Introduction to
Natural Language Processing

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https://tanmoychak.com/

Introduction to Large Language Models

THE TIMES OF INDIA

INCLUSIVE OF EDUCATION TIMES & DELHI TIMES (CIRCULATED ONLY IN DELHI NCR) | *APPLICABLE ONLY ON MONTHLY PURCHASE (IN DELHI NCR)

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Donald Trumps Death

■ Bullet Pierces Ear At Rally ■ Secret Service Kills Shooter ■ 1 Rallygoer Dead, 2 Injured

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In iconic images immediately flashed across the world, a fearless Trump, breaking free from a huddle of Secret Service agents protecting him, raised a clenched fist with blood streaking across his cheek. The indelible moment, consecrated into campaign merchandise within hours of the incident, inflamed and galvanised Trump's supporters, and is expected to power him

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DOWN & BACK UP: 'FIGHT', SAYS DEFIANT DON

Getty Images/AP

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The victim, Riyazuddin, was a labourer who lived with his family in Sriram Nagar, Khajuri Khas. He had been admitted to the hospital on June 23 for treatment of an abdominal infection.

Police personnel investigate at the hospital on Sunday

Sunday's incident took place around 4pm, a senior police officer said. The suspect allegedly came to ward number 24 and fired at least two rounds at the patient, who was receiving dressing from the nurse.

▶20 people, P 3

CRPF jawan killed, 2 cops injured in Manipur attack

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CIVILIAN WOUNDED

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Natural Language Processing

What is a Natural Language?

Any language that has evolved naturally in humans through use and repetition without conscious planning or pre-meditation.

Content credits: https://www.javatpoint.com/nlp

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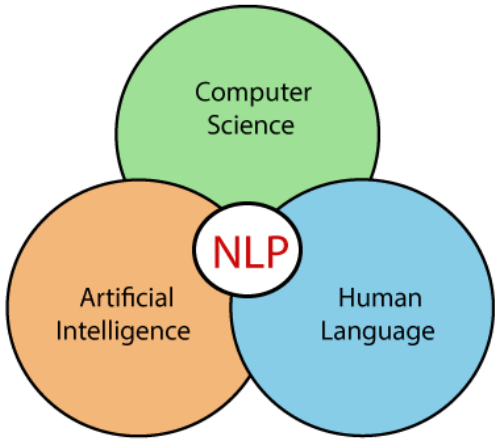
What is a Natural Language Processing?

A field of computer science, artificial intelligence and computational linguistics concerned with the interactions between computers and human (natural) languages.



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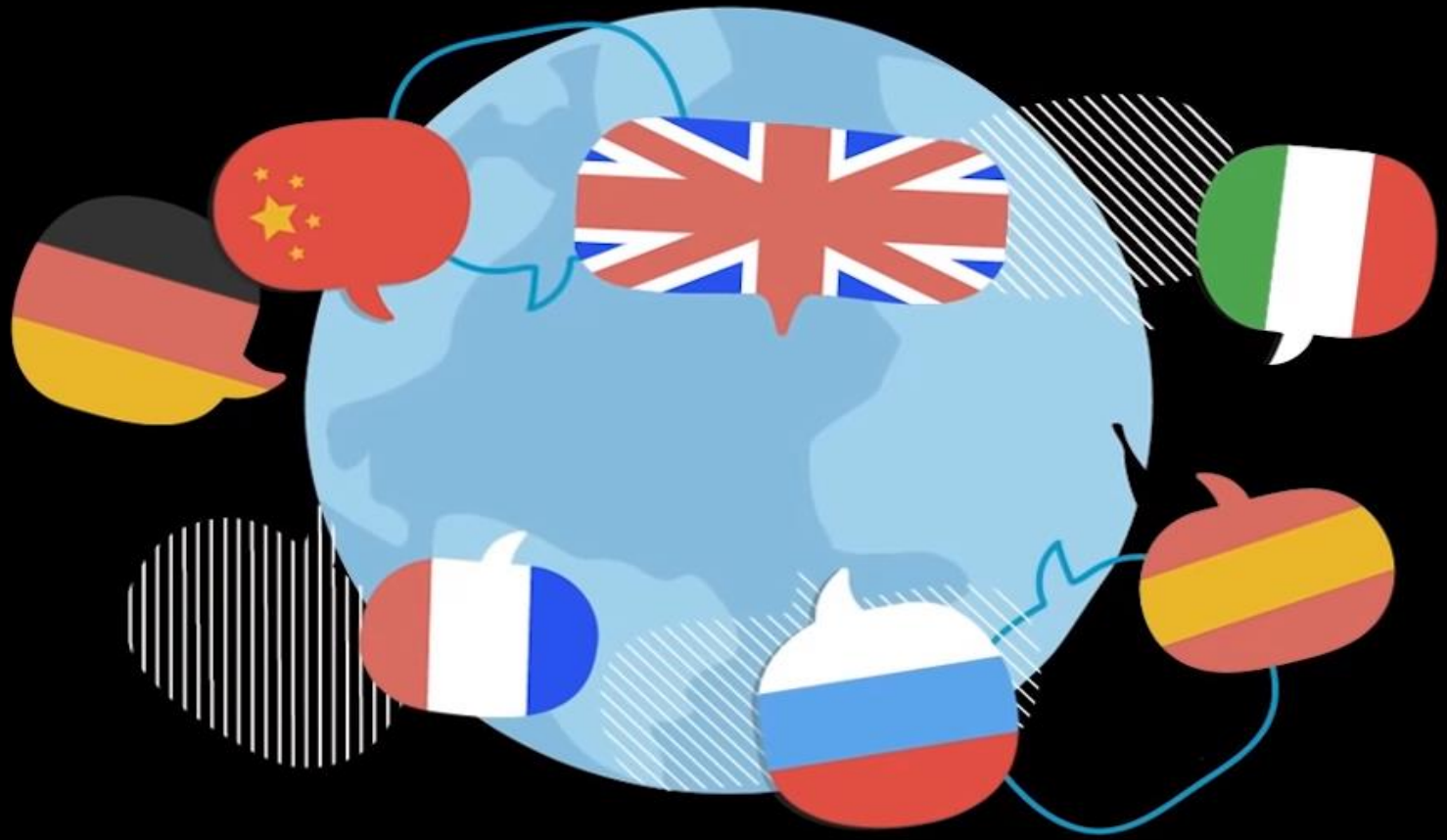
The Human Language



6500 LANGUAGES

The Human Language

Home / India / More than 19,500 mother tongues spoken in India: Census

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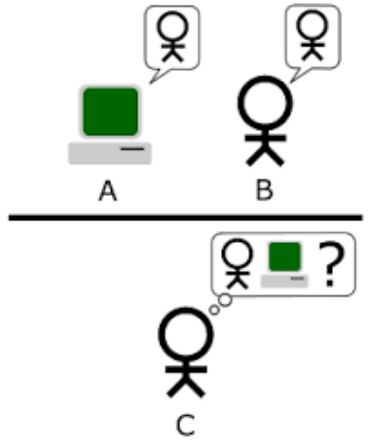
There are 121 languages which are spoken by 10,000 or more people in India, which has a population of 121 crore, the report said.

https://indianexpress.com/article/india/more-than-19500-mother-tongues-spoken-in-india-census-5241056/

Natural Language Processing

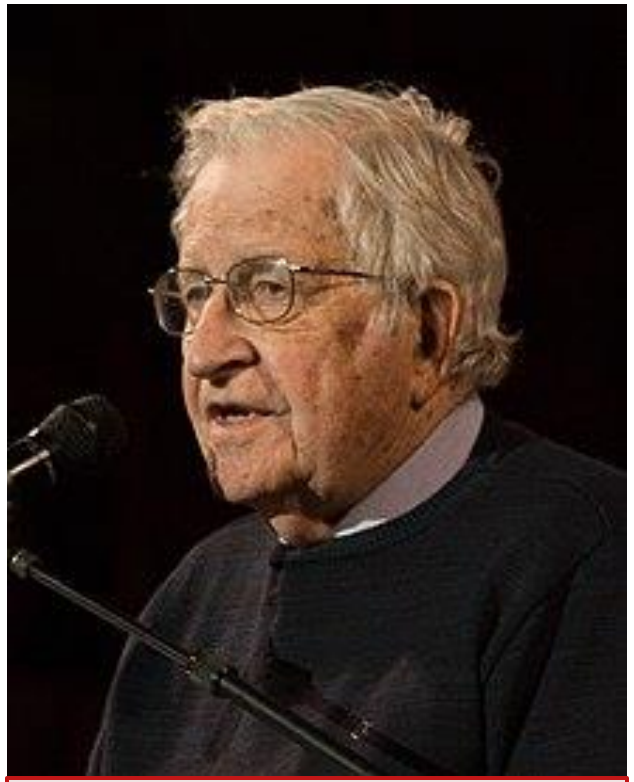
Setup

- Two rooms, two humans, and a computer.
  - Room 1: One human C
  - Room 2: One computer (A) and one human (B)
- Response generated from room 2 (either by A or B)
- C has to figure out the source of the response
  - If C is successful → "A" failed the Turing test
  - Else, → "A" passed the Turing test



"Computing Machinery and Intelligence" proposed what is now called the Turing test .

