceless epiglottal fricative
ʡ Voiced epiglottal fricative
ʔ Epiglottal plosive

Affricates and double articulations can be represented by two symbols joined by a tie bar if necessary. t͡s k͡p

DIACRITICS

◌̥ Voiceless	n̥ d̥	◌̤ Breathy voiced	b̤ a̤	◌̪ Dental	t̪ d̪
◌̬ Voiced	s̬ t̬	◌̰ Creaky voiced	b̰ a̰	◌̺ Apical	t̺ d̺
◌ʰ Aspirated	tʰ dʰ	◌̼ Linguolabial	t̼ d̼	◌̻ Laminal	t̻ d̻
◌̹ More rounded	ɔ̹	◌ʷ Labialized	tʷ dʷ	◌̃ Nasalized	ẽ
◌̜ Less rounded	ɔ̜	◌ʲ Palatalized	tʲ dʲ	◌ⁿ Nasal release	dⁿ
◌̟ Advanced	u̟	◌ˠ Velarized	tˠ dˠ	◌ˡ Lateral release	dˡ
◌̠ Retracted	e̠	◌ˤ Pharyngealized	tˤ dˤ	◌̚ No audible release	d̚
◌̈ Centralized	ë	~ Velarized or pharyngealized	ɫ		
◌̽ Mid-centralized	e̽	◌̝ Raised	e̝ (ɪ̝ = voiced alveolar fricative)		

VOWELS

	Front	Central	Back
Close	i • y	ɨ • ʉ	ɯ • u
	ɪ ʏ		ʊ
Close-mid	e • ø	ɘ • ɵ	ɤ • o
		ə	
Open-mid	ɛ • œ	ɜ • ɞ	ʌ • ɔ
	æ	ɐ	
Open	a • ɶ		ɑ • ɒ

Where symbols appear in pairs, the one to the right represents a rounded vowel.

SUPRASEGMENTALS

ˈ Primary stress ˌfoʊnəˈtɪʃən
ˌ Secondary stress
ː Long eː
ˑ Half-long eˑ
◡ Extra-short ĕ
| Minor (foot) group
‖ Major (intonation) group
. Syllable break ɹi.ækt
‿ Linking (absence of a break)

TONES AND WORD ACCENTS

LEVEL		CONTOUR	
e̋ or	˥ Extra high	ě or	˧˥ Rising
é	˦ High	ê	˥˩ Falling
ē	˧ Mid	e᷄	˦˥ High rising
è	˨ Low	e᷅	˩˧ Low rising
ȅ	˩ Extra low	e᷈	˧˩ Falling
↓	Downstep	↗	Global rise
↑	Upstep	↘	Global fall

Organizational Info

Missing classes

Allowed to miss one class

Late

Up to 15 minutes

Grading

Homework assignments (45%)

Final presentation (55%)

Late assignments submission

5 days overall late

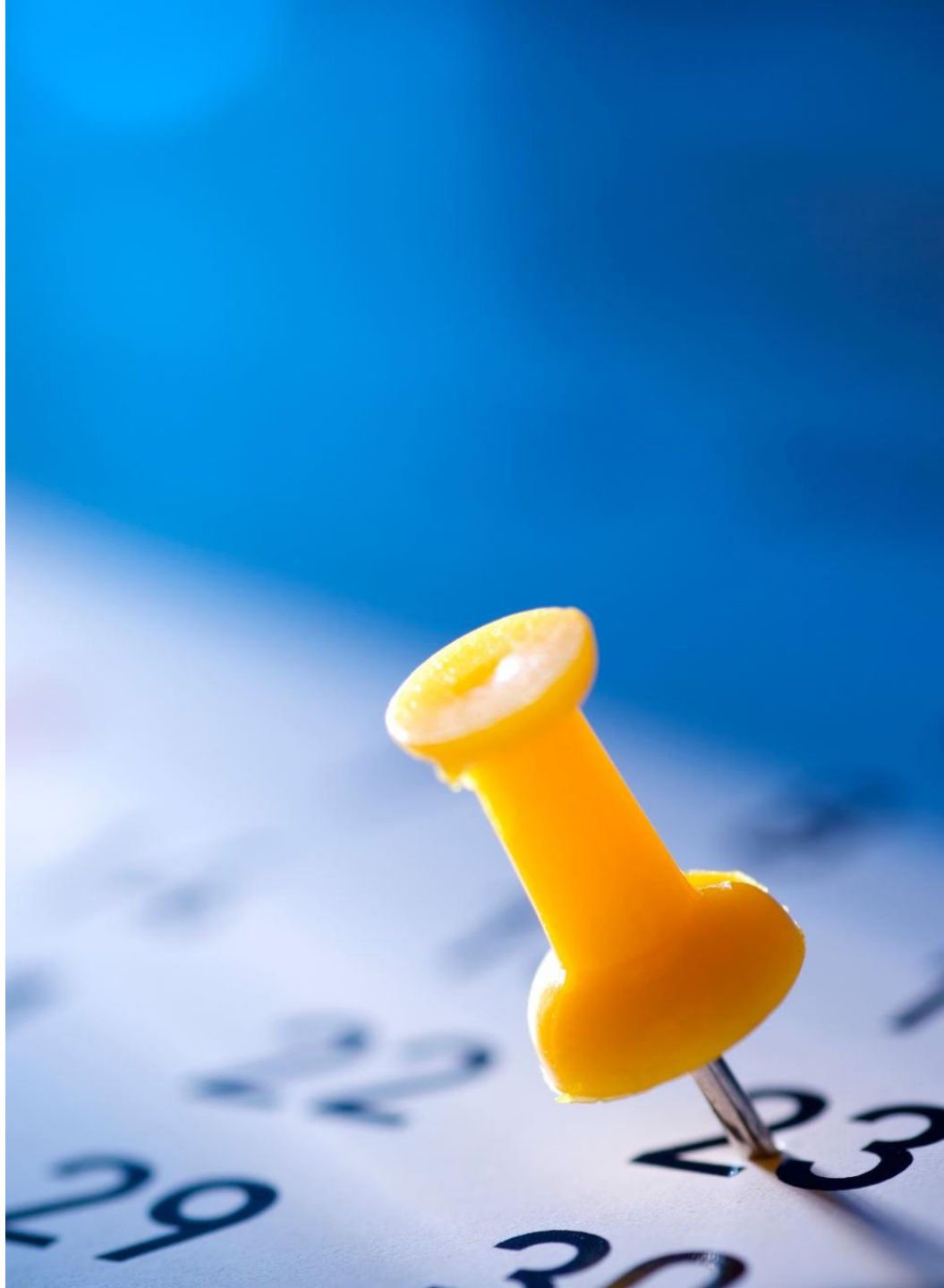
10 points penalty per day afterward

Agenda Today

- NLP – Motivation, Applications & Challenges
- 5 Levels of Linguistics
- Basic Units of Text Processing

If we have time:

- ML Models Definition & Types
- First Classification Model



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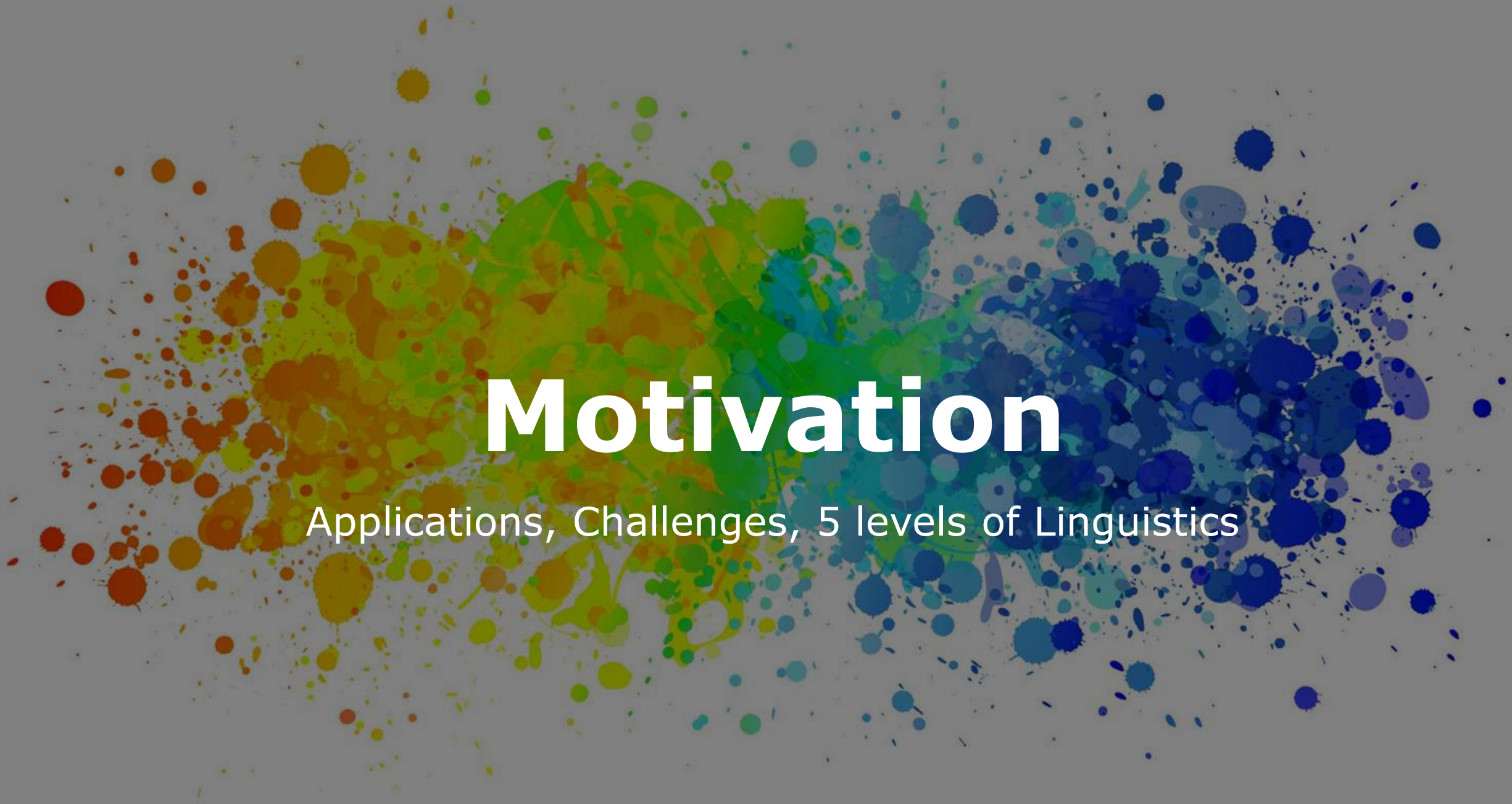
True or False?

Read the statements and decide if they are **correct** or **not**.

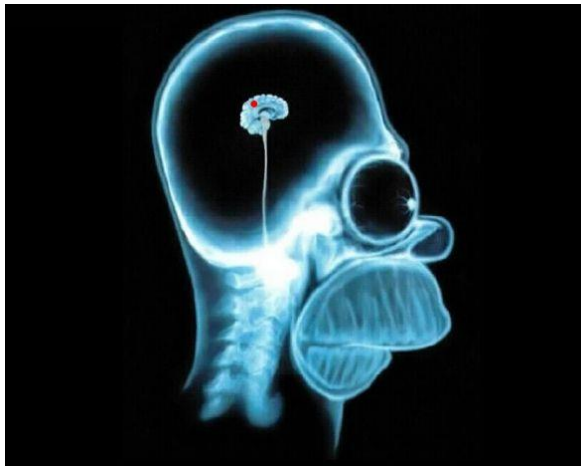


Motivation

Applications, Challenges, 5 levels of Linguistics

What is NLP?

