

# 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

# 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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  - Question: Can judge tell which contestant is human?
- *Crucially:*
  - Posits that passing requires language use and understanding

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- ELIZA ([Weizenbaum, 1966](#)) [[Try it Online](#)]



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- Simple pattern matching technique

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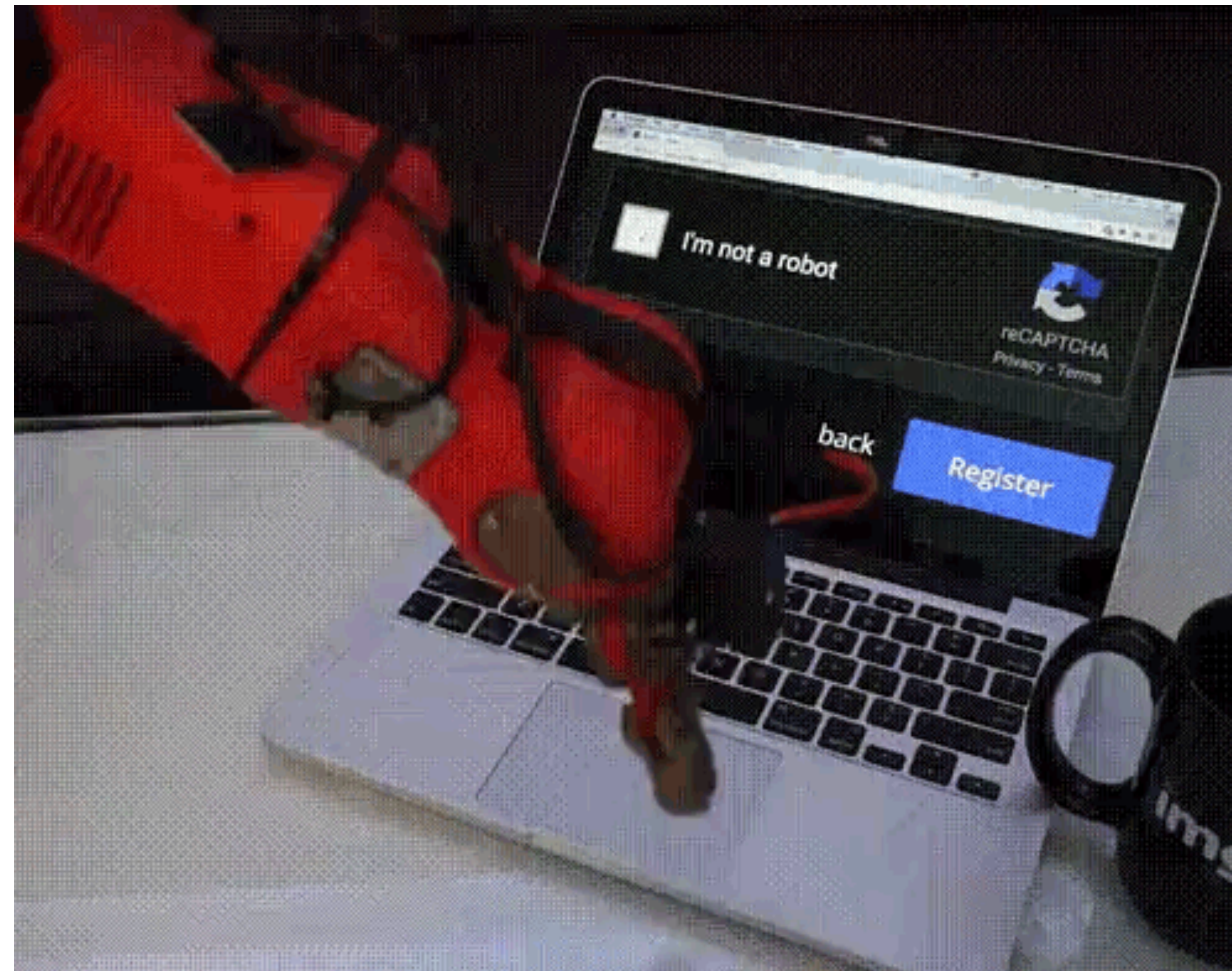
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  - Long-term: Inspires “arms race”