Natural Language Processing



The father of modern linguistics

In 1957, **Noam Chomsky**'s **Syntactic Structures** revolutionized Linguistics with '**universal grammar**', a rule-based system of syntactic structures

He is a laureate professor of linguistics at University of Arizona and an institute professor emeritus at MIT.

Why is NLP Challenging?

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Ambiguity

The Real Reason Why NLP is Hard

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Virat Kohli was on fire last night. He totally destroyed the other team.

Ambiguity

Is ambiguity present in language only?

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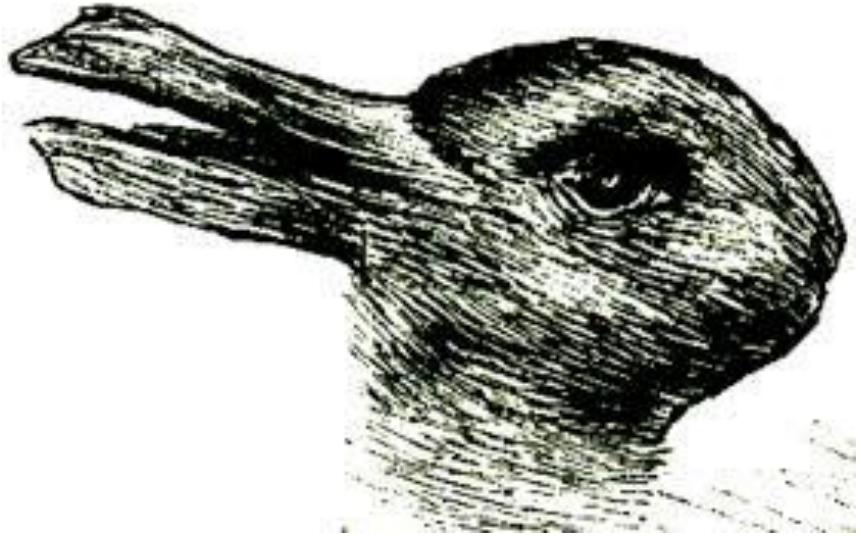
No, ambiguity is prevalent in every dimension!



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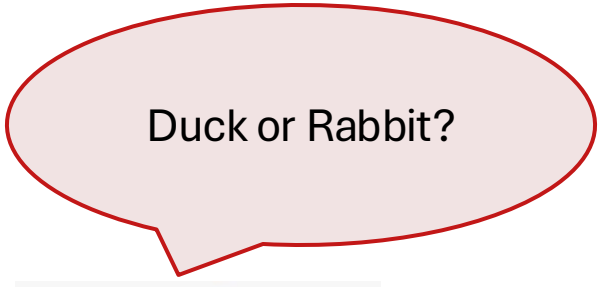

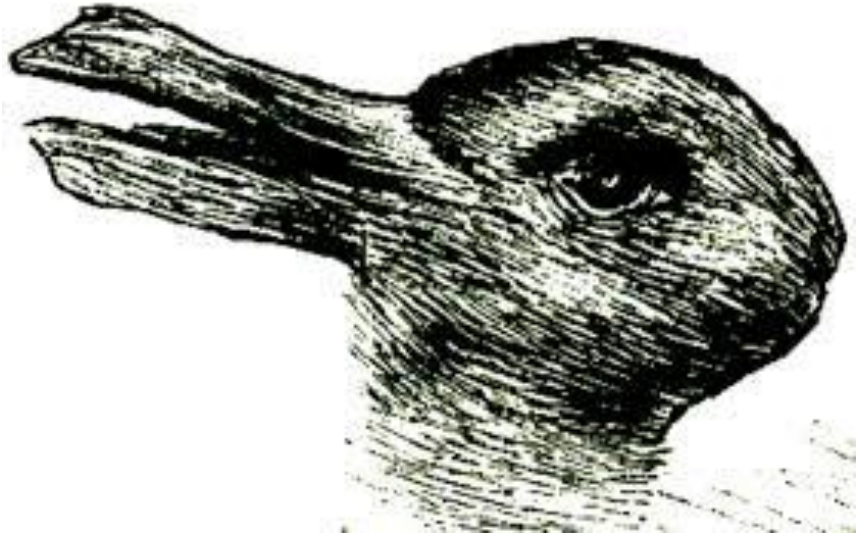

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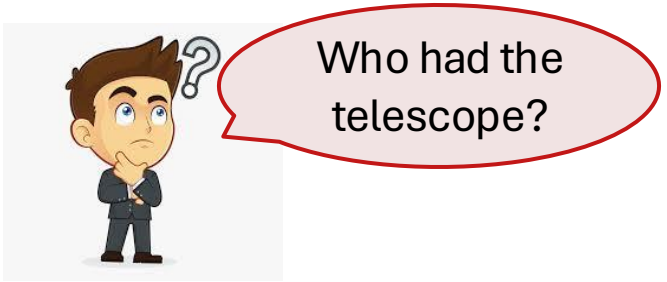

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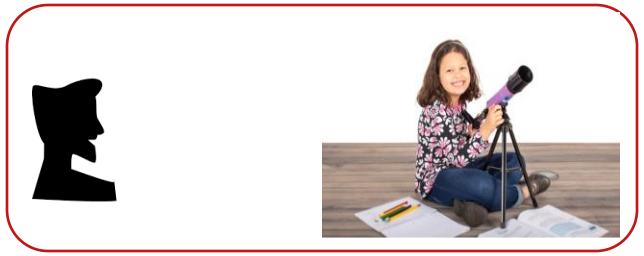

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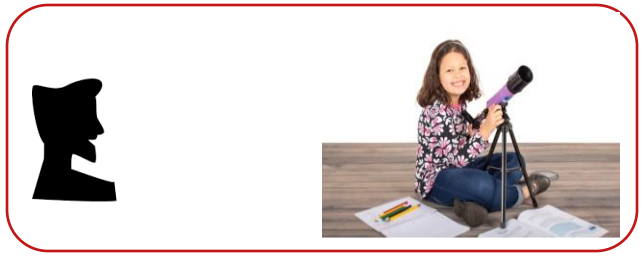
Who had the telescope?

OR



- I saw a girl with a bicycle.

- I saw a bus with a telescope.

No ambiguity!

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- Mary had a little lamb.

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  - Mary was physically bringing a lamb to a location, such as a farm or a home

Ambiguity in Language

- I saw a girl with a telescope.
- Mary had a little lamb.
  - Mary was physically bringing a lamb to a location, such as a farm or a home
  - Mary ate a lamb.

OR

Ambiguity in Language

- I saw a girl with a telescope.
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- Mujhe aapko mithai khilani padegi.

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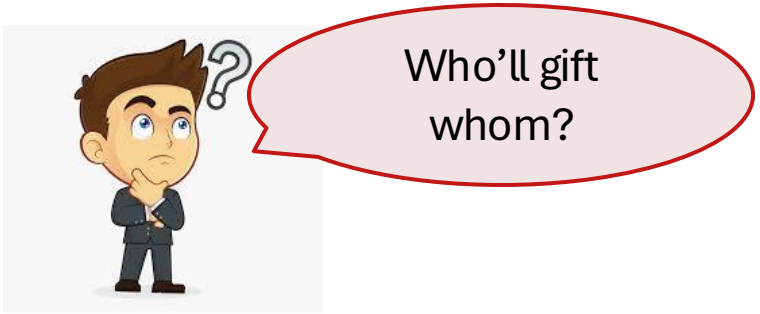

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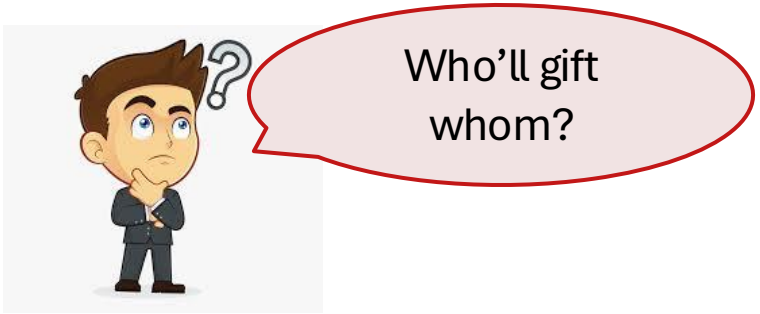

I have to gift you some sweets.

OR

You have to gift me some sweets.

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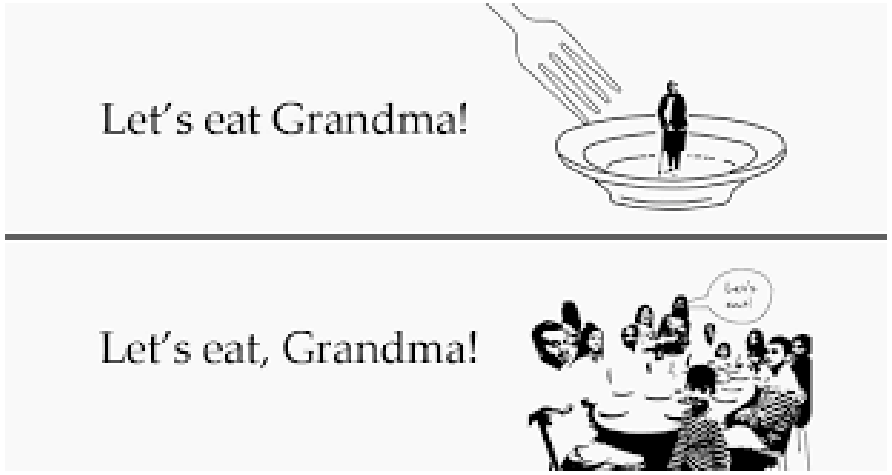
Similar surface structures but different interpretations!

