Introduction

LING 571 — Deep Processing Techniques for NLP
September 29, 2021
Shane Steinert-Threlkeld

Roadmap

- **Motivation**
- Language and Intelligence
- Knowledge of Language
- Course Overview
- Intro to Syntax and Parsing

How are you feeling about the quarter and the return to in-person/hybrid teaching generally?

Motivation: Applications

- Applications of Speech and Language Processing
  - Call Routing
  - Information Retrieval
  - Question Answering
  - Machine Translation
  - Dialog Systems
  - Spell– and Grammar– Checking
  - Sentiment Analysis
  - Information Extraction
  - …

Building on Many Fields

- **Linguistics**: *Morphology, phonology, syntax, semantics…*
- **Psychology**: *Reasoning, mental representations*
- **Formal Logic**
- **Philosophy (of Language)**
- **Theory of Computation**: *Automata theory*
- **Artificial Intelligence**: *Search, Reasoning, Knowledge Representation, Machine Learning, Pattern Matching*
- **Probability**

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Operationalizing Intelligence: The Turing Test (1950)

- Two contestants: Human vs. Computer
  - **Judge**: human
  - **Test**: interact via text questions
  - **Question**: Can judge tell which contestant is human?

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- *Crucially*:
  - Posits that passing requires language use and understanding

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Turing Test Revisited:

"On the web, no one knows you're a…"

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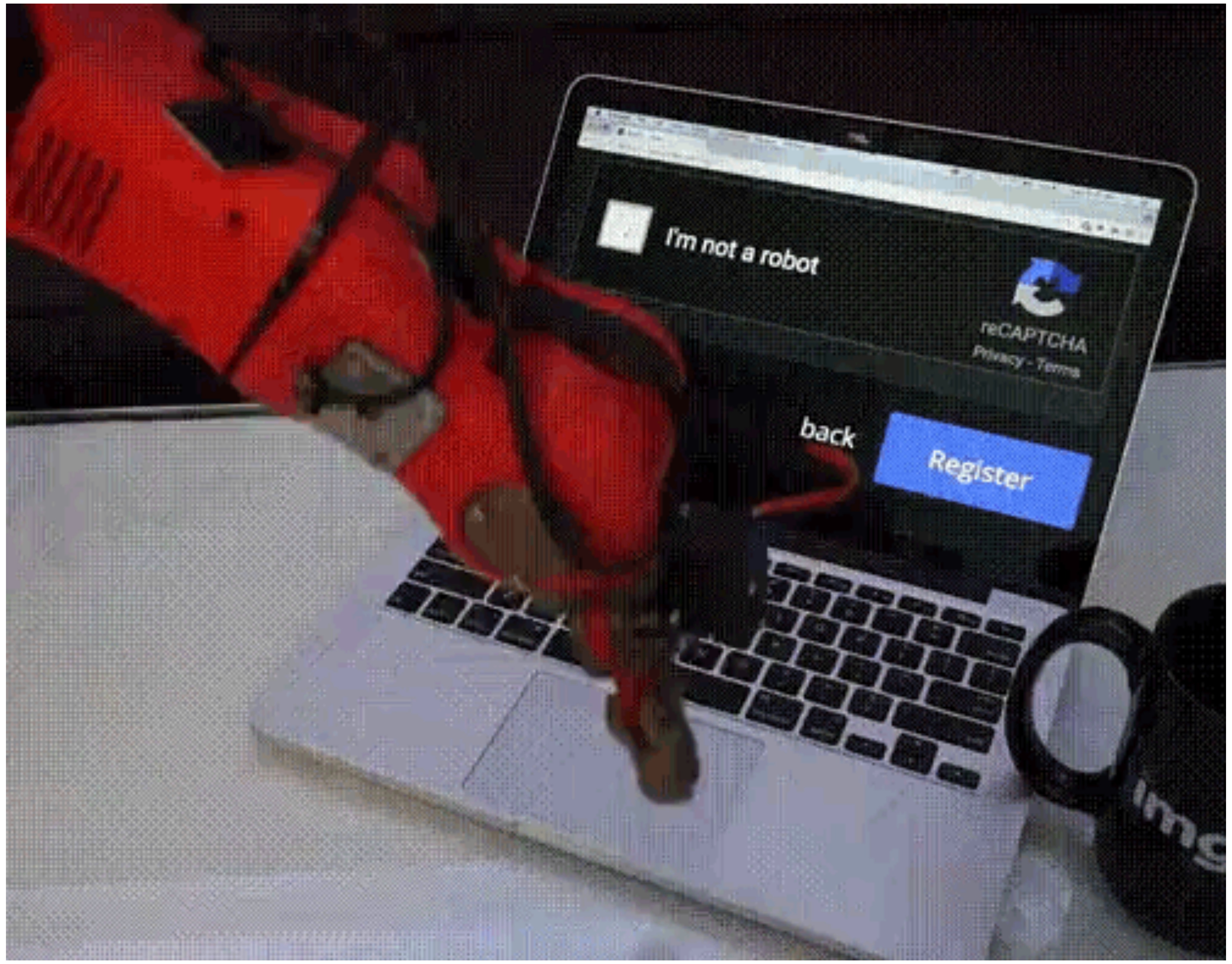
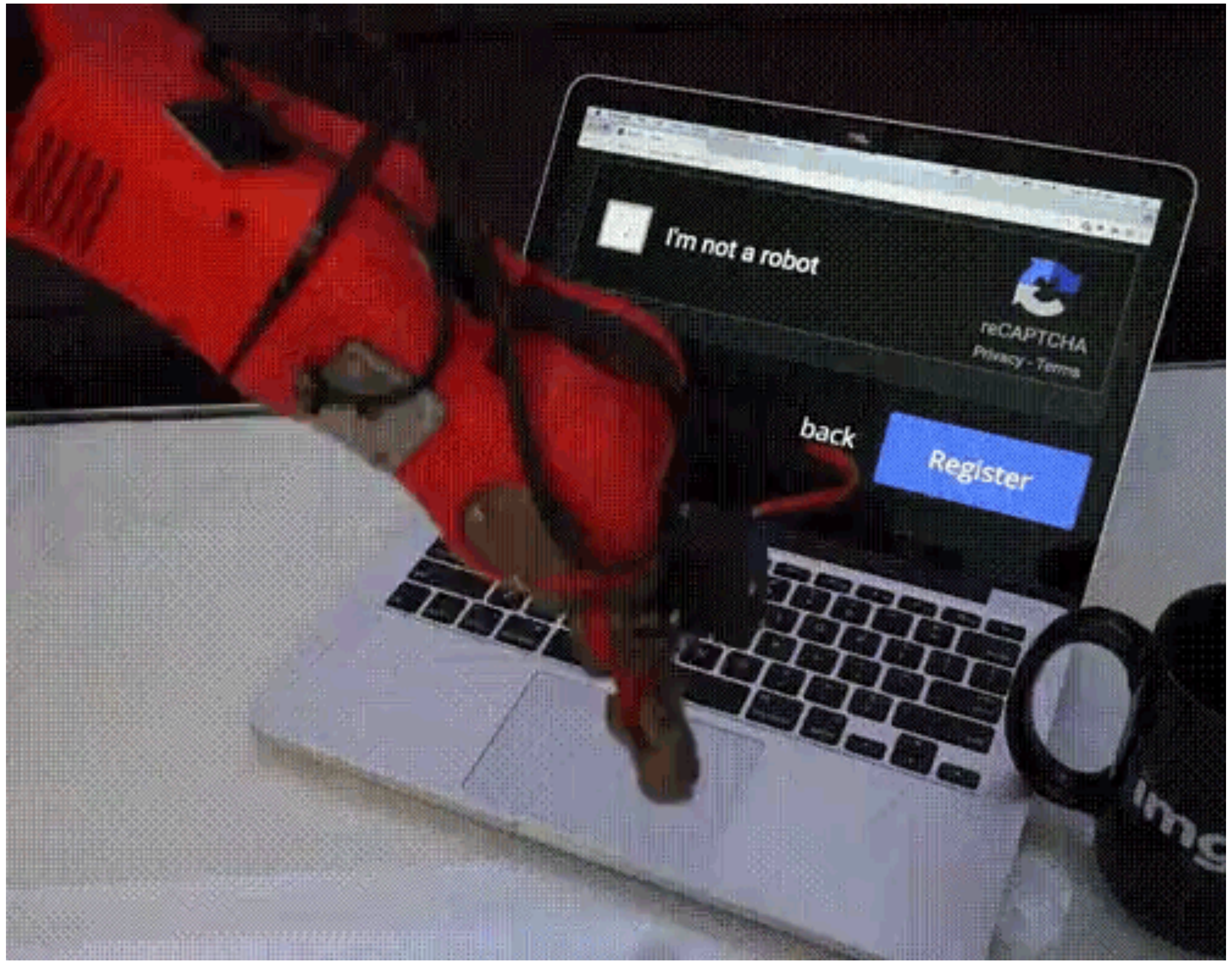
  - Long-term: Inspires “arms race”

CAPTCHA arms race



CAPTCHA arms race



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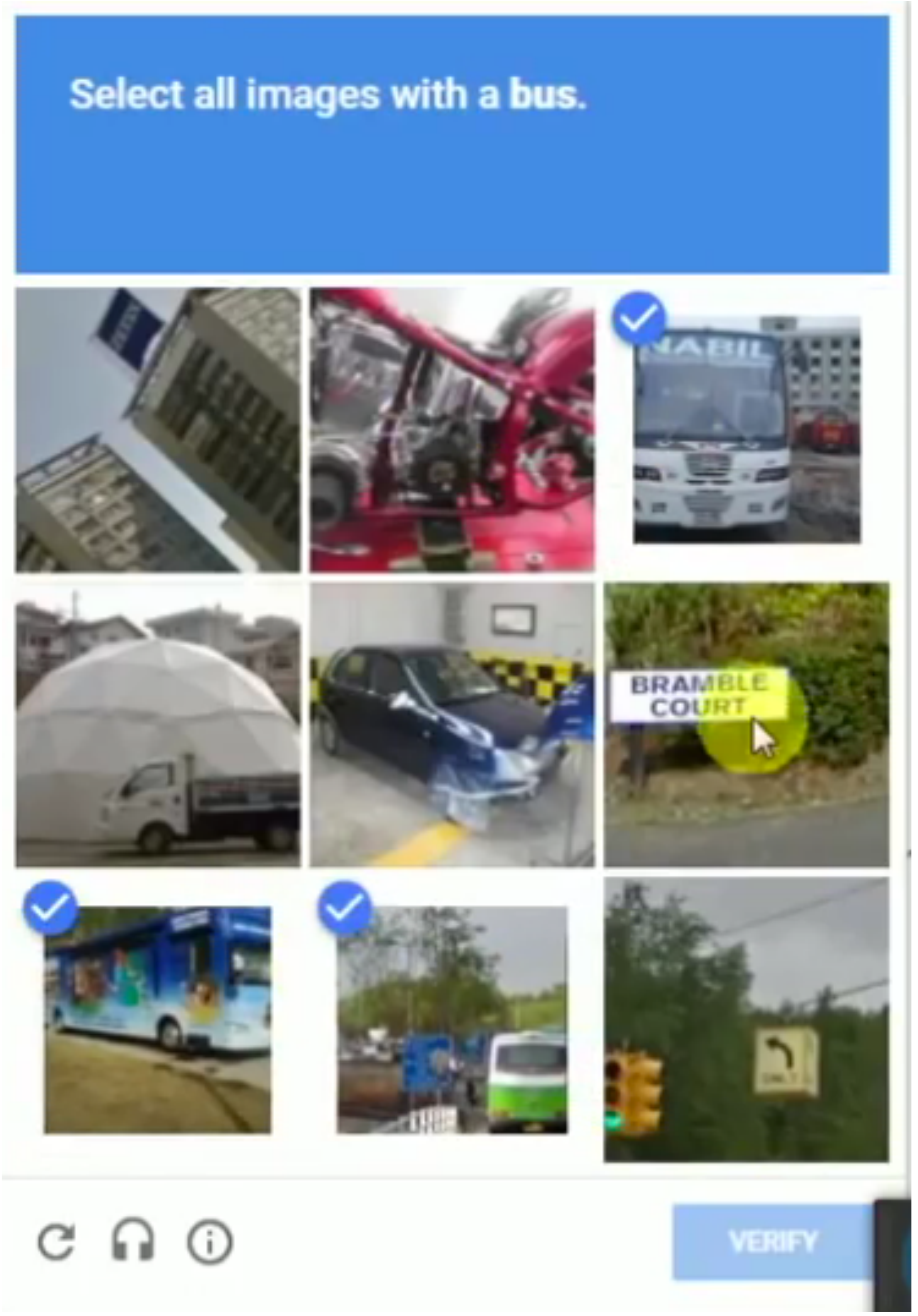

