

Introduction to Natural Language Processing

Tanmoy Chakraborty
Associate Professor, IIT Delhi
<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)

INDIA'S LARGEST ENGLISH NEWSPAPER



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Gang guns down Trinamool man at Bengal dhaba

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City woman, BSES staffer electrocuted

A woman, who went to a hospital to visit her son Saturday, died of electrocution in a waterlogged street in Bhajanpura. In another incident, a BSES staffer check-

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

Chidanand Rajghatta | TNN

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Bullets fired by a lone gunman positioned on a nearby rooftop nicked Trump's right ear and bloodied it — he was later said to be "fine and in great spirits" — but a 50-year-old man, besides the assailant who was immediately shot dead by the Secret Service, was killed in the incident. Two other rallygoers were critically injured.

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Getty Images/USA



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► The much-vaunted Secret Service, often portrayed in heroic

32-year-old patient shot dead 'by teen' in GTB hosp ward

Killing A Case Of Mistaken Identity: Kin
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New Delhi: A 32-year-old patient was shot dead, allegedly by an 18-year-old youth, inside a ward of GTB Hospital in Shahdara Sunday. His family has claimed he was killed in a case of mistaken identity and that the intended target was a history-sheeter, who was admitted to the same ward. 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

► Patrol team bombarded by militants, strategically positioned at 5-6 locations

► CRPF's Ajay Jha at the wheel, first to be struck

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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>

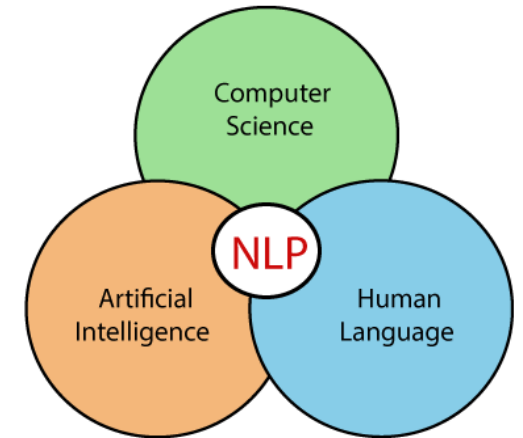
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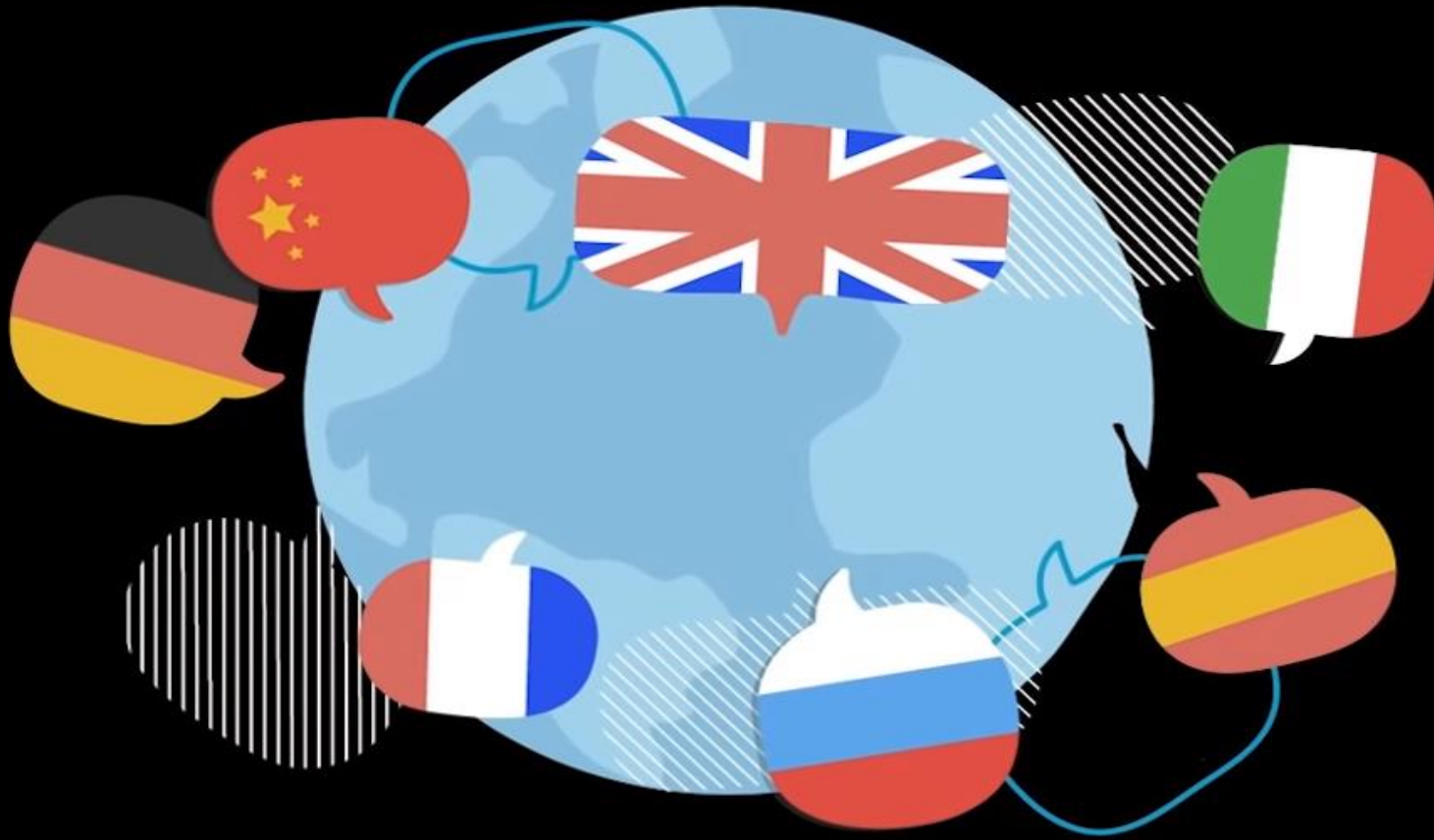
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A field of computer science, artificial intelligence and computational linguistics concerned with the interactions between computers and human (natural) languages.



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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.

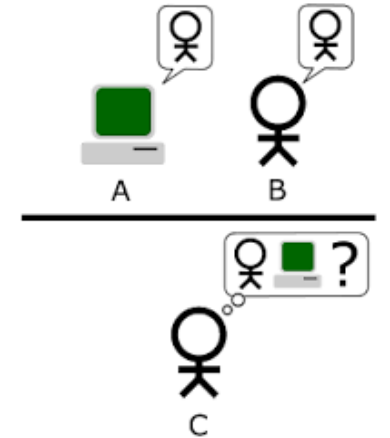
<https://indianexpress.com/article/india/more-than-19500-mother-tongues-spoken-in-india-census-5241056/>

Natural Language Processing



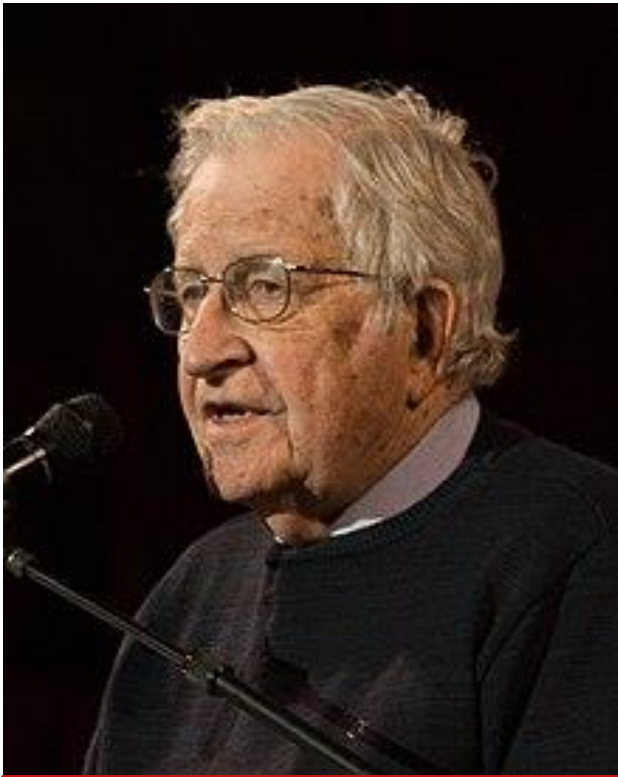
Setup

- 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.