Ambiguity and Punctuations!



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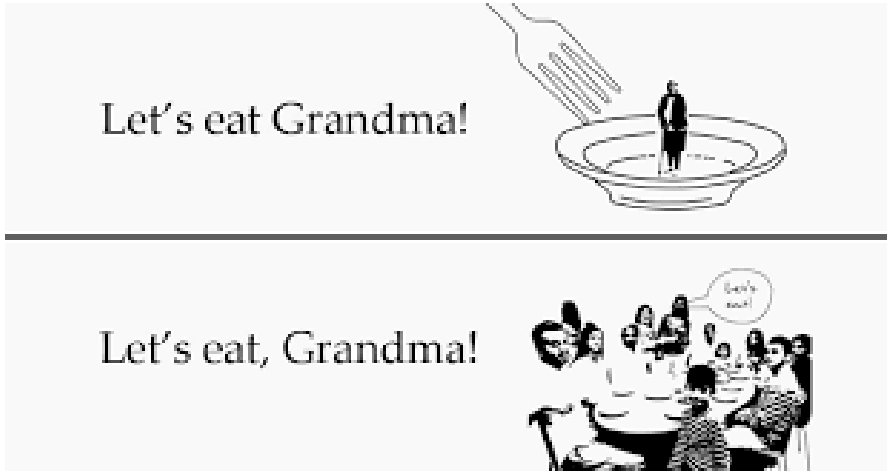

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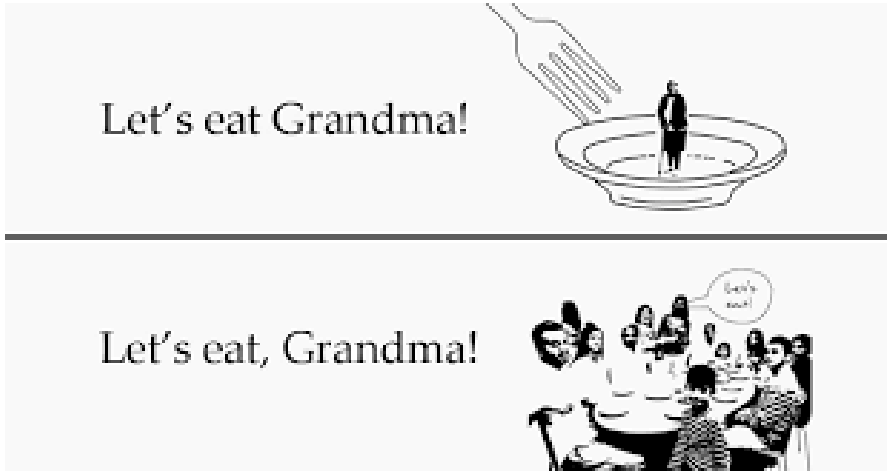

A woman without her man is nothing.

A woman, without her man, is nothing.

A woman: without her, man is nothing.

Punctuation is powerful.

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Dmitri Borgmann's *Beyond Language: Adventures in Word and Thought*. 1967.

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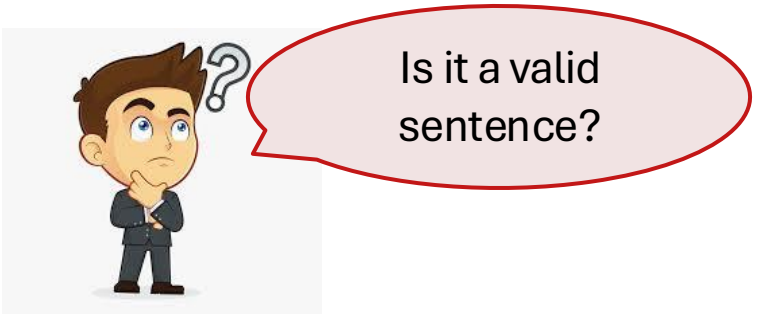

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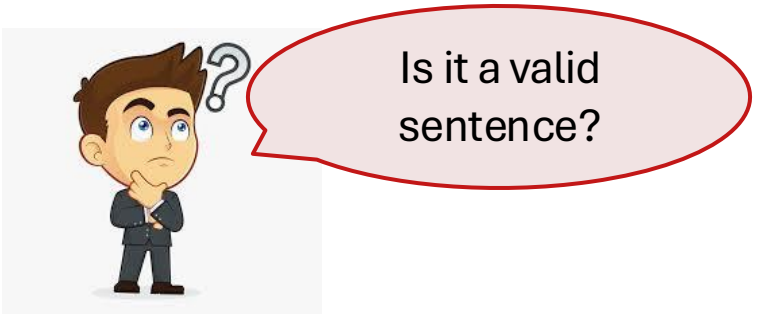

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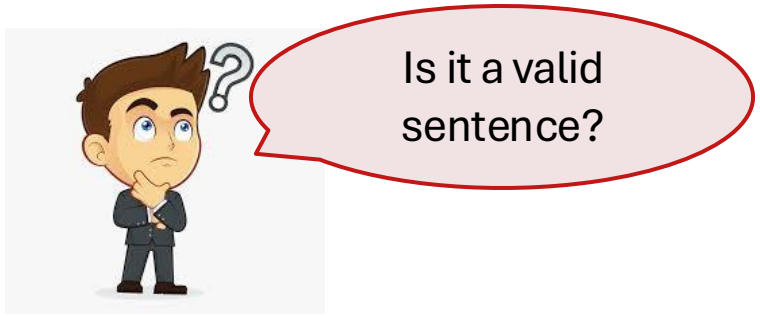

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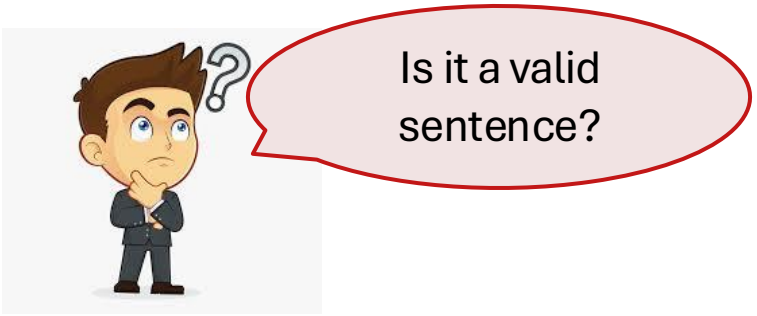

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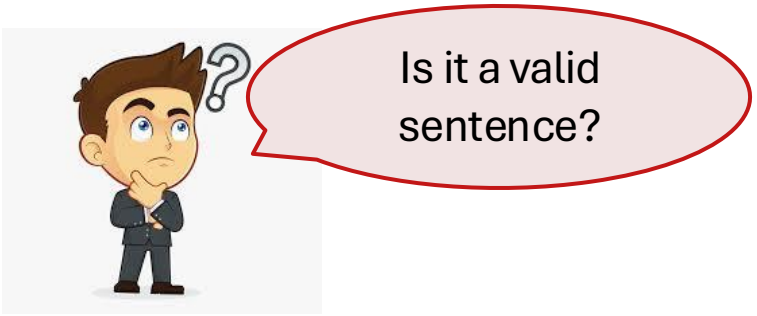

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Why Else is Natural Language Understanding Difficult?

Non-standard English

Great job @justinbieber! Were SOO PROUD of what youve accomplished! U taught us 2 #neversaynever & you yourself should never give up either ♥

Segmentation Issues

the New York-New Haven Railroad

the New York-New Haven Railroad

Idioms / Multiword

dark horse
get cold feet
lose face
throw in the towel
Khana-wana (Echo)

Neologisms

unfriend
Retweet
bromance

World Knowledge

Mary and Juhi are sisters.
Mary and Juhi are mothers.

Tricky Entity Names

Where is *A Bug's Life* playing …
Let It Be was recorded …
… a mutation on the *for* gene …