Human Language

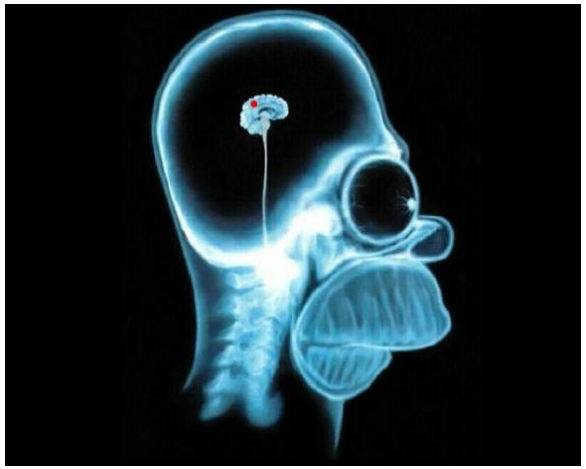


Non-trivial useful output

> **Algorithms** that operate on **Human Language**

What is NLP?

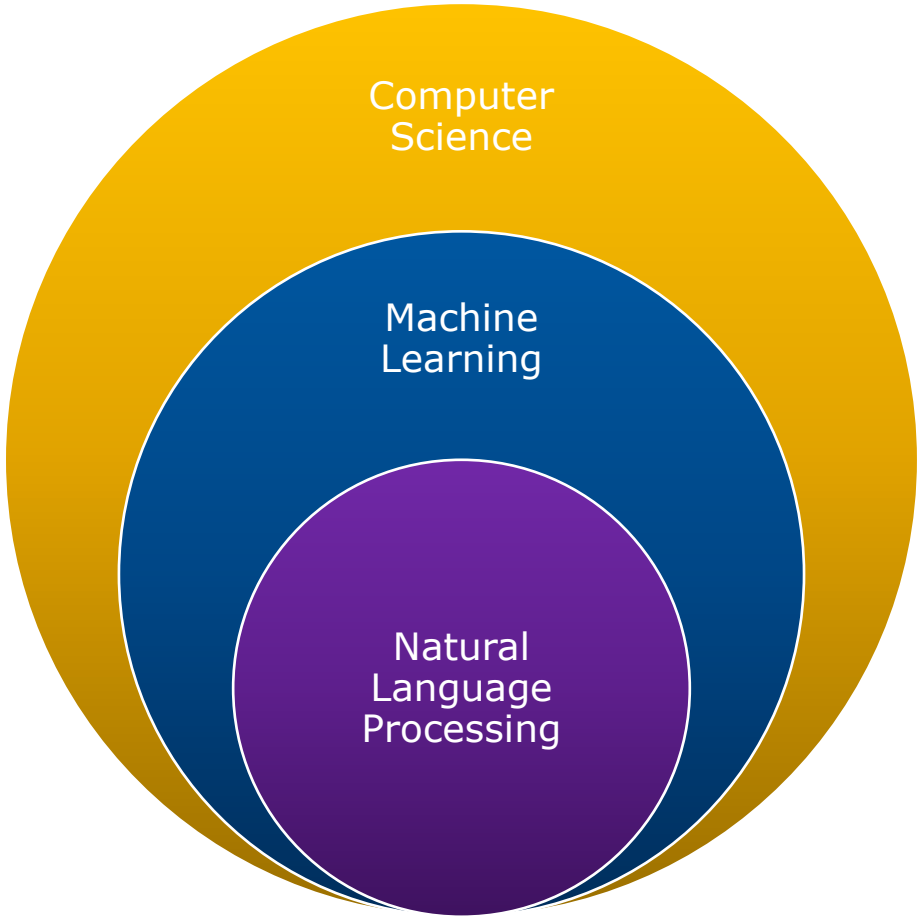
Human Language



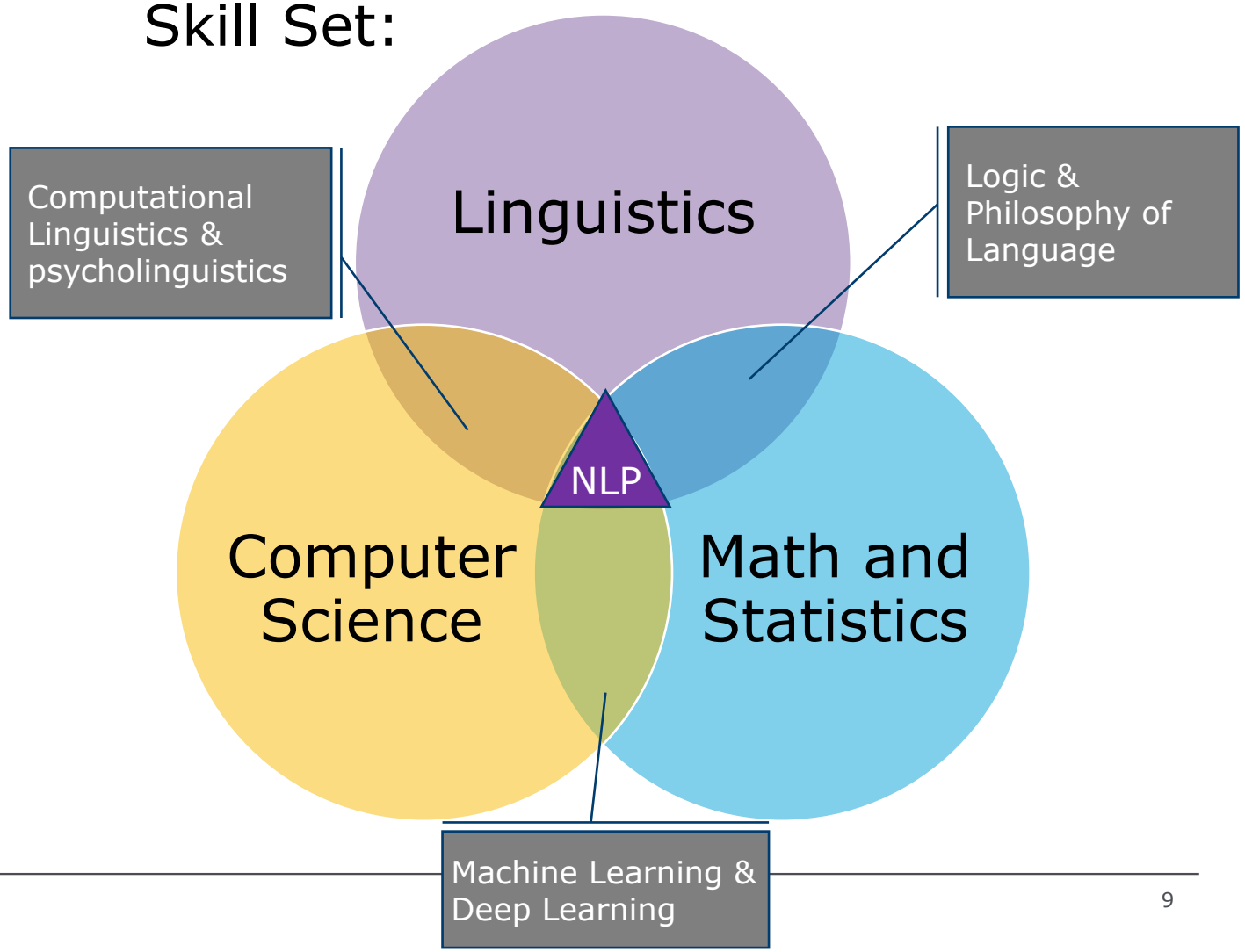
Non-trivial useful output

> Process input text in human language, in a way that suggests an intelligence was involved

What is NLP?

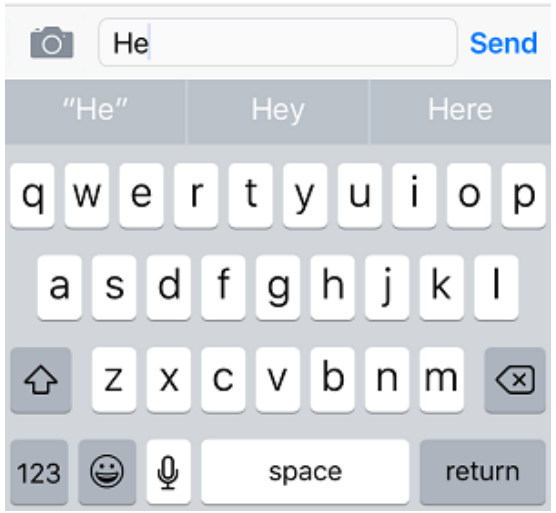


Done With an Interdisciplinary Skill Set:




Where is NLP being Used?

grammarly



NLP Usage

Some selected examples

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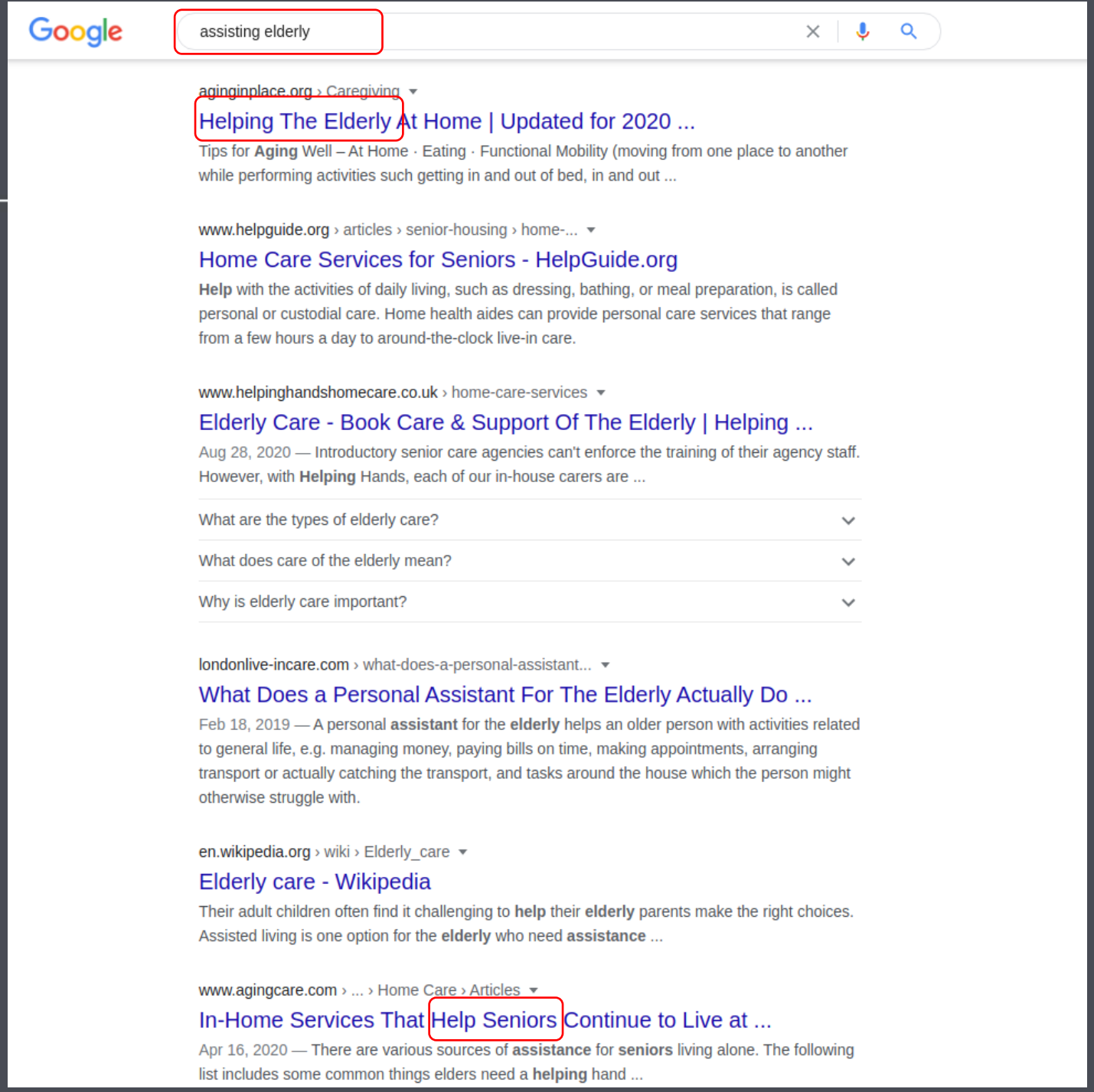
Search Engines