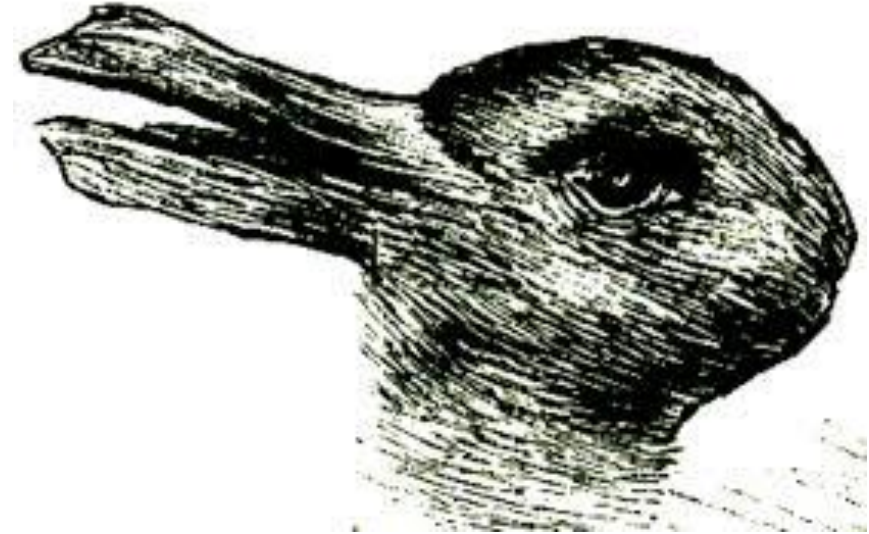
Ambiguity

Is ambiguity present in language only?

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No, ambiguity is prevalent in every dimension!



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Duck or Rabbit?

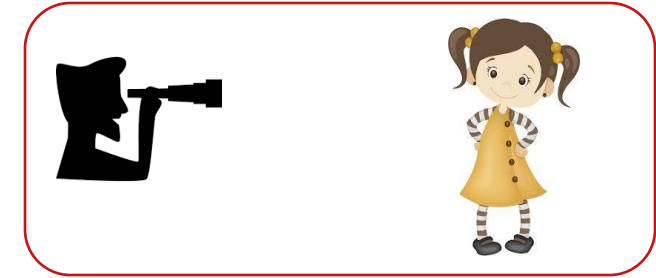
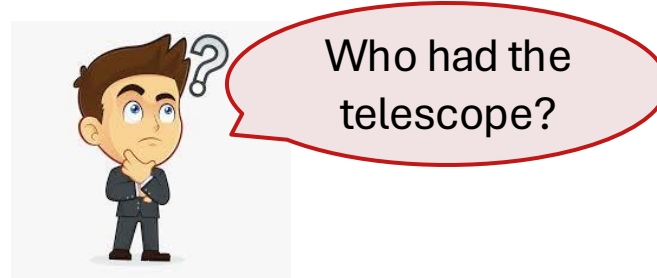


Ambiguity in Language

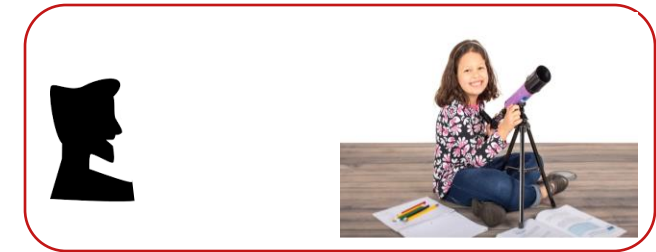
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Ambiguity in Language

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OR



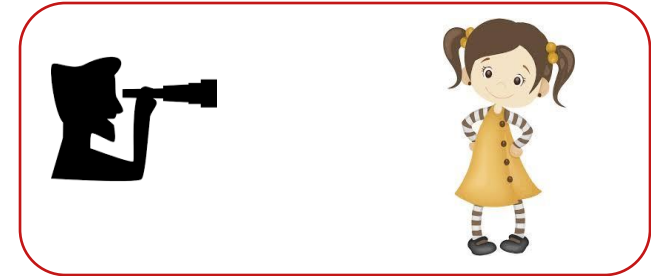
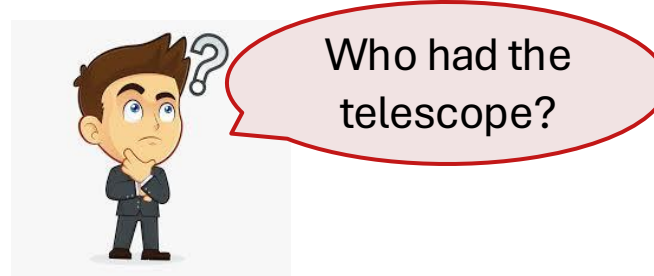
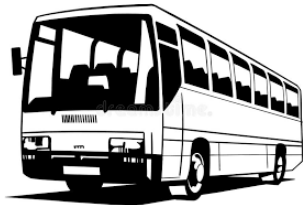
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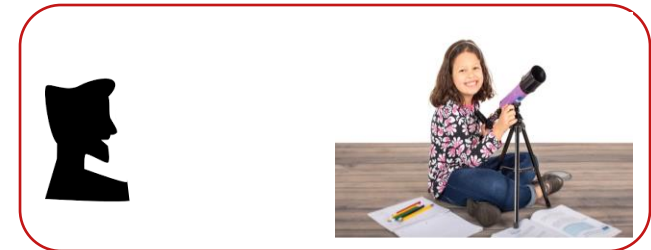
- I saw a girl with a bicycle.



- I saw a bus with a telescope.



OR



No
ambiguity!

Ambiguity in Language

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- Mary had a little lamb.

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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



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

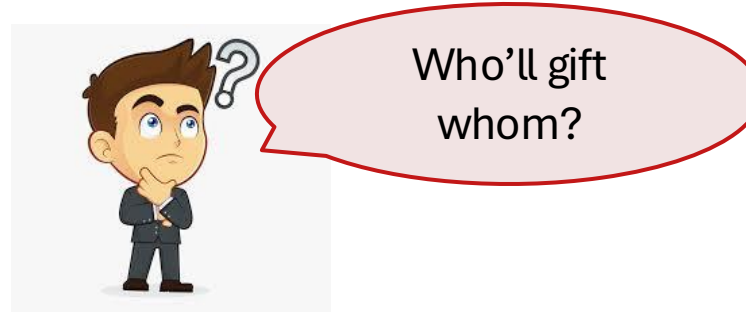


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- Mujhe aapko mithai khilani padegei.

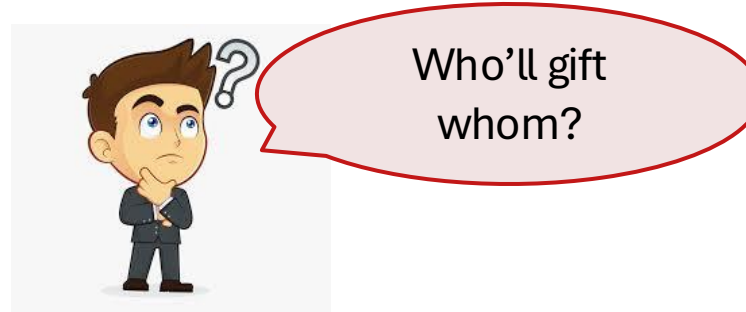
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I have to gift you some sweets.

OR

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Similar surface
structures but
different
interpretations!