Components of NLP

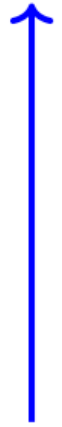
Natural Language Understanding

Natural Language Generation

NLP Layers

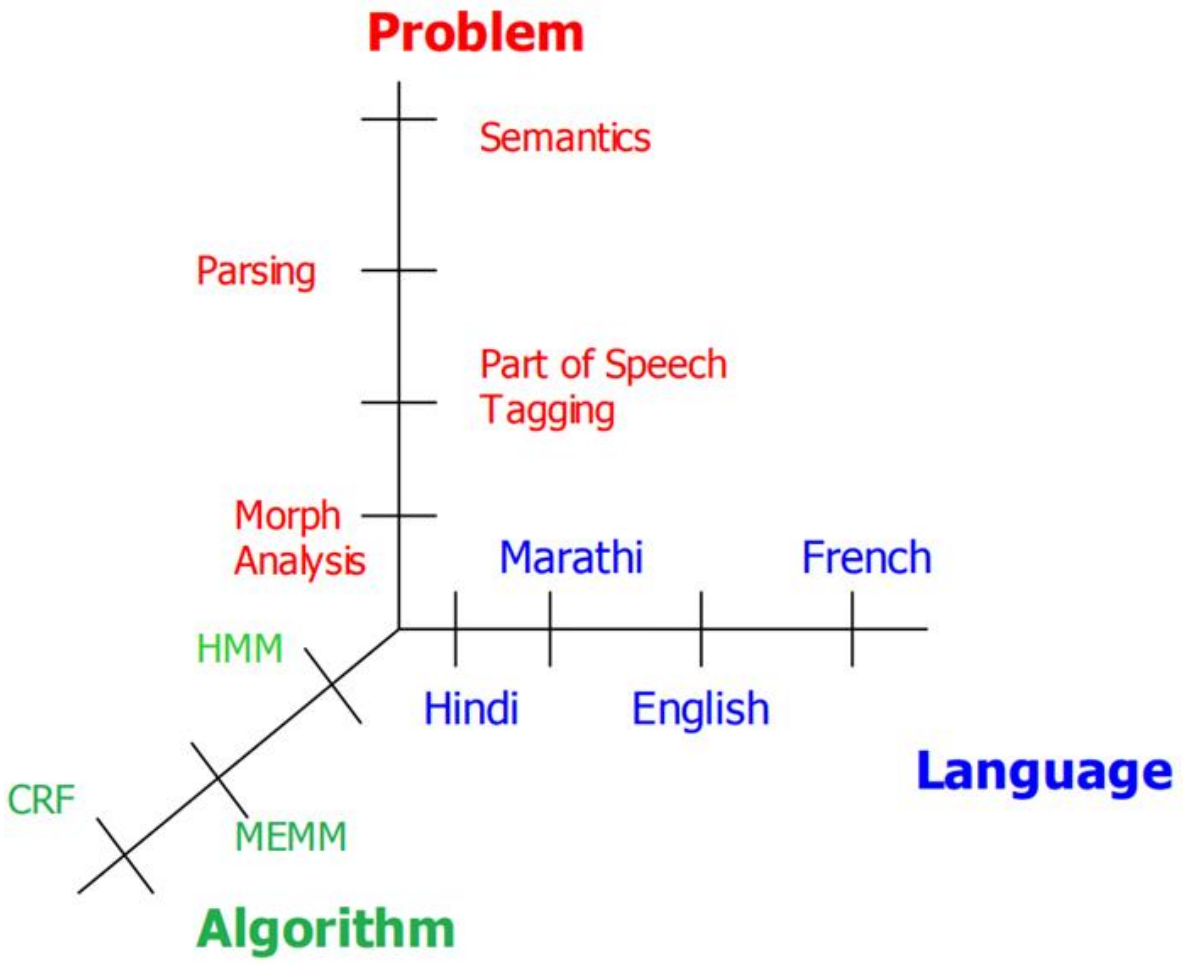
- Understanding the semantics is a non-trivial task.
- Needs to performs a series of incremental tasks to achieve this.
- NLP happens in layers.

Pragmatics & Discourse	*Study of semantics in context.*
Semantics	*Meaning of the sentence.*
Parsing	*Syntactic structure of the sentence.*
Chunking	*Grouping of meaningful phrases.*
Part of speech tagging	*Grammatical classes.*
Morphology	*Study of word structure.*



Increasing Complexity Of Processing

NLP Trinity


Problem
Semantics
Parsing
Part of Speech Tagging
Morph Analysis
Marathi
French
HMM
Hindi
English
Language
CRF
MEMM
Algorithm

Word and Token

Word: Smallest sequence of phonemes of a spoken language that can be uttered in isolation.

Word Segmentation/Tokenization: Breaking a string of characters into a sequence of words.

Token: Smallest sequence of graphemes that are delimited with some predefined characters (space, comma, full-stop, etc.);

Ram, Shyam, and Mohan are playing.	⇒	[Ram] [,] [Shyam] [,] [and] [Mohan] [are] [playing] [.]
21,53,010 COVID cases in India.	⇒	[21] [,] [53] [,] [010] [COVID] [cases] [in] [India] [.]
		[21,53,010] [COVID] [cases] [in] [India] [.] ✅
Check this out...https://www.abc.com	⇒	[Check] [this] [out] [.] [.] [.] [https] [:] [/] [/] [www] [.] [abc] [.] [com]
		[Check] [this] [out] [...] [https://www.abc.com] ✅
#GreatDayEver	⇒	[#] [Great] [Day] [Ever]

Morphology

Morphology is the study of words, how they are formed, and their relationship to other words in the same language. It analyzes the structure of words and parts of words, such as stems, root words, prefixes, and suffixes.

- Field of linguistics that studies the internal structure of words
  - How they are formed
  - Their relationship to other words in the same language.
- It defines word formation rule from the root word.
- *Morpheme* is the smallest linguistic unit that has semantic meaning
  - *Example:*
    - *"Pre", "ed", "ing", "s", "es", etc.*
      - Dogs ⇒ dog + s (plural)
      - Going ⇒ go + ing (present participle)
      - Independently ⇒ independent + ly (Adverb)
        ⇒ in + dependent + ly (Negation)
        ⇒ in + depend + ent + ly (relying)
        ⇒ in + de + pend + ent + ly

pend: (verb) to remain undecided or unsettled.

Morphology

- English, Chinese, etc. are commonly referred as *morphologically-poor* language.
- Hindi, Turkish, Hungarian, etc. are termed as *morphologically-rich* language.

English	Hindi	Linguistic property
I will go.	मैं जाऊँगा।	Different morphological forms of word 'will go' in Hindi
We will go.	हम जाएंगे।	
You will go.	तुम जाओगे।	
He will go.	वह जाएगा।	
She will go.	वह जाएगी।	

Syntax

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Increasing Complexity Of Processing

Parts-of-Speech (POS)

Grammatical class of the word.

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He	ate	an	apple	.
PRP	VBD	DT	NN	.

Tags

PRP: Personal Pronoun
VBD: Verb, Past
DT: Determiner
NN: Noun, Singular, Mass
TO: *to*
IN: Preposition

- 45 tags in Penn Treebank tagset
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He	went	to	the	***park***	in	a	car	.
PRP	VBD	TO	DT	***NN***	IN	DT	NN	.

They	went	to	***park***	the	car	in	the	shed	.
PRP	VBD	TO	***VB***	DT	NN	IN	DT	NN	.

Chunking

Identification of non-recursive phrases (noun, verb, etc.)

- He went to the Indian city Mumbai. ⇒
  [NP He] [VP went] [PP to] [NP the Indian city Mumbai]

- Mumbai green lights women icons on traffic signals earns global praise. ⇒
  [NP Mumbai green lights women icons] [PP on] [NP traffic signals] [VP earns] [NP global praise]

Syntax Processing

Validate the grammatical structure of the sentence.

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Let, vocabulary = [the, mango, he, eats, …]

He eats a mango. ⇒ ✅

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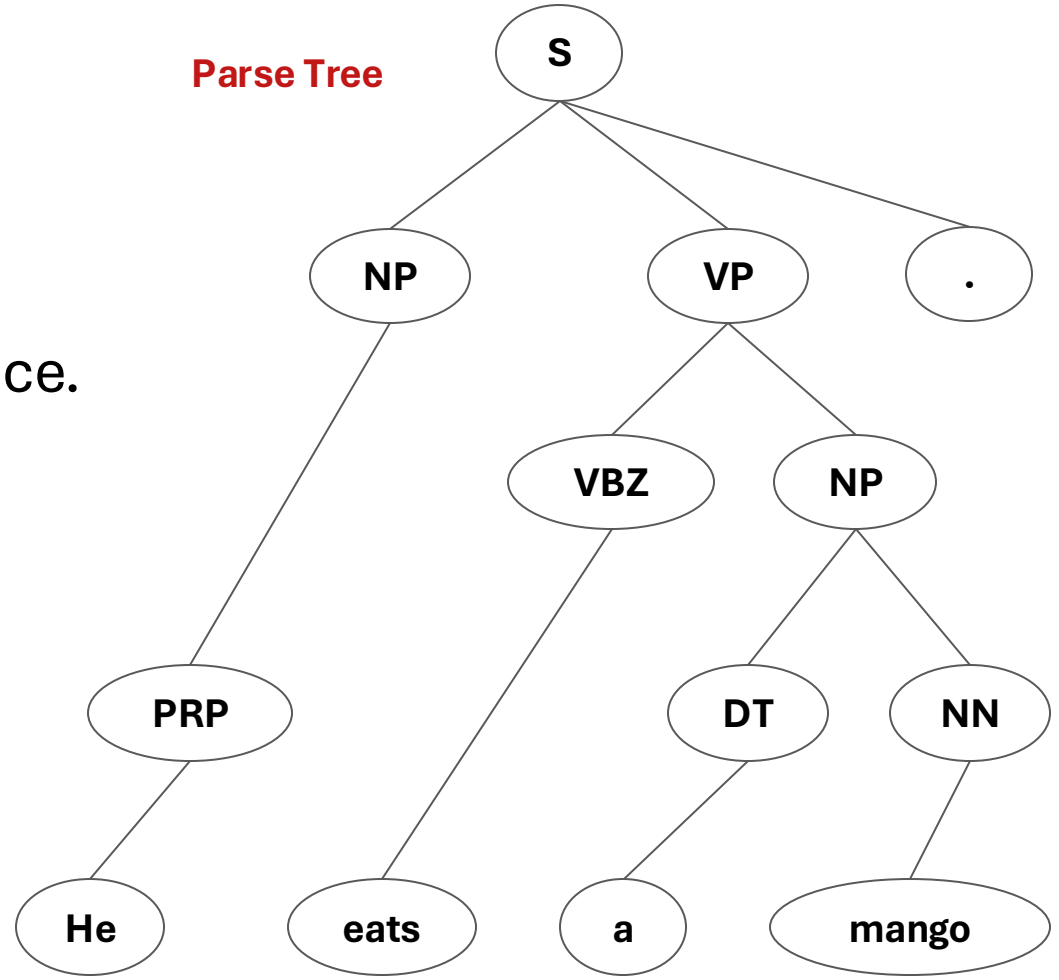

Syntax Processing

Every language has a grammar G = <V, T, P, S>.