- Exact words
- Synonyms



Google

when was Boltzmann born?

All Images News Books Videos More Tools

About 939.000 results (0,78 seconds)

Ludwig Boltzmann / Date of birth

February 20, 1844

Born in Vienna on **February 20, 1844** to an Austrian government official, Boltzmann studied physics at the University of Vienna. He received his doctorate in 1866 and in 1869 was appointed to the chair of theoretical physics at the University of Graz.

https://depts.washington.edu › boltzmann › boltzmannbio

Boltzmann's Biography

People also search for

James Clerk Maxwell
June 13, 1831

Paul Ehrenfest
January 18, 1880

Josef Stefan
March 24, 1835

Feedback

https://en.wikipedia.org › wiki › Ludwig_Boltzmann

Ludwig Boltzmann - Wikipedia

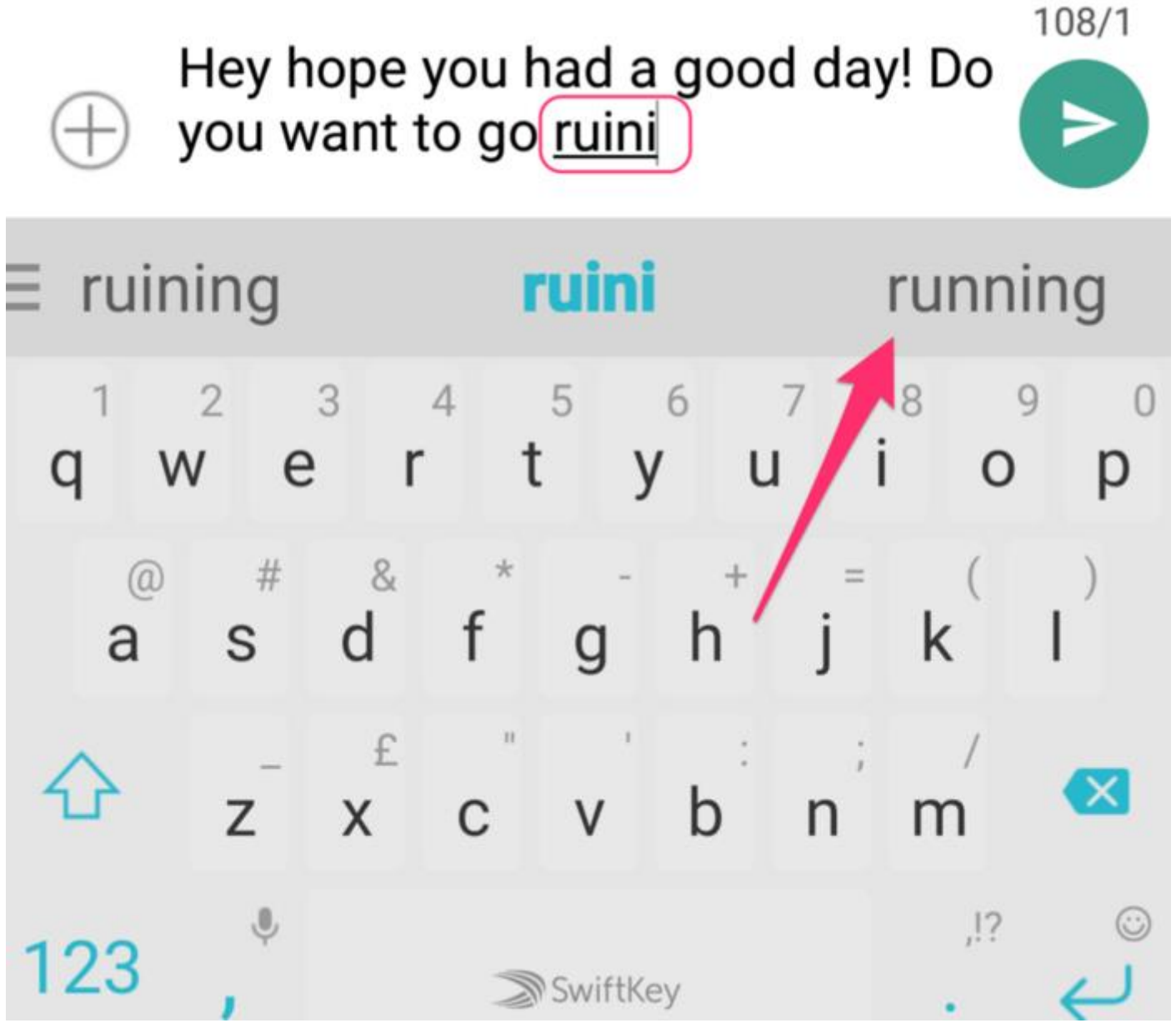
Ludwig Eduard Boltzmann (German pronunciation: [ˈluːtvɪç ˈbɔl͡tsman]; **20 February 1844 – 5 September 1906**) was an Austrian physicist and philosopher.

Ludwig Boltzmann

Austrian physicist

Ludwig Eduard Boltzmann was an Austrian physicist and philosopher. His greatest achievements were the

Word Prediction & Spelling Correction



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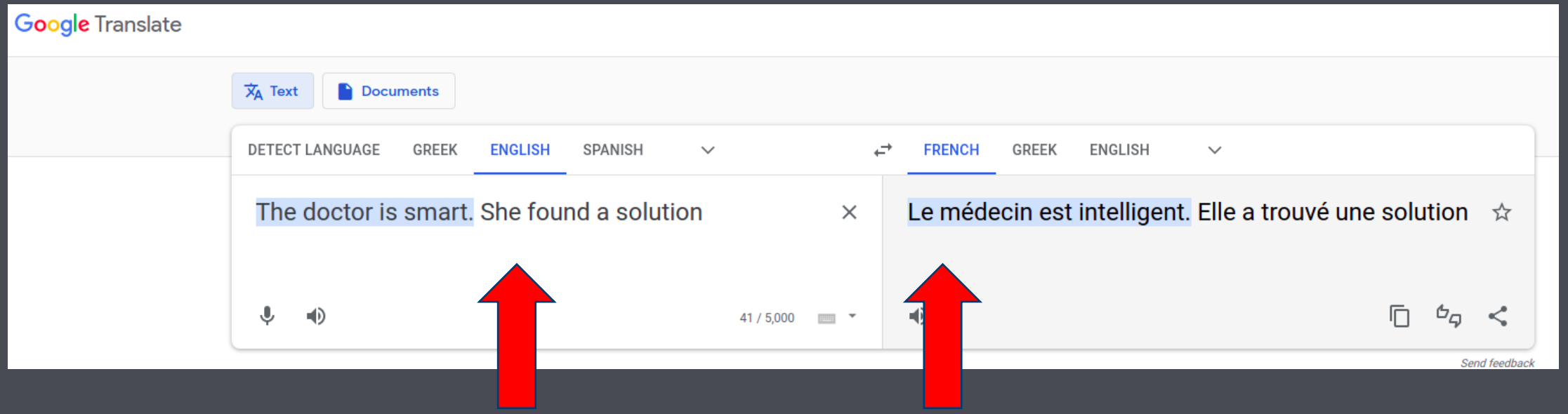
Machine Translation



… How would you translate this passage to French / German / Spanish / Italian / Portuguese / Arabic?

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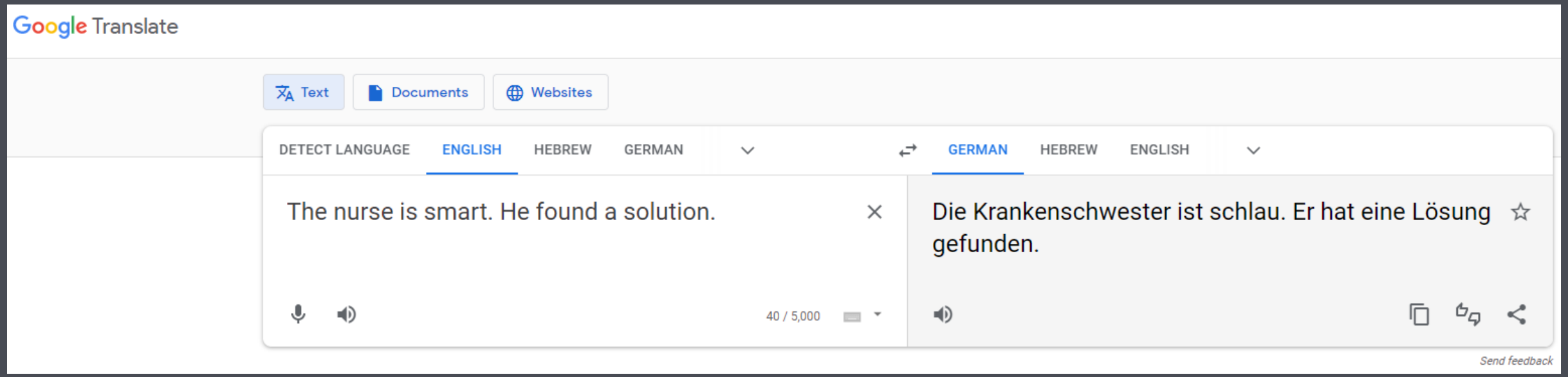
Hidden Model Bias



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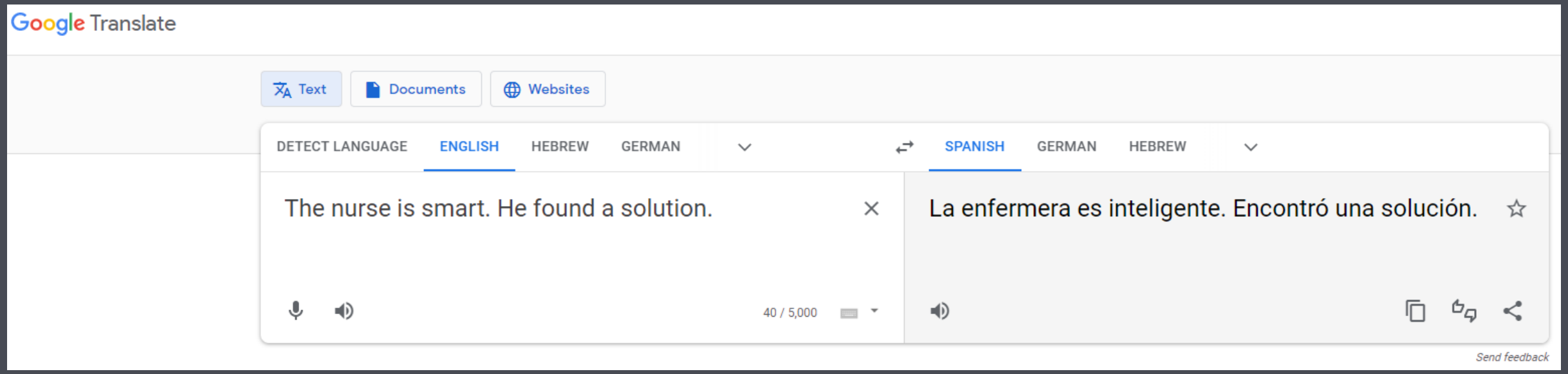
Hidden Model Bias



Customer reviews

4.4 out of 5

11,242 global ratings

5 star	71%
4 star	13%
3 star	5%
2 star	4%
1 star	6%

How are ratings calculated?