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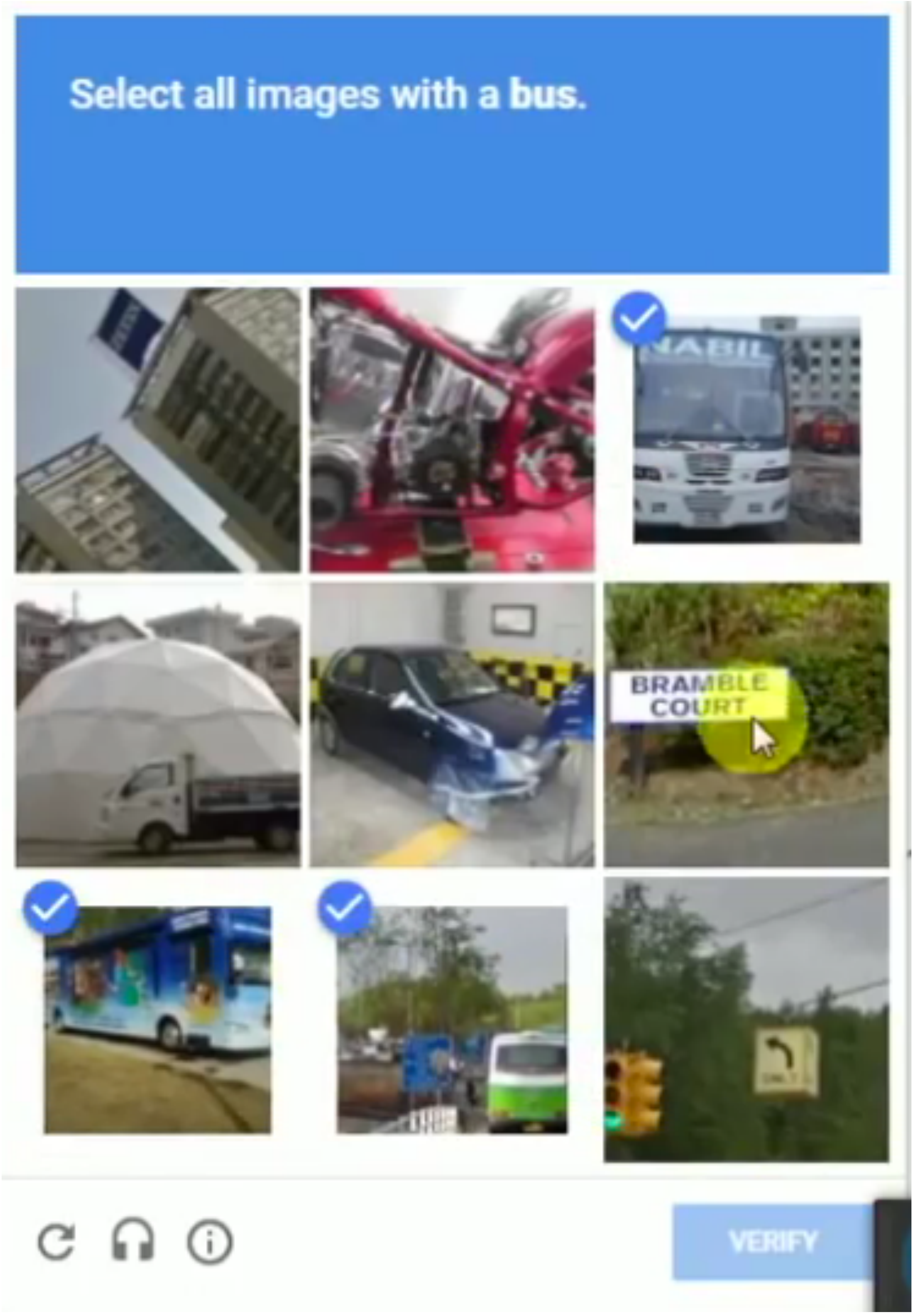

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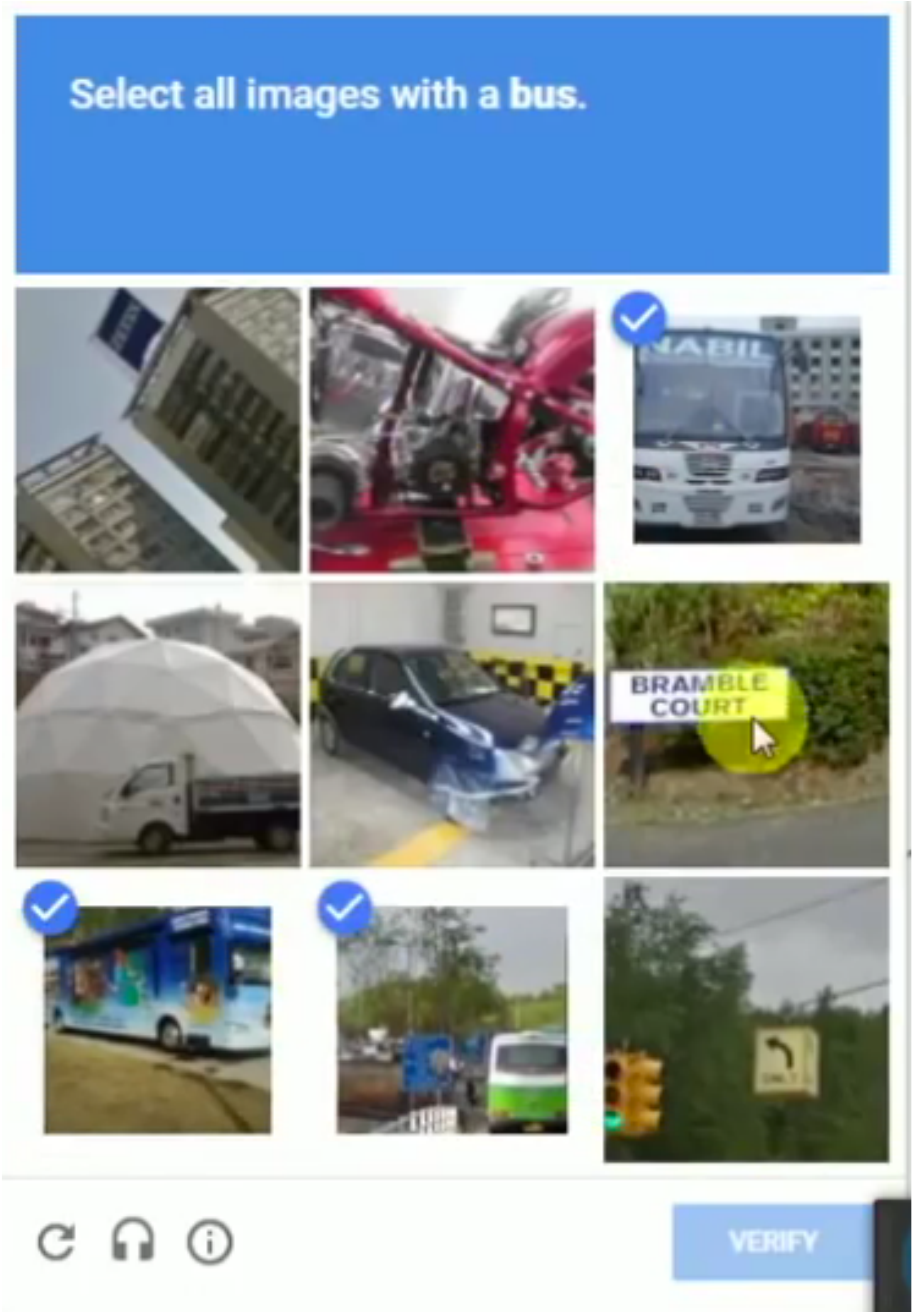

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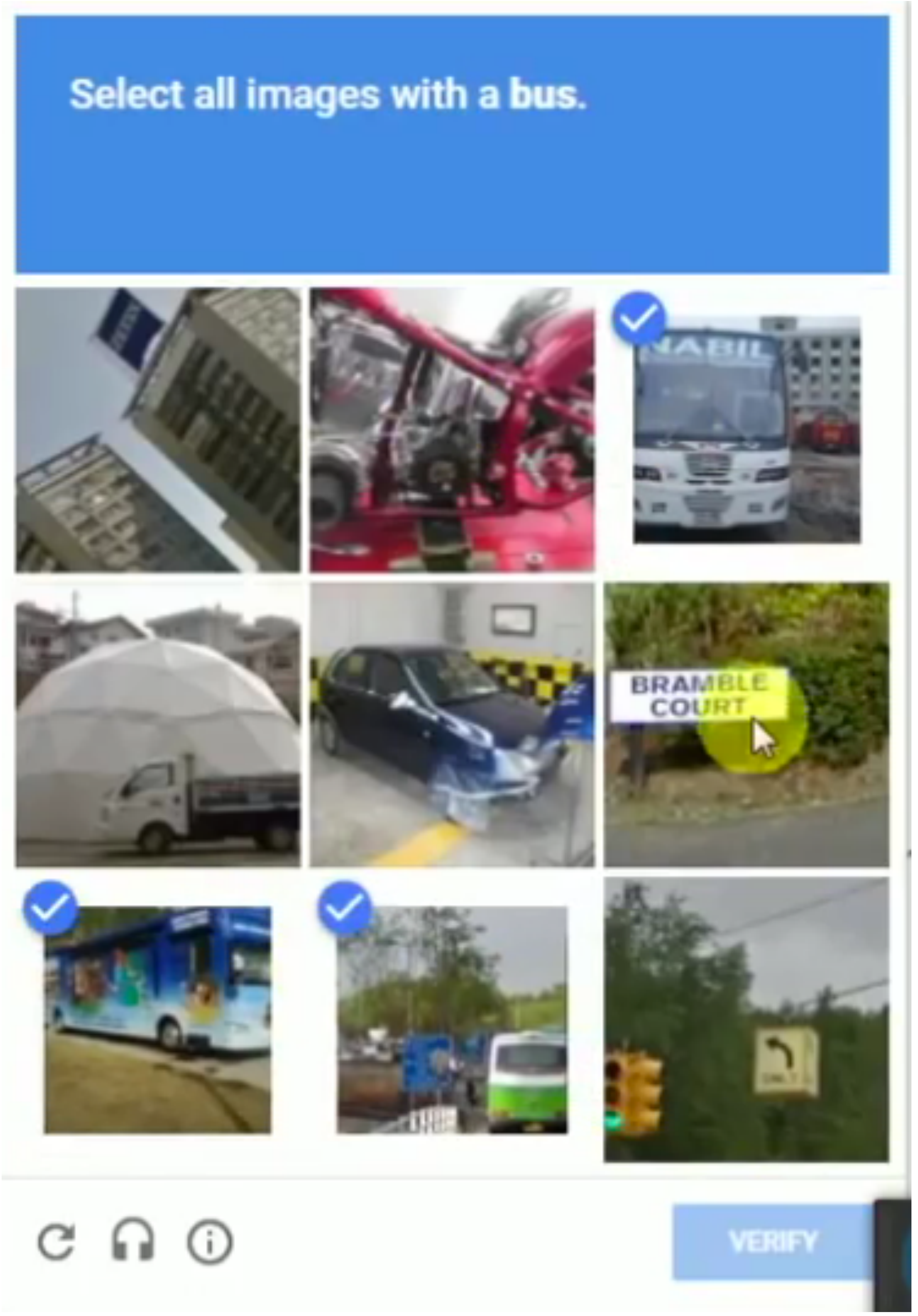