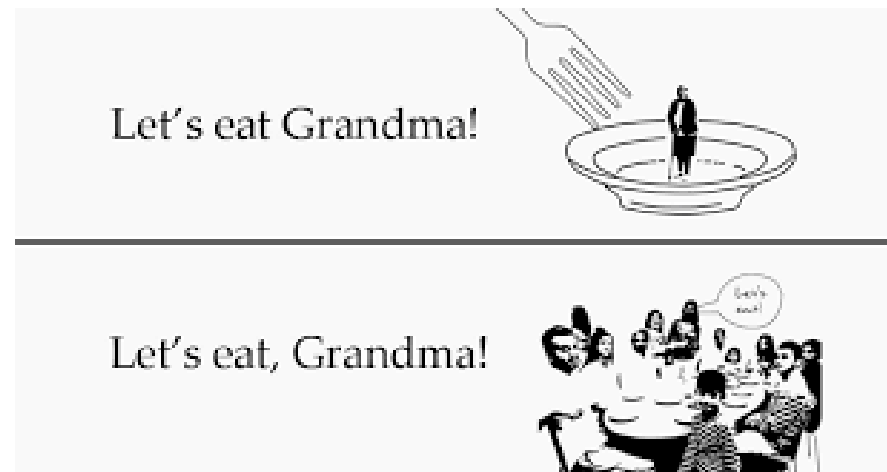


Ambiguity and Punctuations!



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A woman without her man is nothing.



Ambiguity and Punctuations!



A woman without her man is nothing.

A woman, without her man, is nothing.

A woman: without her, man is nothing.

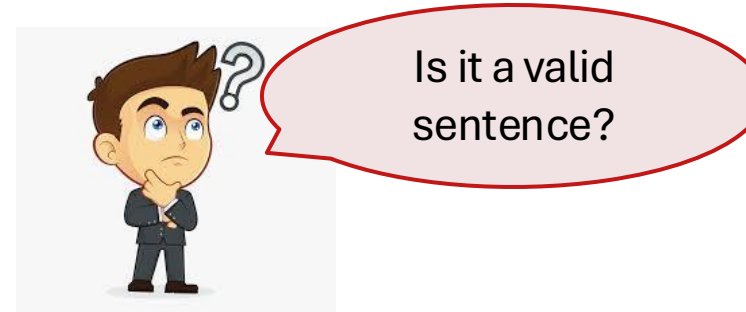
Punctuation is powerful.

What About This?

Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo

[Dmitri Borgmann's *Beyond Language: Adventures in Word and Thought*](#). 1967.

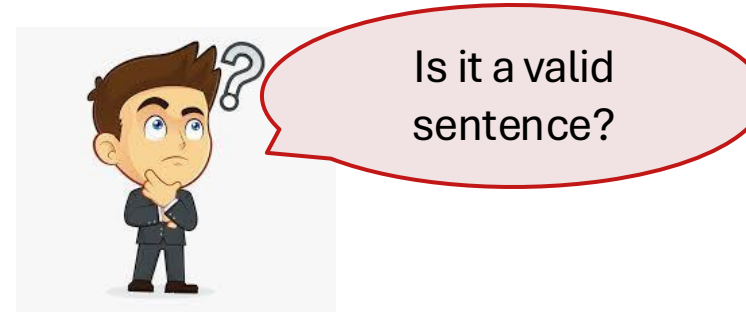
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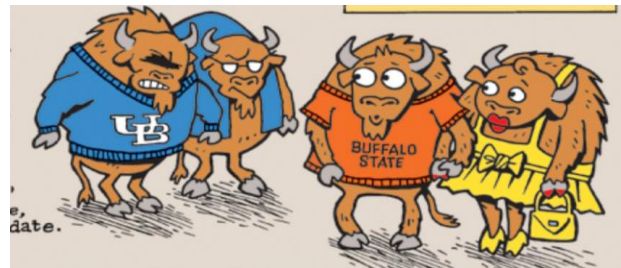
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Is it a valid sentence?

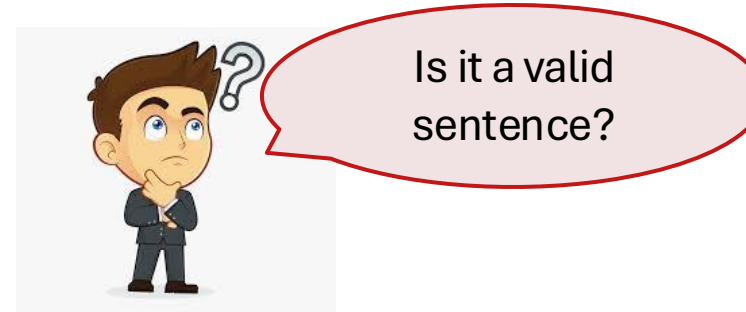
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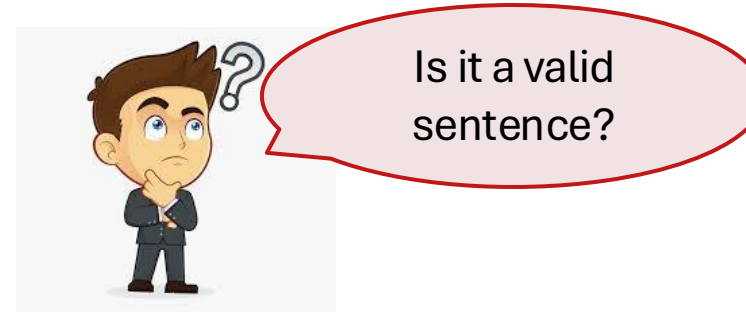
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Why Else is Natural Language Understanding Difficult?

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

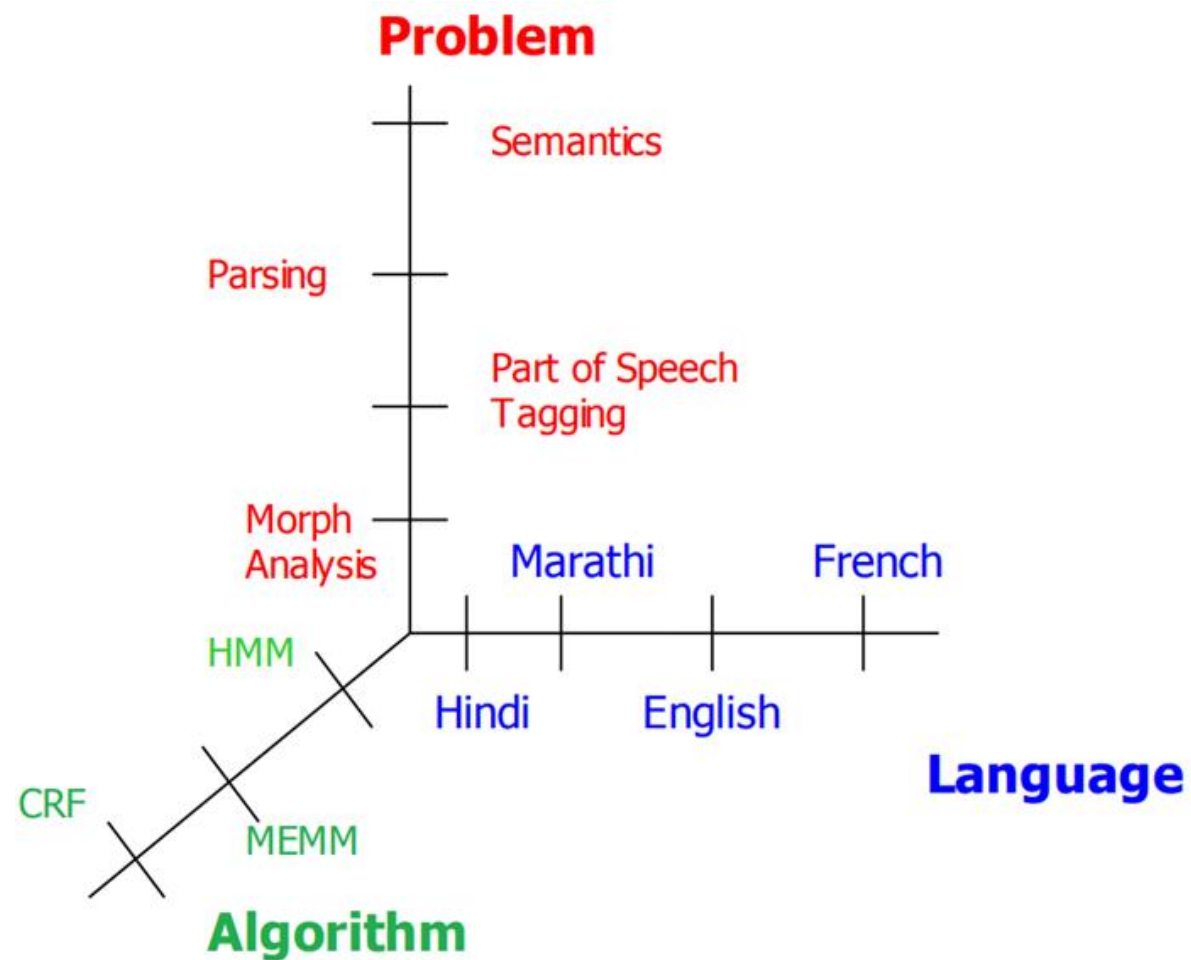
- Understanding the semantics is a non-trivial task.
- Needs to performs a series of incremental tasks to achieve this.
- NLP happens in layers.