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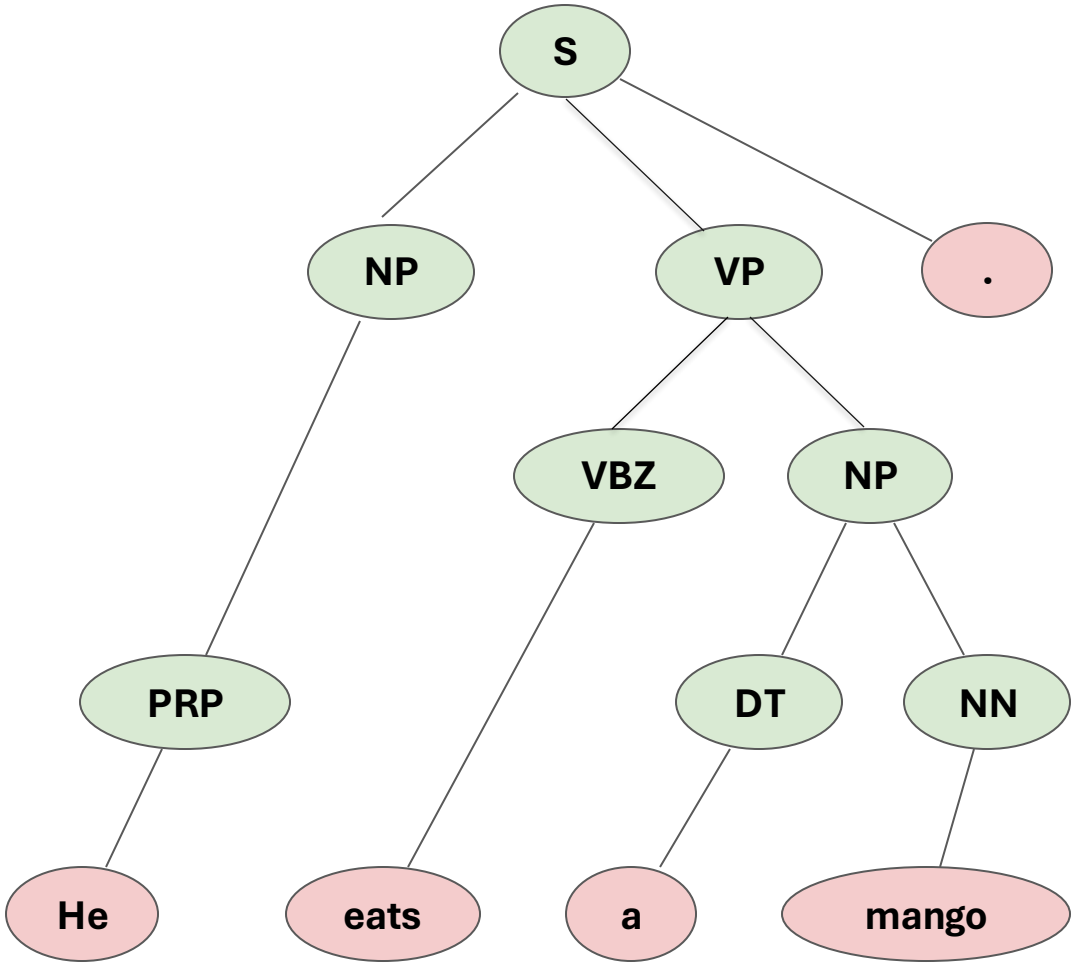
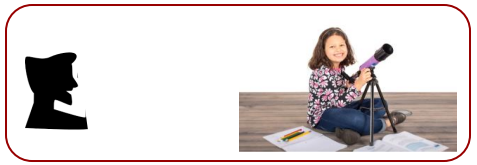
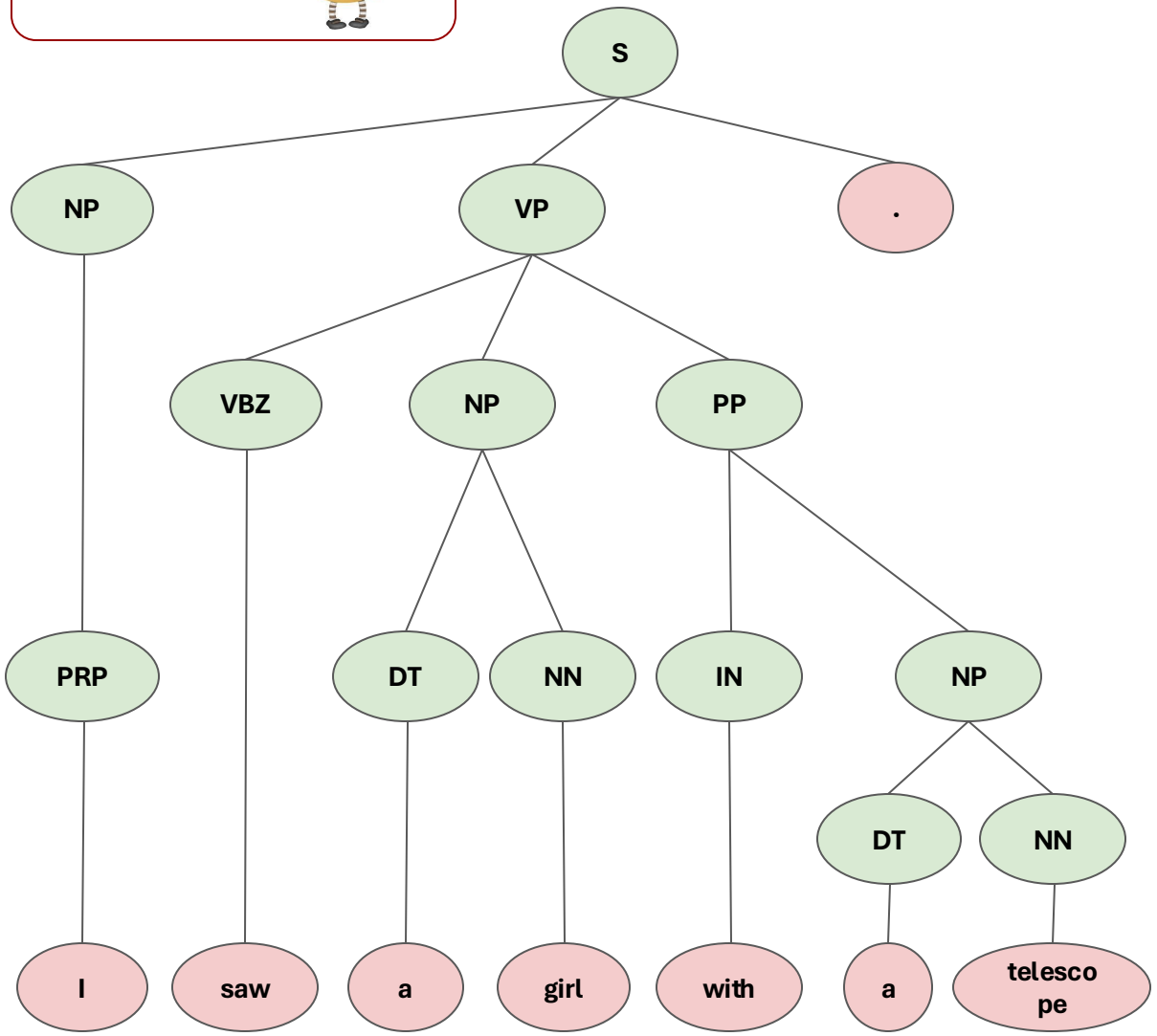
Productions (P) or rules:

