Introduction

LING 571 — Deep Processing Techniques for NLP

September 28, 2022

Shane Steinert-Threlkeld

Roadmap

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

How are you feeling about the start of the quarter and a new academic year generally?

Total Results: 0

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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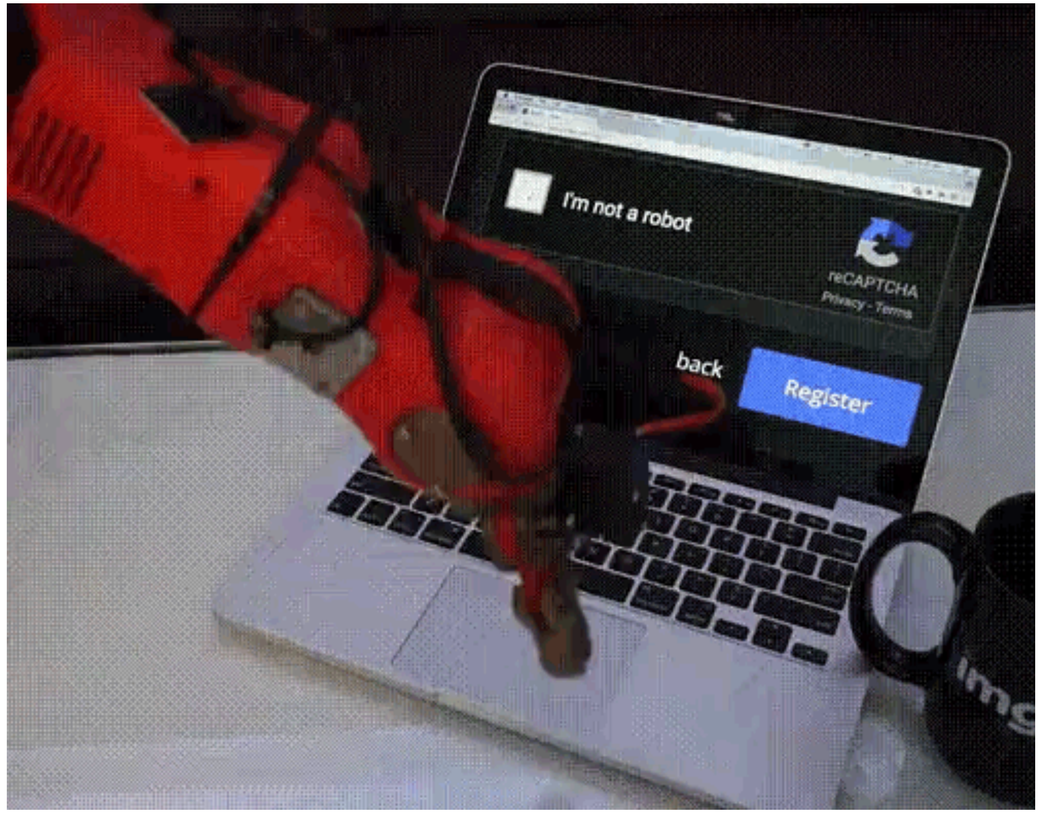
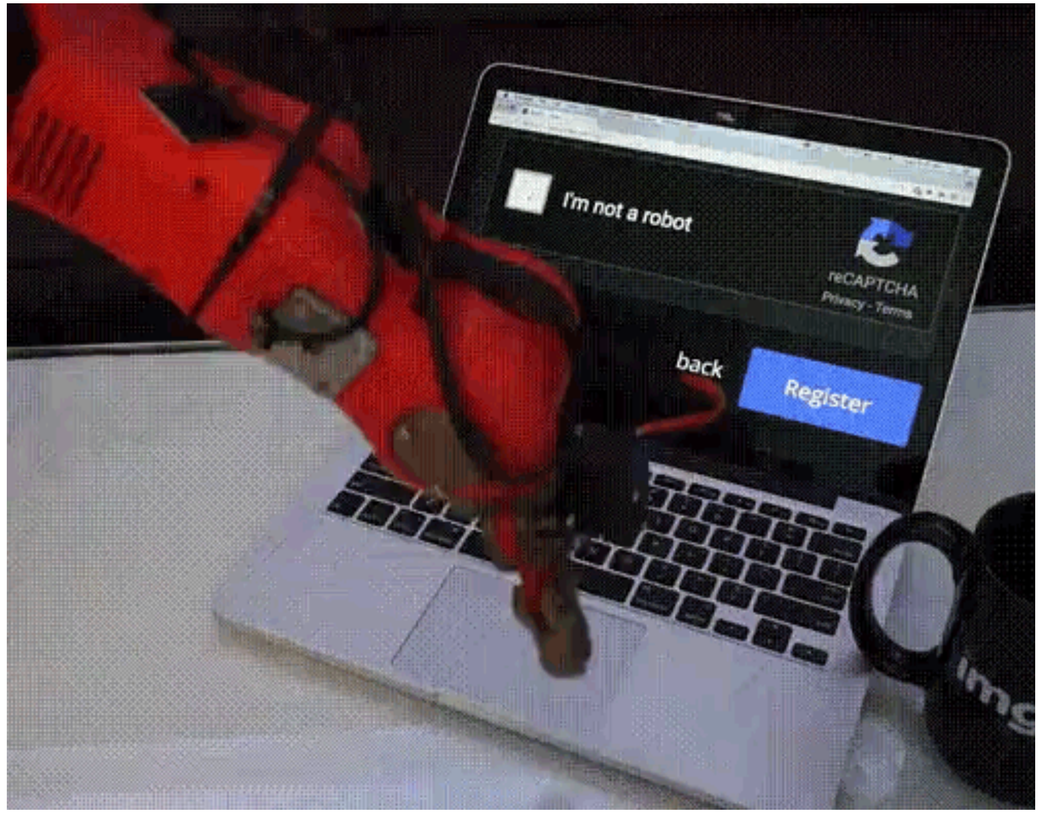
  - Long-term: Inspires "arms race"

CAPTCHA arms race



CAPTCHA arms race



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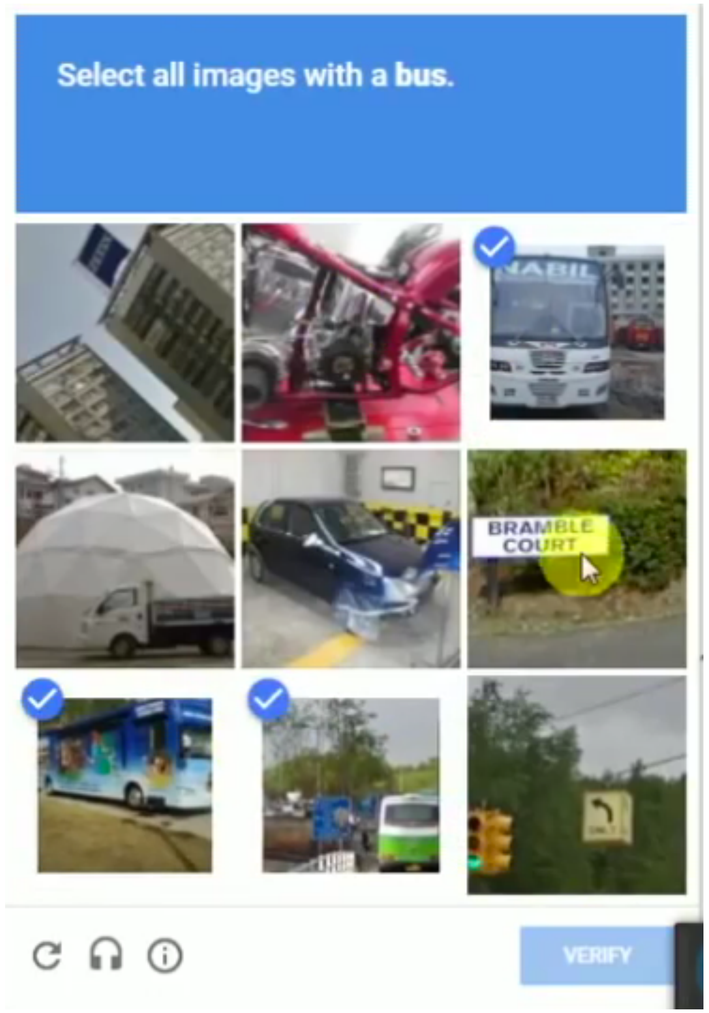