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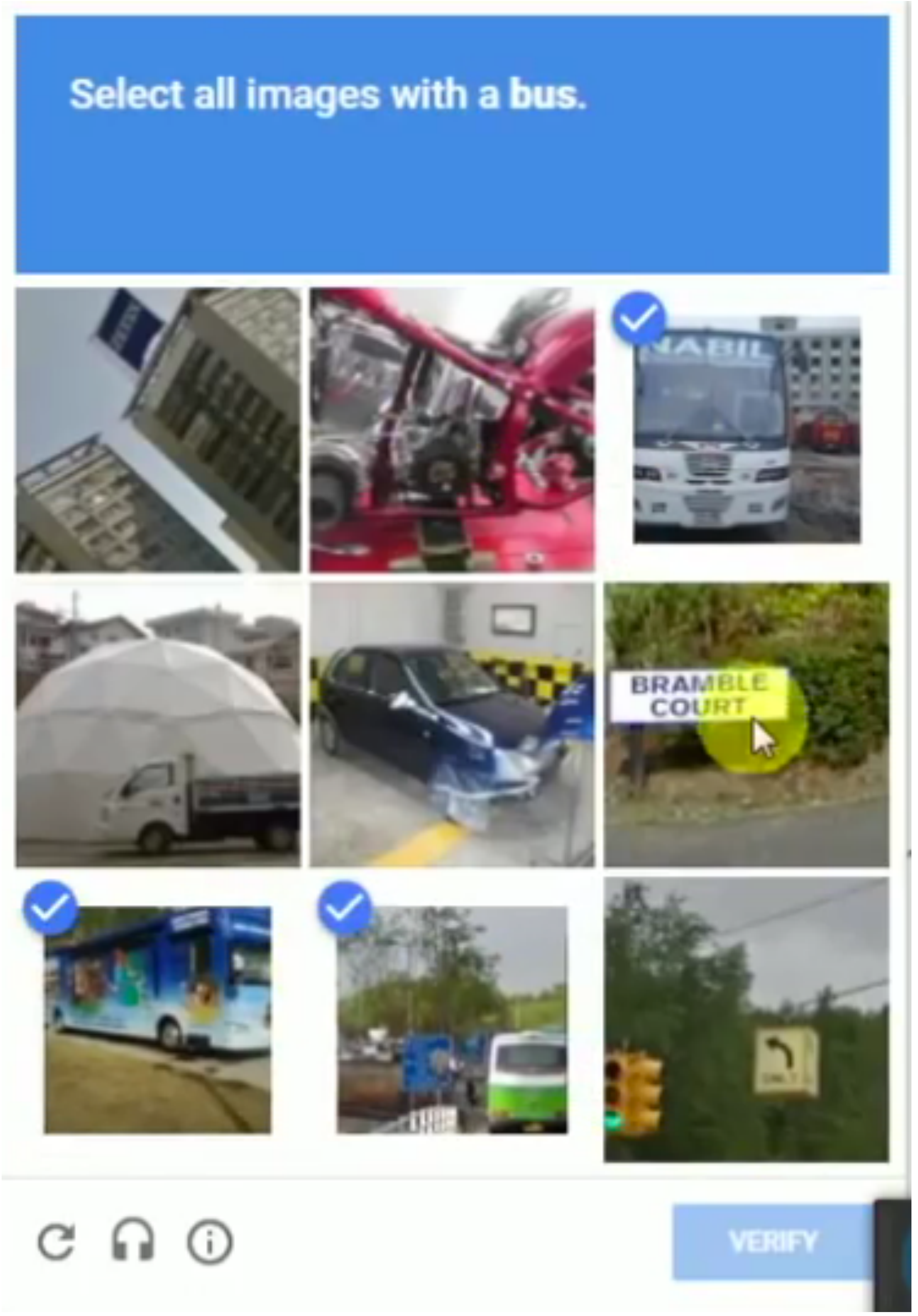

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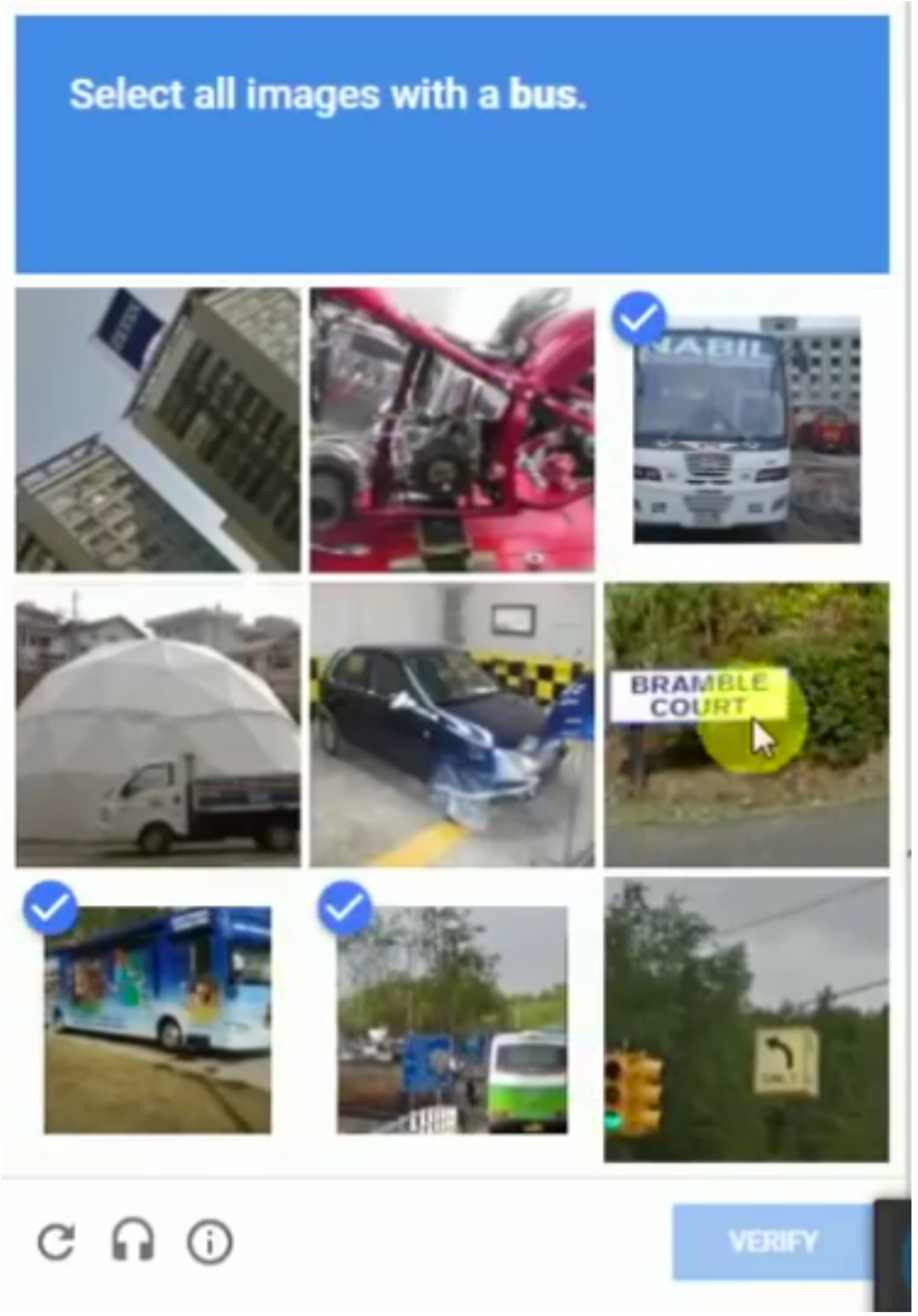

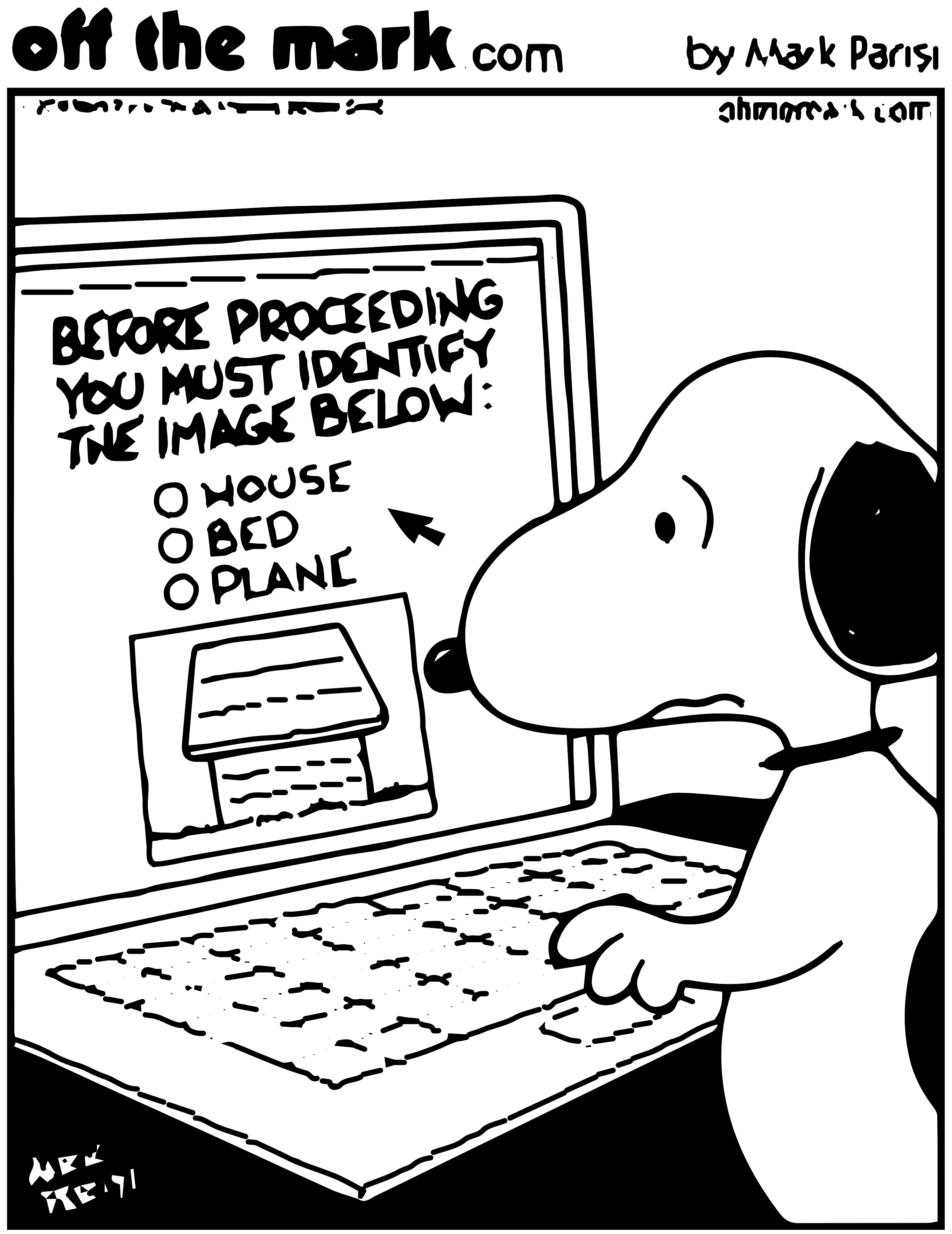

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  - Counts total number of bytes, words, and lines in text file
  - bytes and lines → data processing
  - words → *what do we mean by "word"?*

Knowledge of Language

- What does HAL (of *2001, A Space Odyssey*) need to know to converse?

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- **Phonetics & Phonology** (Ling 450/550)
  - Sounds of a language, acoustics
  - Legal sound sequences in words

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- **Morphology** (Ling 570)
  - Recognize, produce variation in word forms
  - Singular vs. plural: `Door + sg → "door"` `Door + pl → "doors"`
  - Verb inflection: `be + 1st Person + sg + present → "am"`

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- **Part-of-speech Tagging** (Ling 570)
  - Identify word use in sentence
  - Bay (Noun) — Not verb, adjective

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- **Syntax**
  - (566: Analysis, 570: Chunking, 571: Parsing)
  - Order and group words in sentence
    - cf. *"*I'm I do, sorry that afraid Dave I can't*"

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- **Semantics** (Word Meaning)
  - Individual (lexical) + Combined (Compositional)
  - `'Open'` : `AGENT` **cause** `THEME` **to become** *`open`*;
    - 'pod bay doors' → doors to the 'pod bay' → the bay which houses the pods.

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  - Reference resolution: `“I”=[`**`HAL`**`]; “that”=[`**`open…doors`**`]`
  - Politeness: “***I'm sorry***, ***I'm afraid I can't***…”

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Course Overview: Shallow vs. Deep Processing

- Shallow processing (LING 570)
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    - Usually relies on surface forms (e.g. words)
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- Shallow processing (LING 570)
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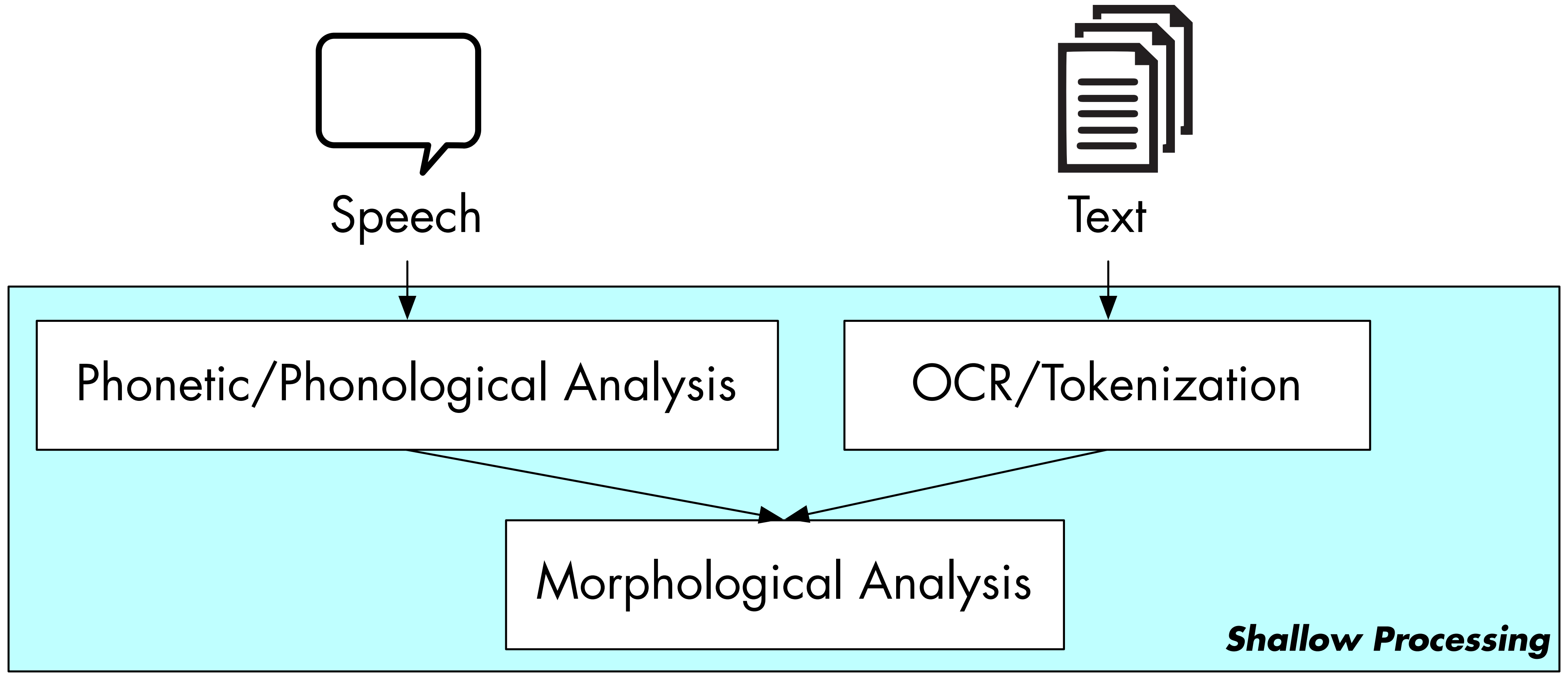
  - Examples: HMM POS-tagging; FST morphology
- Deep processing (LING 571)
  - Relies on ***more elaborate*** linguistic representations
    - Deep syntactic analysis (Parsing)
    - Rich spoken language understanding (NLU)