By feature

Quality of material	4.5
Battery life	4.5
Ergonomic	4.4

See more

Review this product

Share your thoughts with other customers

Write a customer review

Customer images


See all customer images

Read reviews that mention

battery life | stopped working | wireless mouse | great mouse | programmable buttons | thumb buttons | highly recommend | extra buttons | thumb rest | wireless gaming | buttons on the side | ever owned

Top reviews

Top reviews from the United States

Showing 1-8 of 161 reviews with "highly recommend". Clear filter

Smitty83

Excellent mouse for general use! Can't comment on gaming experience

Reviewed in the United States on December 9, 2019

Verified Purchase

...are all very good. I wish I had bought one of these for the office years ago. Highly recommended for $25! G1 - Left Mouse G2 - Right Mouse G3 - Enter G4 - Backwards G5 - Redo G6 - Paste G7 - Forward G8 - Undo G9 - Copy G10 - DPI Shift (2200 ->... Read more ›

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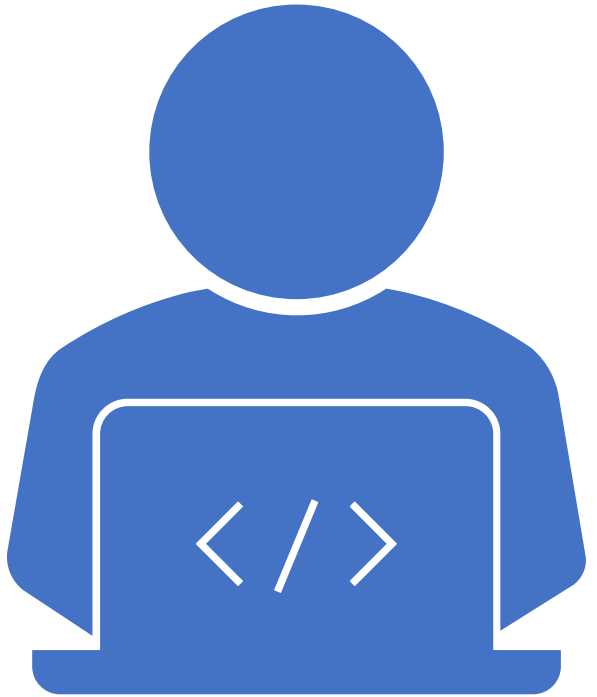
True NLP is AI-Complete

- Turing Test: is a computer program intelligent? (1954)
  - Would a human find out that he speaks (chats) with a computer?



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True NLP

True NLP isn't keyword matching but rather **real understanding of language.**

AKA **Computational Linguistics.**

… But unfortunately, this is not yet feasible...

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Layers of Linguistic Knowledge

Phonology
- Sounds combination

Morphology
- Word Structure

Syntax
- Sentence Structure

Semantics
- Utterance Meaning

Pragmatics
- Intention / Act

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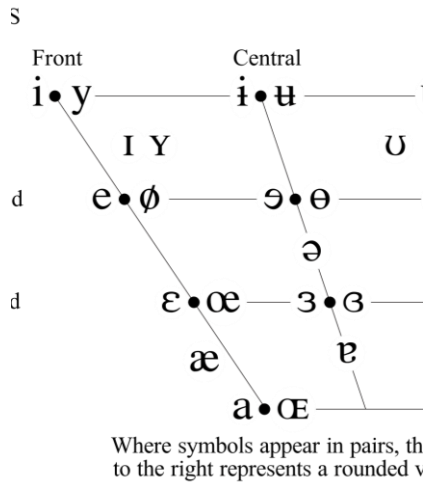
Phonology: sound combination

- Frequent sounds combination
- Language differences

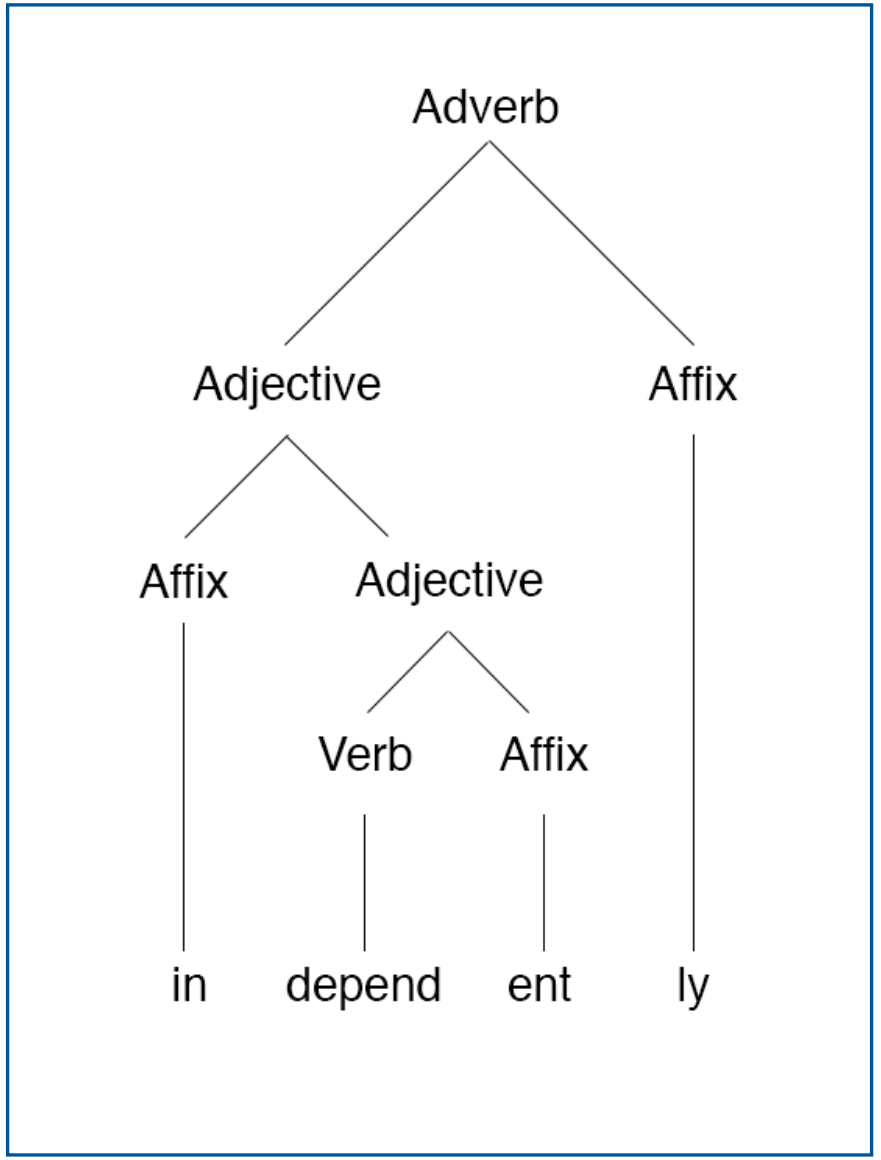


Morphology: Word Structure

Independently: in | depend | ent | ly

Tanıştırılamazlar (Turkish)
they can not be introduced

Lebensversicherungsgesellschaftsang esteller



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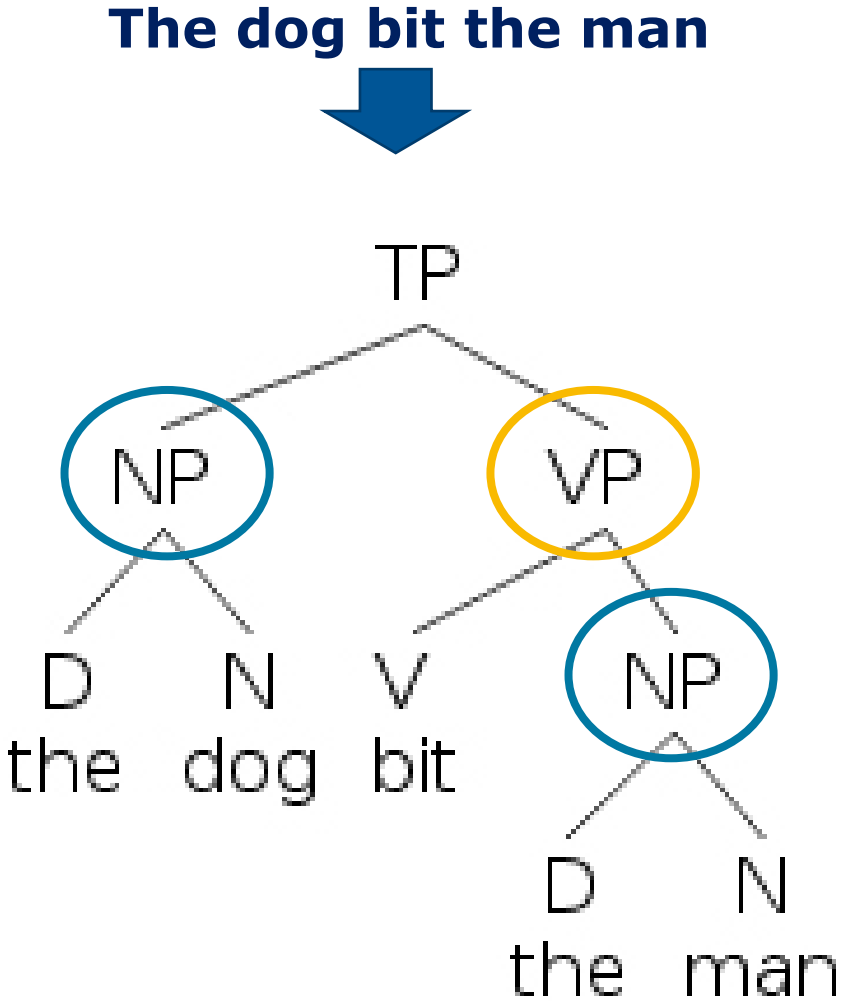
Syntax: Sentence Structure