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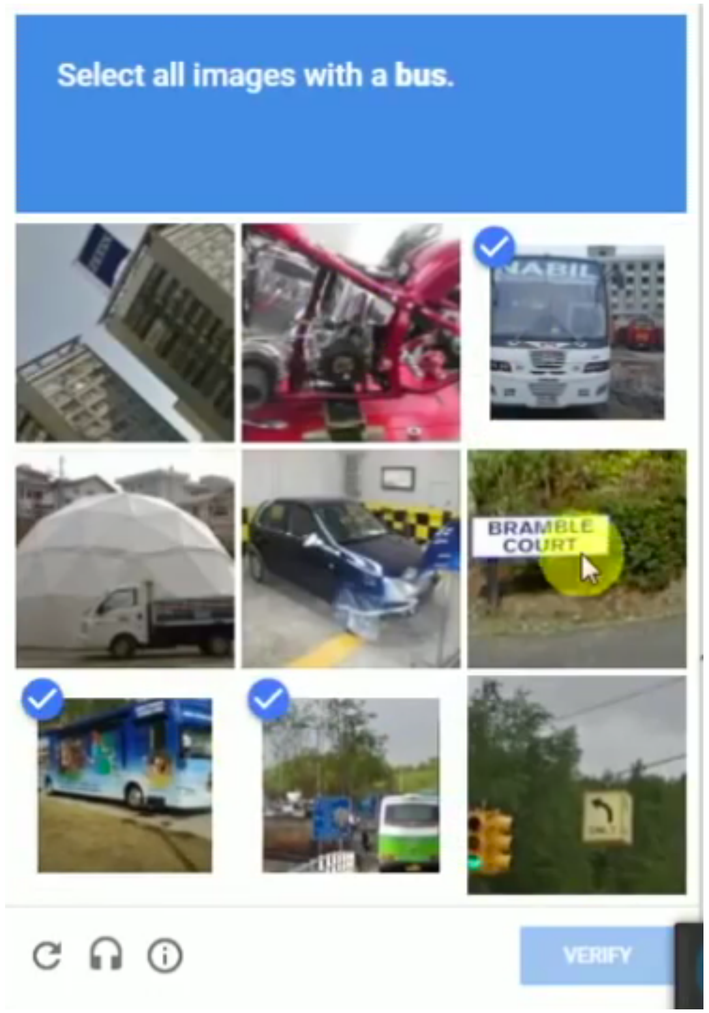

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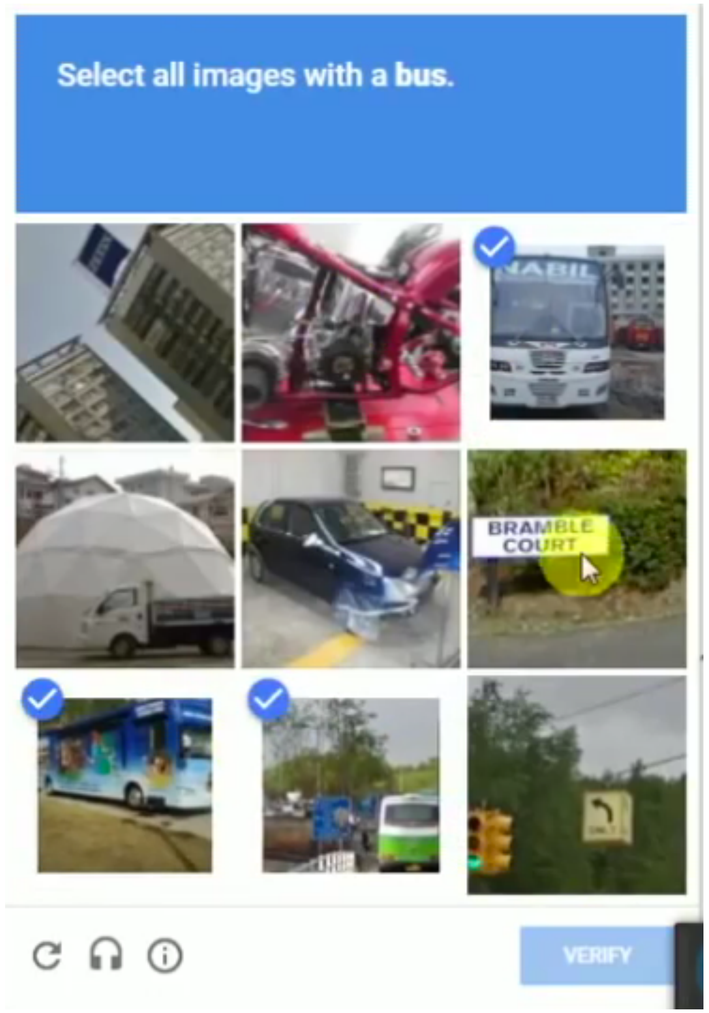

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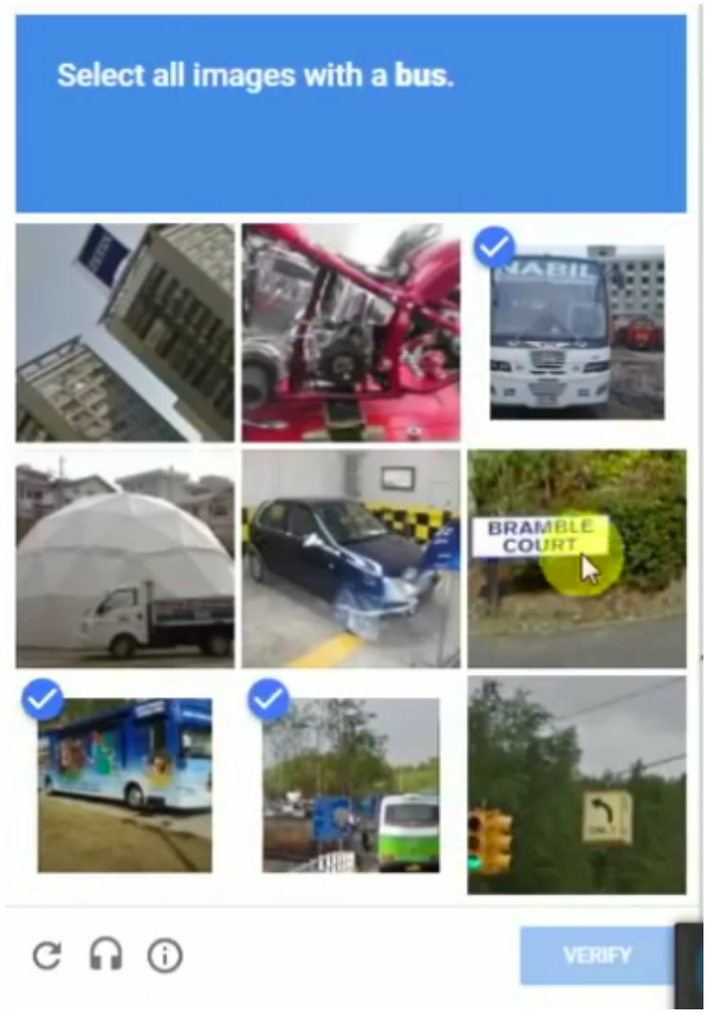