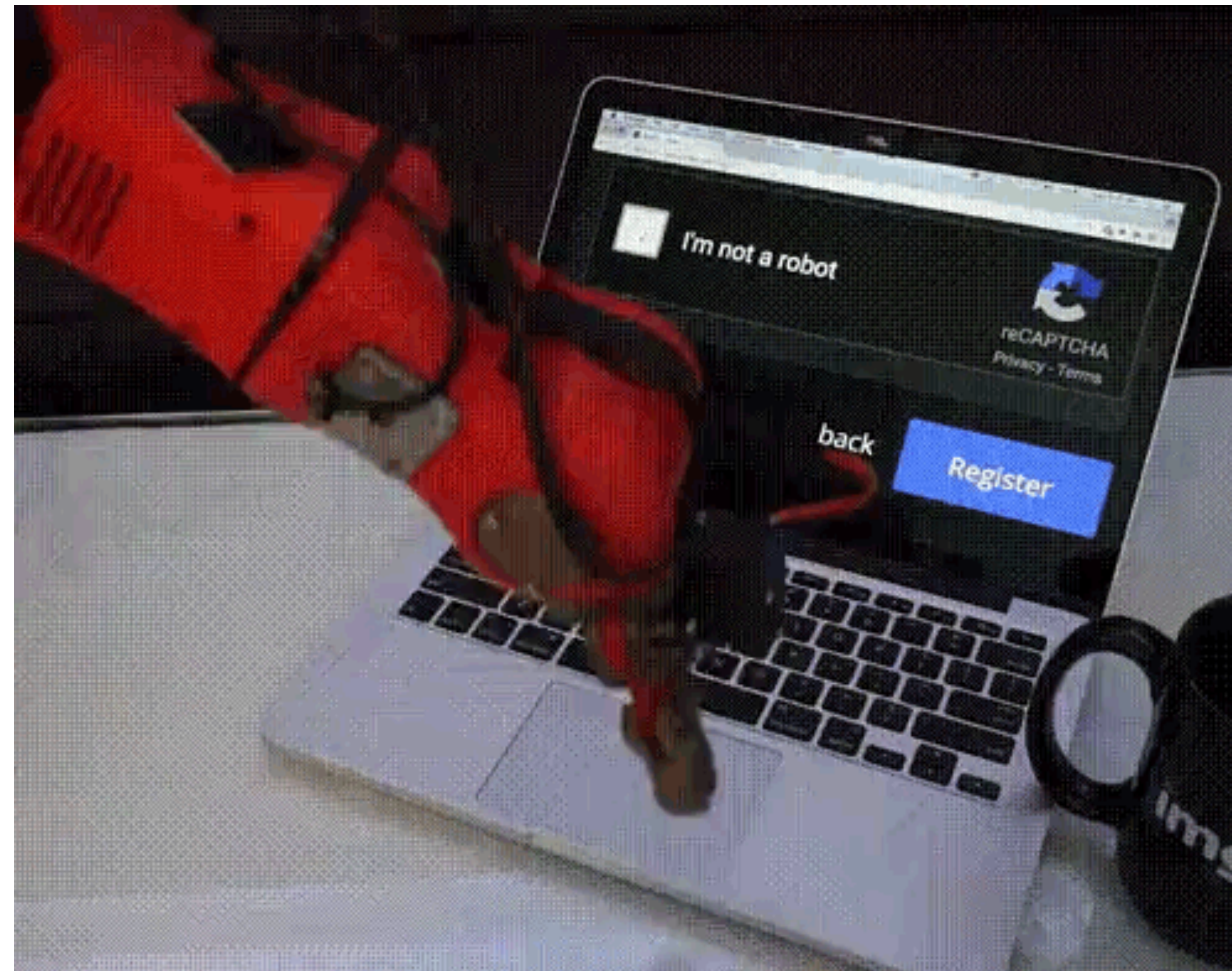


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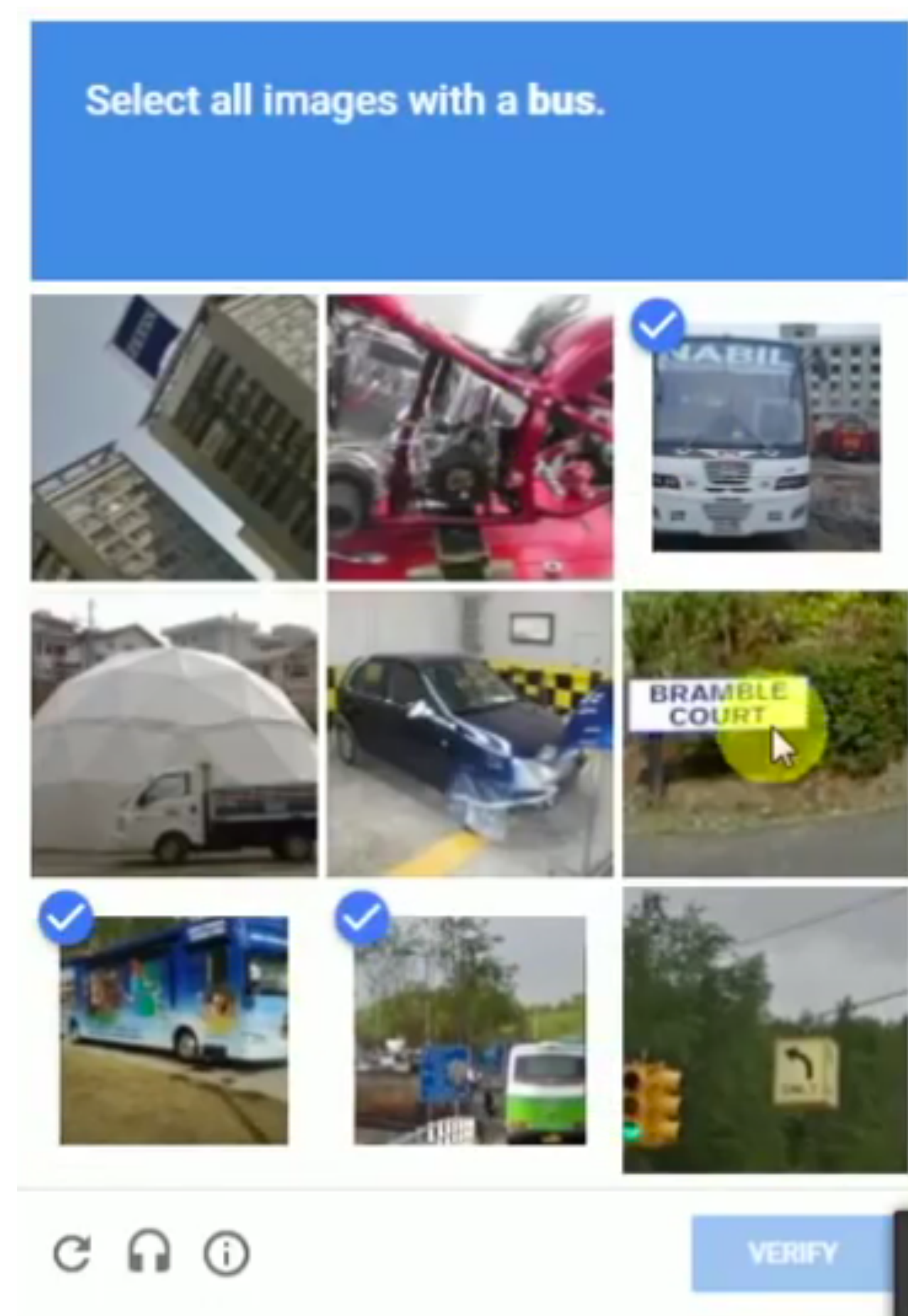
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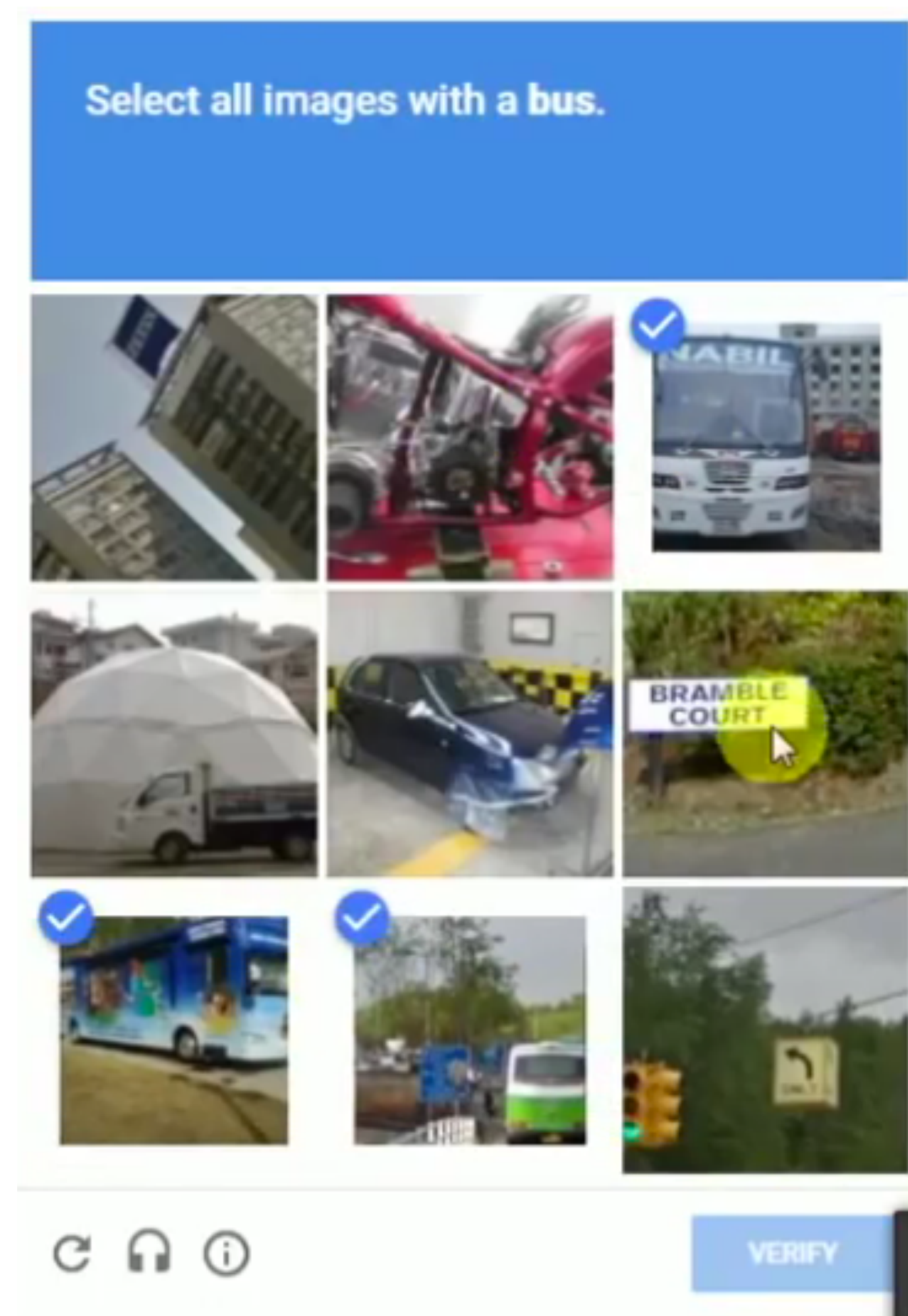
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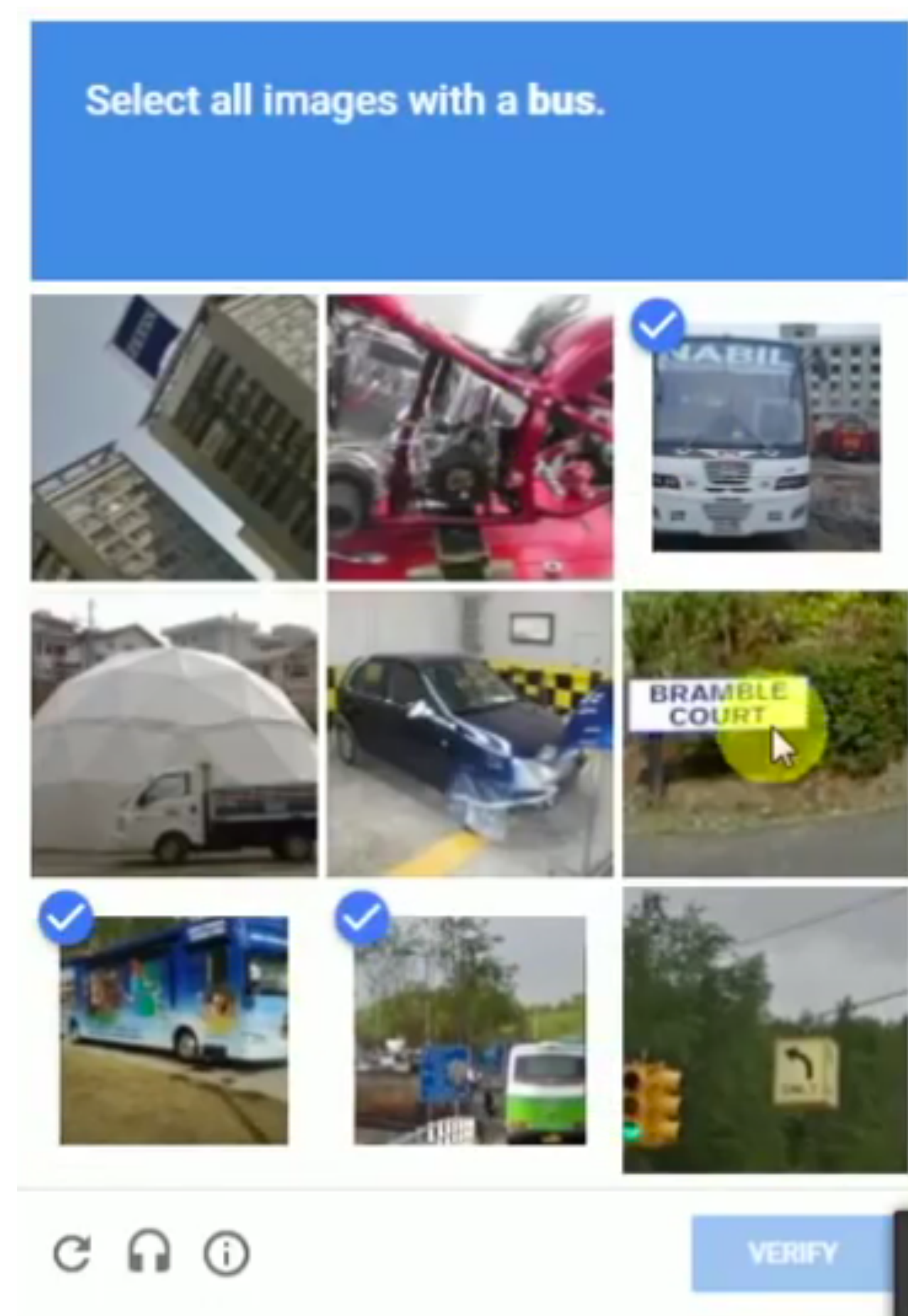