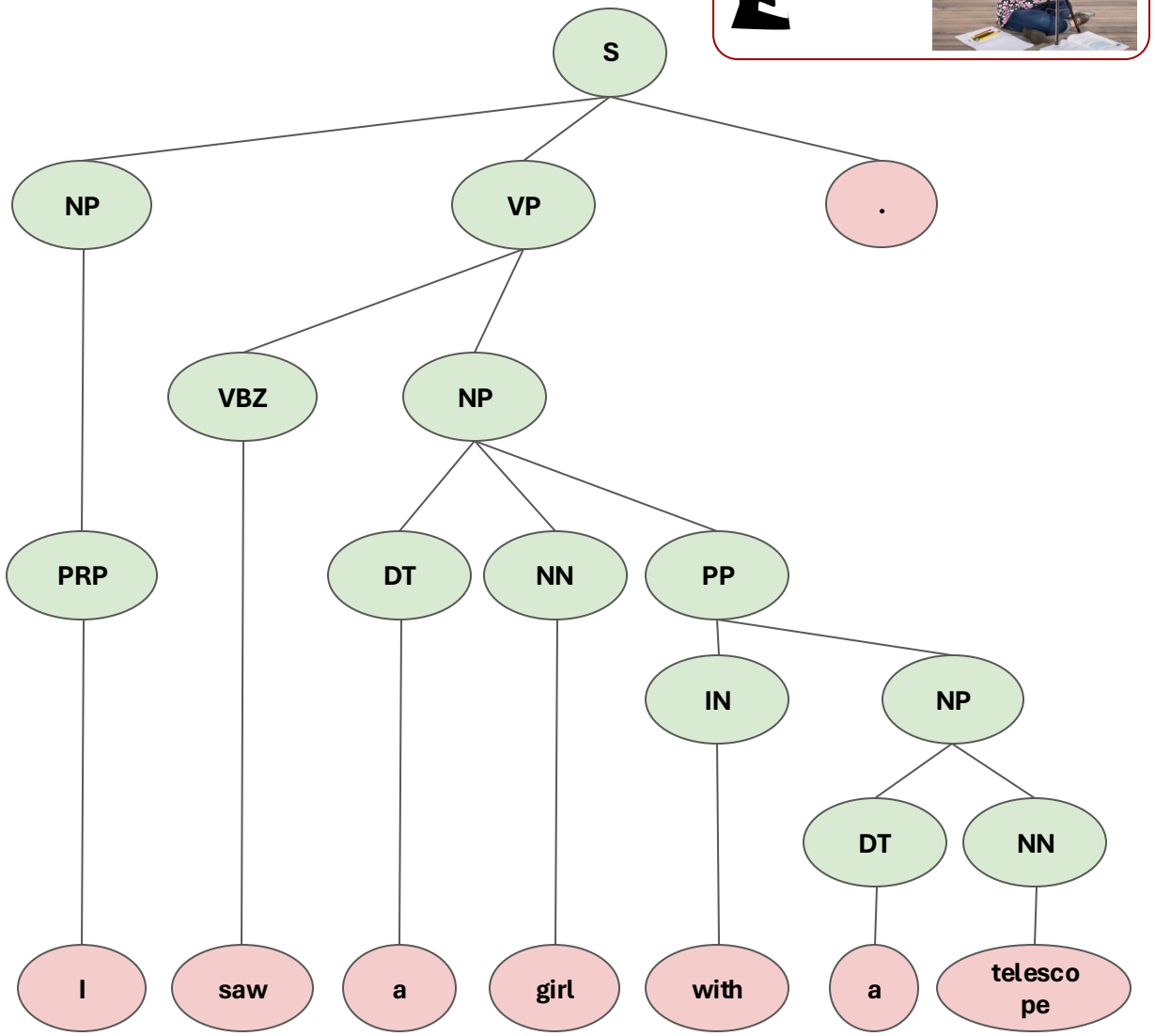
S	→	NP VP .
NP	→	PRP | NN | DT NP
VP	→	VBZ NP
PRP	→	He
VBZ	→	eats
DT	→	a
NN	→	mango



Syntactic Ambiguity







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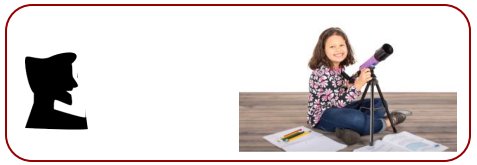