> Categorization - Part of Speech (POS)
> Phrases (more than one word)
> Sentence Hierarchy

Good for:

> Question Answering
> Entity & Information Extraction

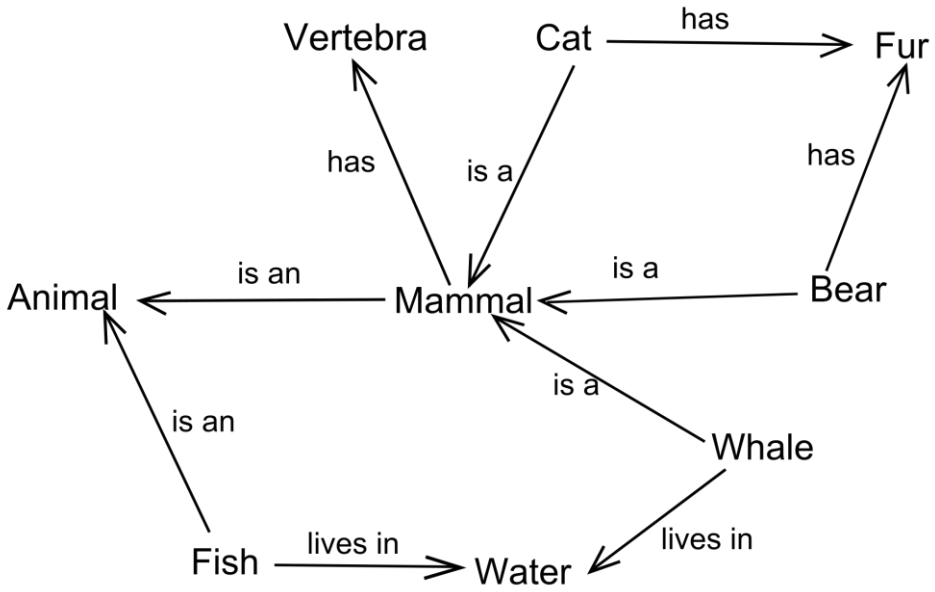


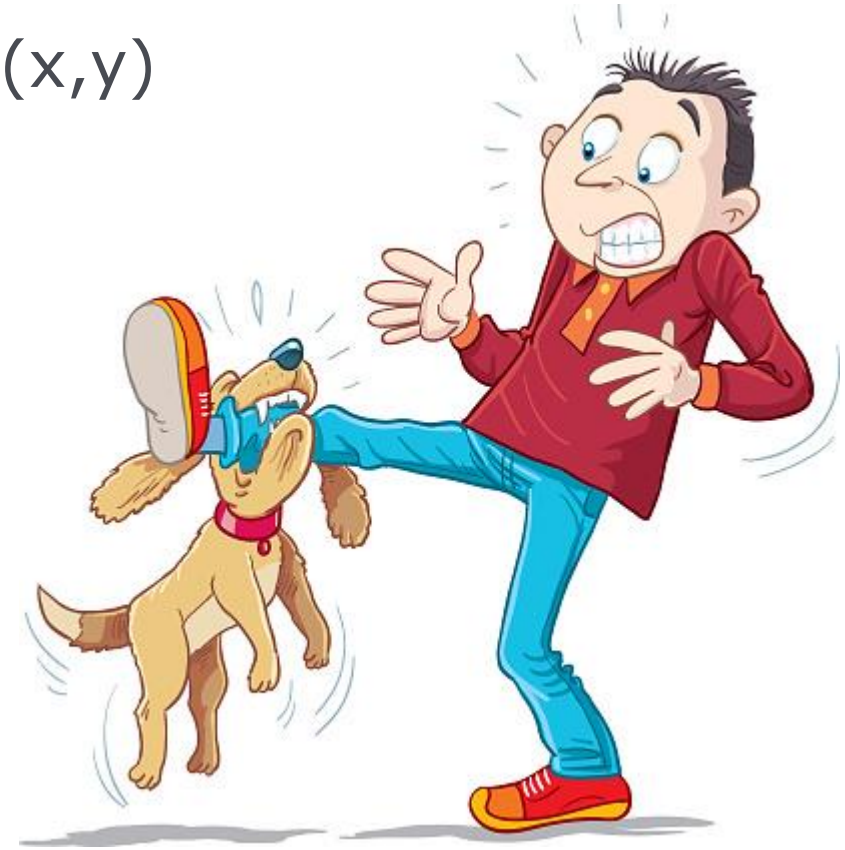
Semantics: Meaning

The dog bit the man

\exists x,y: Dog(x) & Man(y) & BITE(x,y)

Semantic Graph:





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Pragmatics: Intention / Act

> Aspects beyond the text
> Social relationship / Context
> Time & Place

- I **heart** you!
- Gosh, would you look at the time!
- Will you **crack** open the door? It’s hot in here...
- It’s cold in here, isn’t it?

Why is NLP hard?

Why Linguistics isn’t enough?

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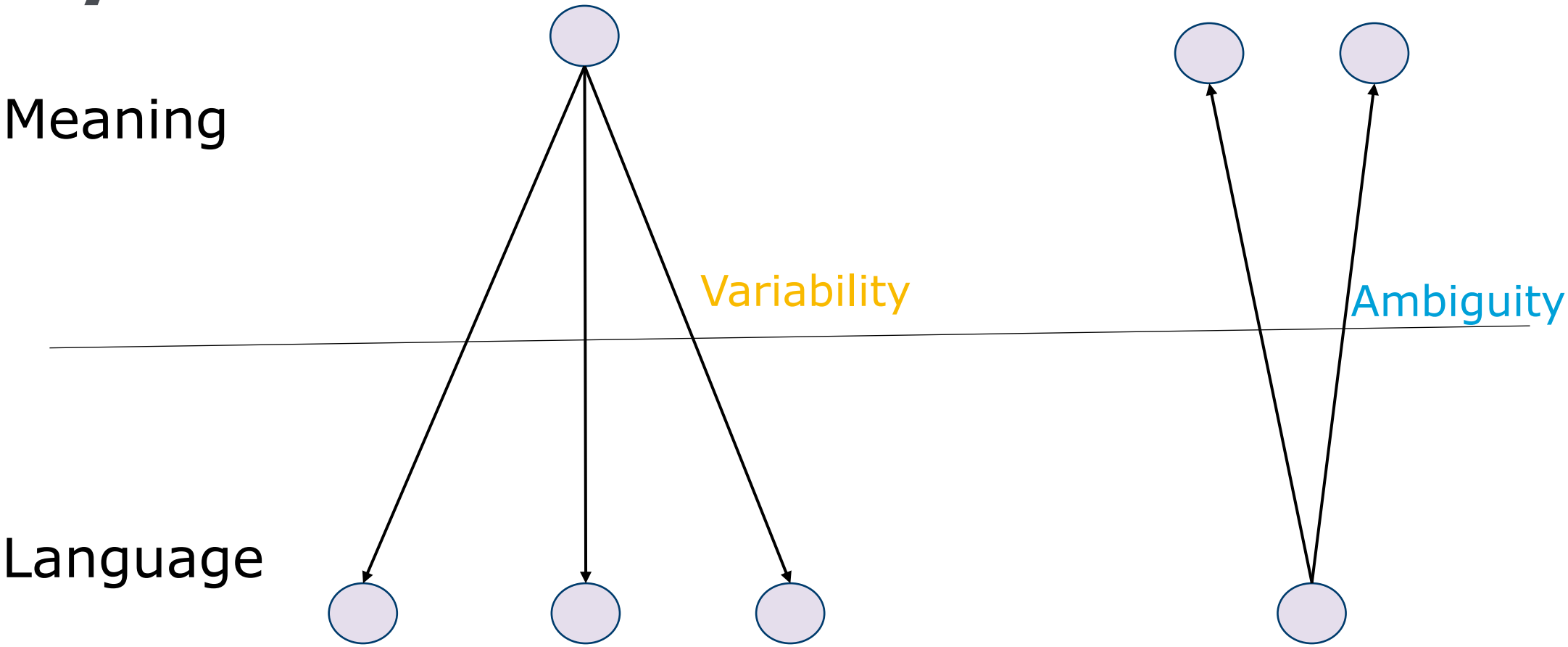
Why is NLP hard?



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Variability

Semantical / Pragmatical

He acquired it
He purchased it
He bought it
It was bought by him
It was sold to him
She sold it to him
She sold him that

Lexical *

I looooooove it!
everytime → every time
oscar nom'd doc → Oscar-nominated documentary
is bananas → is great

* Wei Xu:
https://cocoxu.github.io

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Negativity and Restrictivity

Martin is a great Data Scientist

Martin is **not** a great data scientist

Martin is a Data Scientist

Martin is **not** a data Scientist

Martin is **not** a Data Scientist

Martin is **not** a Mad Scientist

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Ambiguity:
Across all levels of Description

Phonology:

Ship // Sheep

eat // it

Seite (page) // Saite (string)

(isst // ist)

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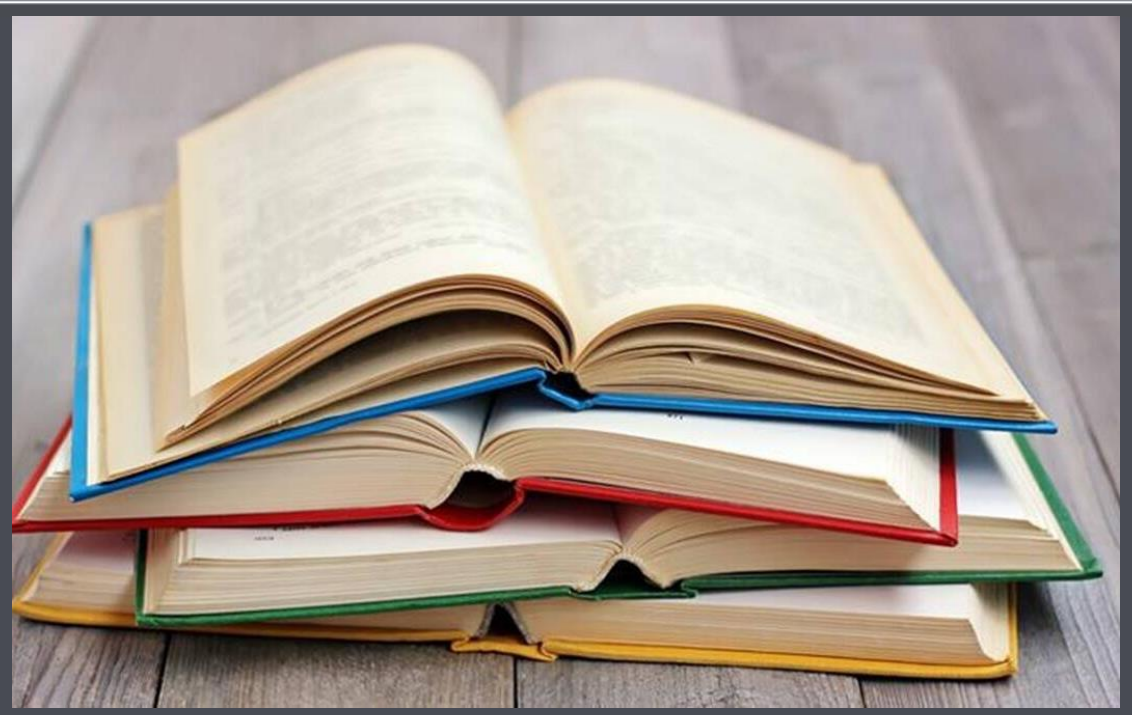