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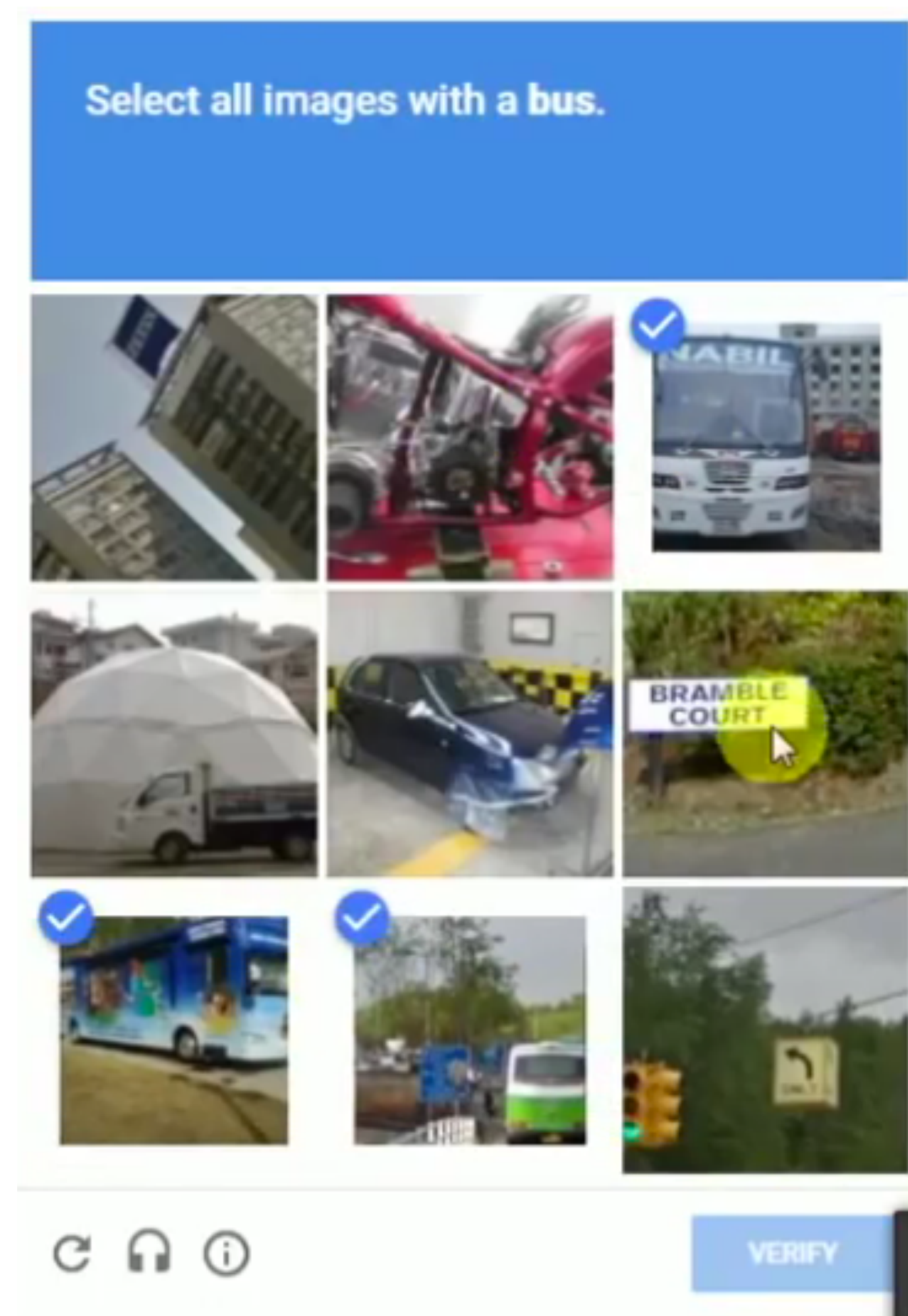
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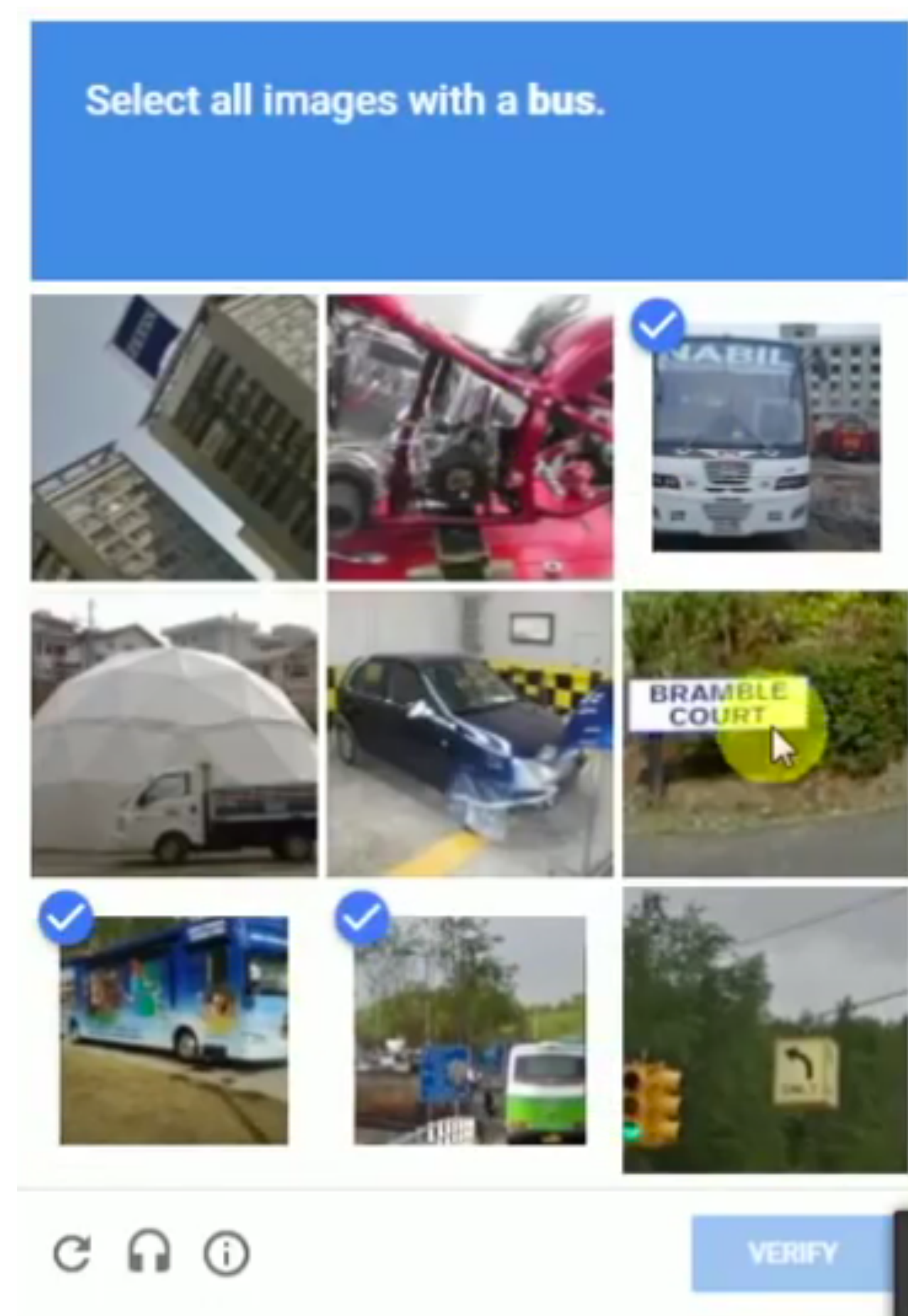




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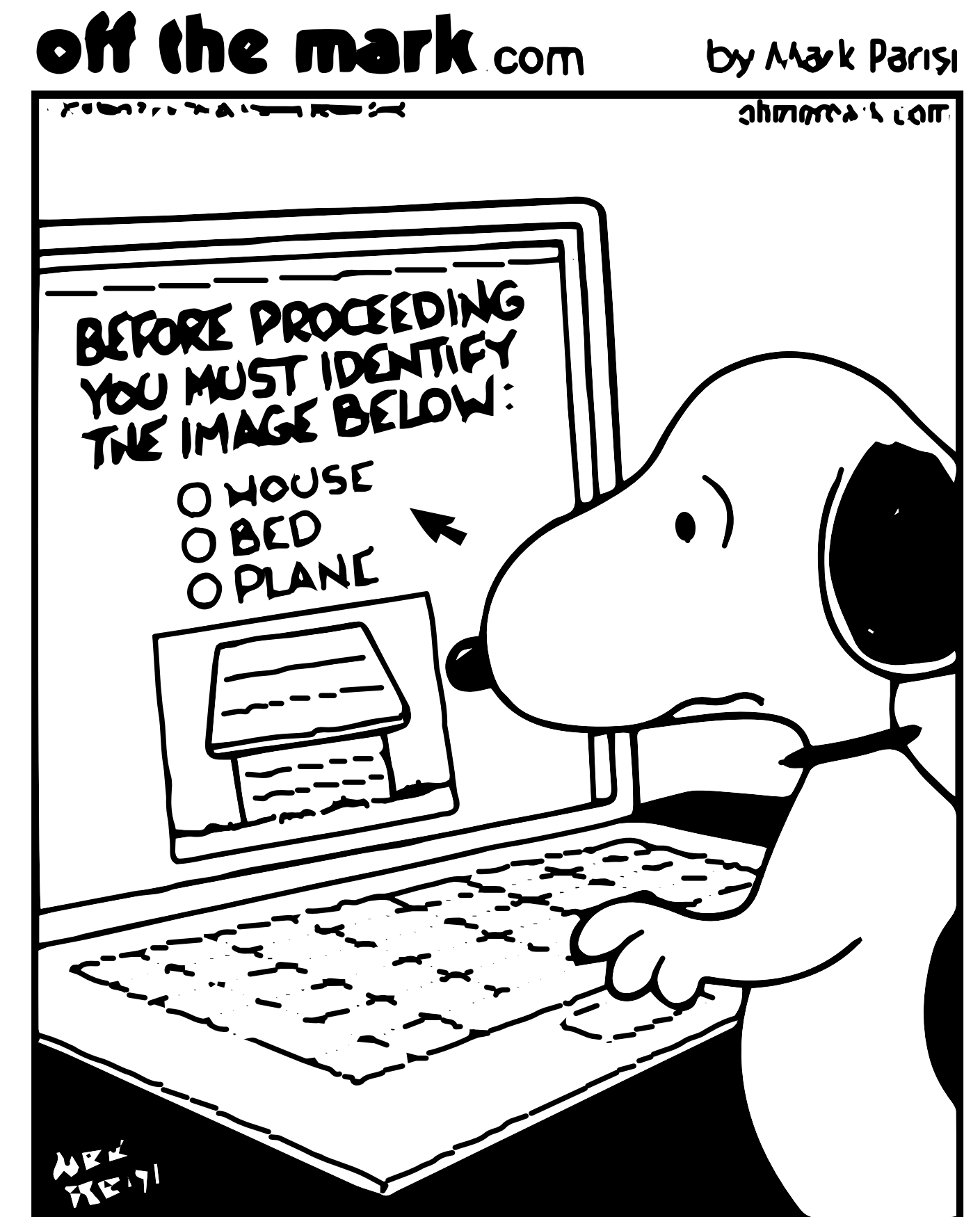
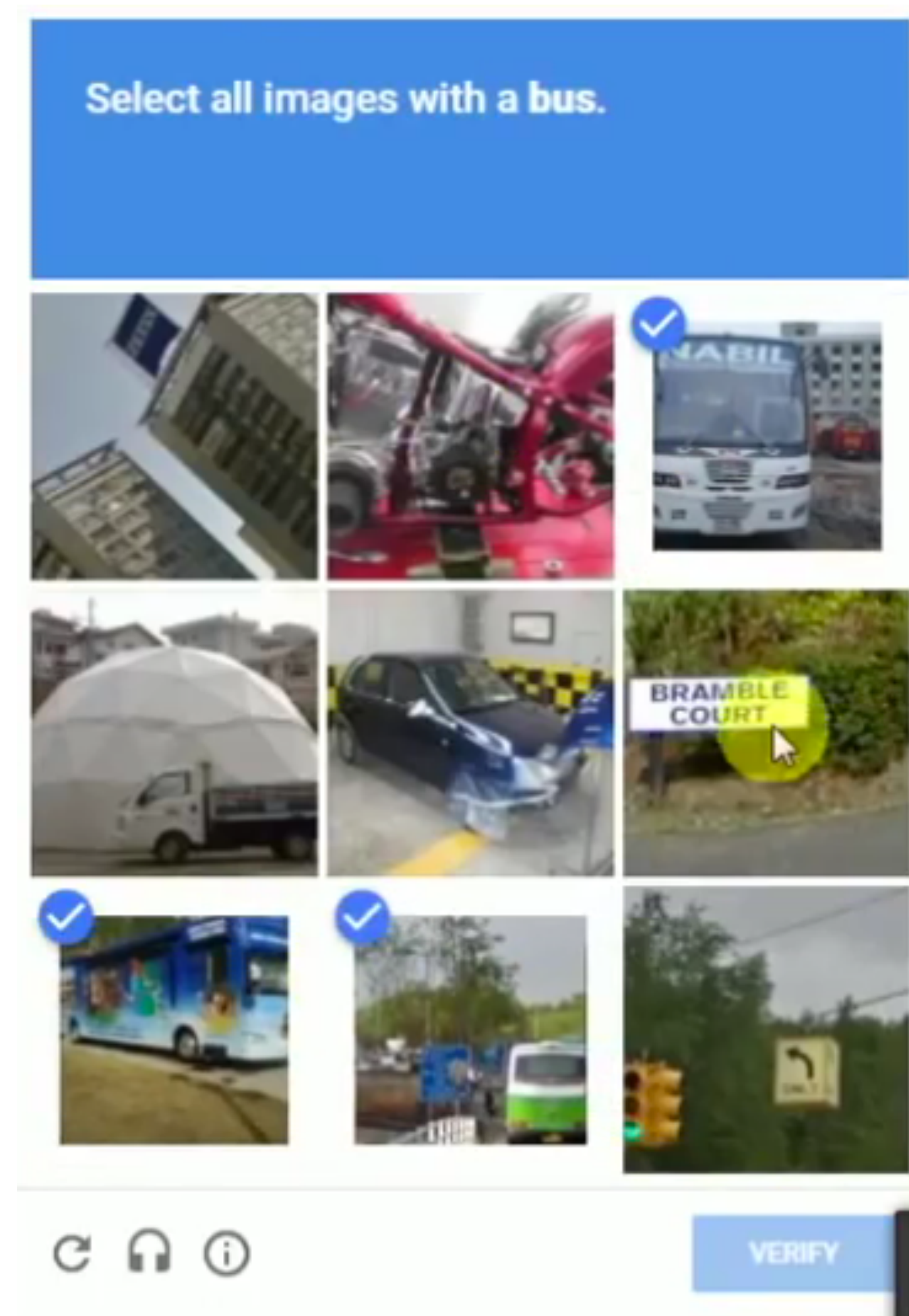
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# Knowledge of Language