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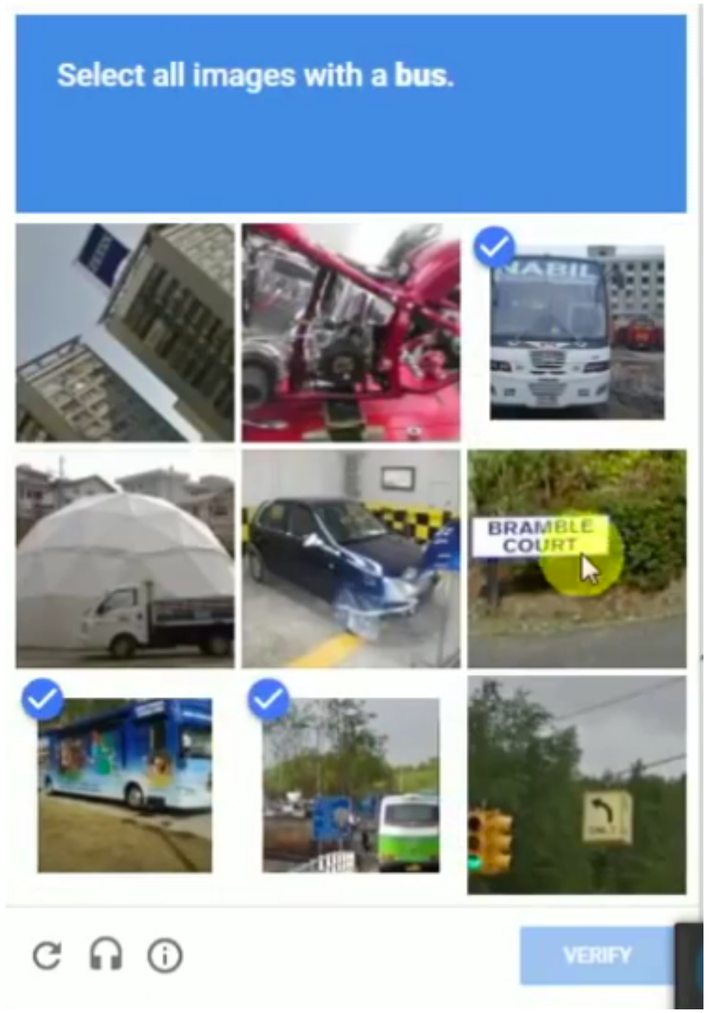

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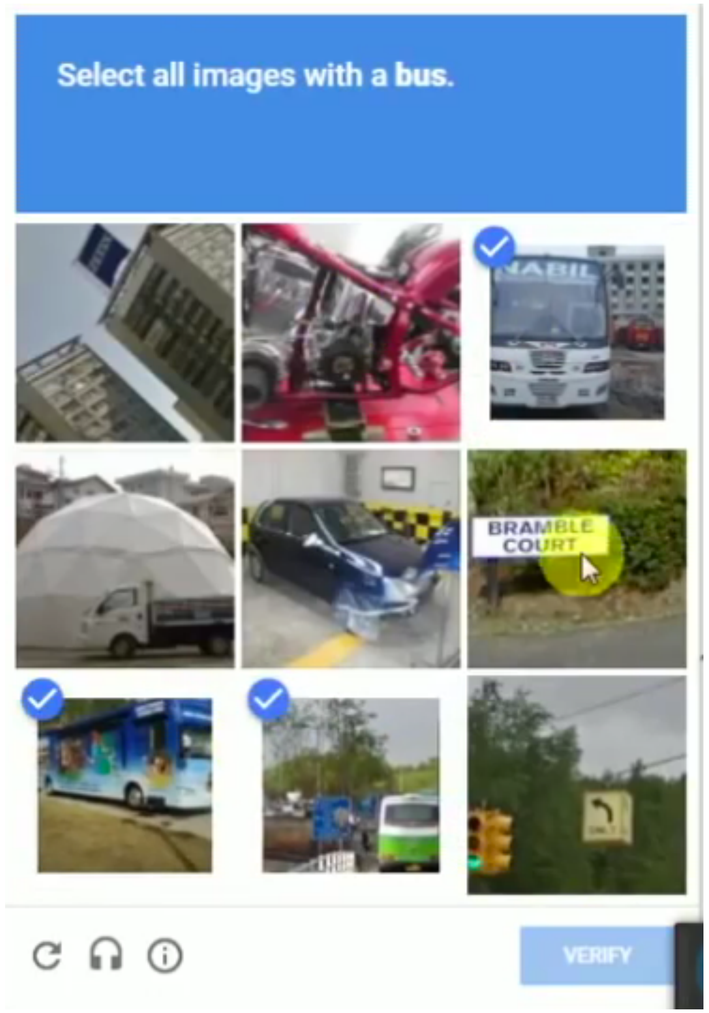

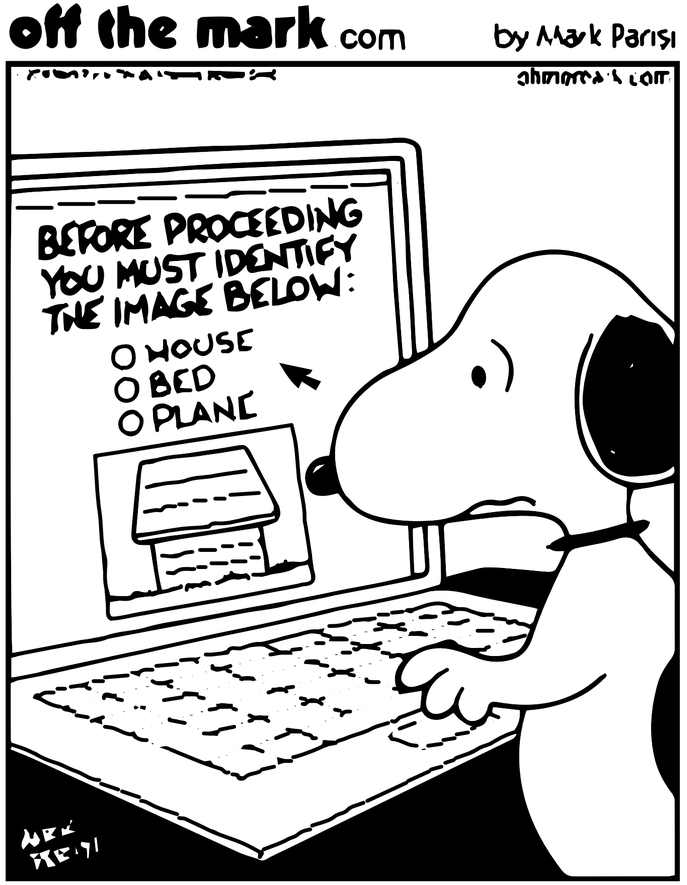

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  - bytes and lines → data processing
  - words → *what do we mean by "word"?*

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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> ***Dave***: *Open the pod bay doors, HAL.*
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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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  - 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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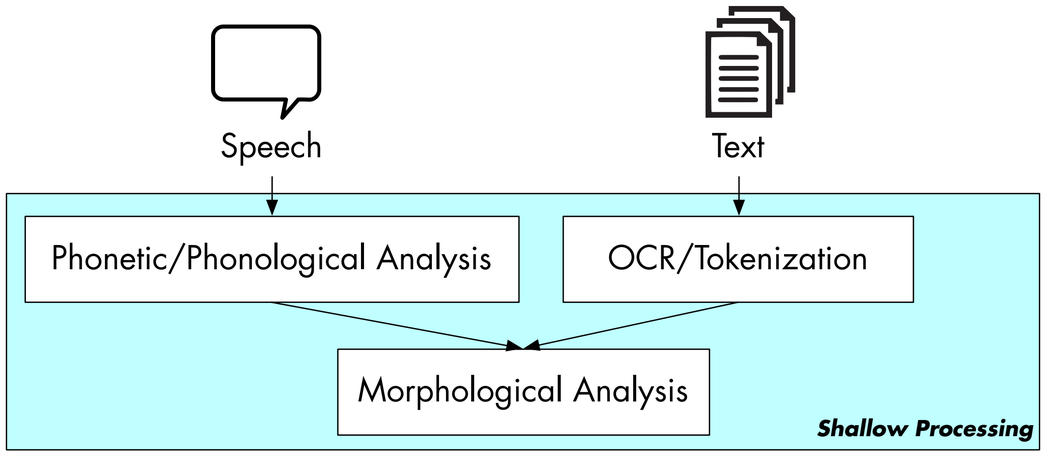
  - Examples: HMM POS-tagging; FST morphology
- Deep processing (LING 571)
  - Relies on ***more elaborate*** linguistic representations
    - Deep syntactic analysis (Parsing)
    - Rich spoken language understanding (NLU)