Language Processing Pipeline



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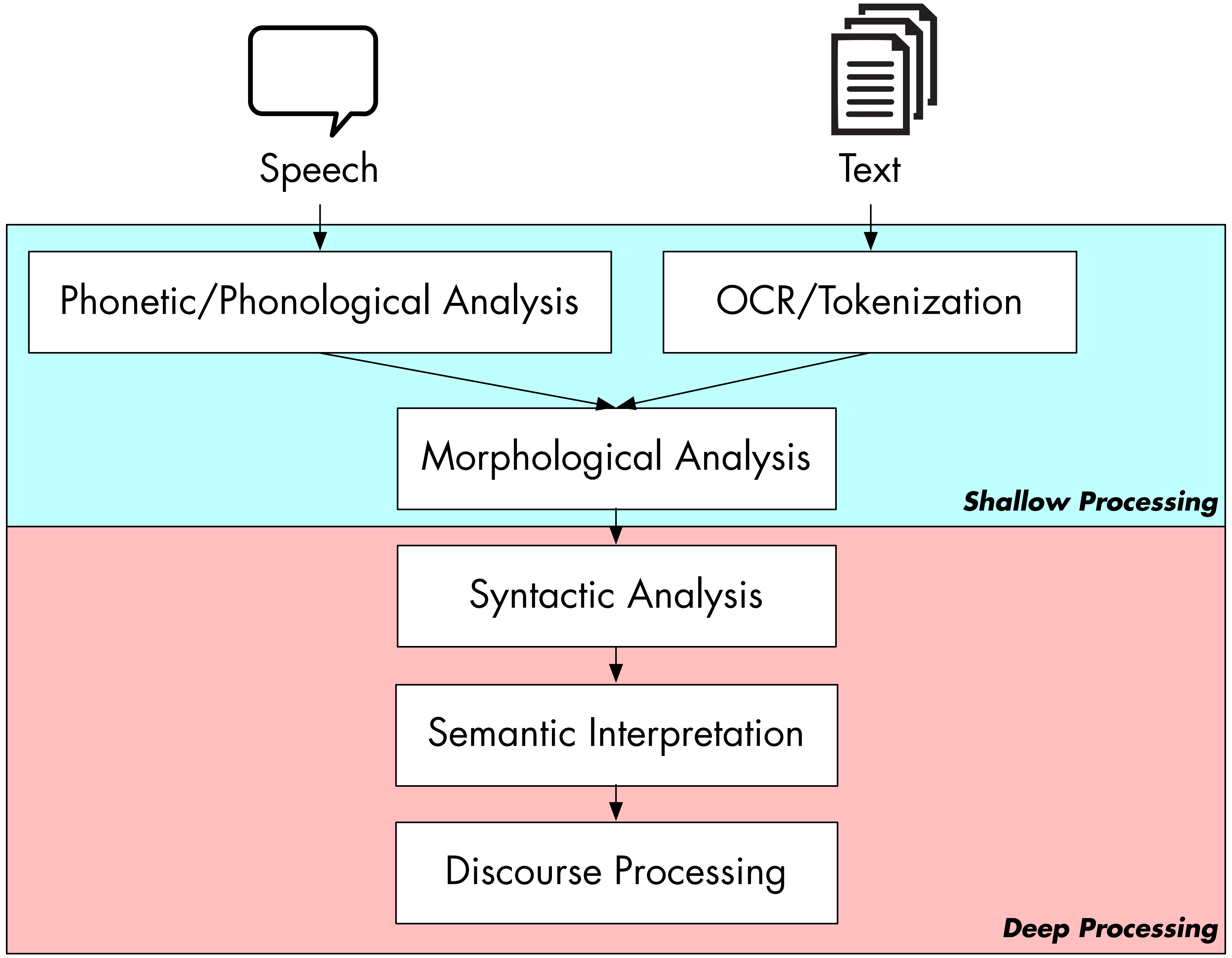

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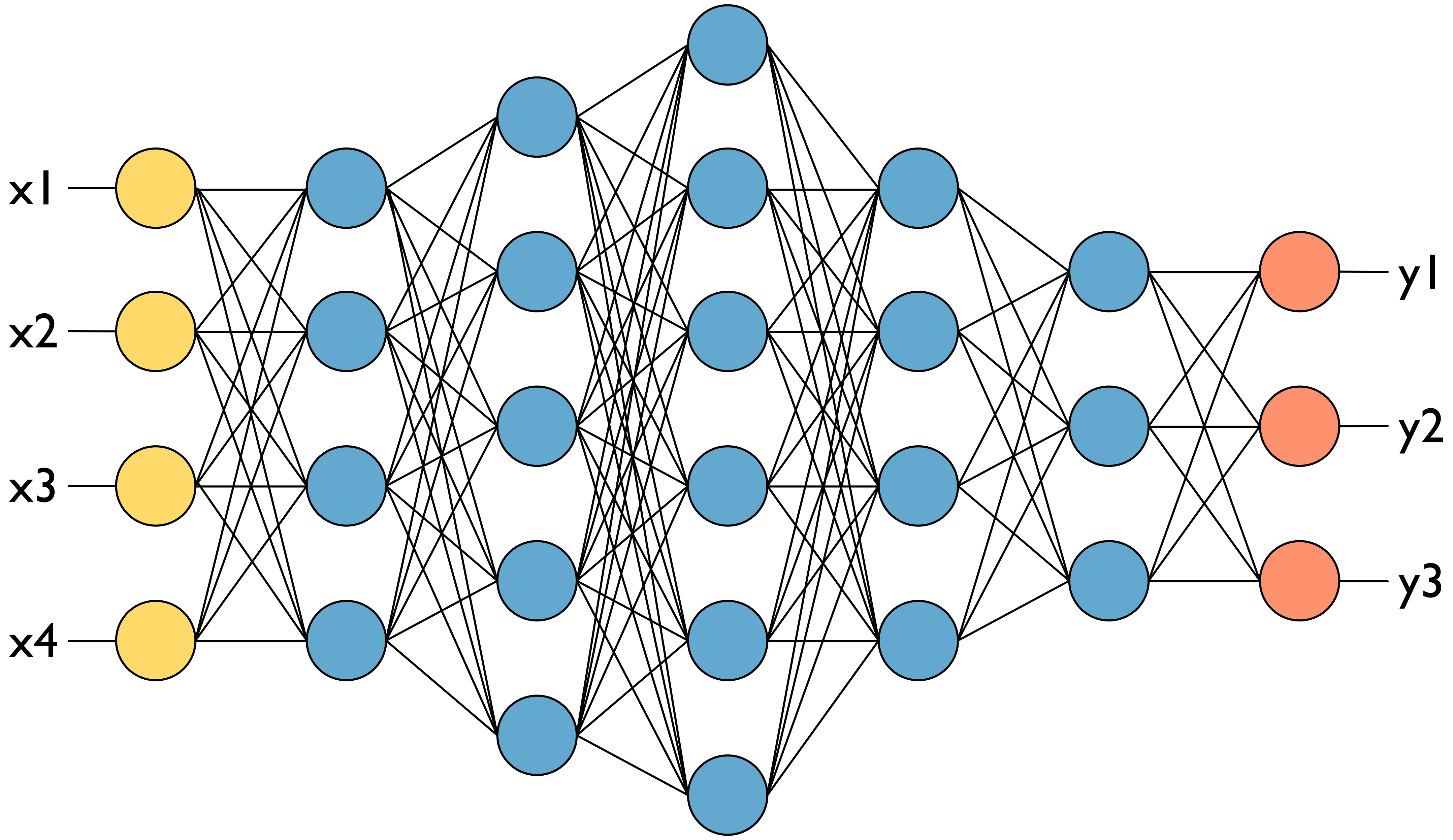

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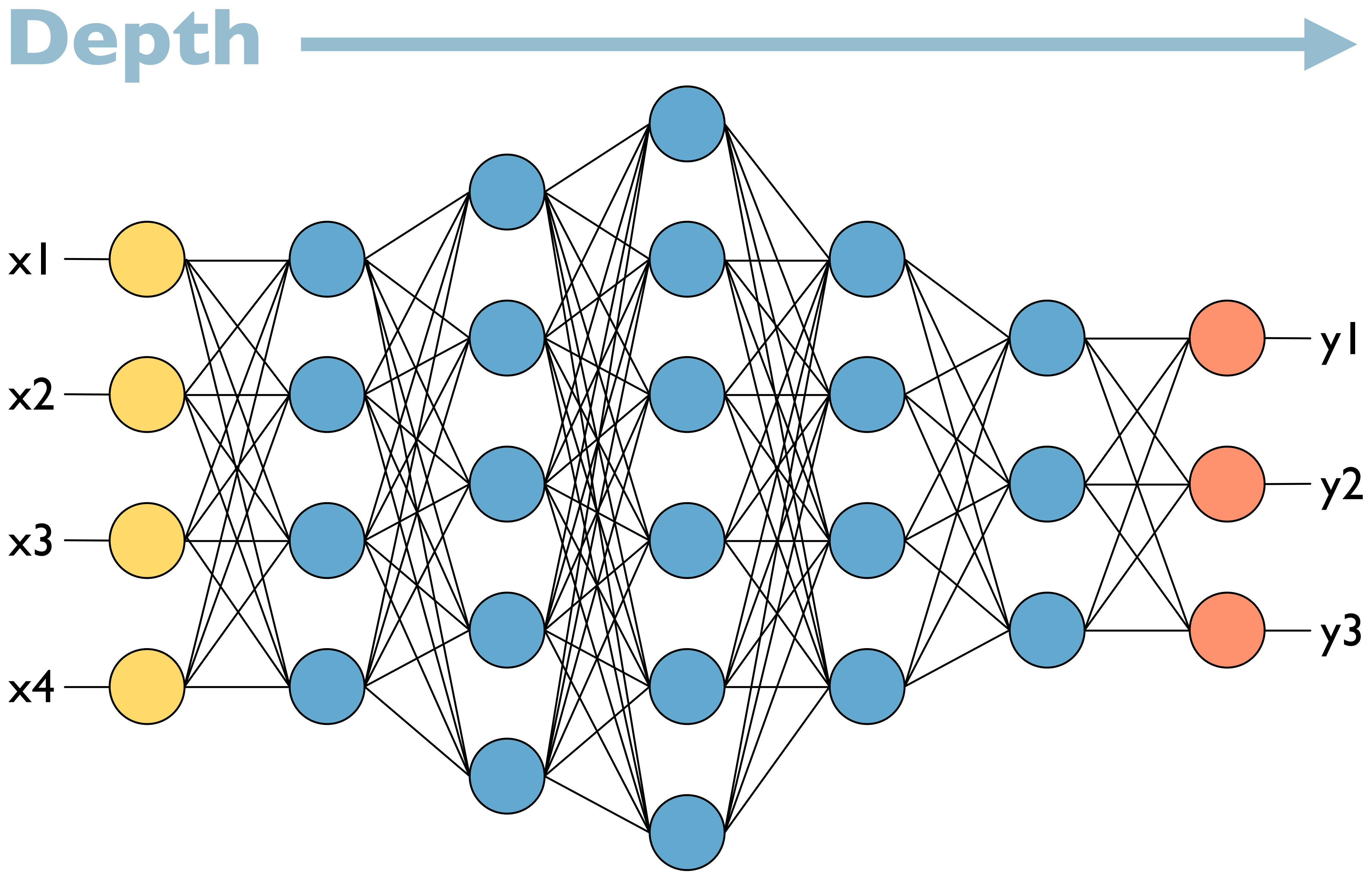