- NLP vs. Data Processing
- POSIX command “wc”
  - Counts total number of bytes, words, and lines in text file
  - bytes and lines → data processing
  - words → *what do we mean by “word”?*

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- 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:  $\text{Door} + \text{sg} \rightarrow \text{"door"}$      $\text{Door} + \text{pl} \rightarrow \text{"doors"}$

- Verb inflection:  $\text{be} + \text{1st Person} + \text{sg} + \text{present} \rightarrow \text{"am"}$

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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

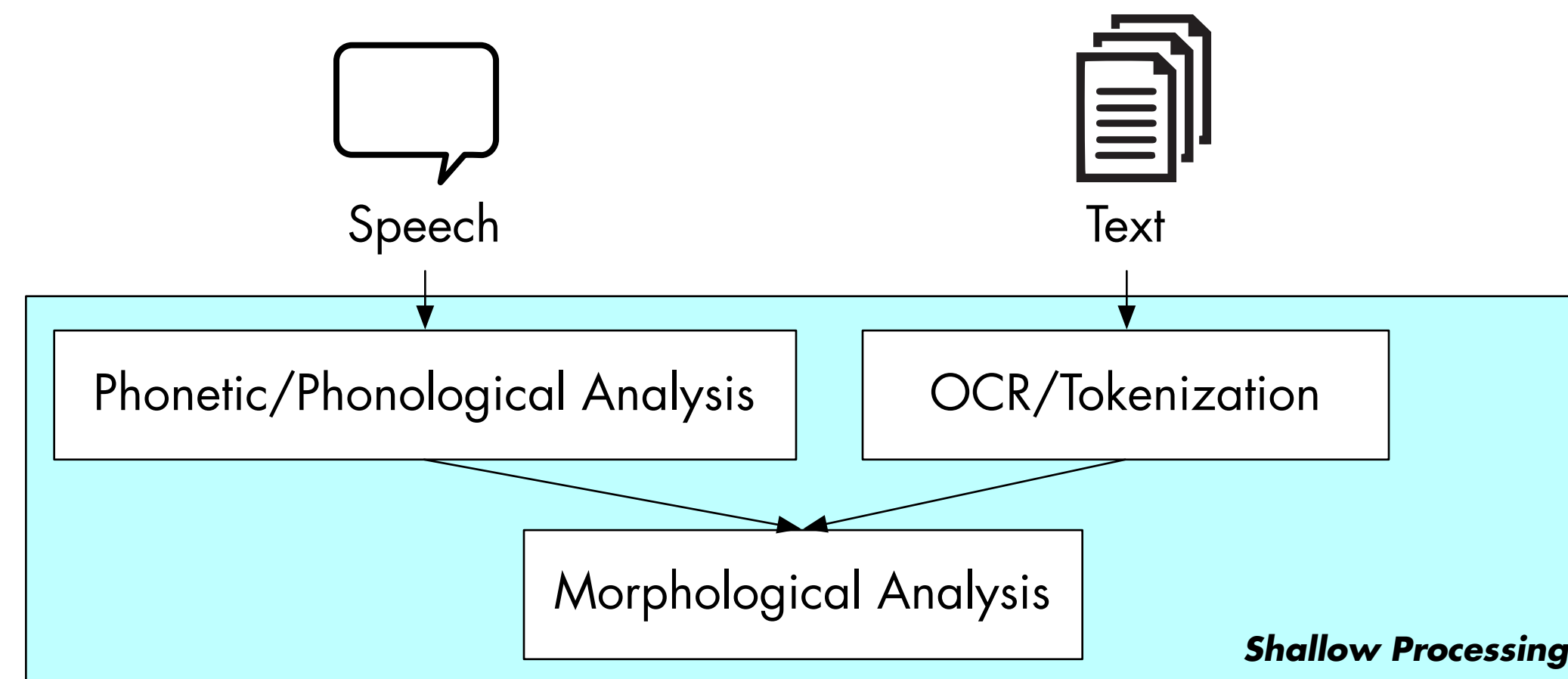
- Shallow processing (LING 570)
  - ***Less elaborate*** linguistic representations
    - Usually relies on surface forms (e.g. words)
  - Examples: HMM POS-tagging; FST morphology

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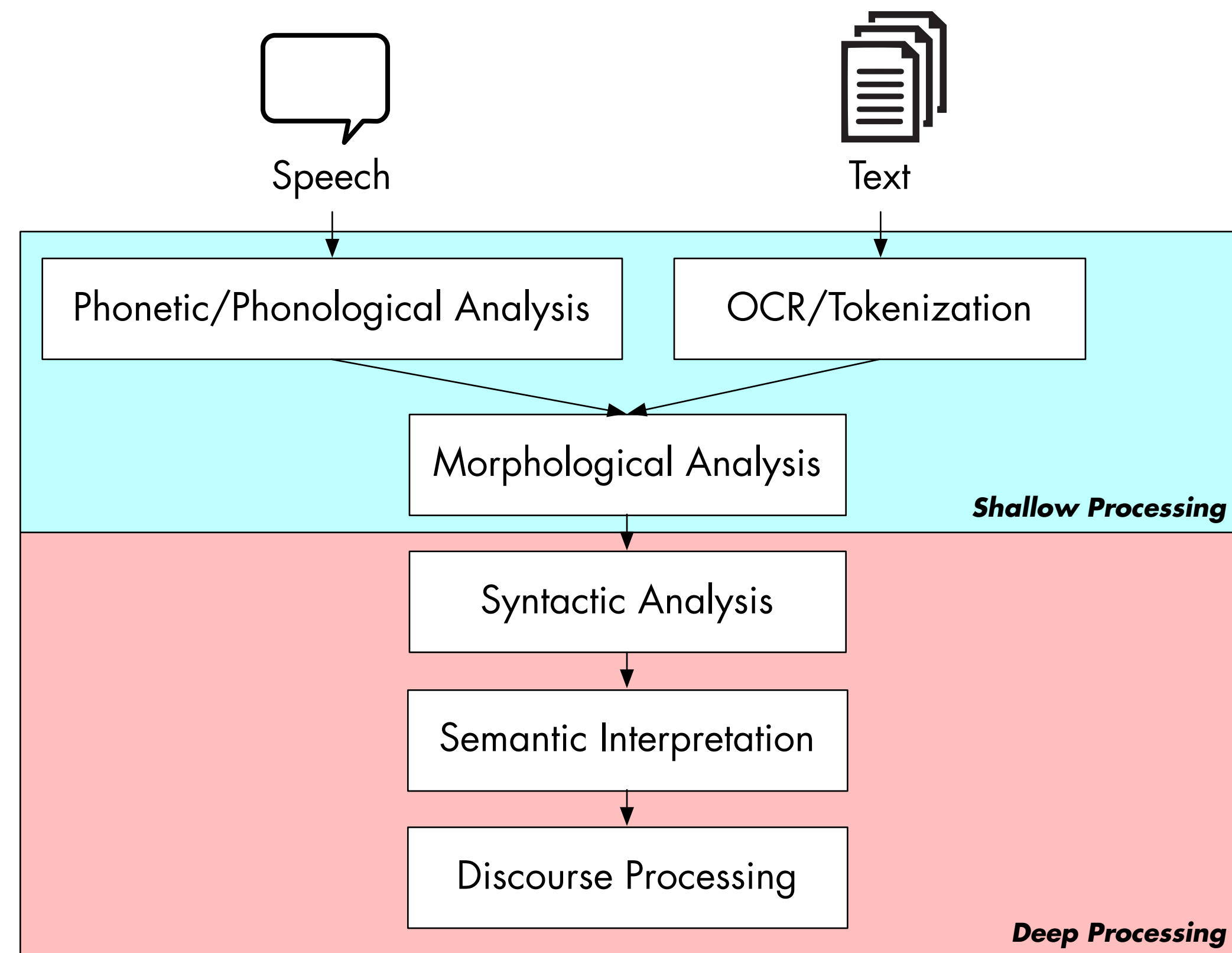
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  - Examples: HMM POS-tagging; FST morphology
- Deep processing (LING 571)
  - Relies on **more elaborate** linguistic representations
    - Deep syntactic analysis (Parsing)
    - Rich spoken language understanding (NLU)