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



Increasing
Complexity Of
Processing

NLP Trinity



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

- 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 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.

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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Parts-of-Speech (POS)

Grammatical class of the word.

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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
- 146 tags in C7

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PoS disambiguation:

- A word can belong to different grammatical classes.

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]

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Validate the grammatical structure of the sentence.

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

He eats a mango. ⇒ 

He mango eats a. ⇒ 


- The sequence of words must follow the grammatical structure of the language to form a valid sentence.
 - Construct a parse tree.

Syntax Processing

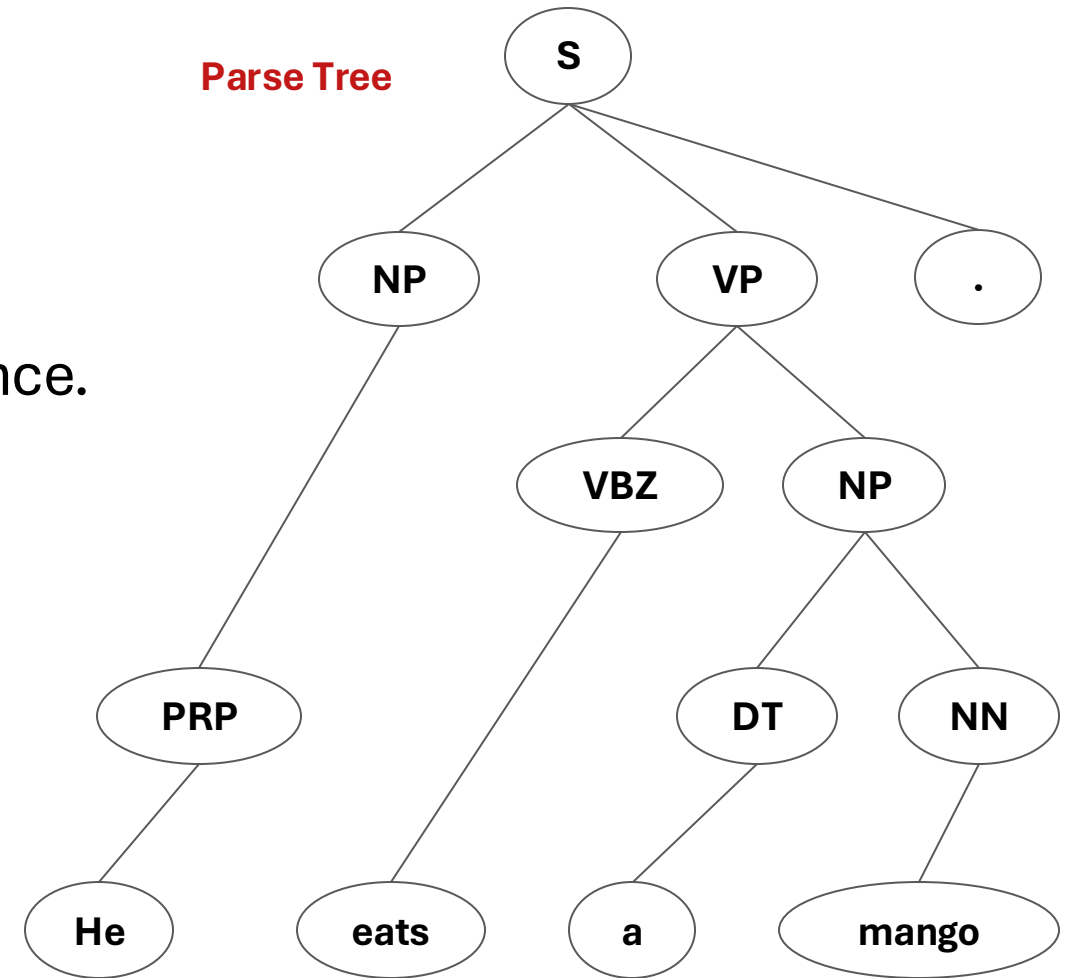
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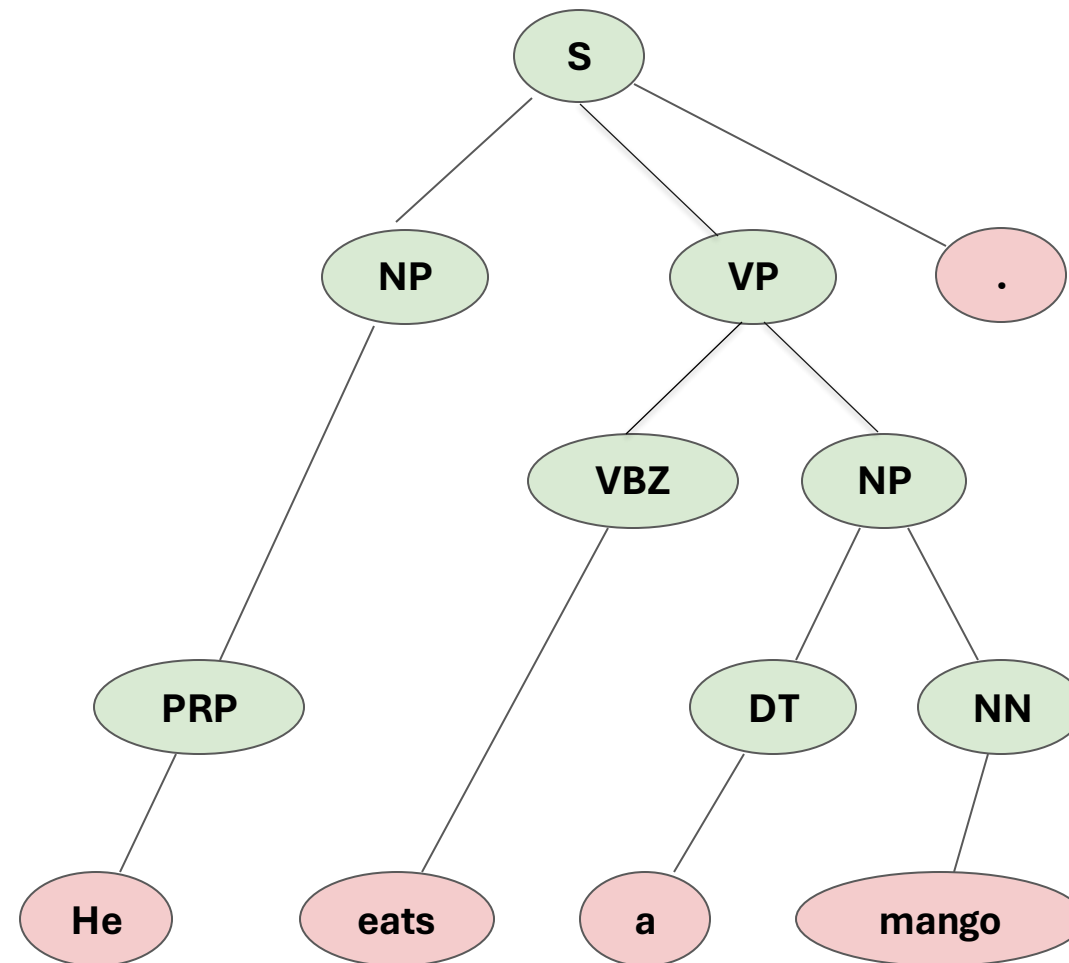
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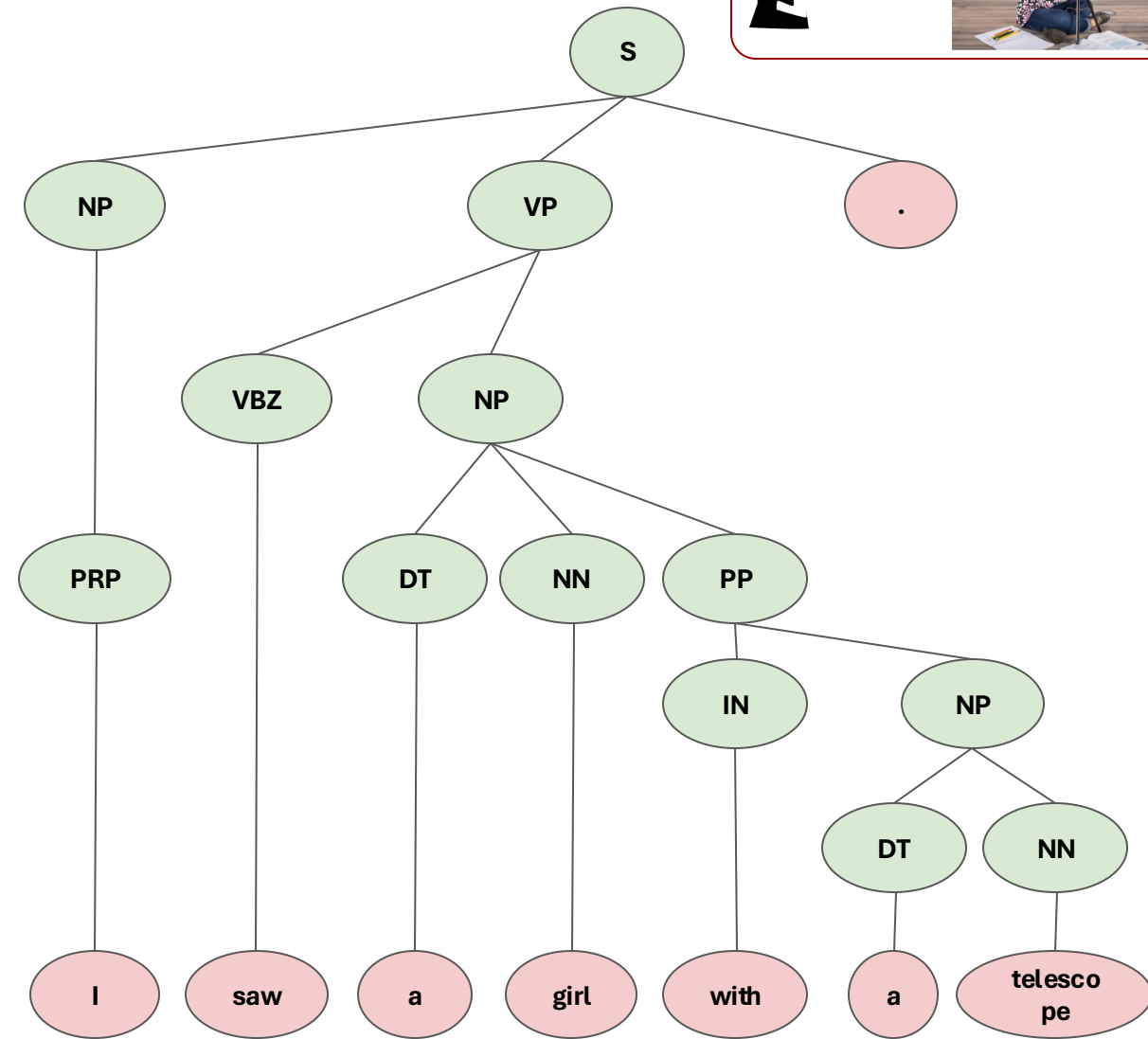
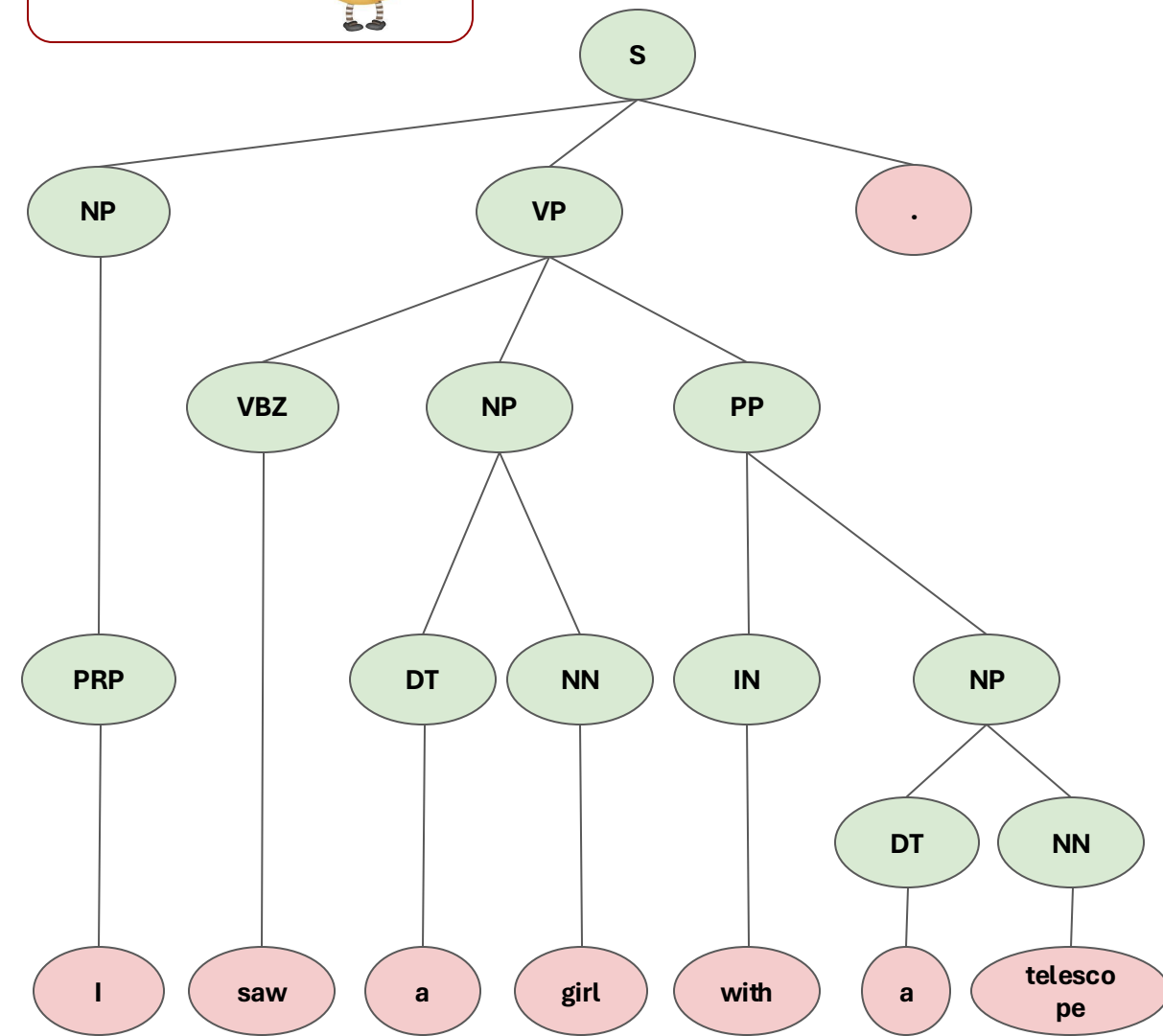
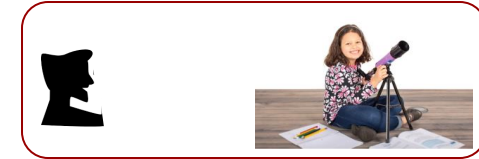
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Productions (P) or rules:

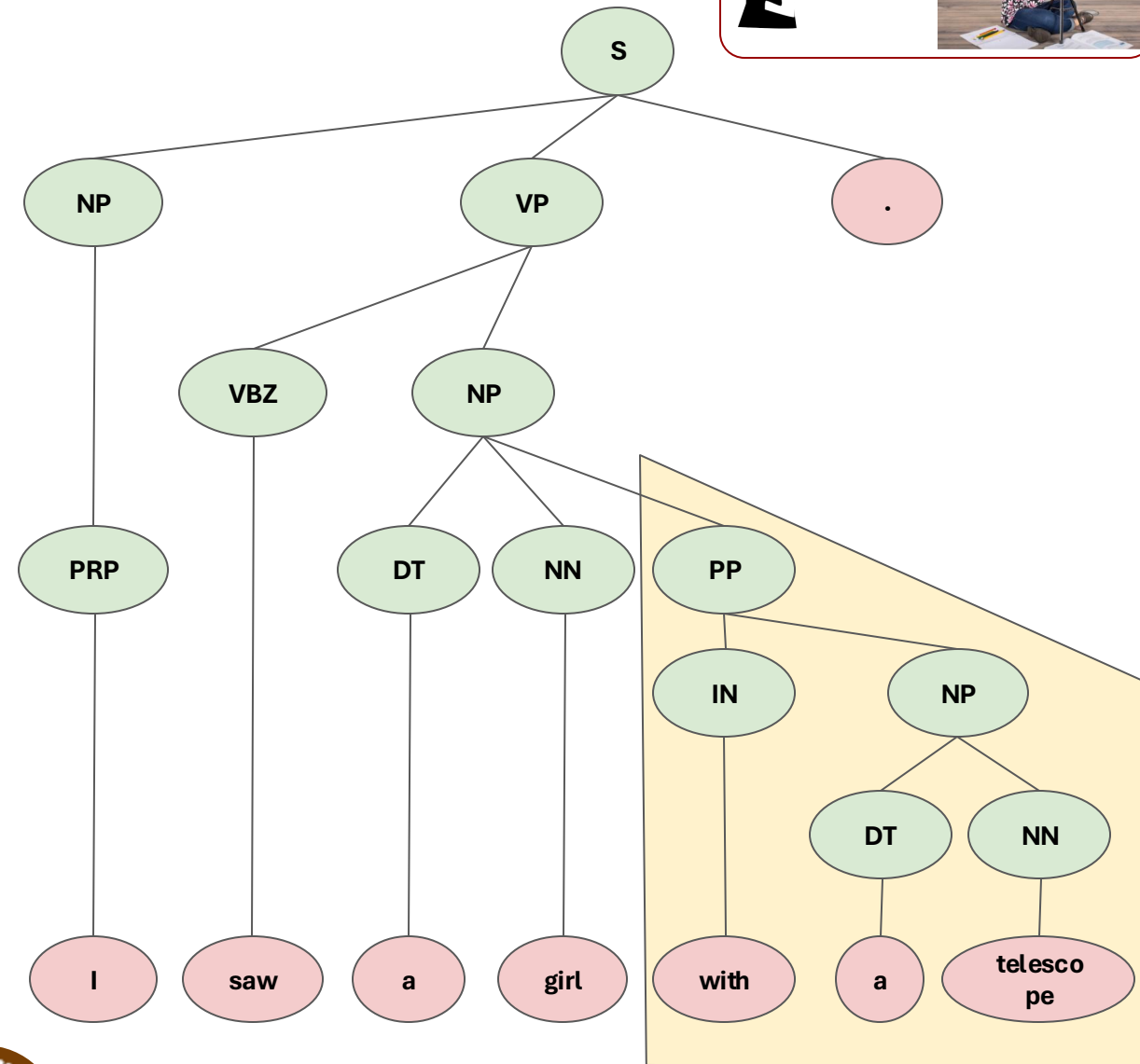
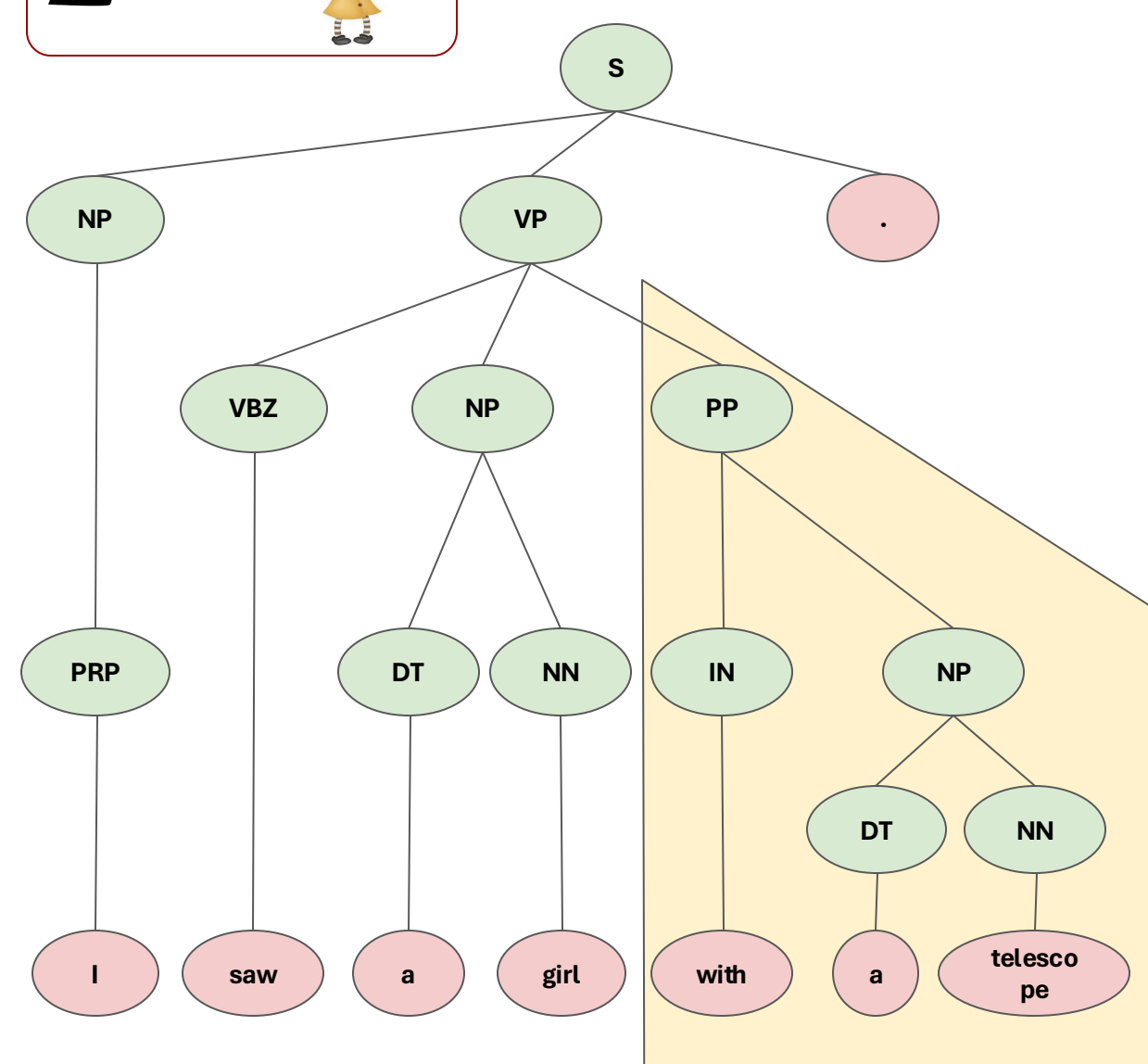
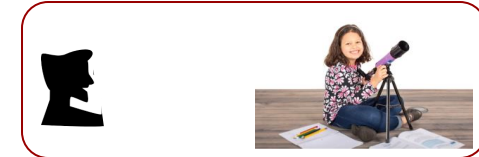
S	→	NP VP .
NP	→	PRP NN DT NP
VP	→	VBZ NP
PRP	→	He
VBZ	→	eats
DT	→	a
NN	→	mango



Syntactic Ambiguity



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- **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

$$\begin{bmatrix} +\text{human} \\ -\text{female} \\ -\text{adult} \end{bmatrix}$$

girl

$$\begin{bmatrix} +\text{human} \\ +\text{female} \\ -\text{adult} \end{bmatrix}$$

man

$$\begin{bmatrix} +\text{human} \\ -\text{female} \\ +\text{adult} \end{bmatrix}$$

woman

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- **Synonymy**—equivalence
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- **Hyponymy**—subset; is-a relation
 - <dog, mammal>
- **Hypernymy**—superset
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- A graph
- A taxonomy
- An ontology