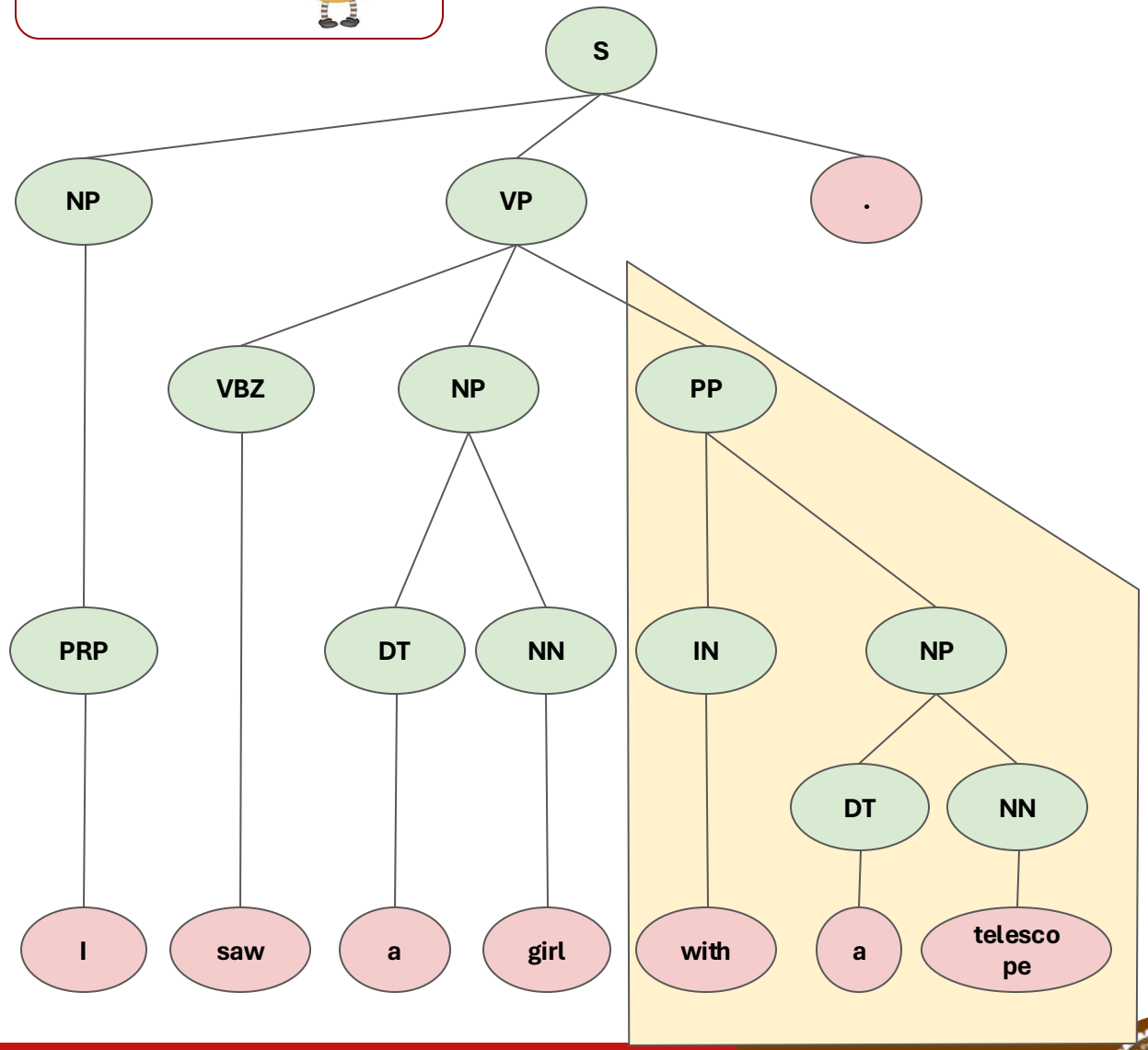

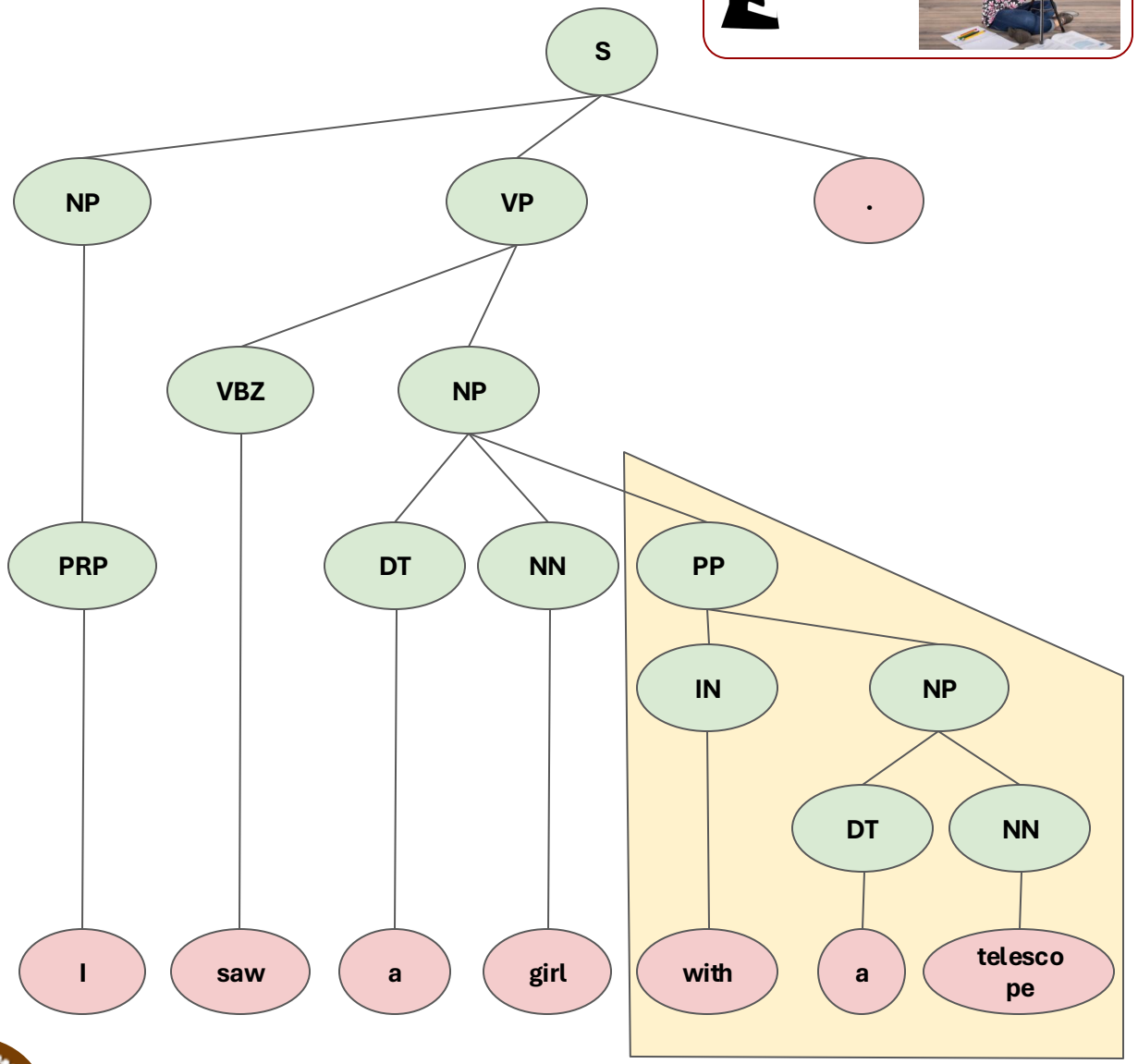

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- **Decompositional** – What the "components" of meaning "in" a word are
- **Ontological** – How the meaning of the word relates to the meanings of other words
- **Distributional** – What contexts the word is found in, relative to other words

Decompositional Semantics

Decompositional Semantics Divides the Meaning of Words into Components

What are its strengths and weaknesses?

boy [+human −female −adult]	girl [+human +female −adult]
man [+human −female +adult]	woman [+human +female +adult]

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The Basic (Ontological) Semantic Relations

- Synonymy—equivalence
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- Antonymy—opposition
  - <small, large>
- Hyponymy—subset; is-a relation
  - <dog, mammal>
- Hypernymy—superset
  - <mammal, dog>
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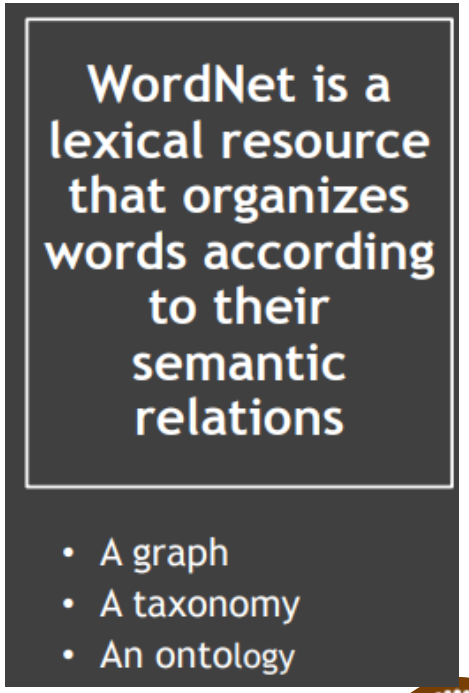

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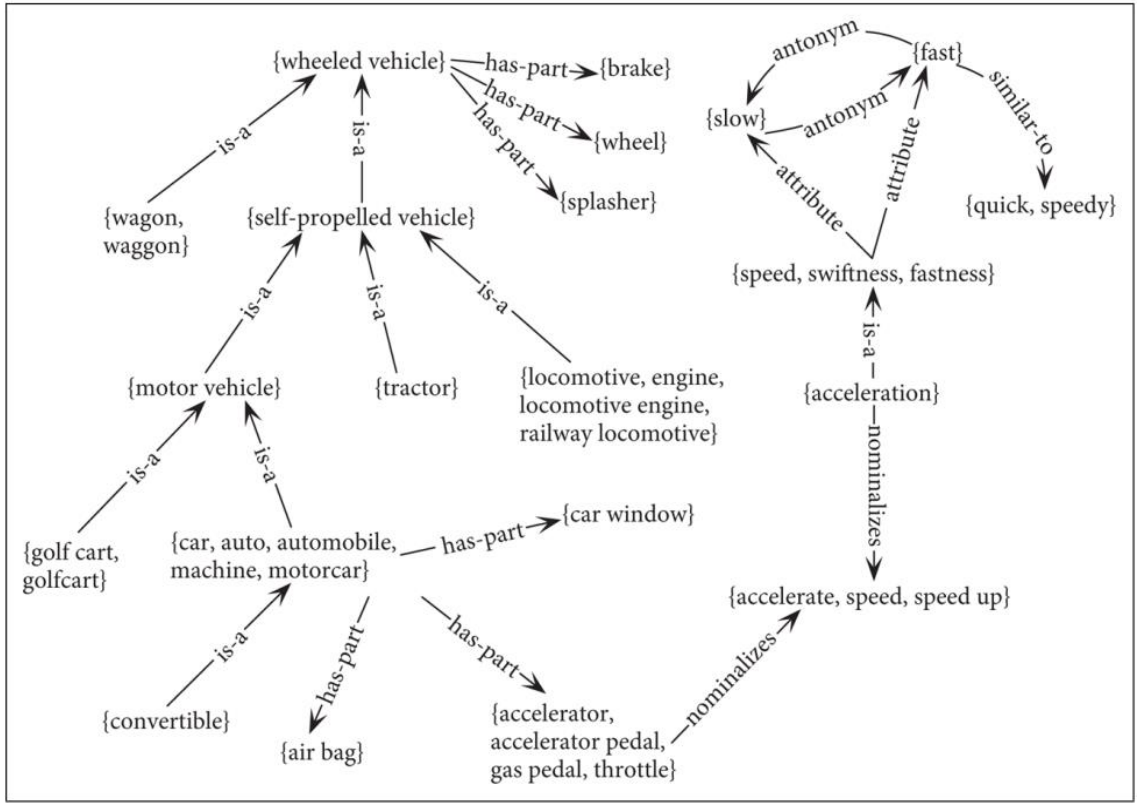
WordNet is a lexical resource that organizes words according to their semantic relations

- A graph
- A taxonomy
- An ontology



Distributional Semantics

The meanings of words can be derived from their distributional properties in large corpora of text. It relies on the context in which words appear.

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Example: The meaning of the word "cat" can be inferred from the contexts it appears in, such as sentences where it co-occurs with words like "pet," "animal," "meow," and "feline."

The co-occurrence matrix

	leash	walk	run	owner	pet	bark
dog	3	5	2	5	3	2
cat	0	3	3	2	3	0
lion	0	3	2	0	1	0
light	0	0	0	0	0	0
bark	1	0	0	2	1	0
car	0	0	1	3	0	0

Pragmatics

Pragmatics considers [Thomas, 1995]:

- the negotiation of meaning between speaker and listener.
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- Context/World knowledge: An employee coming late to the office.
  - Utterance: Do you know what time is it?
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- Intention:
  - Utterance: Can you pass the water bottle?
  - Literal meaning: Are you able to pass the water bottle? (Response: Yes, I can.)
  - Pragmatic meaning: Pass me the water bottle. (Response: Handover the water bottle)

Discourse

Processing of sequence of sentences.

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Discourse processing helps answering these questions:

- What is open?
- Bunk what?
- Why the father will be angry?

Tasks we want to solve in NLP

Semantic Role Labelling (SRL)

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Identify the semantic role of each argument (noun phrase) w.r.t. the predicate (main verb) of the sentence.

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John	**drove**	Mary	from	Delhi	to	Pune	in	his	car
Agent		Patient		source		destination			instrument

Ram	**hit**	Shyam	with	a	hockey	stick	yesterday
Agent		Patient			instrument		time

Textual Entailment

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Determine whether one natural language sentence entails (implies) another under an ordinary interpretation.