Language Processing Pipeline



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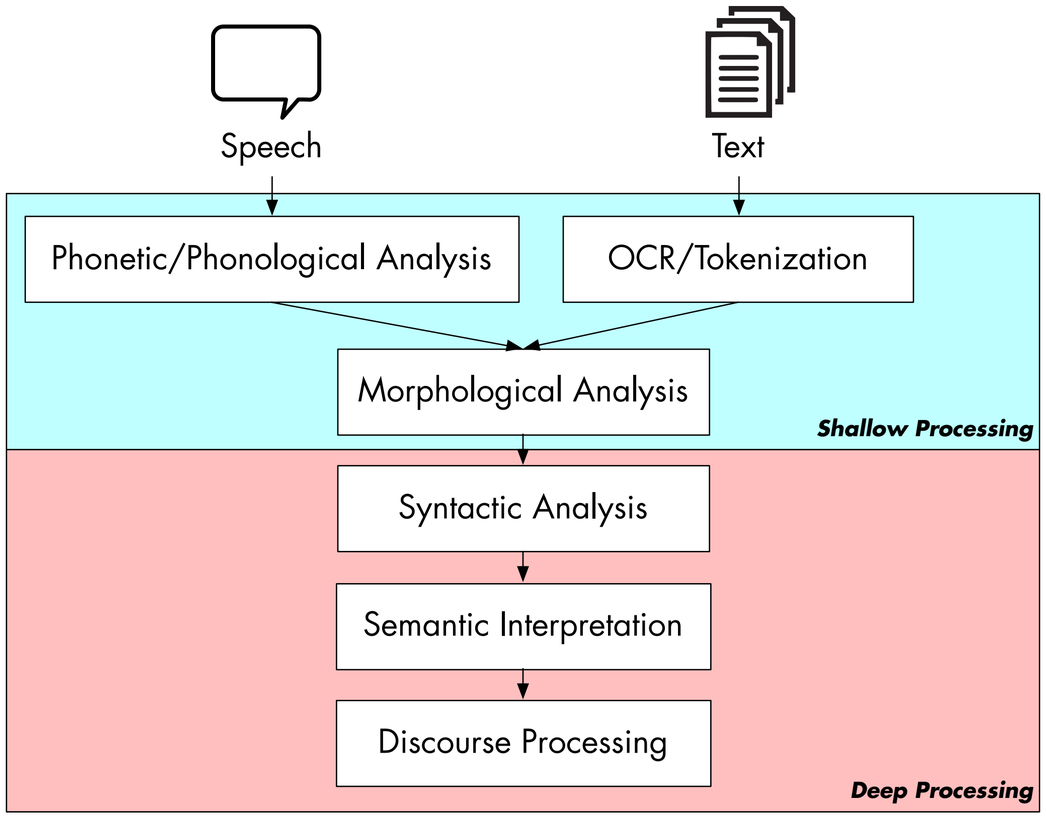

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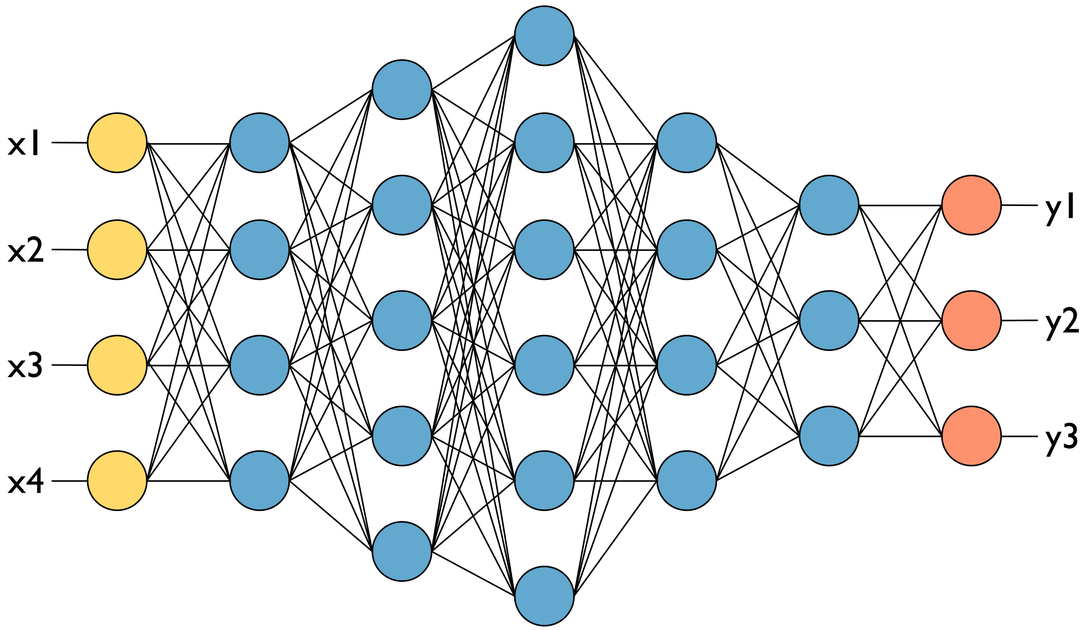

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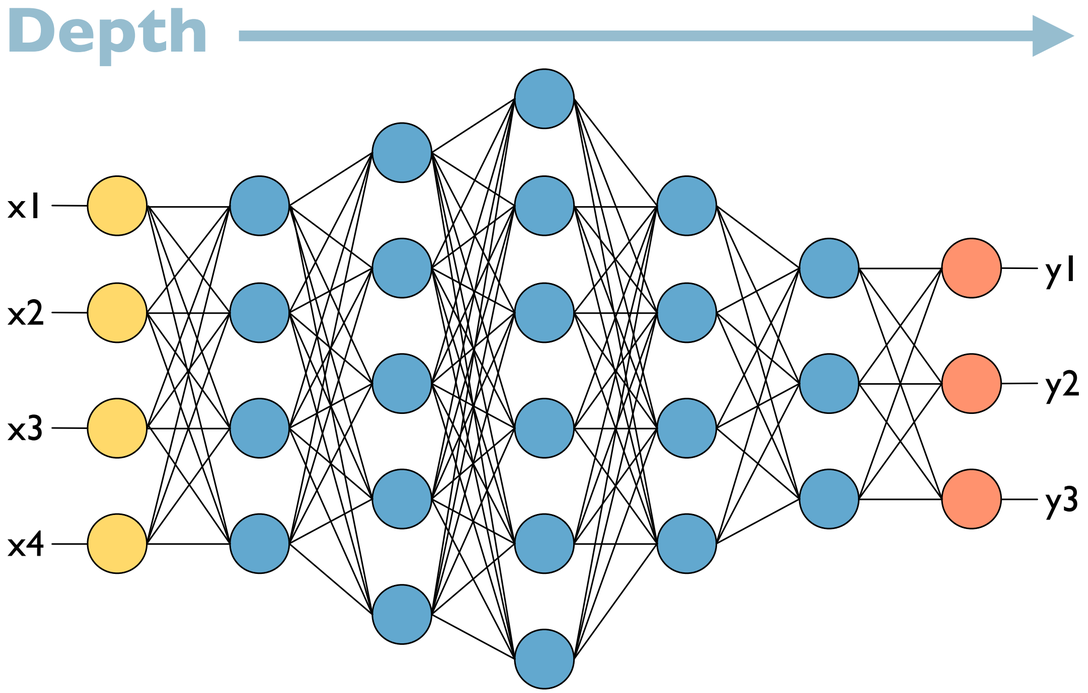