# Language Processing Pipeline





# Language Processing Pipeline



# A Note On “Depth”

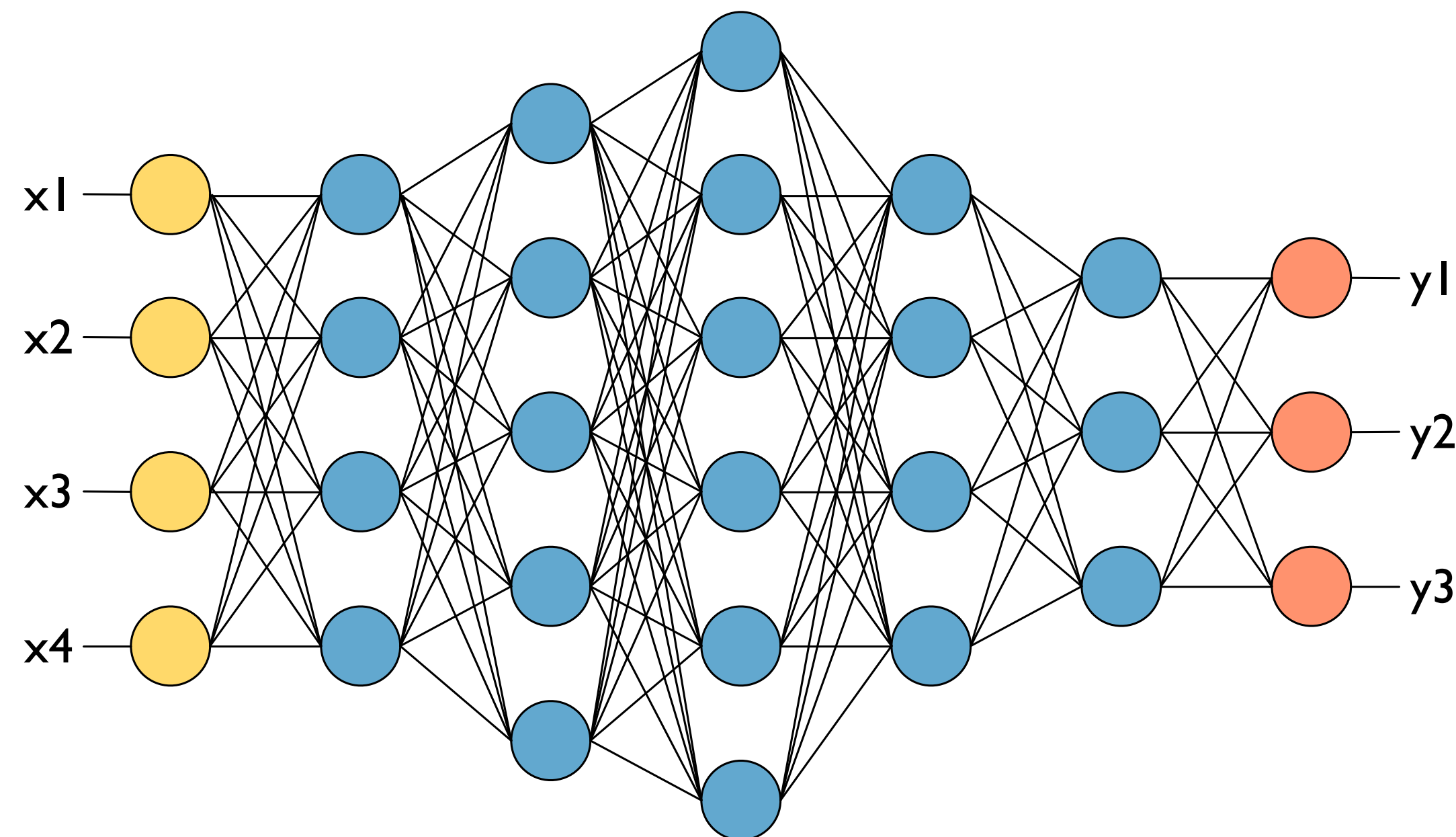
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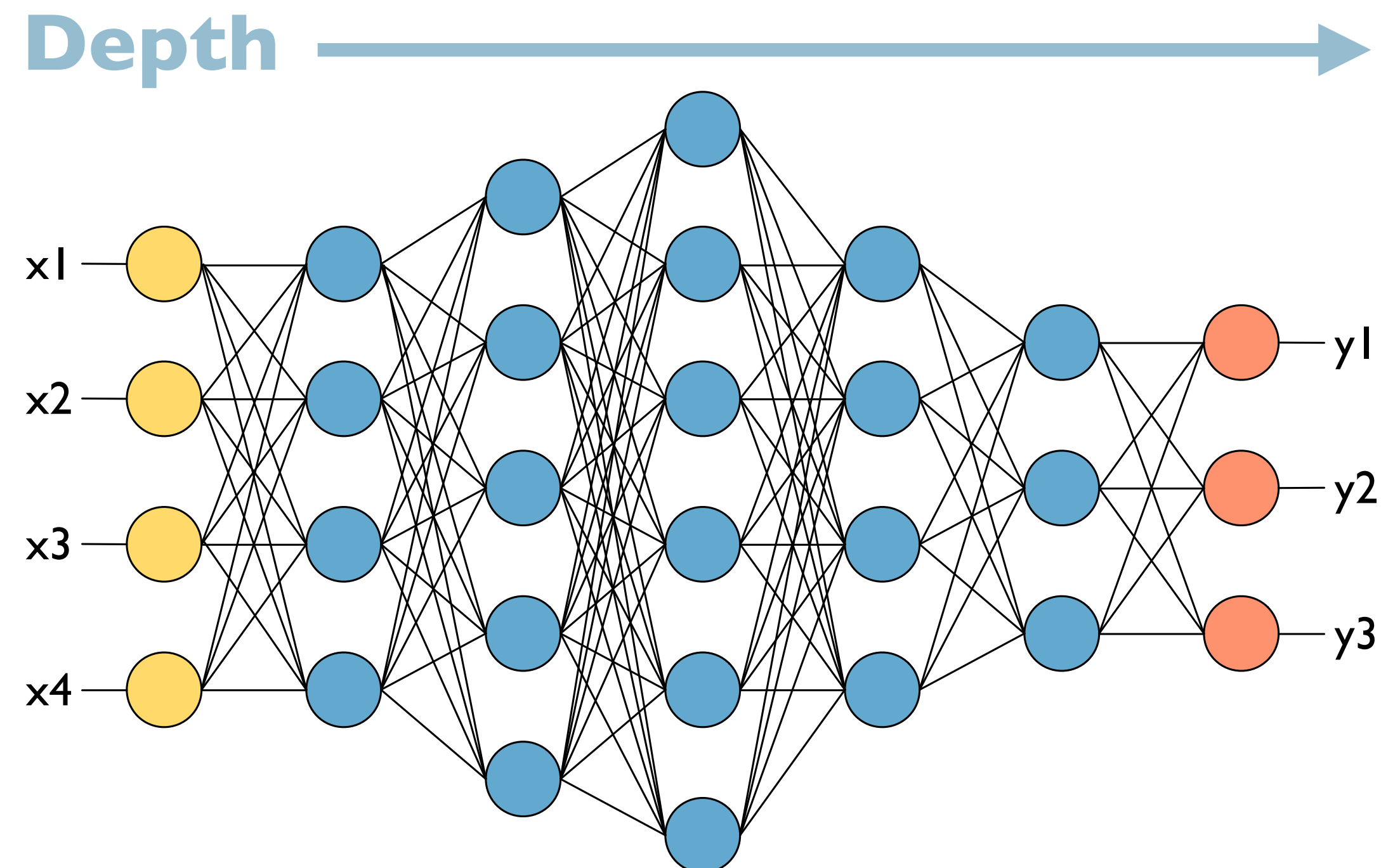
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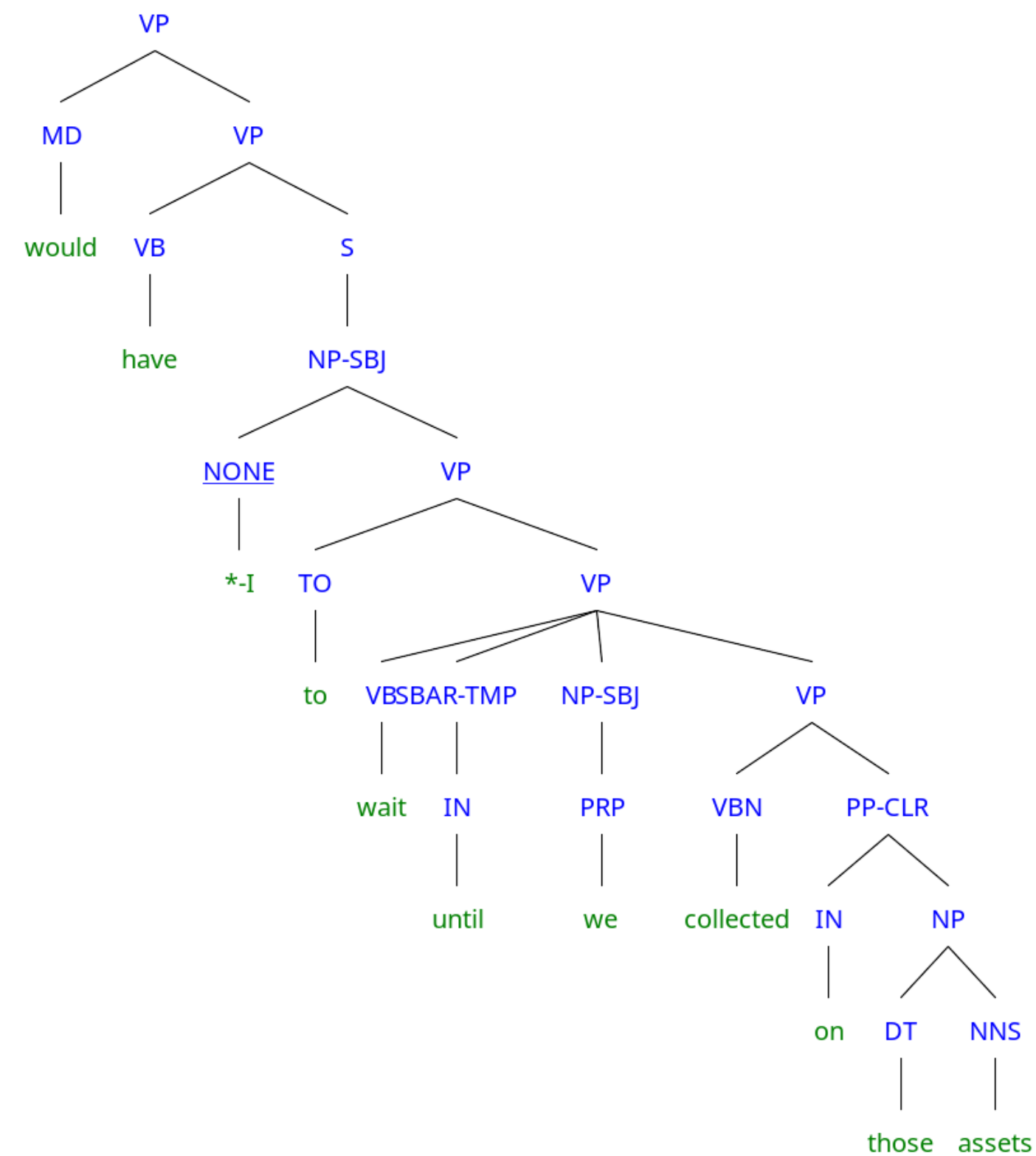
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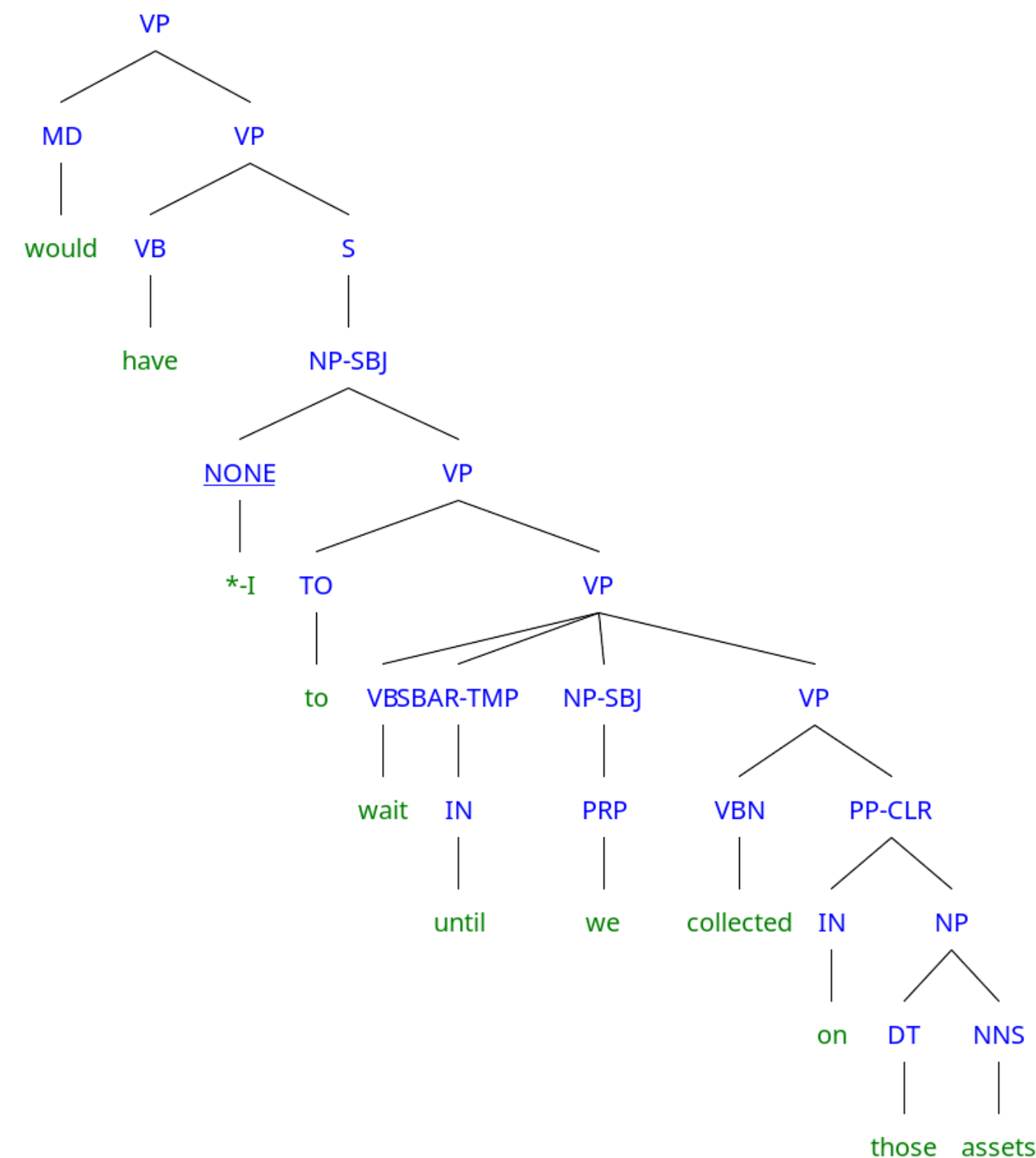
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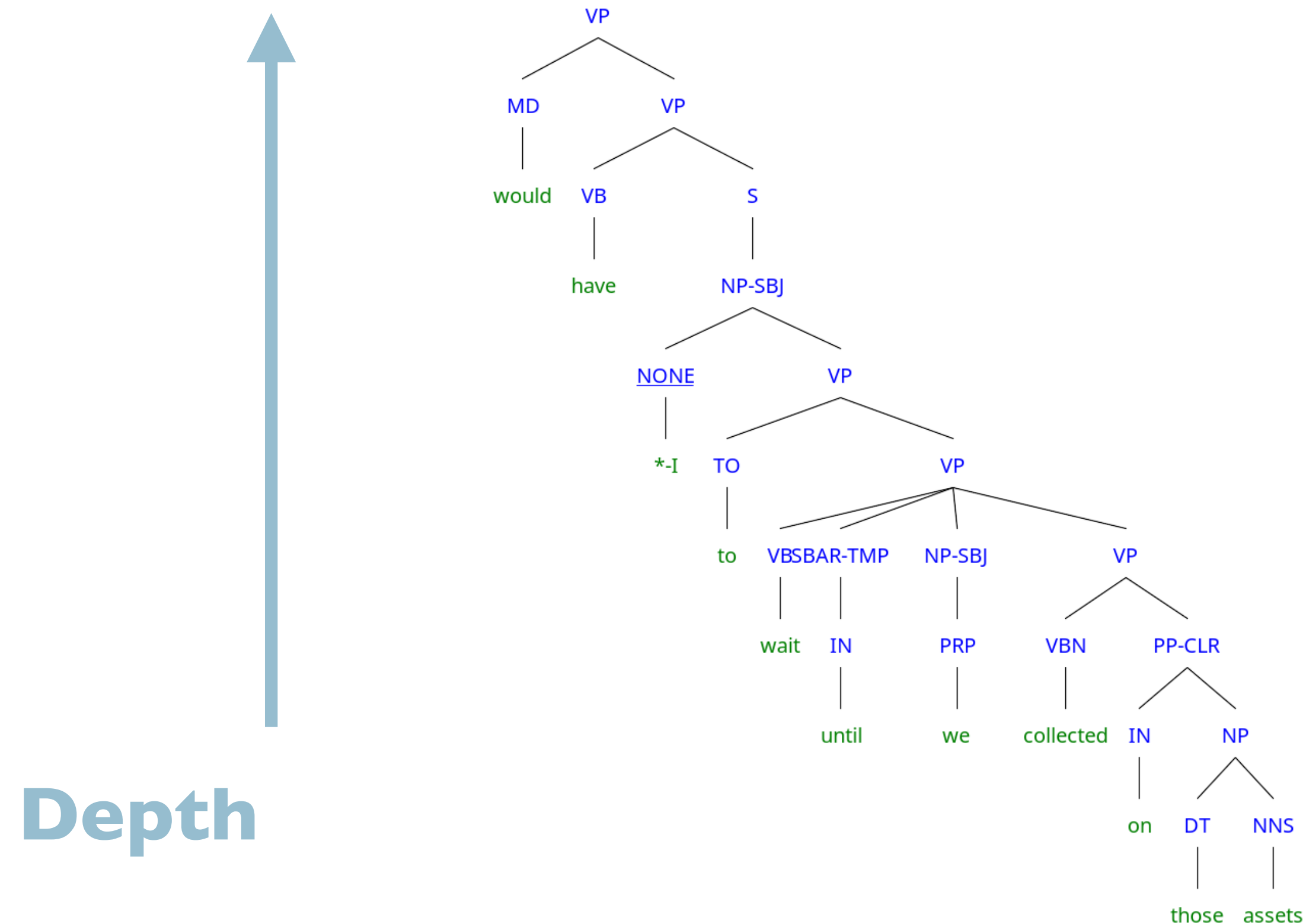
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- In both paradigms, graph depth aids, but  $\Rightarrow$  abstraction