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(*Ram hit Shyam with a hockey stick yesterday*. → *Shyam got hurt*) ⇒ Positive TE

(*Ram hit Shyam with a hockey stick yesterday*. → *Shyam did not get hurt*) ⇒ Negative TE

(*Ram hit Shyam with a hockey stick yesterday*. → *Shyam got his first goal*) ⇒ Non TE

Co-reference Resolution

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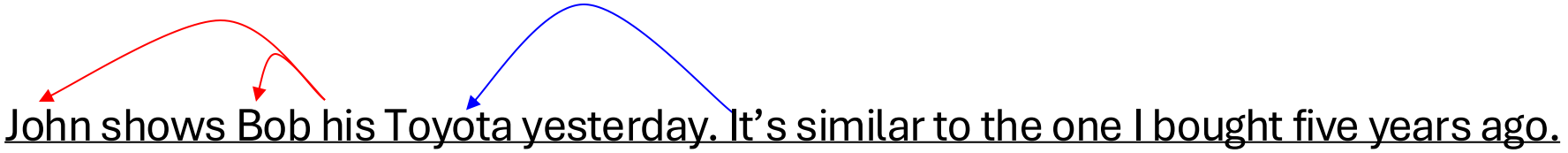

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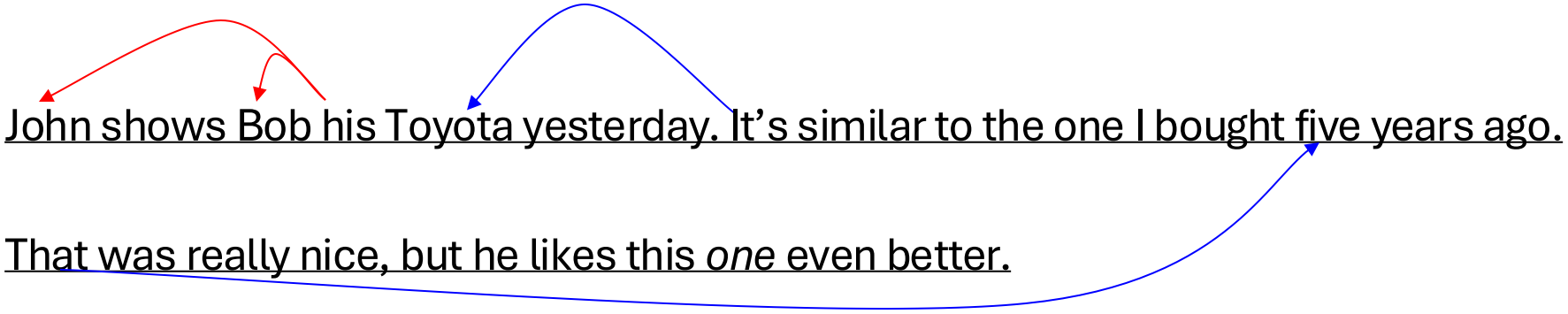

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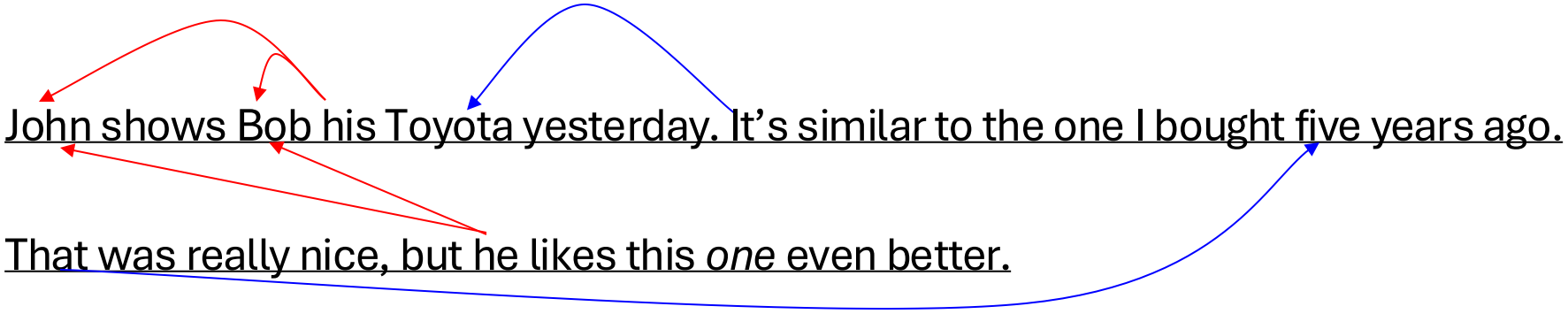

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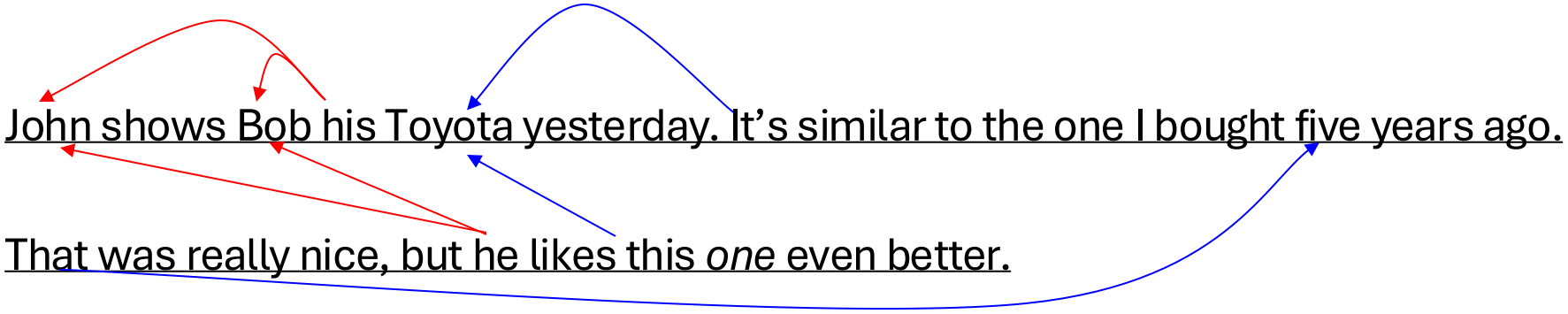

Information Extraction

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- Named Entity Recognition (NER):
  - Identify names (Proper nouns)
    - [India]$_{\text{Location}}$ born [Sundar Pichai]$_{\text{Person}}$ is the CEO of [Google]$_{\text{Organization}}$ and its parent company [Alphabet]$_{\text{Organization}}$

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- Relation Extraction:
  - Relation among entities
    - CEO(Sundar Pichai, Google), CEO(Sundar Pichai, Alphabet), Born-at(Sundar Pichai, India), ParentOrg(Alphabet, Google)

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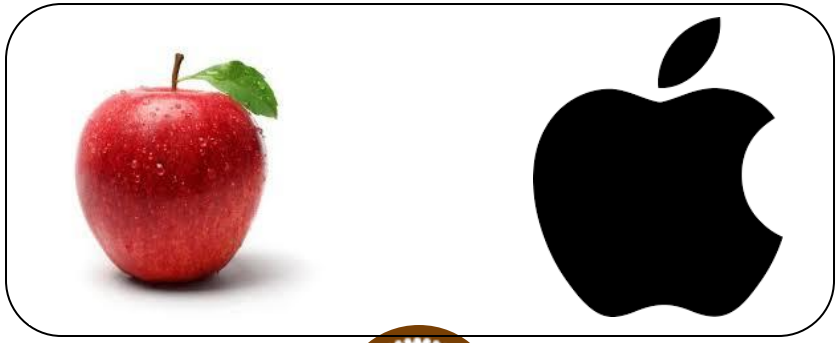

Sentiment Analysis

Extract polarity orientation of the subjectivity.

- Really superb pillow. Love to sleep on it.. very comfortable… ⇒ Positive
- It's a mass Chinese product. Too expensive. Thin and useless ⇒ Negative
- My neighbours are home and it’s good to wake up at 3am in the morning. ⇒ Negative?
- Campus has deadly snakes. ⇒ Negative
- Shane Warne is a deadly spinner. ⇒ Positive?
- The food was cheap. ⇒ Positive?
- Not to mention the cheap service I got at the restaurant. ⇒ Negative
- Movie was 4 hours long. ⇒ Neutral?

Machine Translation

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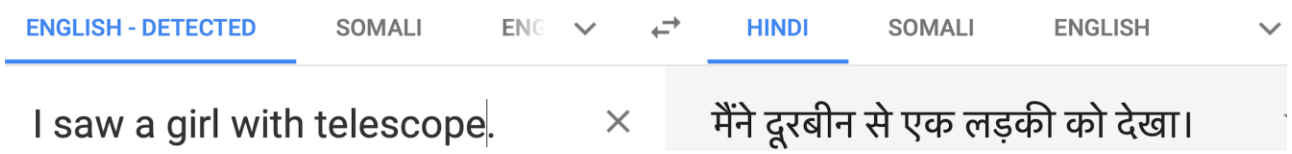

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Summary

Barack Obama is the Democratic presidential candidate.

Question Answering

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Answer natural language questions based on information presented in the repository.

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Factoid Questions

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Descriptive Questions

- Question: What is Greenhouse effect?
- Answer: The analogy used to describe the ability of gases in the atmosphere to absorb heat from the earth's surface.

Dialog System and Chatbot

Dialog System and Chatbot

C_1:	. . . I need to travel in May.
A_1:	And, what day in May did you want to travel?
C_2:	OK uh I need to be there for a meeting that's from the 12th to the 15th.
A_2:	And you're flying into what city?
C_3:	Seattle.
A_3:	And what time would you like to leave Pittsburgh?
C_4:	Uh hmm I don't think there's many options for non-stop.
A_4:	Right. There's three non-stops today.
C_5:	What are they?
A_5:	The first one departs PGH at 10:00am arrives Seattle at 12:05 their time. The second flight departs PGH at 5:55pm, arrives Seattle at 8pm. And the last flight departs PGH at 8:15pm arrives Seattle at 10:28pm.
C_6:	OK I'll take the 5ish flight on the night before on the 11th.
A_6:	On the 11th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115.
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User:	Do you like Doctor Who?
Cleverbot:	Yes, so funny.
User:	What's your favorite show?
Cleverbot:	I don't have one.
User:	What's your name?
Cleverbot:	Jason I already told you.
User:	No your real name.
Cleverbot:	Stephanie IS my real name.
User:	I thought it was Jason?
Cleverbot:	How did you come to that conclusion.
User:	Because you said so.
Cleverbot:	I have to do my homework.

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We will explore
how LLMs solve these tasks!