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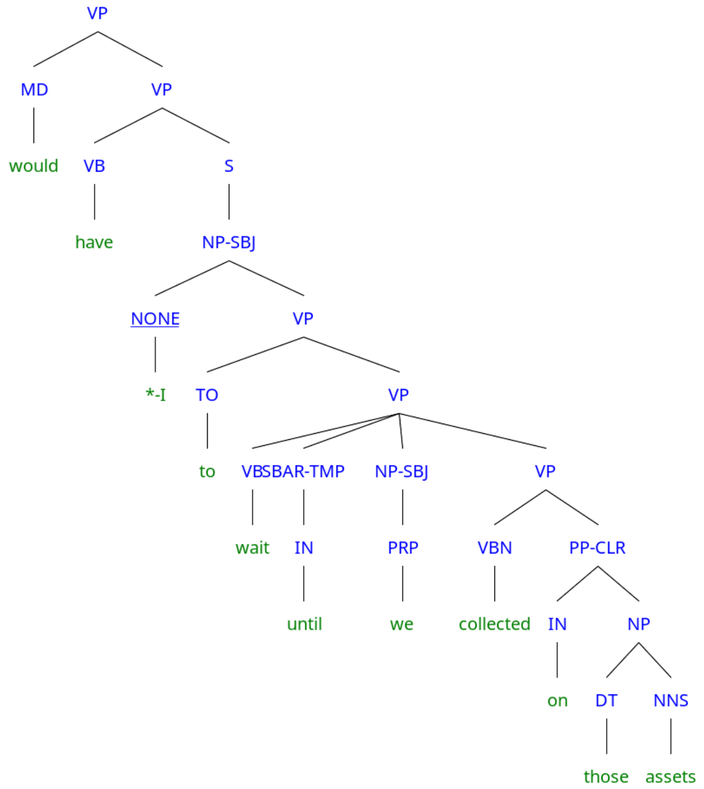

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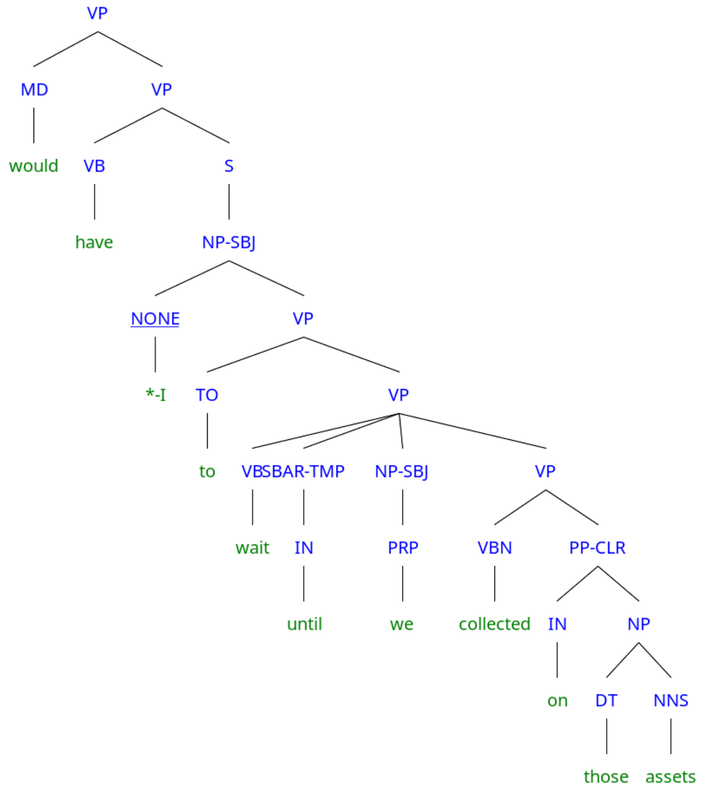

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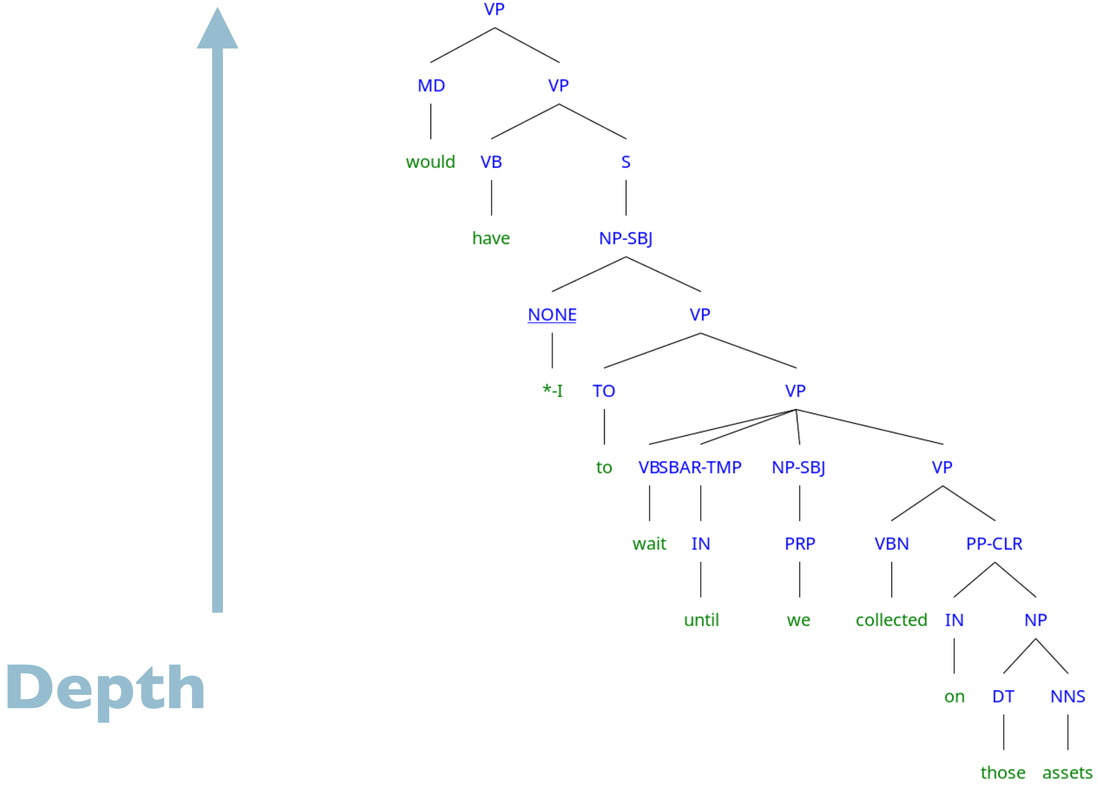

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- In both paradigms, graph depth aids, but ⇏ abstraction

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- **Multilinguality**
  - Can we apply the same approach to other languages?
  - How much must it be modified to do so?