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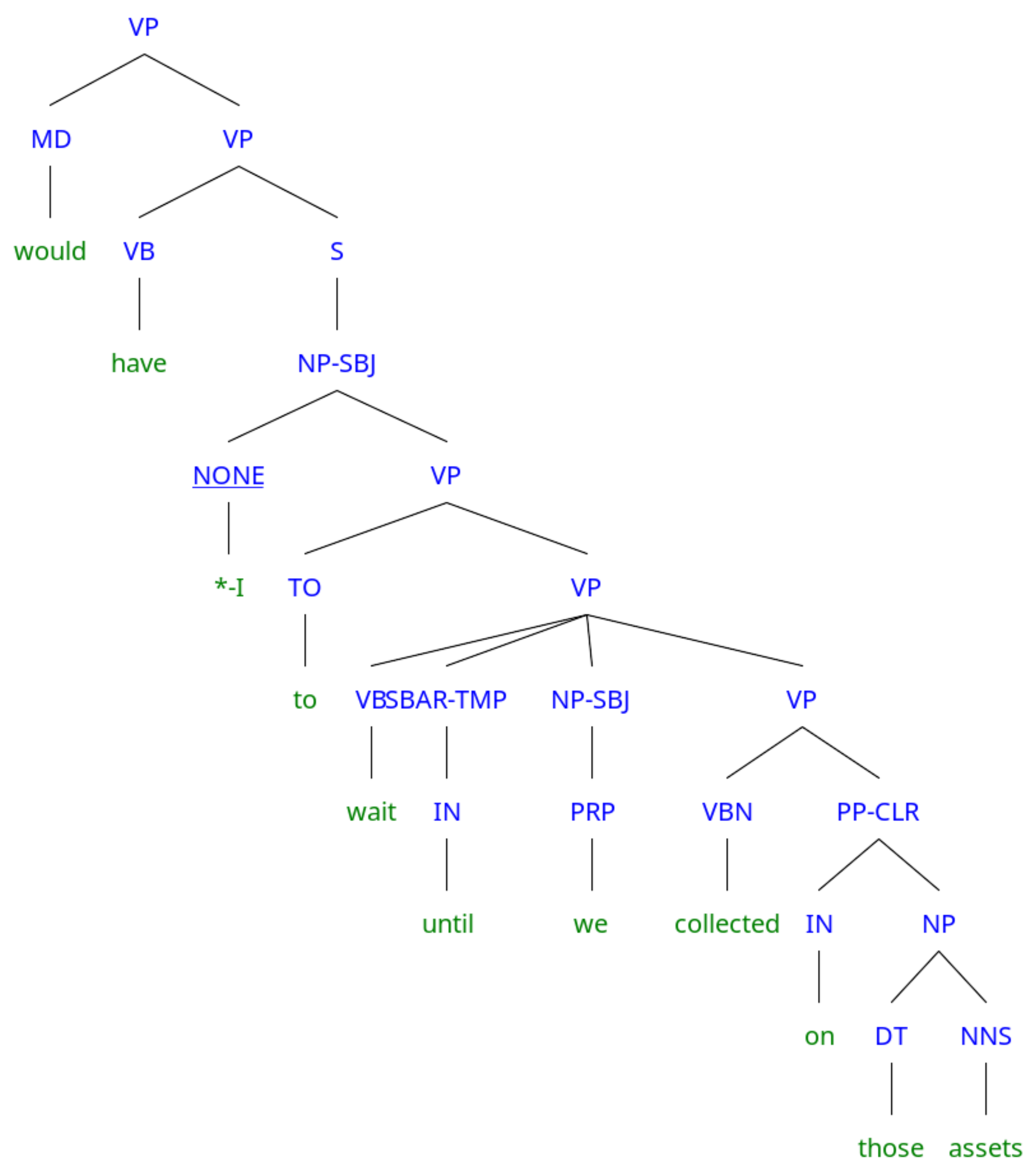

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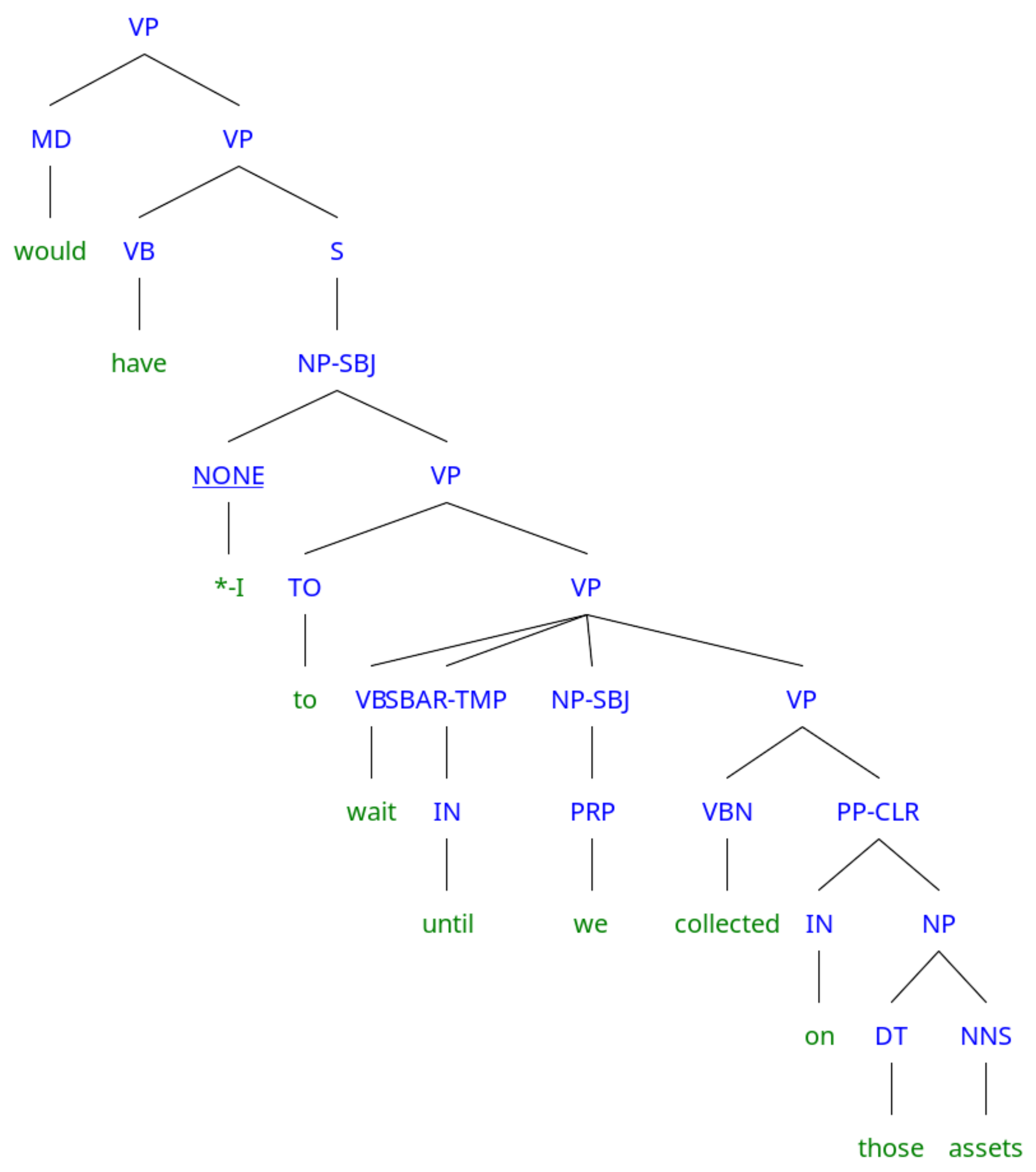

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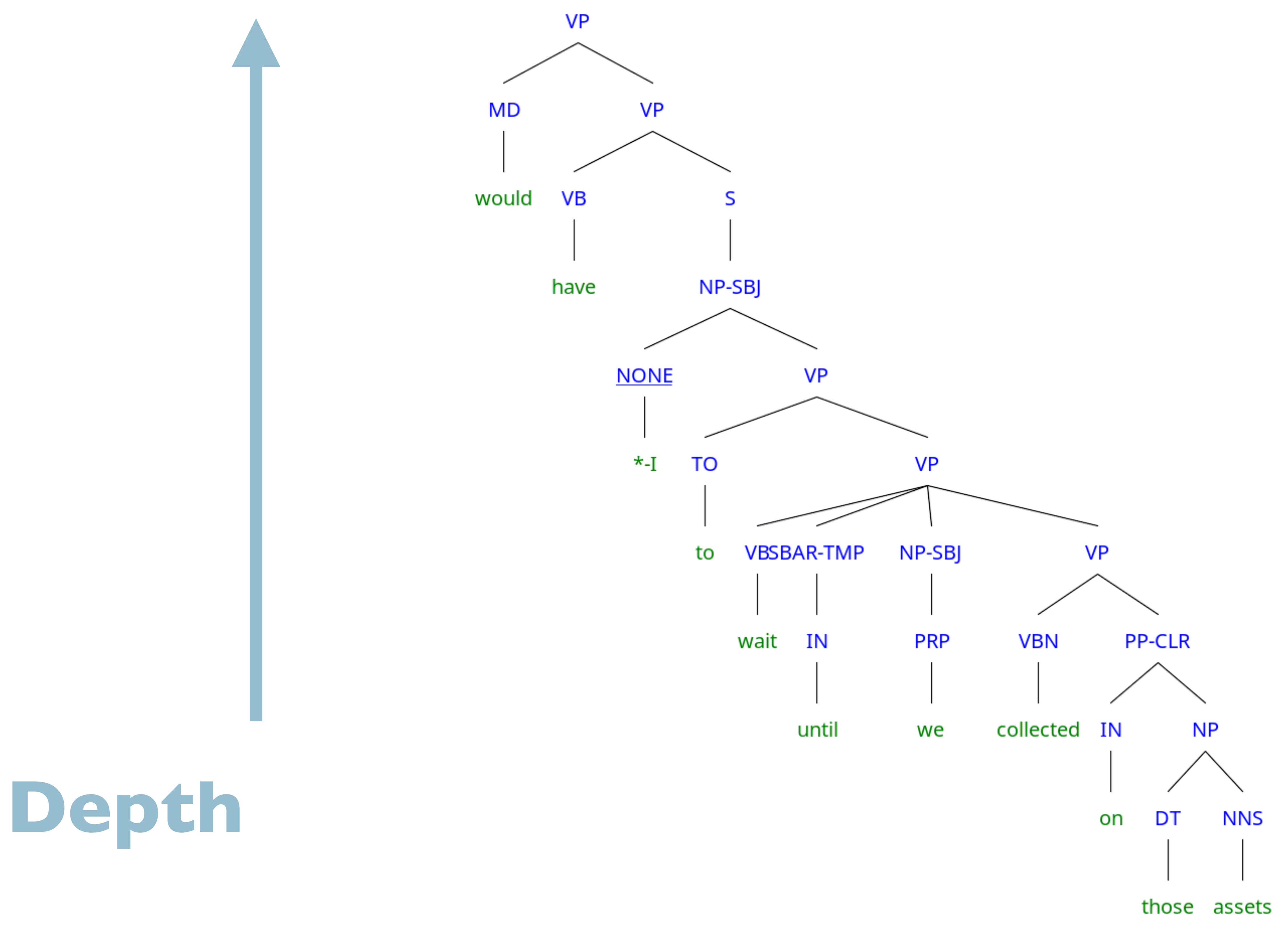

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- In both paradigms, graph depth aids, but $\not\Rightarrow$ abstraction

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- **Evaluation**
  - How well does this approach perform:
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- **Multilinguality**
  - Can we apply the same approach to other languages?
  - How much must it be modified to do so?