Ontological Semantics

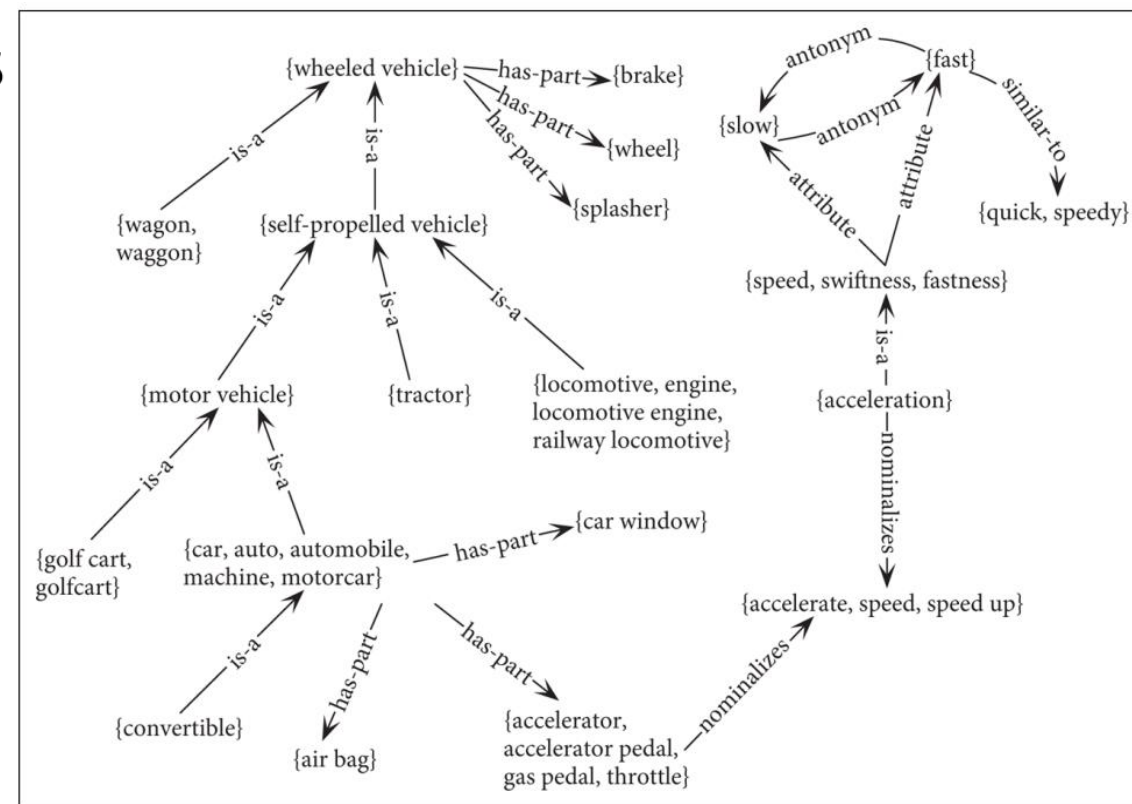
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Example: The meaning of the word "cat" can be inferred from the contexts it appears in, such as sentences where it co-occurs with words like "pet," "animal," "meow," and "feline."

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

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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**)

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Processing of sequence of sentences.

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Mother said to John: Go to school. It is open today. Are you planning to bunk? Father will be very angry.

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

(*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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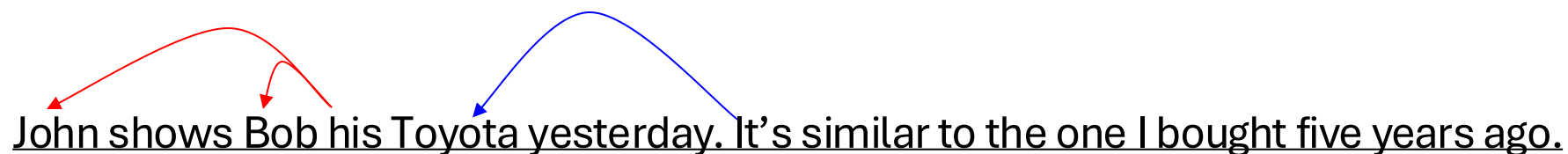
A diagram illustrating co-reference resolution. Two red curved arrows originate from the word "one" in the second sentence and point back to "John" and "Bob" in the first sentence, indicating that "one" refers to both of them.

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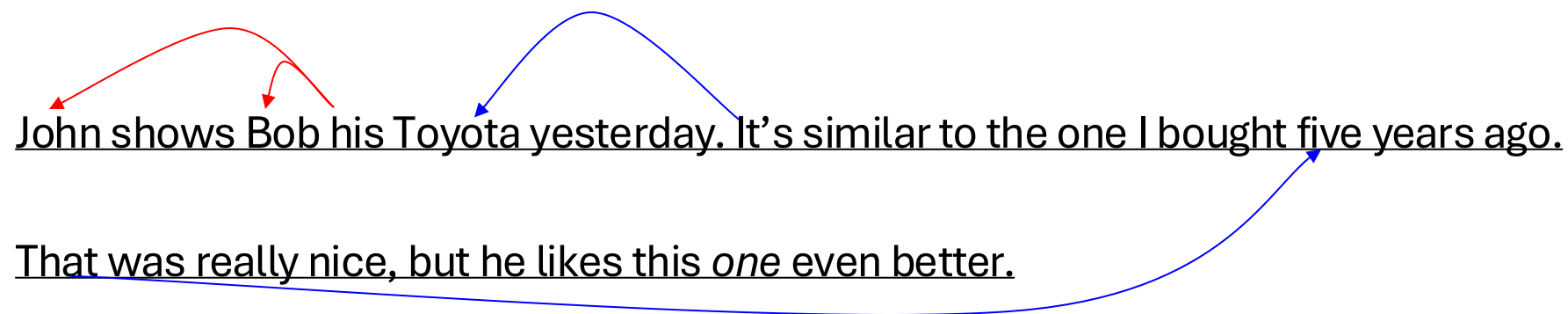
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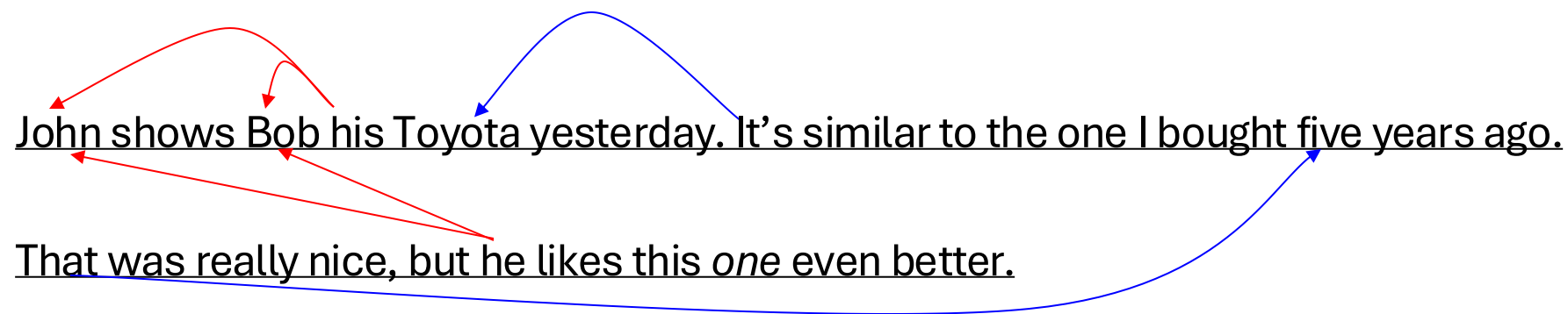
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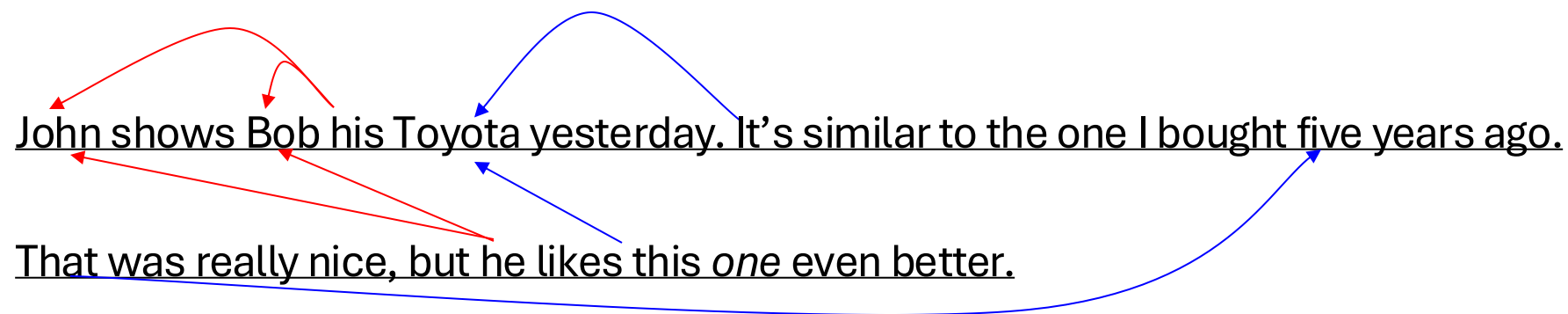
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- Relation Extraction:
 - Relation among entities
 - CEO(Sundar Pichai, Google), CEO(Sundar Pichai, Alphabet), Born-at(Sundar Pichai, India), ParentOrg(Alphabet, Google)