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- **Ambiguity**
  - How can we select from among alternative analyses?



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# Cross-cutting Themes

- **Ambiguity**
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- **Evaluation**
  - How well does this approach perform:
    - On a standard data set?
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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.
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  - I magically turned her into a duck.



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VERB

NOUN

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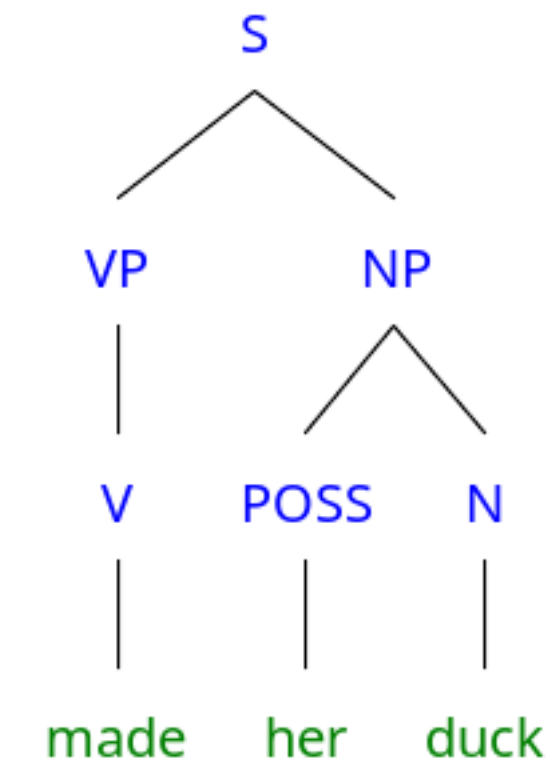
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POSS

PRON

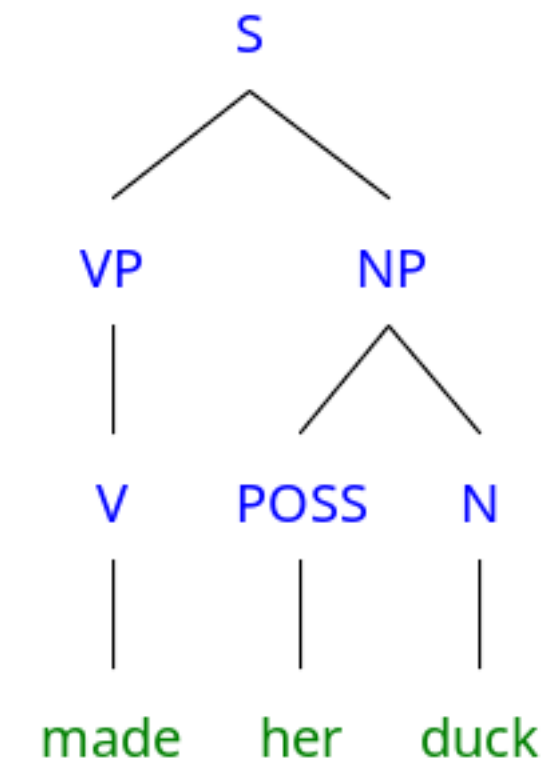
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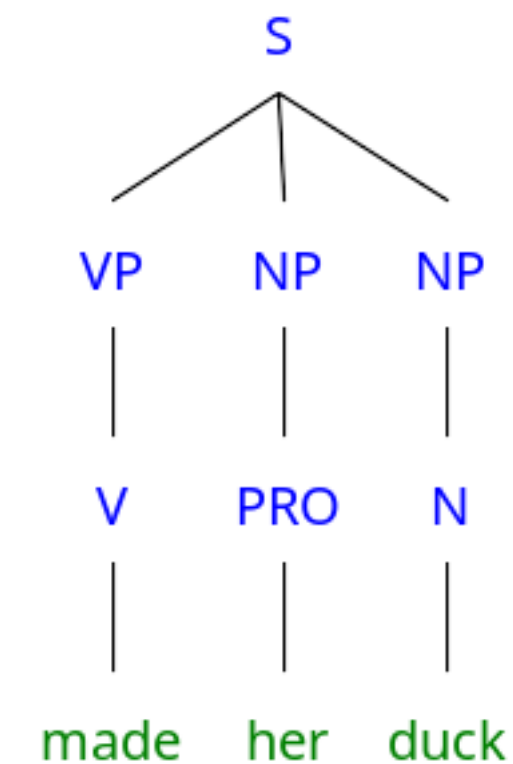


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<i>I magically turned her into a duck</i>	<b>made</b> = [AG] <b>transformed</b> [TH] <b>duck</b> = <b>animal</b>

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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.

# Syntax Crash Course

LING 571 — Deep Processing Techniques for NLP

September 30, 2020

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# 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

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  - 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

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- Choice of structure can impact:
  - 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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- **Phrases:**
  - Noun Phrase (NP)
  - Verb Phrase (VP)
  - Prepositional Phrase (PP)
  - ...
- Single unit: type determined by “head”
  - e.g. N heads NP

# Representing Sentence Structure

- Basic Units
  - Phrases (**NP**, **VP**, etc...)
  - Capture constituent structure

# Representing Sentence Structure

- Basic Units
  - Phrases (**NP**, **VP**, etc...)
  - Capture constituent structure
- Subcategorization
  - (**NP**-**SUBJ**, **VP**-**INTRANS**, etc...)
  - Capture argument structure
    - Components expected by verbs

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    - Components expected by verbs
- Hierarchical

# Representation: Context-free Grammars

- CFGs: 4-tuple
  - A set of **terminal** symbols:  $\Sigma$ 
    - [think: words]
  - A set of **nonterminal** symbols:  $N$ 
    - [think: phrase categories]
  - A set of **productions**  $P$ :
    - of the form  $A \rightarrow \alpha$
    - 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...*