Ambiguity: POS

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- “I made her duck.”
- Could mean…
  - I caused her to duck down.
  - I made the (carved) duck she has.
  - I cooked duck for her.
  - I cooked a duck that she owned.
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VERB

NOUN

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POSS

PRON

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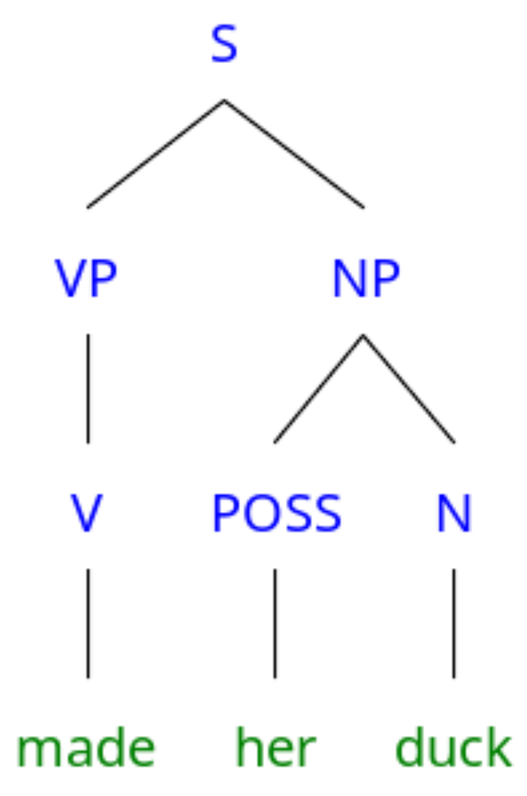

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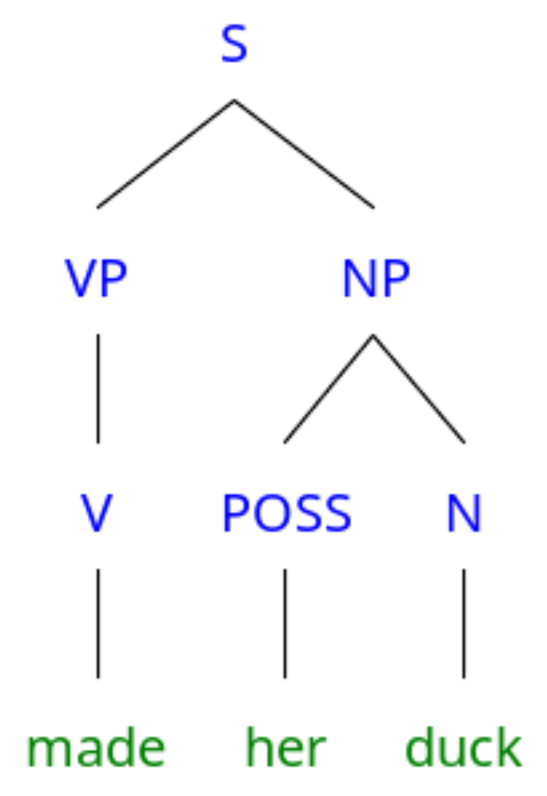

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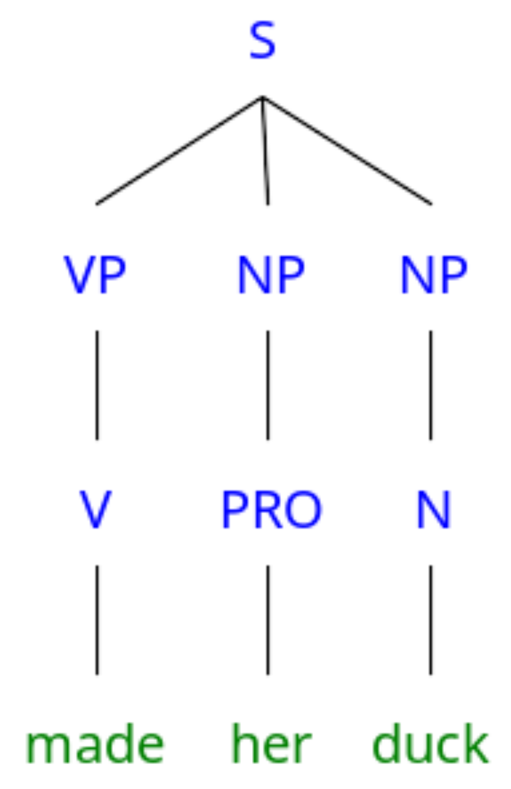

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I magically turned her into a duck	**made** = [AG] **transformed** [TH] **duck** = **animal**

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Ambiguity

- Pervasive in language
- Not a bug, a feature! (Piantadosi et al 2012)
- *"I believe we should all pay our tax bill with a smile.*
  I tried—but they wanted cash."
- What would language be like without ambiguity?

Ambiguity

- Challenging for computational systems

Ambiguity

- Challenging for computational systems
- Issue we will return to again and again in class.

Course Information

Course Information

- Website is main source of information: https://www.shane.st/teaching/571/aut21/
  - slides, office hours, resources, etc
- Canvas: lecture recordings, homework submission / grading
  - Communication!!! Please use the discussion board for questions about the course and its content.
  - Other students have same questions, can help each other.
  - May get prompter reply. The teaching staff will not respond outside of normal business hours, and may take up to 24 hours.

Course Information

- Grading, policies, etc: see link under “Policies” on course page
  - Shared policies for 570, 571, 572
- Office hours:
  - Shane: M 230-330 (GUG 418D), W 230-330 (Zoom; see website)
  - Haotian: TBA
- Homeworks:
  - 9, released on Wednesday, due the following Wednesday
  - With a pause during Thanksgiving week
  - [NB: also no class the Wednesday before Thanksgiving]

Course Content

- Syntax
  - (Probabilistic) Context-Free Grammars
    - Parsing algorithms (CKY, Earley)
  - Dependency Parsing
- Semantics
  - Logical / event semantics, lambda calculus
  - Distributional semantics, lexical semantics
  - Semantic Role Labeling
- Pragmatics / Discourse
  - Reference, Co-reference, structure / discourse parsing

What are you most looking forward to in 571 this quarter?

Syntax Crash Course

LING 571 — Deep Processing Techniques for NLP
September 29, 2021
Shane Steinert-Threlkeld

Roadmap

- Sentence Structure
  - More than a bag of words
- Representation
  - Context-free Grammars
    - Formal Definition

Applications

- Shallow techniques useful, but limited
- Deeper analysis supports:
  - Grammar checking — and teaching
  - Question-answering
  - Information extraction
  - Dialogue understanding
  - …

Grammar and NLP

- “Grammar” in linguistics is **NOT** prescriptive high school grammar
  - Explicit rules
  - “Don’t split infinitives!” etc.

Grammar and NLP

- "Grammar" in linguistics is **NOT** prescriptive high school grammar
  - Explicit rules
  - "Don't split infinitives!" etc.
- "Grammar" in linguistics **IS**:
  - How to capture structural knowledge of language as a native speaker would have
  - Largely implicit
  - Learned early, naturally

More than a Bag of Words

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- Choice of structure can impact:

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  - Meaning:
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More than a Bag of Words

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  - Meaning:
    - *Dog bites man.* **vs.** *Man bites dog.*
  - Acceptability:
    - *Colorless green ideas sleep furiously.*
    - ** Colorless sleep ideas furiously green.*
    - ** Dog man bites*

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  - Noun Phrase (NP)
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  - …
- Single unit: type determined by “head”
  - e.g. **N** heads NP

Representing Sentence Structure

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    - Components expected by verbs
- Hierarchical

Representation: Context-free Grammars

- CFGs: 4-tuple
  - A set of **terminal** symbols: Σ
    - [think: words]
  - A set of **nonterminal** symbols: N
    - [think: phrase categories]
  - A set of **productions** P:
    - of the form $\boldsymbol{A} \rightarrow \alpha$
    - Where A is a non-terminal and $\alpha \in \{\Sigma \cup N\}^*$
  - A **start** symbol $S \in N$

Representation: Context-free Grammars

- Altogether a grammar defines a language *L*
  - $L = \{w \in \Sigma^* \mid S \Rightarrow^* w\}$
    - The language *L* is the set of all words in which:
    - $S \Rightarrow^* w$: *w* can be *derived* starting from *S* by some sequence of productions

CFG Components

- **Terminals**:
  - Only appear as leaves of parse tree (hence the name)
  - Right-hand side of productions (RHS)
  - Words of the language
    - *cat, dog, is, the, bark, chase…*

CFG Components

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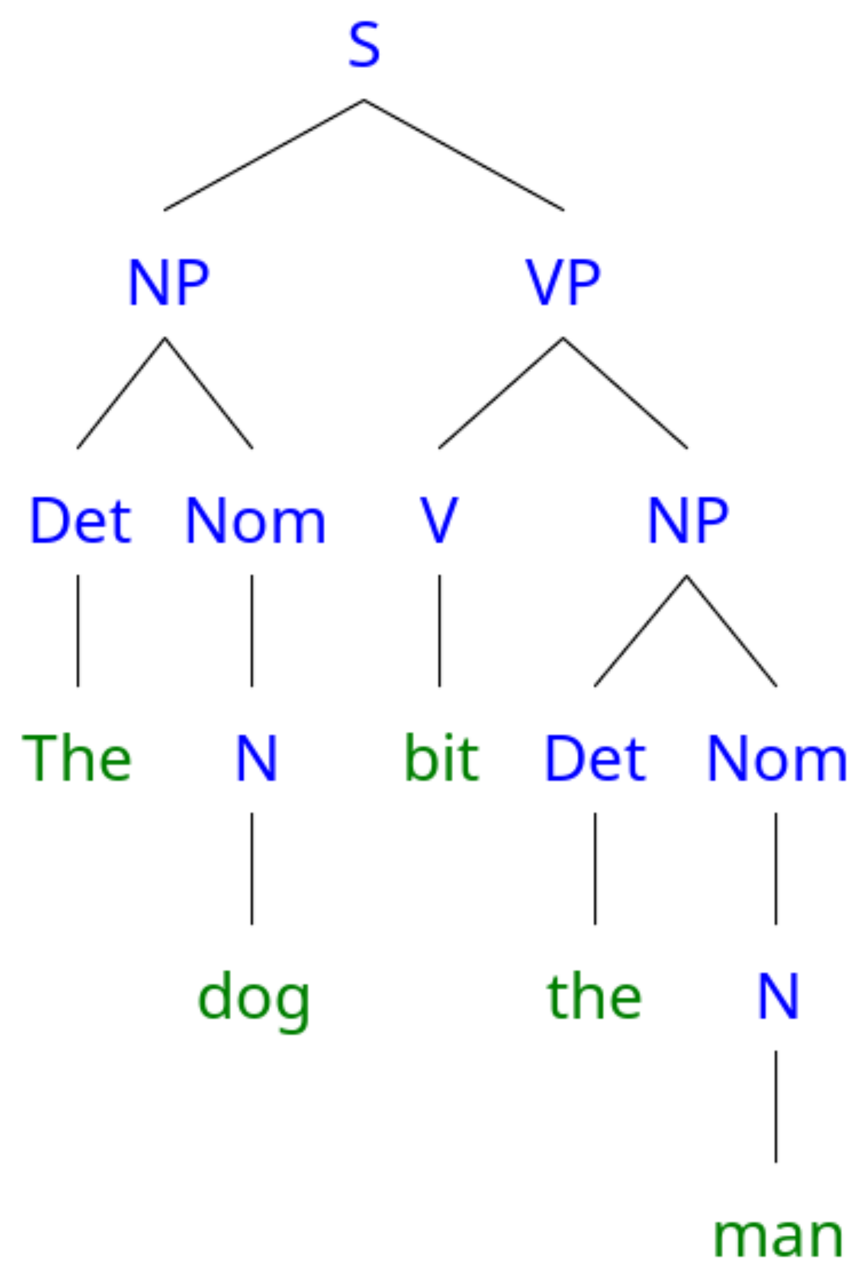
  - Only appear as leaves of parse tree (hence the name)
  - Right-hand side of productions (RHS)
  - Words of the language
    - *cat, dog, is, the, bark, chase…*
- **Non-terminals**
  - Do not appear as leaves of parse tree
  - Appear on left or right side of productions
  - Represent constituent phrases of language
    - NP, VP, S[entence], etc…

Representation: Context-free Grammars

- Partial example:
  - Σ: *the, cat, dog, bit, bites, man*
  - *N*: NP, VP, Nom, Det, V, N, Adj
  - *P*:
    - S→NP VP;
    - NP→Det Nom;
    - Nom→N Nom | N;
    - VP→V NP;
    - N→*cat*; N→*dog*; N→*man*;
    - Det→*the*;
    - V→*bit*; V→*bites*
  - *S*: S



Parsing Goals

- Acceptance
  - Legal string in language?
    - Formally: rigid
    - Practically: degrees of acceptability