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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?

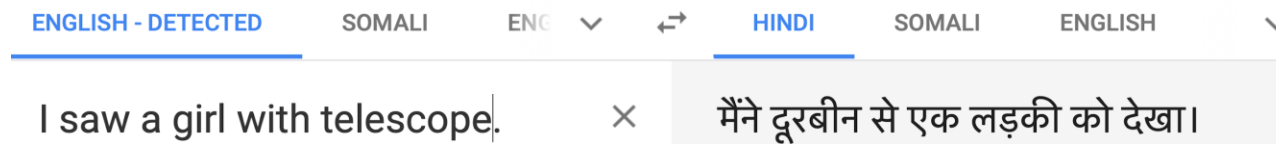
Machine Translation

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Given a sentence in the source language L_1 , convert it to the target language L_2 , such that the semantic (adequacy and fluency) is preserved.

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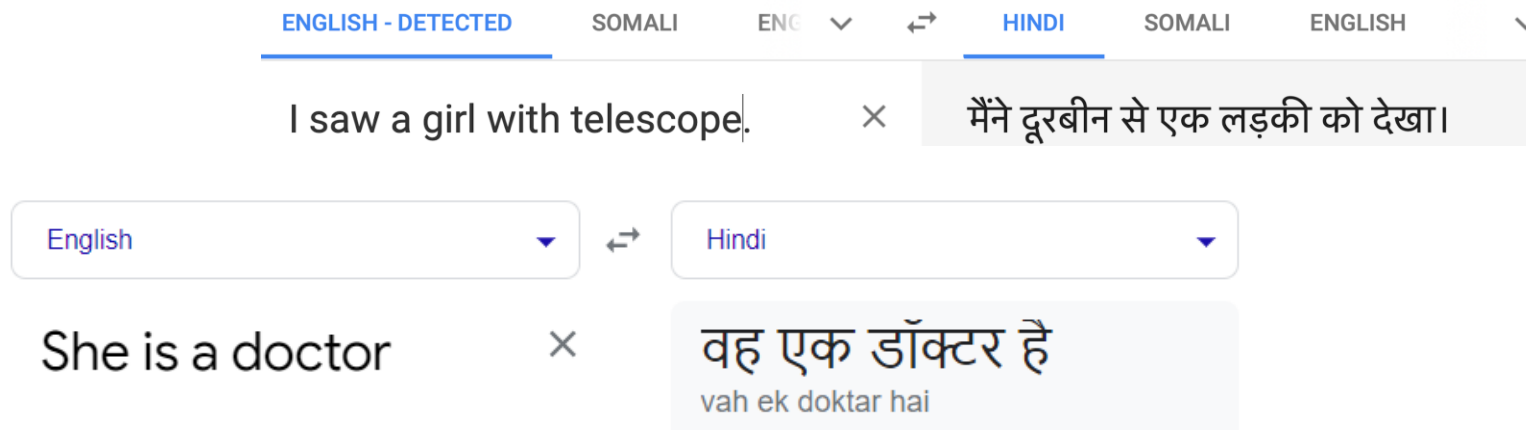
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The screenshot displays the Google Translate web interface. At the top, there are tabs for 'ENGLISH - DETECTED', 'SOMALI', 'ENG', 'HINDI', 'SOMALI', and 'ENGLISH'. Below these, the first example shows the English sentence 'I saw a girl with telescope.' being translated into Hindi as 'मैंने दूरबीन से एक लड़की को देखा।'. The second example shows 'She is a doctor' translated into Hindi as 'वह एक डॉक्टर है' with the phonetic transcription 'vah ek doktor hai' below it. The third example shows the Hindi sentence 'वह एक डॉक्टर है' being translated back into English as 'He is a doctor'. Each example includes a close button (X) to the right of the source text.

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ENGLISH - DETECTED SOMALI ENG ↔ HINDI SOMALI ENGLISH

I saw a girl with telescope. × मैंने दूरबीन से एक लड़की को देखा।

English ↔ Hindi

She is a doctor × वह एक डॉक्टर है
vah ek doktor hai

Hindi ↔ English

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Given a document, summarize the semantics (extract relevant information) in shorter length text.

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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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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

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C₁: ...I need to travel in May.
A₁: And, what day in May did you want to travel?
C₂: OK uh I need to be there for a meeting that's from the 12th to the 15th.
A₂: And you're flying into what city?
C₃: Seattle.
A₃: And what time would you like to leave Pittsburgh?
C₄: Uh hmm I don't think there's many options for non-stop.
A₄: Right. There's three non-stops today.
C₅: What are they?
A₅: 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.
C₆: OK I'll take the 5ish flight on the night before on the 11th.
A₆: On the 11th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115.
C₇: OK.

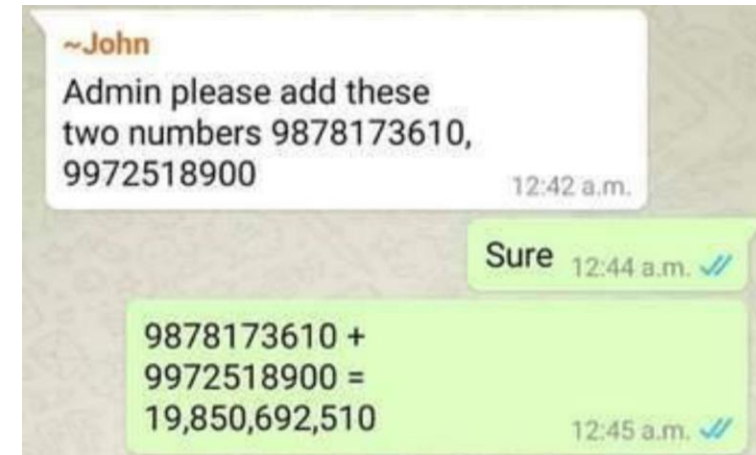
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User: Do you like Doctor Who?
Cleverbot: Yes, so funny.
User: What's your favorite show?
Cleverbot: I don't have one.
User: What's your name?
Cleverbot: Jason I already told you.
User: No your real name.
Cleverbot: Stephanie IS my real name.
User: 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.

Dialog System and Chatbot

C₁: ...I need to travel in May.
A₁: And, what day in May did you want to travel?
C₂: OK uh I need to be there for a meeting that's from the 12th to the 15th.
A₂: And you're flying into what city?
C₃: Seattle.
A₃: And what time would you like to leave Pittsburgh?
C₄: Uh hmm I don't think there's many options for non-stop.
A₄: Right. There's three non-stops today.
C₅: What are they?
A₅: 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.
C₆: OK I'll take the 5ish flight on the night before on the 11th.
A₆: On the 11th? OK. Departing at 5:55pm arrives Seattle at 8pm, U.S. Air flight 115.
C₇: OK.



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We will explore
how LLMs solve these tasks!