Ambiguity:
Across all levels of Description

Morphology (polysemy): books, parks

Verb Phrase // Noun Phrase

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Ambiguity:
Across all levels of Description

Morphology (Lexical): Bank

Noun // Noun

Der/Das Spektakel

Ambiguity:
Across all levels of Description

Syntactical:

I ate pizza **with olives**

I ate pizza **with fork & knife**

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Ambiguity:
Across all levels of Description

Semantical:

> The chicken is ready to eat

> Jeder Mann liebt eine Frau

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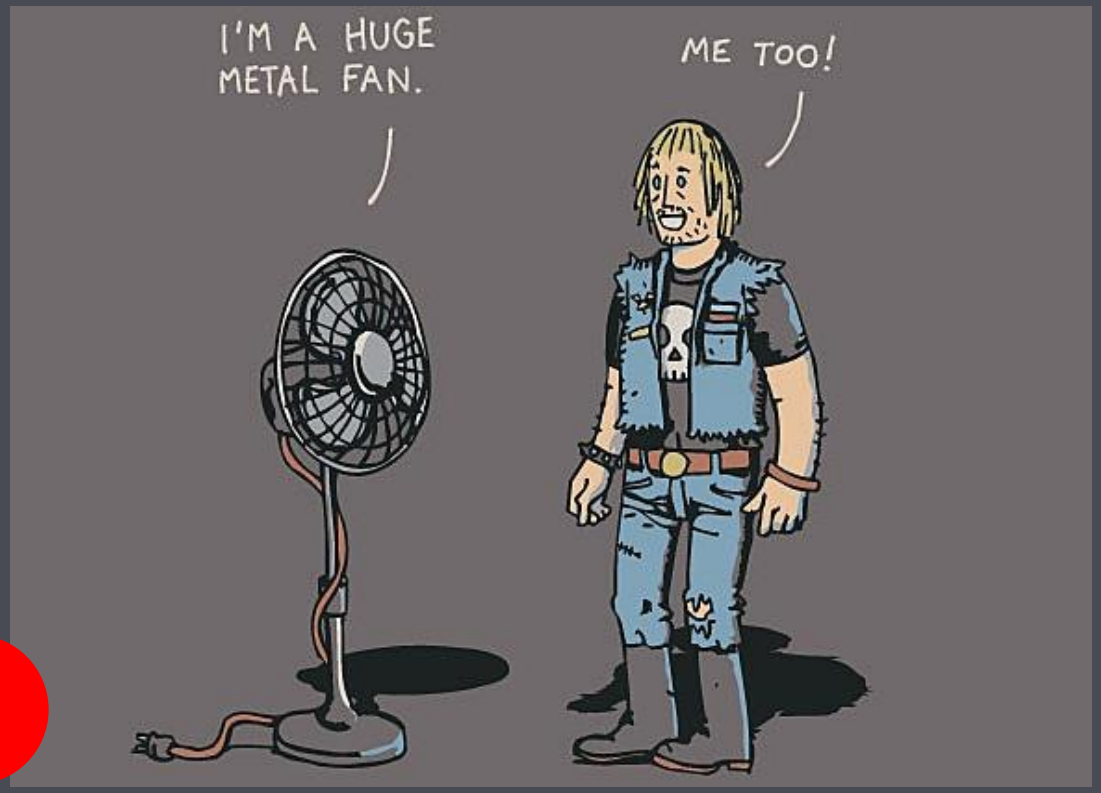
Ambiguity:

Across all levels of Description

Pragmatics



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Extreme Ambiguity (Real Headlines!)

> Scientists count whales from space
> The pope's baby steps on gays
> Girl hit by car in the hospital
> Iraqi head seeks arms
> Lung cancer in women mushrooms
> Students get first hand job experience
> Squad helps dog bite victim
> Miners refuse to work after death
> Stolen painting found by tree
> Actor sent to jail for not finishing sentence
> Stadium air conditioning fails — Fans protest

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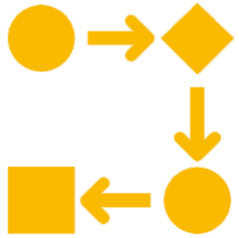
Pop Quiz!

Which linguistic level is this ambiguity example?

Modeling

How is NLP done?

NLP – How is it done?



Rule-based modeling

Many rules (with many exceptions)

Statistical Modeling (Data Driven)

Like children who learn by listening and trying

Input sets of 'correct' samples (X, Y)

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Rule-Based Modeling

> The soup was cold.

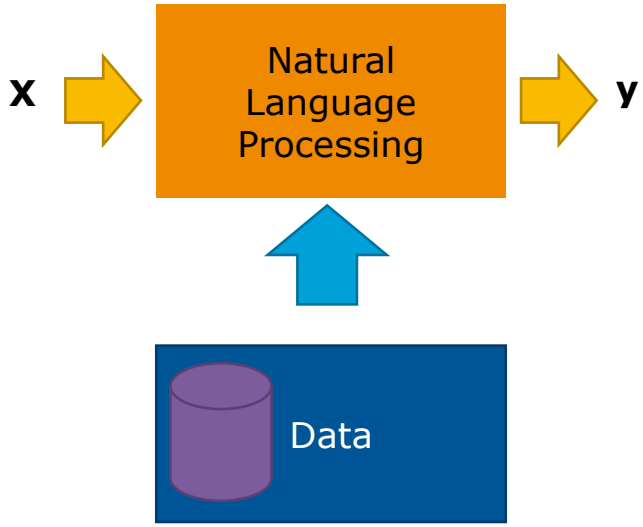
> The pudding was warm.

> The waiter was rude.

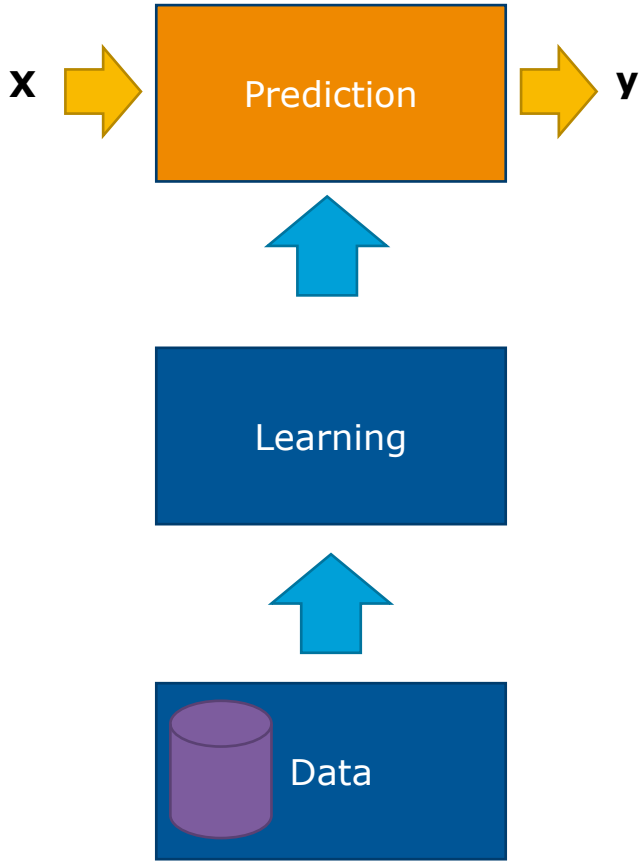
> Rule: The <X> was <Y>

> Rule: If <Bank> && <Bill> in **text** → bank statement

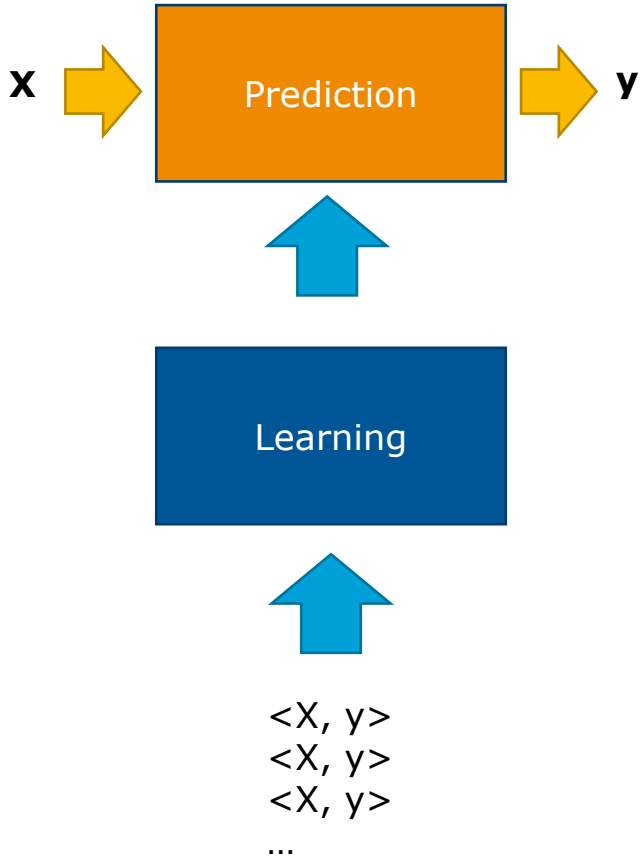
Statistical Modeling



Statistical Modeling



Statistical Modeling



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Statistical Modeling

> Define x

> Define y

> Curate Data {(x, y)}

> Devise Learning

> Devise Prediction

> Evaluate y* =? y

Basic Units of Text Processing

What is this X?
What do we process?

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What do we process?