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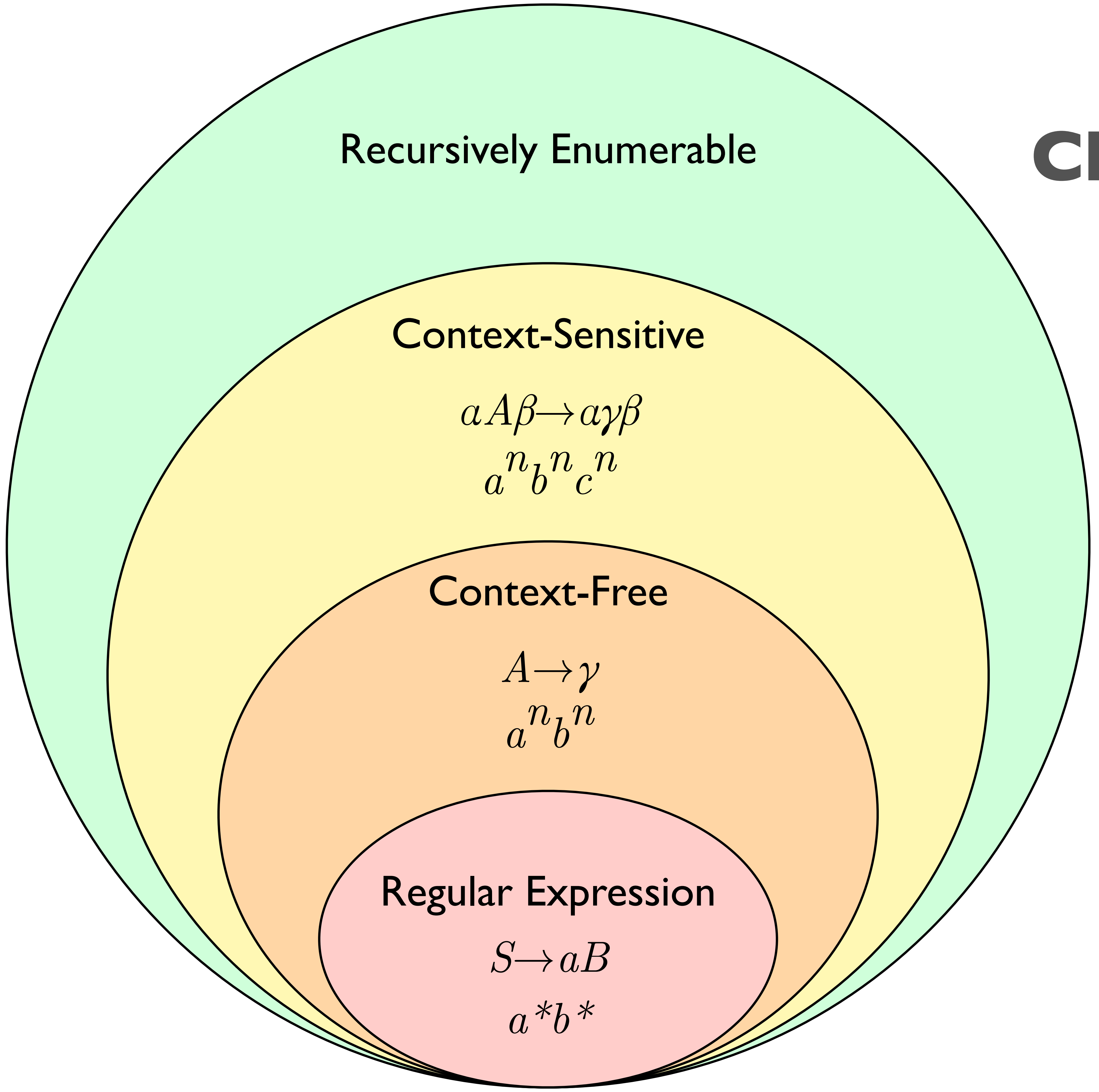
  - Legal string in language?
    - Formally: rigid
    - Practically: degrees of acceptability
- Analysis
  - What structure produced the string
    - Produce one (or all) parses for the string
- Will develop techniques to produce analyses of sentences
  - Rigidly accept (with analysis) or reject
  - Produce varying degrees of acceptability

Sentence-level Knowledge: Syntax

- Different models of language that specify the ***expressive power*** of a formal language



Chomsky Hierarchy

S, A, B: non-terminals
a, b: terminals
α, β, γ: sequence of terminals + non-terminals
[γ: never empty]

Representing Sentence Structure

- Why not just Finite State Models (Regular Expressions)?
  - Cannot describe some grammatical phenomena
  - Inadequate expressiveness to capture generalization

Representing Sentence Structure: Center Embedding

- **Regular Language**: $A \rightarrow w; A \rightarrow w^*B$
- **Context-Free**: $A \rightarrow \alpha A \beta$ (e.g.)
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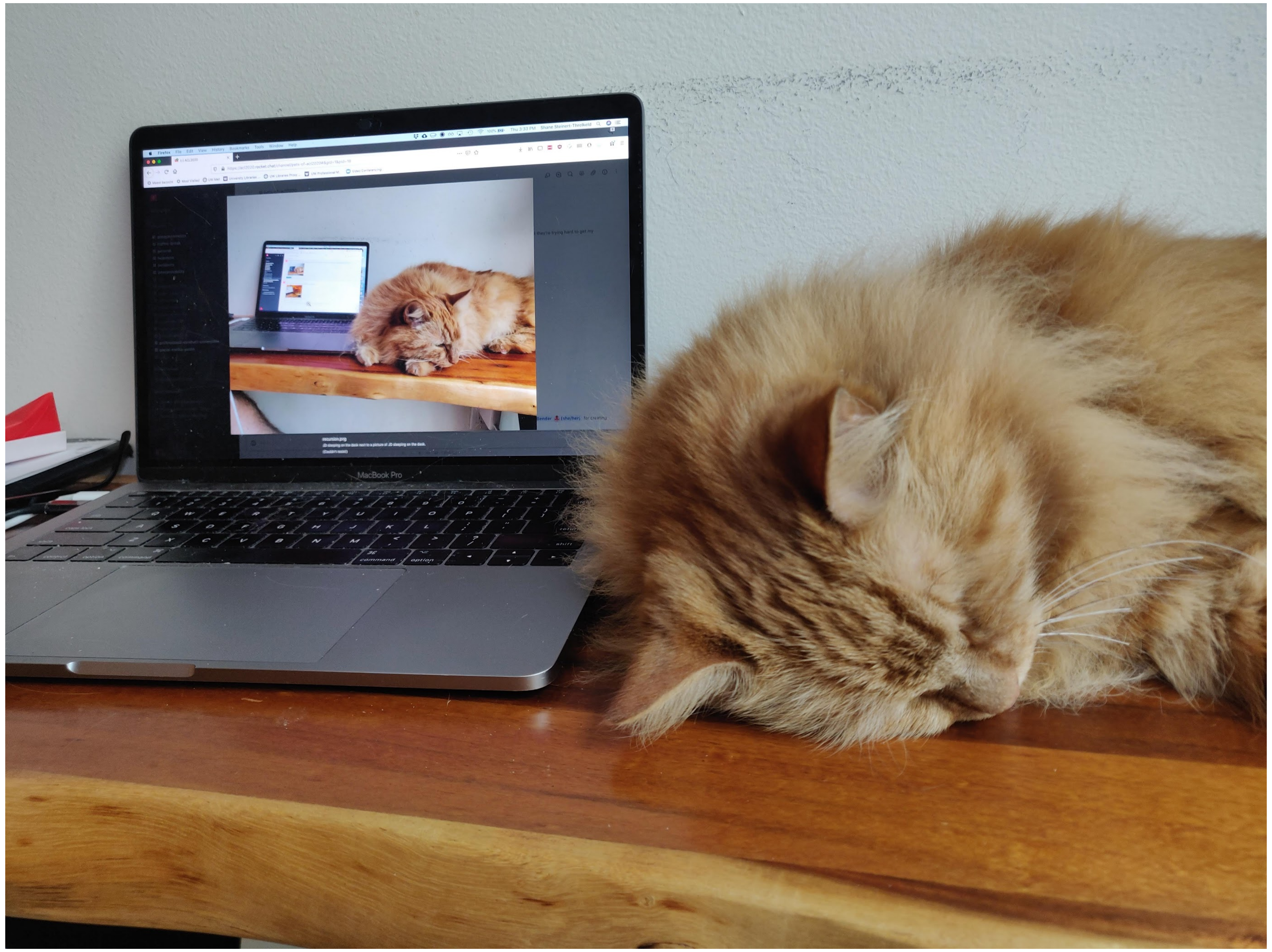
    - The luggage arrived
    - The luggage that the passengers checked arrived
    - The luggage that the passengers **whom the storm delayed** checked arrived

Recursion in Grammar



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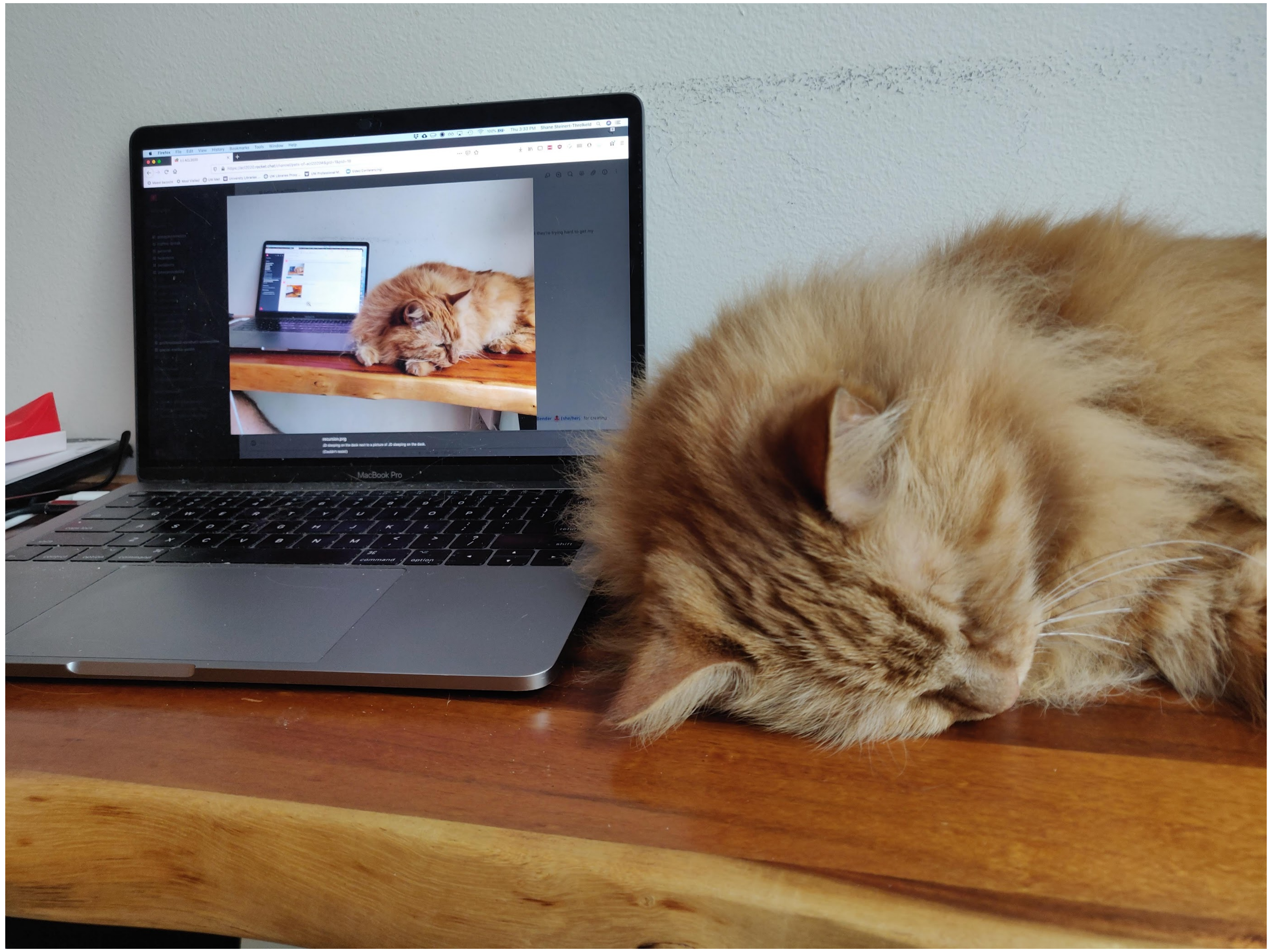
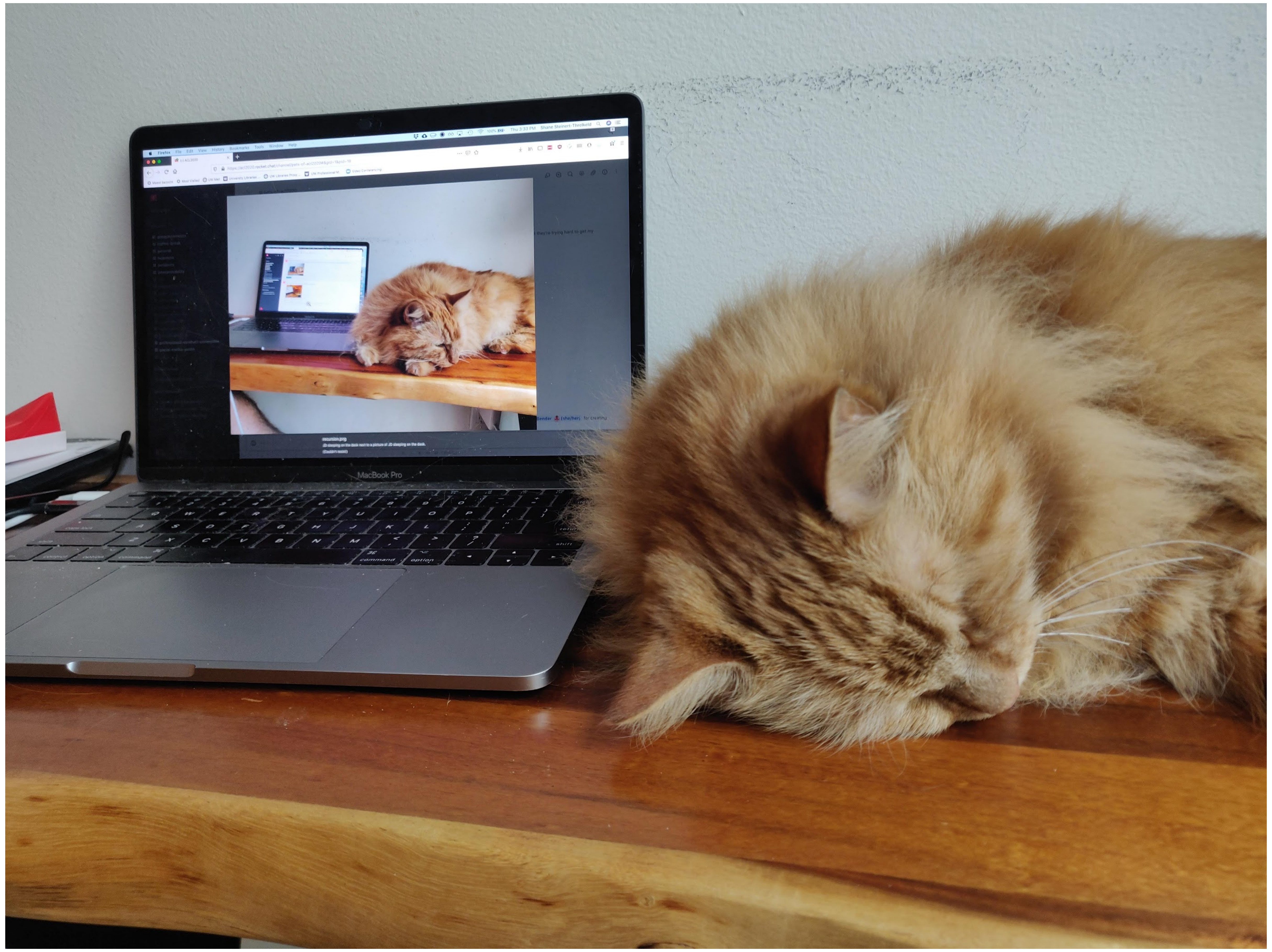