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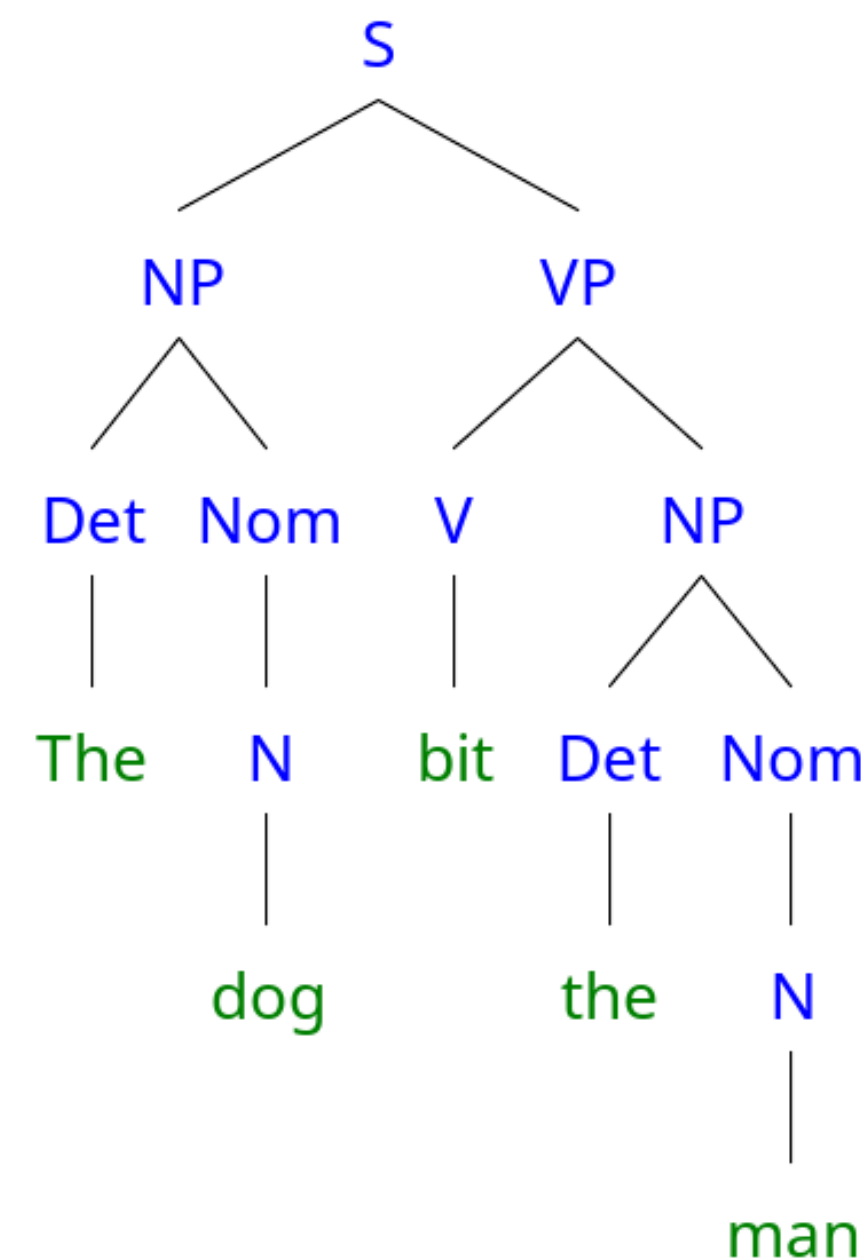
- **Non-terminals**

- 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:
  - $\Sigma$ : *the, cat, dog, bit, bites, man*
  - $N$ : NP, VP, Nom, Det, V, N, Adj
  - $P$ :
    - $S \rightarrow NP VP$ ;
    - $NP \rightarrow Det Nom$ ;
    - $Nom \rightarrow N Nom \mid N$ ;
    - $VP \rightarrow V NP$ ;
    - $N \rightarrow cat$ ;  $N \rightarrow dog$ ;  $N \rightarrow man$ ;
    - $Det \rightarrow the$ ;
    - $V \rightarrow bit$ ;  $V \rightarrow bites$
  - $S$ : S



# Parsing Goals

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

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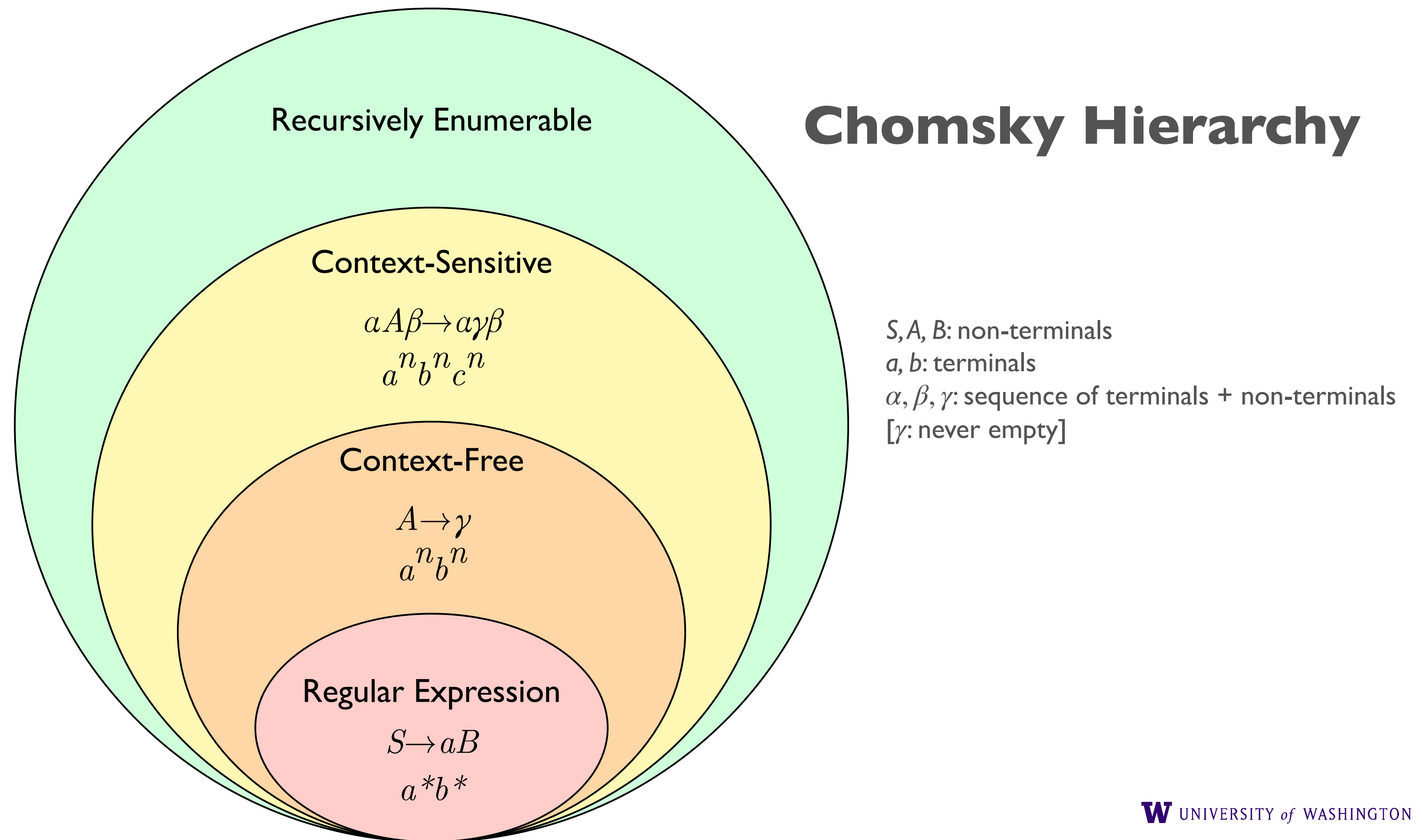
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- Analysis
  - What structure produced the string
    - Produce one (or all) parses for the string

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- Acceptance
  - 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



# 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.)
  - Allows recursion:

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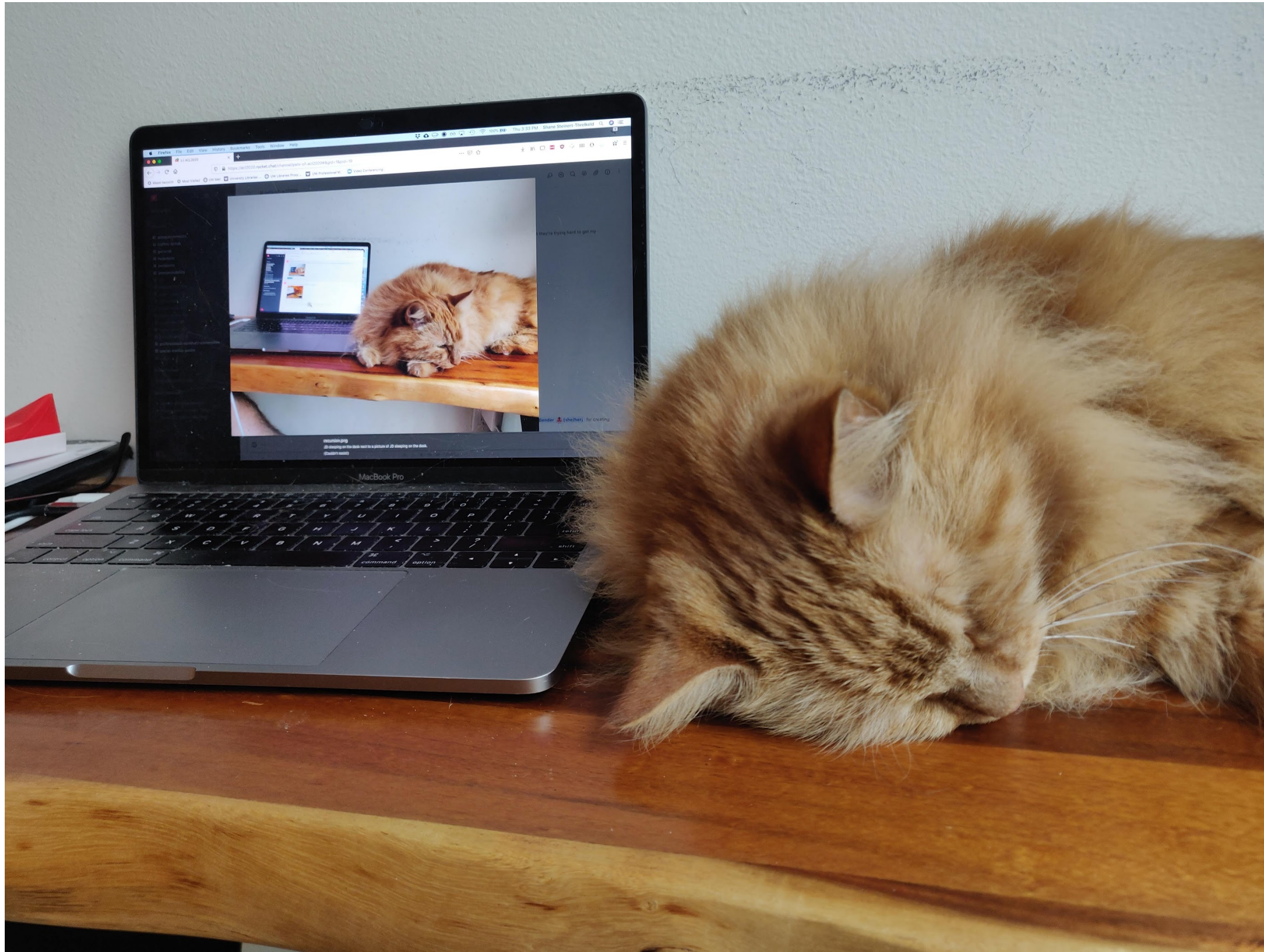
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    - The luggage that the passengers checked arrived
    - The luggage that the passengers whom the storm delayed checked arrived