> A Collection of Documents

By Date
By Topic
By Web Domain
…

> Document

> Section

Subsection

> Paragraph

> Sentence

Phrases

> Word

Characters, morphemes

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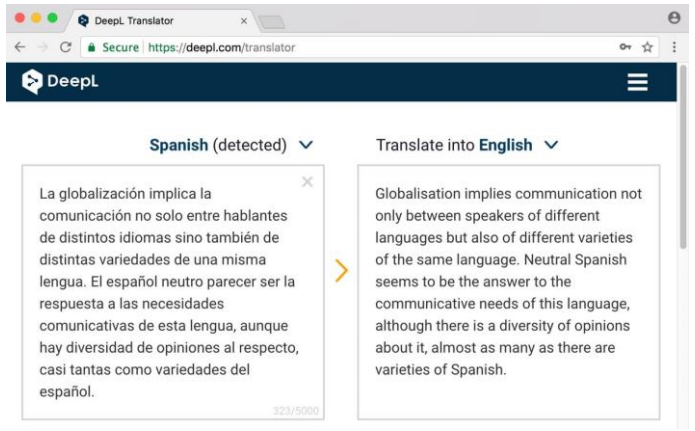
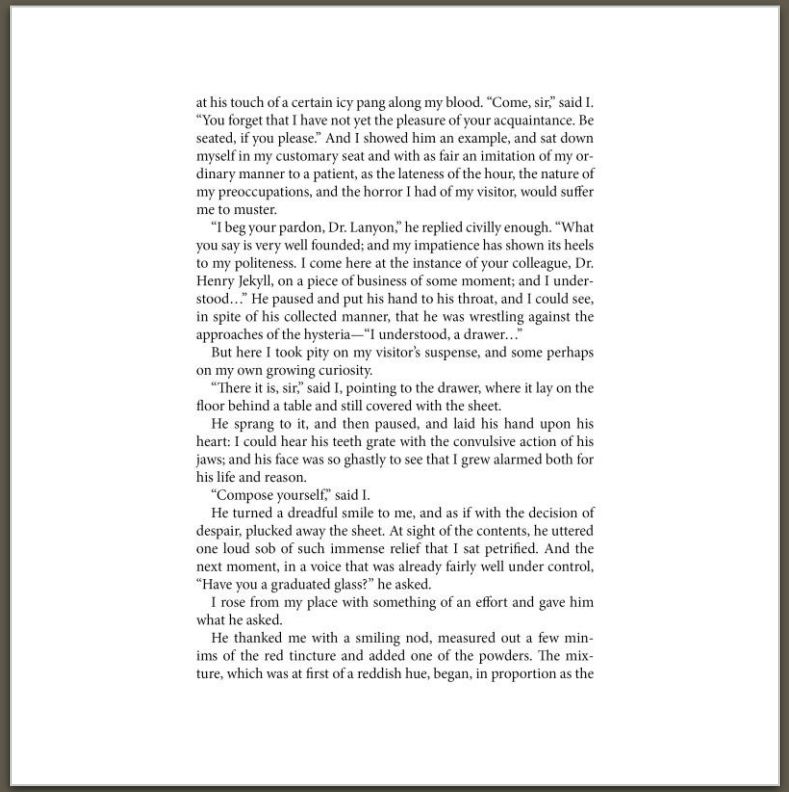
What do we process?

> A Collection of Documents
> **Document**
> Section
> Paragraph
> Sentence
> Word

What is a Document?





at his touch of a certain icy pang along my blood. "Come, sir," said I. "You forget that I have not yet the pleasure of your acquaintance. Be seated, if you please." And I showed him an example, and sat down myself in my customary seat and with as fair an imitation of my ordinary manner to a patient, as the lateness of the hour, the nature of my preoccupations, and the horror I had of my visitor, would suffer me to muster.

"I beg your pardon, Dr. Lanyon," he replied civilly enough. "What you say is very well founded; and my impatience has shown its heels to my politeness. I come here at the instance of your colleague, Dr. Henry Jekyll, on a piece of business of some moment; and I understood…" He paused and put his hand to his throat, and I could see, in spite of his collected manner, that he was wrestling against the approaches of the hysteria—"I understood, a drawer…"

But here I took pity on my visitor's suspense, and some perhaps on my own growing curiosity.

"There it is, sir," said I, pointing to the drawer, where it lay on the floor behind a table and still covered with the sheet.

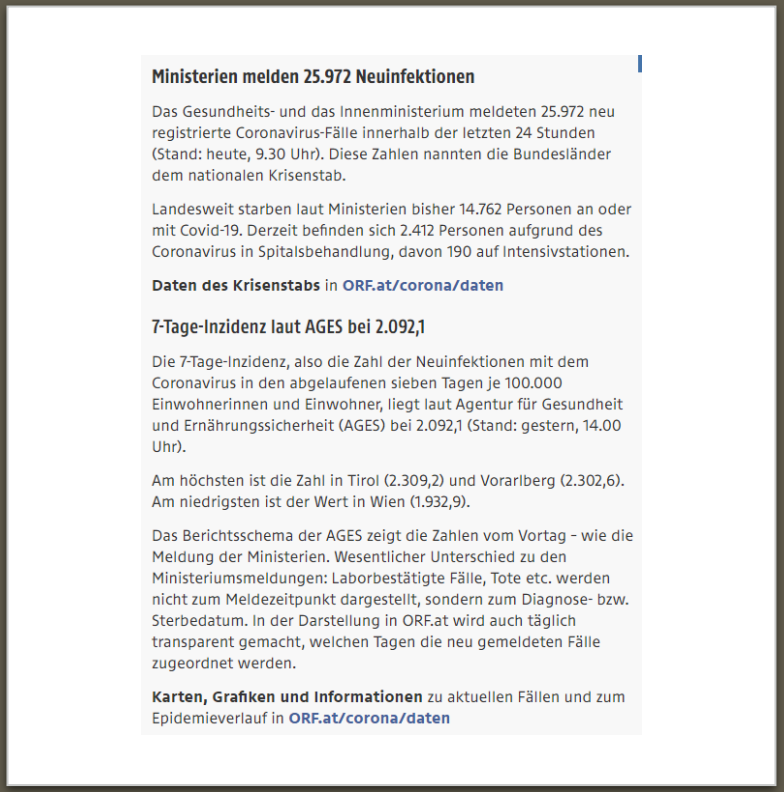
He sprang to it, and then paused, and laid his hand upon his heart: I could hear his teeth grate with the convulsive action of his jaws; and his face was so ghastly to see that I grew alarmed both for his life and reason.

"Compose yourself," said I.

He turned a dreadful smile to me, and as if with the decision of despair, plucked away the sheet. At sight of the contents, he uttered one loud sob of such immense relief that I sat petrified. And the next moment, in a voice that was already fairly well under control, "Have you a graduated glass?" he asked.

I rose from my place with something of an effort and gave him what he asked.

He thanked me with a smiling nod, measured out a few minims of the red tincture and added one of the powders. The mixture, which was at first of a reddish hue, began, in proportion as the



Ministerien melden 25.972 Neuinfektionen

Das Gesundheits- und das Innenministerium meldeten 25.972 neu registrierte Coronavirus-Fälle innerhalb der letzten 24 Stunden (Stand: heute, 9.30 Uhr). Diese Zahlen nannten die Bundesländer dem nationalen Krisenstab.

Landesweit starben laut Ministerien bisher 14.762 Personen an oder mit Covid-19. Derzeit befinden sich 2.412 Personen aufgrund des Coronavirus in Spitalsbehandlung, davon 190 auf Intensivstationen.

Daten des Krisenstabs in ORF.at/corona/daten

7-Tage-Inzidenz laut AGES bei 2.092,1

Die 7-Tage-Inzidenz, also die Zahl der Neuinfektionen mit dem Coronavirus in den abgelaufenen sieben Tagen je 100.000 Einwohnerinnen und Einwohner, liegt laut Agentur für Gesundheit und Ernährungssicherheit (AGES) bei 2.092,1 (Stand: gestern, 14.00 Uhr).

Am höchsten ist die Zahl in Tirol (2.309,2) und Vorarlberg (2.302,6). Am niedrigsten ist der Wert in Wien (1.932,9).

Das Berichtsschema der AGES zeigt die Zahlen vom Vortag - wie die Meldung der Ministerien. Wesentlicher Unterschied zu den Ministeriumsmeldungen: Laborbestätigte Fälle, Tote etc. werden nicht zum Meldezeitpunkt dargestellt, sondern zum Diagnose- bzw. Sterbedatum. In der Darstellung in ORF.at wird auch täglich transparent gemacht, welchen Tagen die neu gemeldeten Fälle zugeordnet werden.

Karten, Grafiken und Informationen zu aktuellen Fällen und zum Epidemieverlauf in ORF.at/corona/daten

Document Processing

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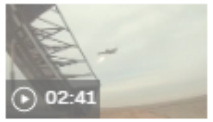
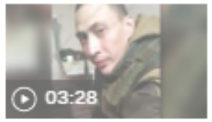
02:51
At least 440 unmarked graves found in recently liberated...


02:41
Russia steps up 'kamikaze' drone attacks on Ukraine


03:28
Video reveals a major problem for new Russian soldiers


03:22

Kyiv, Ukraine (CNN) — Mykhailo Yatsentiuk left the basement to make tea for his granddaughter just as the bomb struck. When he came to his senses a half hour later the entire middle section of his apartment block had been destroyed; the basement where he had been sheltering with his family and neighbors was engulfed in flames.

The Ukrainian government says 54 people died at the apartment complex on 2 Pershotravneva street in Izium, eastern Ukraine, on March 9, almost half of the building's residents. Entire families were killed in the attack, including the Yatsentiuks, Kravchenkos and Stolpakovas.

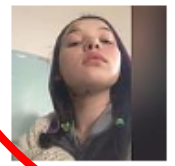
Their fates remained largely unknown until a few weeks ago when Ukrainian forces pursuing a counter-offensive reclaimed Izium after six months of Russian occupation, revealing a mass burial site on the outskirts of the city.

Most of the residents of 2 Pershotravneva were buried there among more than 400 graves, few with identifying marks other than numbers daubed on rough wooden crosses.

After speaking to a survivor, ex-residents and family members, and reviewing photos and video taken in the aftermath of the attack and following the town's liberation, CNN can now tell the story of what happened at 2 Pershotravneva on that day.

News & Buzz


Putin says war could continue until "last Ukrainian is left standing"


Injured, alone and destined for a Russian orphanage, a 12-year-old Ukrainian girl is recruited fo...

What do we process?

> A Collection of Documents
> Document
> Section
> Paragraph
> Sentence
> **Word**

What is a Word?

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What is a word?

> A sequence of characters?

> A basic unit of meaning?

> white-space tokenized?

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What is a word?

Doesn’t

John’s

Unlucky

Freundschaftsbeziehungen

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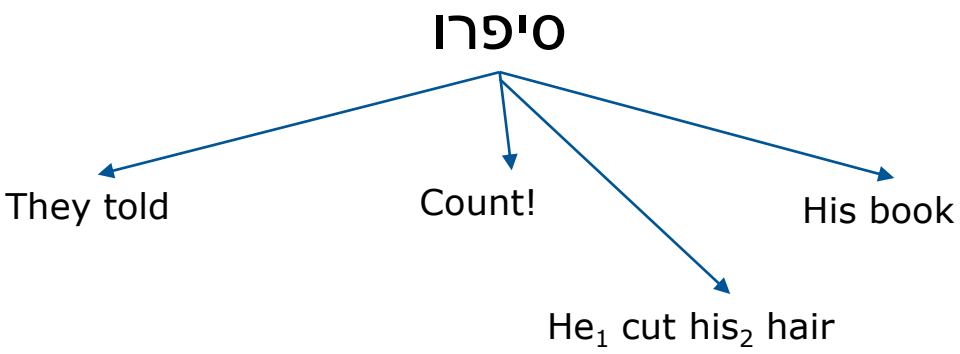
What is a word?



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What is a word?

> Whitespace isn’t enough…

我开始写小说 = 我 开始 写 小说

I start(ed) writing novel(s)

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What is a word?

Ice cream

Web site

New York

New York-Based

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What is a word?

Gave up

Made sense

Took a picture

Took apart

Took the toy apart

brechen ab

steigen ein/aus

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Reflexive verbs // Verb conjunction

- **French**:
  Tu te llaves
- **Portuguese**:
  Sente-se
- **Spanish**:
  Recuérdame / le dijeron
- **Albanian**:
  Laj duart

  Noun conjunction: duar -> duart

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What do we process?

> A Collection of Documents
> Document
> Section
> Paragraph
> **Sentence**
> Word

What is a Sentence?