This is JD lying on the desk next to a picture of JD lying on the desk next to a picture of JD lying on the desk.

Recursion in Grammar



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Exercise: write a toy grammar for producing this sentence!

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  - …many have failed.

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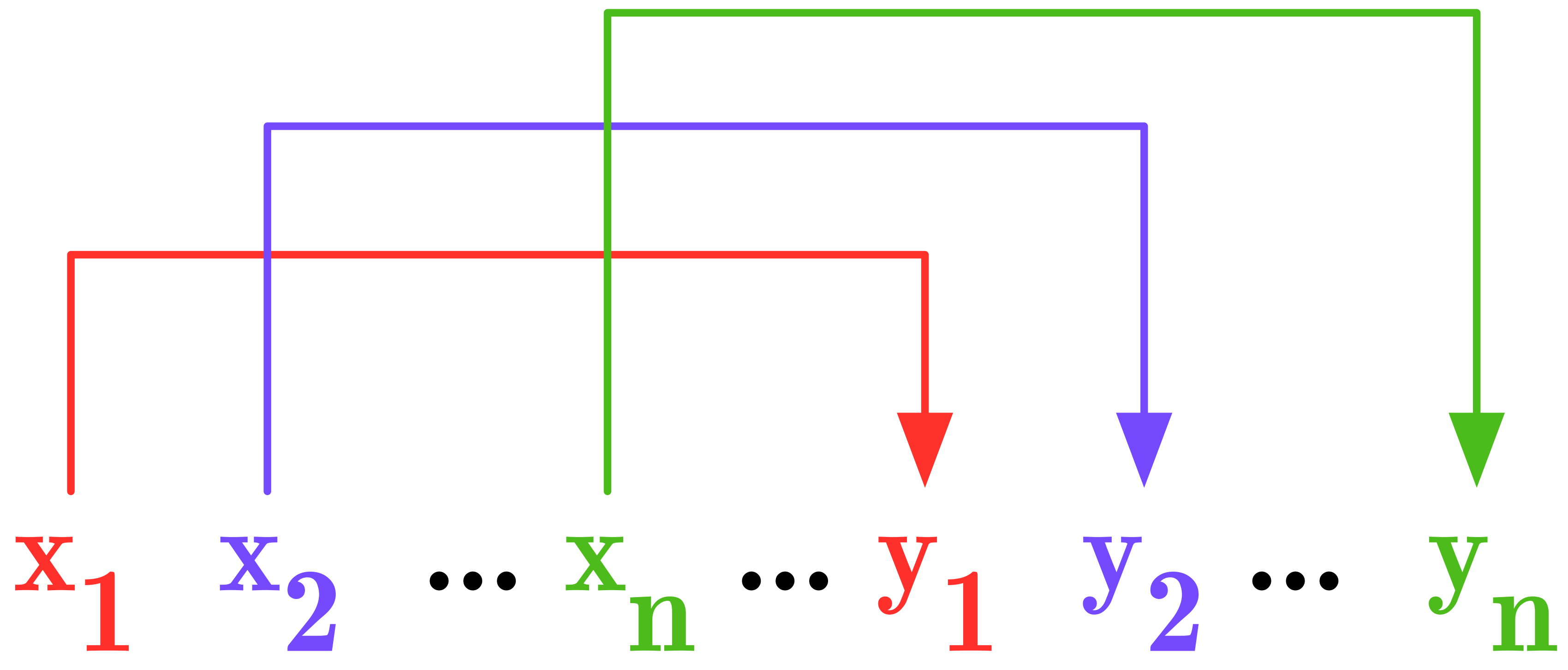
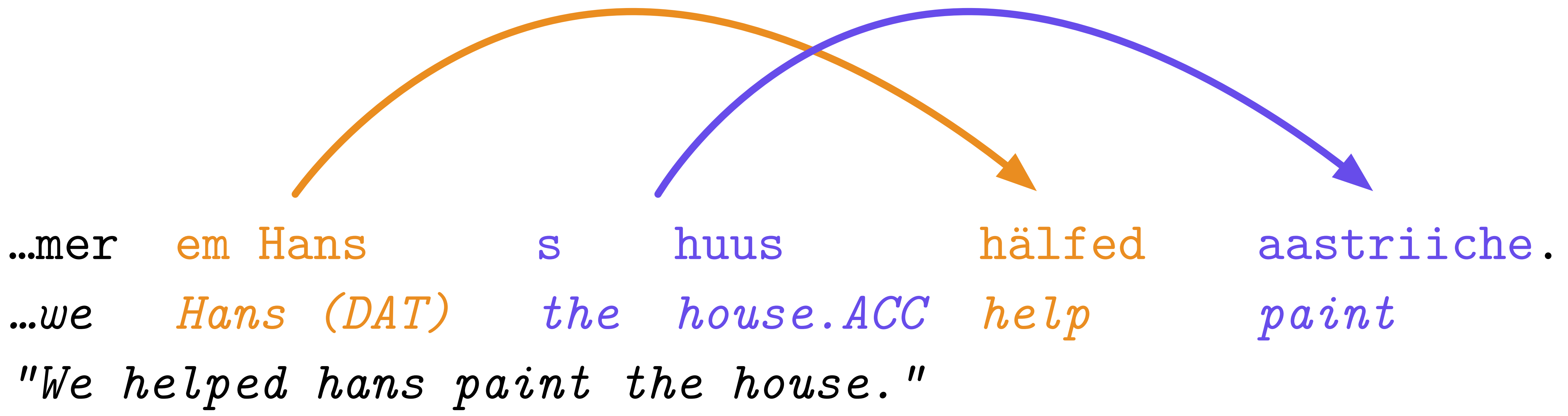
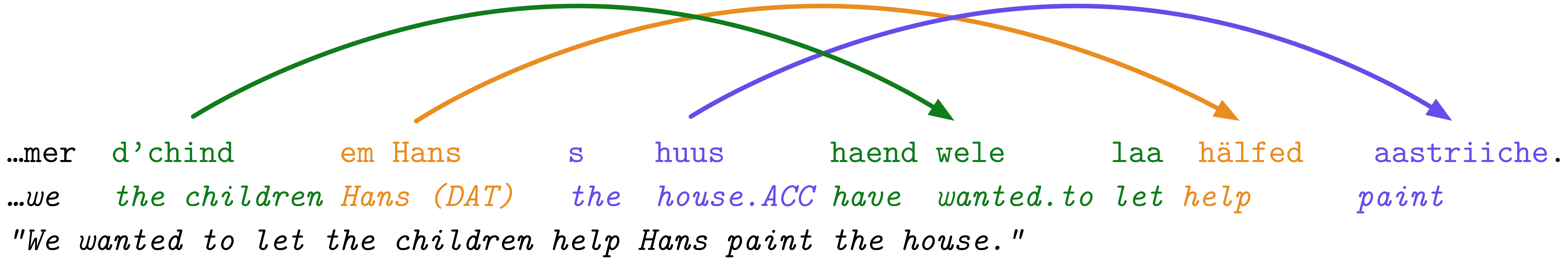
- …but do we need context-sensitivity?
  - Many articles have attempted to demonstrate we do
  - …many have failed.
- Solid proof for Swiss German: ***Cross-Serial Dependencies*** (Shieber, 1985)
  - $a^i b^j c^i d^j$



Context-Sensitive Example

- Verbs and their arguments must be ordered ***cross-serially***
  - Arguments and verbs must match





Questions so far?

HW#1 & Getting Started

LING 571 — Deep Processing Techniques for NLP
September 29, 2021
Shane Steinert-Threlkeld

Department Cluster

- Assignments are **required** to run on department cluster
  - If you don't have a cluster account, request one ASAP!
    - Link to account request form on Canvas or below:
    - vervet.ling.washington.edu/db/accountrequest-form.php
- You are not required to develop on the cluster, but code must run on it

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- You are not required to develop on the cluster, but code must run on it
- ***Reminder:*** *All but most simple tasks must be run via Condor*

Condor

- Parallel computing management system
- All homework will be run via condor
- See documentation on CLMS wiki for:
  - Construction of condor scripts
  - Link also on course page under “Course Resources”

NLTK

- Most assignments will use NLTK in Python
- **N**atural **L**anguage **T**ool**K**it (NLTK)
  - Large, integrated, fairly comprehensive
    - Stemmers
    - Taggers
    - Parsers
    - Semantic analysis
    - Corpus samples
    - …& More
  - Extensively documented
  - Pedagogically Oriented
    - Implementations Strive for Clarity
    - …sometimes at the expense of efficiency.

NLTK

- nltk.org
  - Online book
  - Demos of software
  - How-Tos for specific components
  - API information, etc.

Python & NLTK

- NLTK is installed on the Cluster
  - Use Python 3.4+ with NLTK
  - **N.B.:** Python 2.7 is default
    - Use: **`python3`** to run, not **`python`**
    - More versions in `/opt/python-*/bin/`
    - You can make a personal alias, but your bash scripts will not run in your personal environment, so keep that in mind (e.g. use full path).
- Data is also installed:
  - /corpora/nltk/nltk-data
- Written in Python
  - Some introductions at:
    - **python.org**, **docs.python.org**

Python & NLTK

- Interactive mode allows experimentation, introspection:

```
patas$ python3
>>> import nltk
>>> dir(nltk)
['AbstractLazySequence', 'AffixTagger', 'AlignedSent',
'Alignment', 'AnnotationTask', 'ApplicationExpression',
'Assignment', 'BigramAssocMeasures', 'BigramCollocationFinder',
'BigramTagger', 'BinaryMaxentFeatureEncoding',…
>>> help(nltk.AffixTagger)
```

Turning In Homework

- Will be using Canvas' file submission mechanism
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- 11:59 PM, Pacific Time
- Generally, each assignment will include:
  - `readme.{txt|pdf}`
  - `hwX.tar.gz`
    - Where "X" is the assignment number
    - **`tar -cvzf hwX.tar.gz <hw_path>`**

HW #1

- Read in sentences and corresponding grammar
- Use NLTK to parse those sentences
- Goals:
  - Set up software environment for rest of course
  - Get familiar with NLTK
  - Work with parsers and CFGs

HW #1: Useful Tools

- Loading data:
  - **`nltk.data.load(resource_url)`**
    - Reads in and processes formatted CFG/FCFG/treebank/etc
    - Returns a grammar from CFG
    - **examples:**

      ```
      nltk.data.load('grammars/sample_grammars/toy.cfg')
      nltk.data.load('file://' + my_grammar_path)
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    - (NB: absolute path!)

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- Tokenization:
  - **`nltk.word_tokenize(mystring)`**
    - Returns array of tokens in string

HW #1: Useful Tools

- Parsing:
  - **`parser = nltk.parse.EarleyChartParser(grammar)`**
    - Returns parser based on the grammar
  - **`parser.parse(token_list)`**
    - Returns iterator of parses:

```
>>> for item in parser.parse(tokens):
>>>     print(item)

(S (NP (Det the) (N dog)) (VP (V chased) (NP (Det the) (N cat))))
```