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- Could mean…
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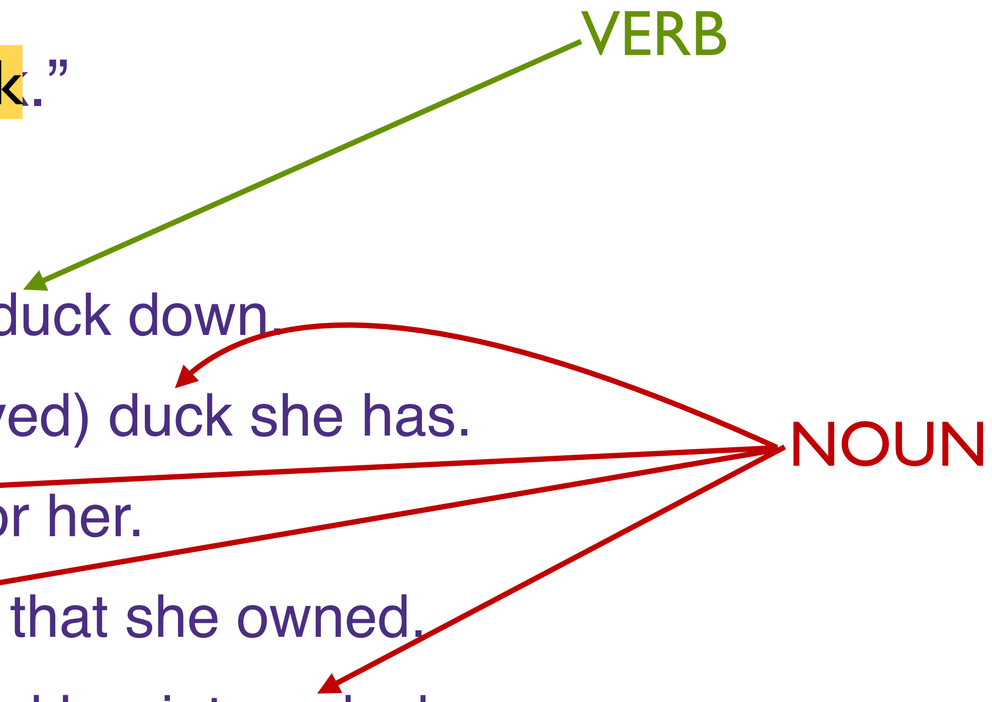

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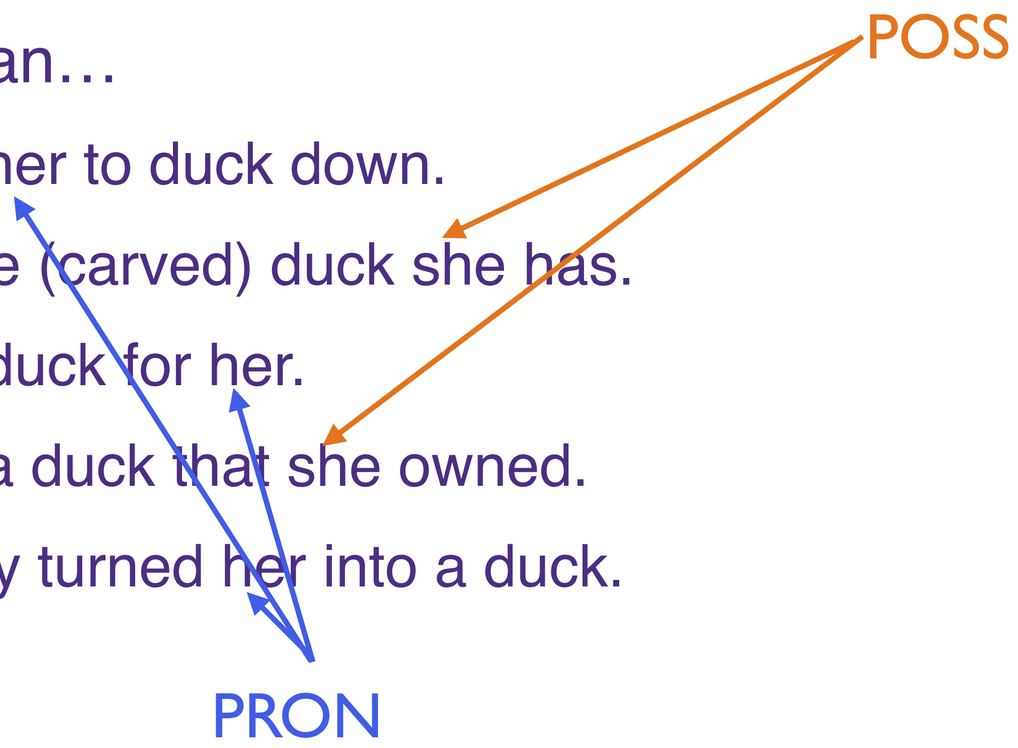

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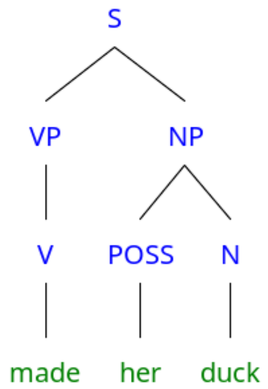

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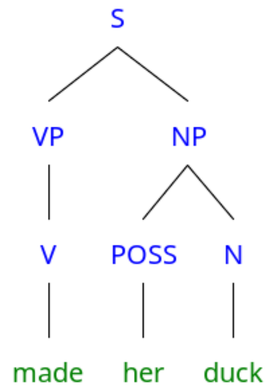

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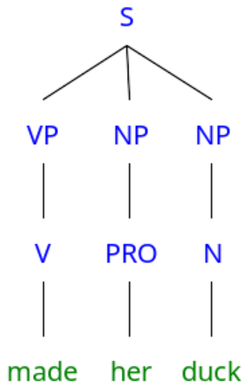

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I made the (carved) duck she has	***made*** = [AG] **sculpted** [TH] ***duck*** = **duck-shaped-figurine**
I magically turned her into a duck	***made*** = [AG] **transformed** [TH] ***duck*** = **animal**

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- Not a bug, a feature! (Piantadosi et al 2012)

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.”*

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

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- Website is main source of information: https://www.shane.st/teaching/571/aut22/
  - 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, 574
- Office hours:
  - Shane: MW 230-330 (GUG 415K + Zoom; see website)
  - Cassie: T 9-10AM, Th 12-1PM (GUG 407 + Zoom)
- 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?

Total Results: 0

Syntax Crash Course

LING 571 — Deep Processing Techniques for NLP
September 28, 2022
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

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  - Explicit rules
  - "Don't split infinitives!" etc.

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- "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:

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

Representing Sentence Structure

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  - Capture argument structure
    - 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 $A \rightarrow \alpha$
    - 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/morphemes of the language
    - *cat, dog, is, the, bark, chase…*

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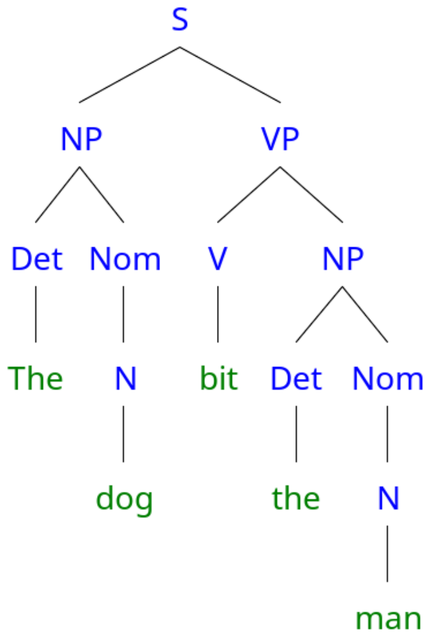
  - Right-hand side of productions (RHS)
  - Words/morphemes of the language
    - *cat, dog, is, the, bark, chase…*
- **Non-terminals**
  - Do not appear as leaves of parse tree
  - Appear on left or right side of productions
  - Represent constituent phrases of language
    - NP, VP, S[entence], etc…