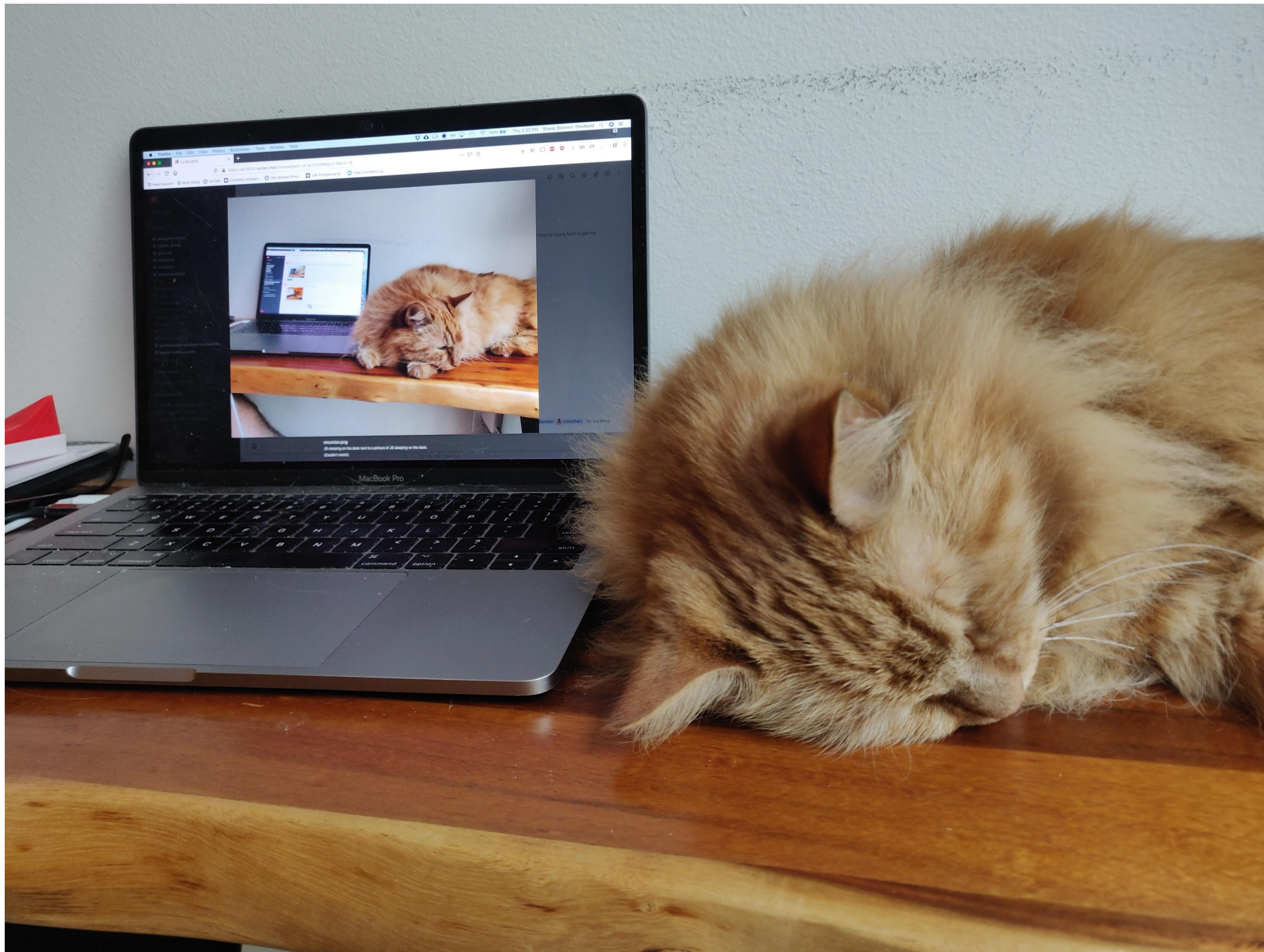


# Recursion in Grammar





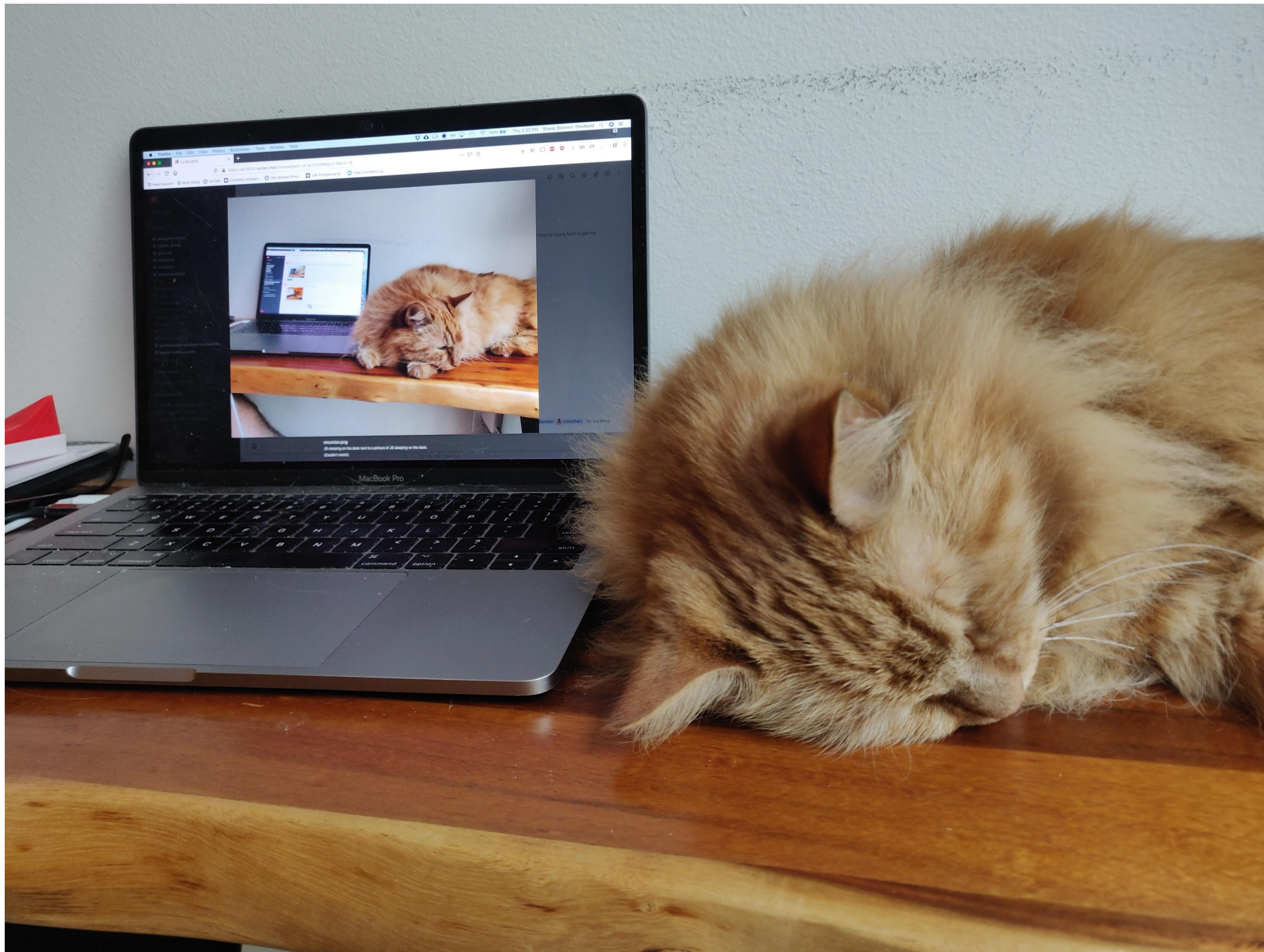
# Recursion in Grammar



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



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.

Exercise: write a toy grammar for producing this sentence!



# Is Context-Free Enough?

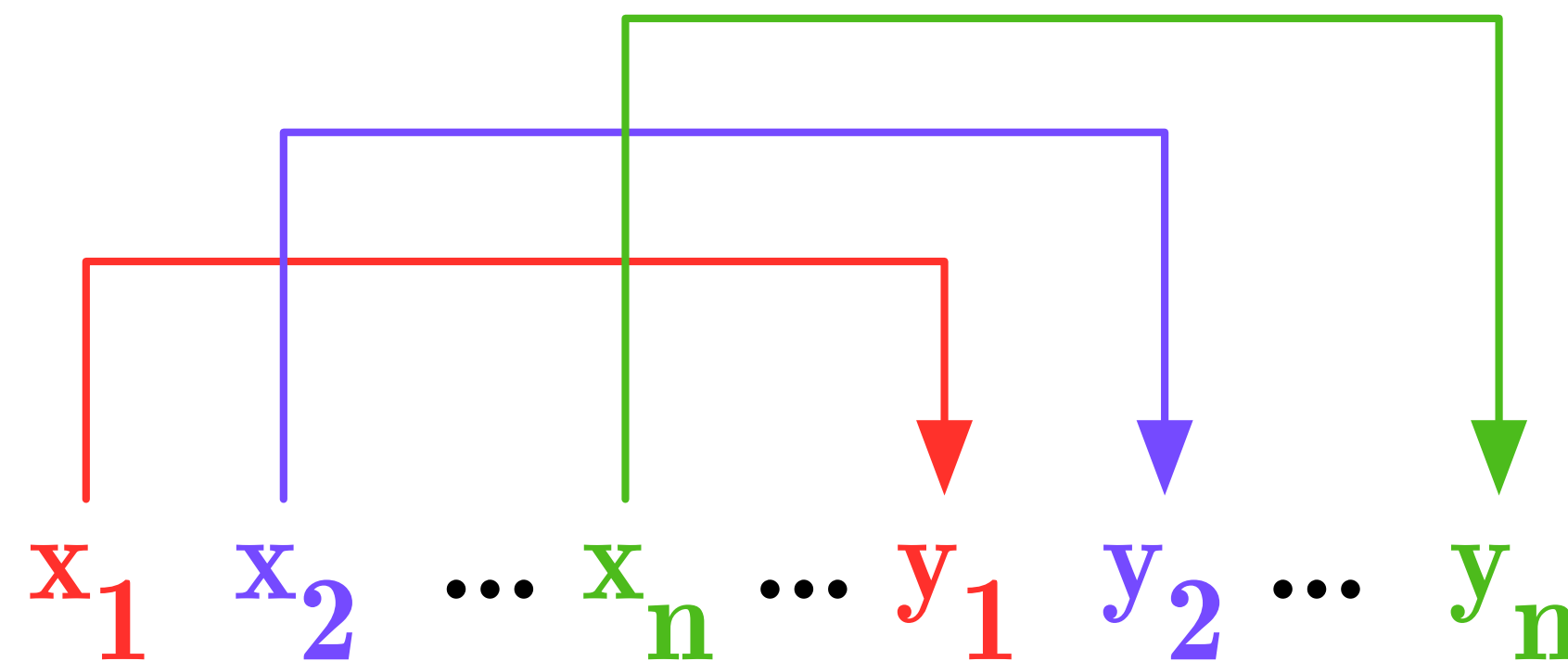
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  - Many articles have attempted to demonstrate we do
  - ...many have failed.

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- Natural language not finite state
- ...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'ib'ic'di*





# Context-Sensitive Example

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

...mer em Hans s huus hjälfed aastriiche.  
...we Hans (DAT) the house.ACC help paint  
"We helped hans paint the house."

...mer d'chind em Hans s huus haend wele laa hjälfed aastriiche.  
...we the children Hans (DAT) the house.ACC have wanted.to let help paint  
"We wanted to let the children help Hans paint the house."

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](http://vervet.ling.washington.edu/db/accountrequest-form.php)
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- ***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
- **Natural Language ToolKit (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](http://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](https://python.org), [docs.python.org](https://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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- Homeworks due on **Wednesday** nights
- 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')`
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  - (NB: absolute path!)



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    - (NB: absolute path!)
- 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))))
```