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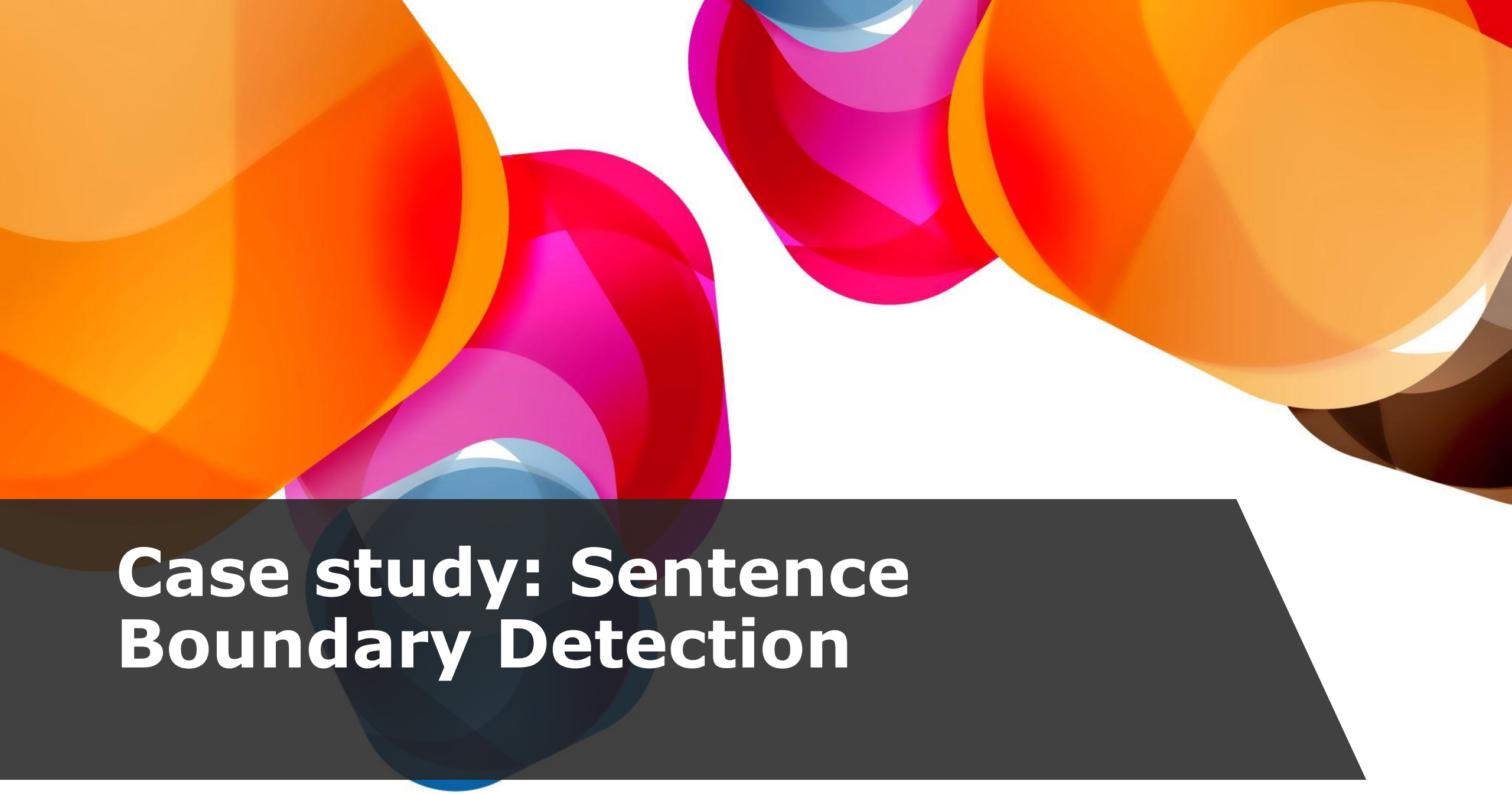
What is a Sentence?

```
sentences = text.split(".")?
```



Case study: Sentence Boundary Detection

Question:

When do we need (or don't need) to divide a document into sentences?

Not needed:

if it’s already divided; Search Query; Working on a document-level (e.g., document classification)

What about translation – needed or not?

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Anaphora / Cataphora / Co-reference resolution

Human: What do we want?

Computer: Natural-Language Processing!

Human: When do we want it?

Computer: When do we want what?

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Sentence Boundary Detection

Python:

```
sentences = text.split(".")
```

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Sentence Boundary Detection

However, if you picked up a certain book from the library, you can opt to start up your own biplane instead of boarding the zeppelin and forgo the hassle of having to navigate around the blimp's infrastructure. Flying the plane requires you to utilize the number pad (in a slightly less frustrating way than the fights) to dodge the Luftwaffe assault while Henry blasts the enemy planes. Depending on how many planes you destroy before you get shot down, you will have to face fewer roadblocks on the way to Alexandretta when you continue the rest of the journey by car. The guards you stop you at each roadblock act as in Brunwald; i.e., find out a way to talk or bribe your way around them, or just get to punching their faces in. A certain item can even help you skip over every single guard just by showing it to them!

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Sentence Boundary Detection

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Sentence Boundary Detection

Python:

```
sentences = text.split(". ")
```

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Sentence Boundary Detection

WASHINGTON — Former President **George W. Bush** called on Americans on Saturday to put aside partisan differences, heed the guidance of medical professionals and show empathy for those stricken by the coronavirus and the resulting economic devastation.

In a three-minute video message, **Mr. Bush**, who rarely speaks out on current events, struck a tone of unity that contrasted with the more combative approach taken at times by President Trump as the former president evoked the sense of national solidarity in the wake of the attacks of **Sept. 11, 2001**.

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Sentence Boundary Detection

Learning system, that **learns**, according to text features, which ones are attributed to sentence ends.

- Q: How to get annotated data?
- Q: Which kind of data to use?
- Q: Which clues could hint at the end-of-sentences?

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Clues to identify end-of-sentence

- A dictionary of safe-words:
  Mr. Dr. Ltd. Inc. U.S. e.g. i.e.
- Hinting words in a windowed neighborhood
- An ensemble or a combination of clues:
  - *Capital letter after ". "*
    Though not perfect: *George W. Bush*
- Word length: short words are probably part of a word

Statistical (ML Task): Weighting the hints as a learnable solution.

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Weighting the hints as a learnable solution

- Collect the data
- Annotate
- Define the 'hints' (a.k.a. *feature engineering*)
- Identify the problem: Binary classification
  - Decide which of the hints to use to determine end-of-sentence
- Train
- Evaluate

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Worth Reading

Sentence Boundary Detection and the Problem with the U.S.

Dan Gillick
Computer Science Division
University of California, Berkeley
dgillick@cs.berkeley.edu

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SOTA is still not 100% solved

It's not a good time. (It's never a good time).

In a quiet voice, he said
"this will not work. I am quitting",
and then he left the room.

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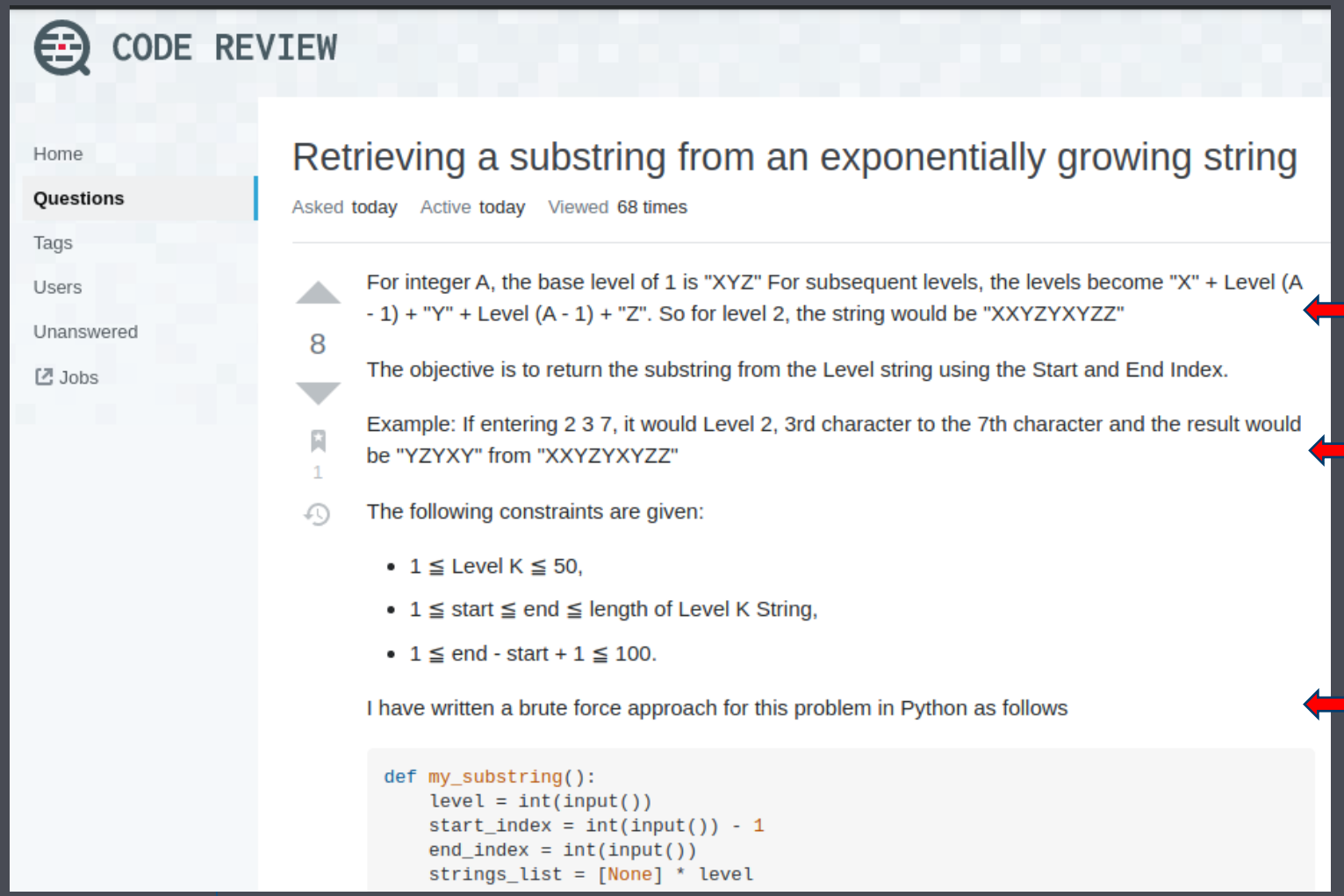

Real world example

Sentence Boundary Detection

- Probably the most basic task…
- …but still non-trivial
- Requires considering:
  - which corpus to use
  - features
  - annotation procedure
  - potential biases
- Depends on the use case:
  - choose a sentence definition, methods, and trade-offs.

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Natural Language is Hard

Two main takeaways from this course (and maybe the degree…):

> Natural Language Processing is hard
- Why is it hard?
- (hence, why is it interesting!)
- How to cope with it?

> NLP is about compromising
- Perform a reasonable compromise
- Understand that you compromised
- Understand what the compromise was
- Try to improve it, if needed, as much as possible.