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



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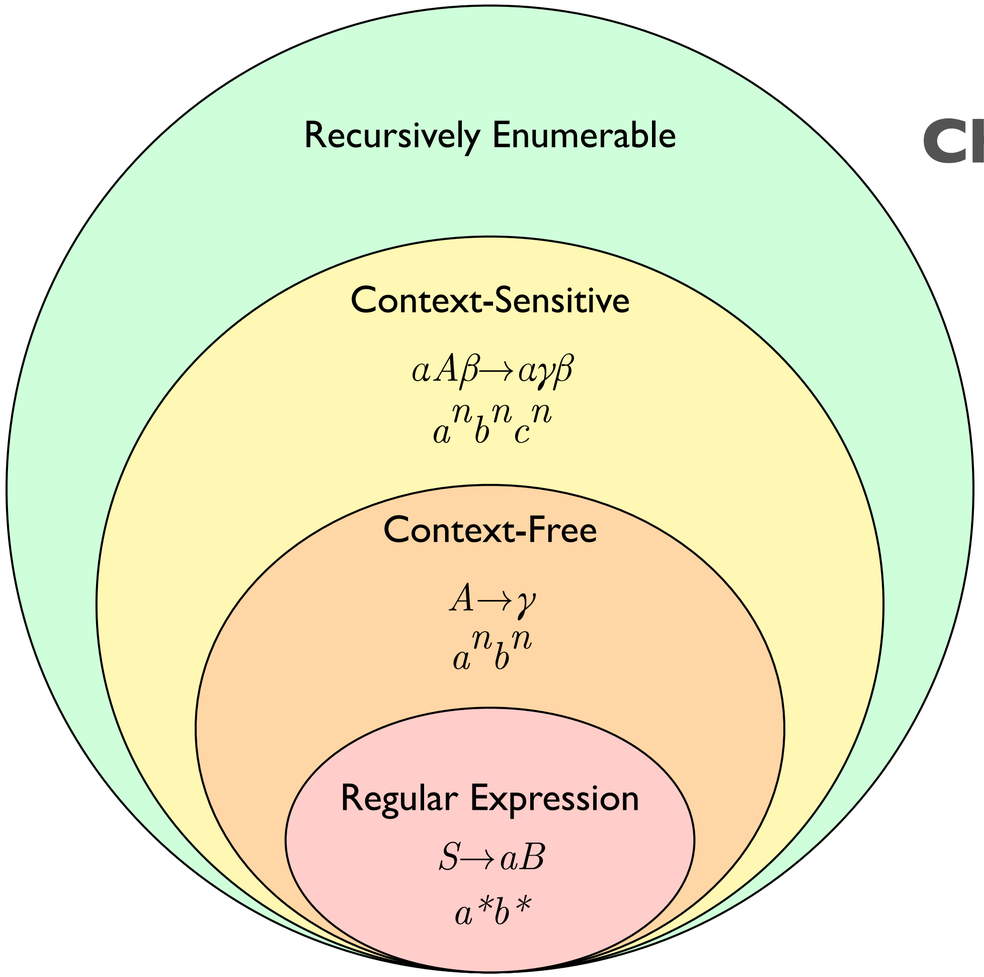
- Analysis
  - What structure produced the string
    - Produce one (or all) parses for the string
- Will develop techniques to produce analyses of sentences
  - Rigidly accept (with analysis) or reject
  - Produce varying degrees of acceptability

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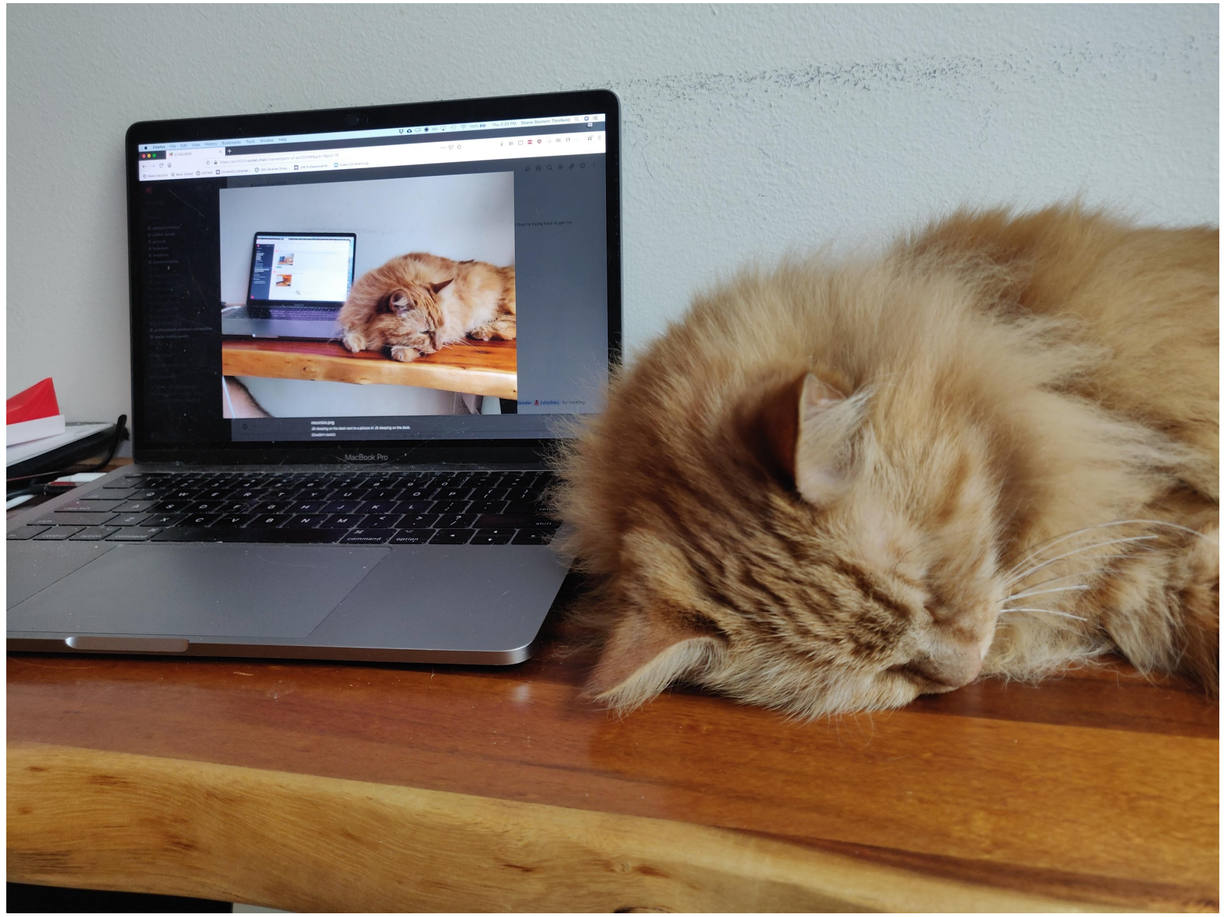
    - The luggage arrived
    - The luggage that the passengers checked arrived
    - The luggage that the passengers **whom the storm delayed** checked arrived

Recursion in Grammar



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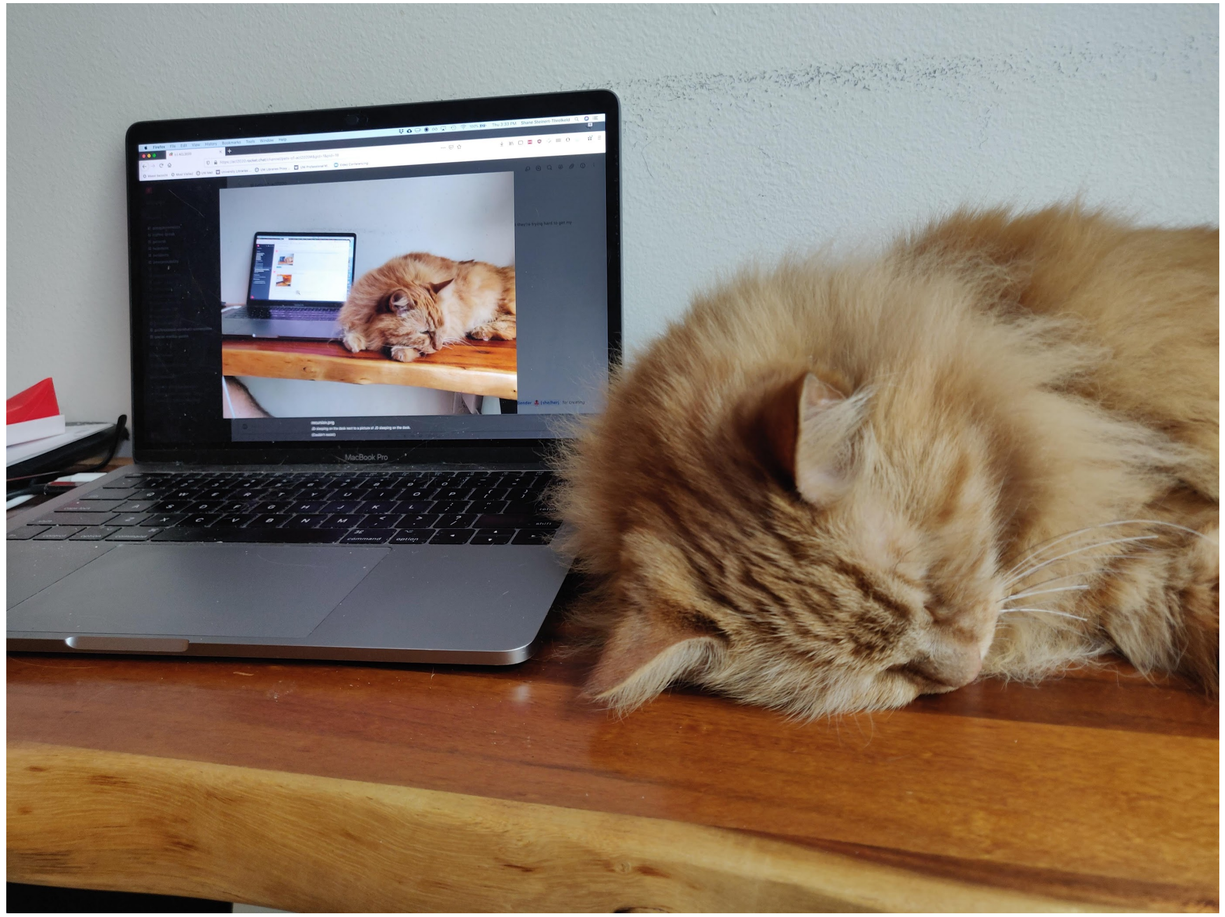
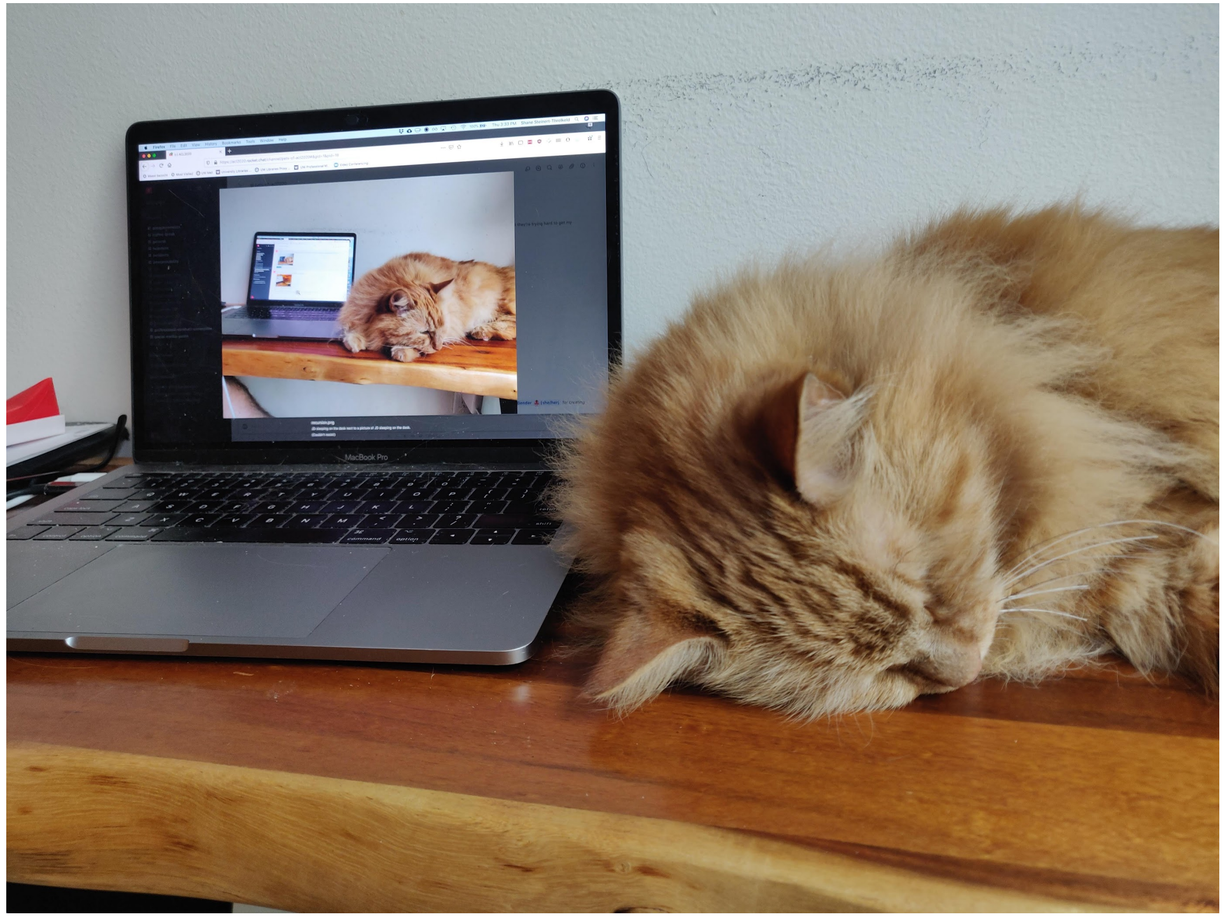


This is JD lying on the desk next to a picture of JD lying on the desk next to a picture of JD lying on the desk.

Recursion in Grammar



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Exercise: write a toy grammar for producing this sentence! Is context-free-ness required?

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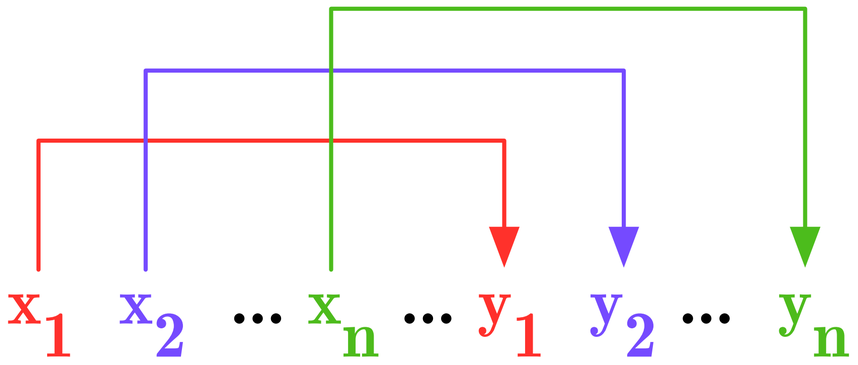
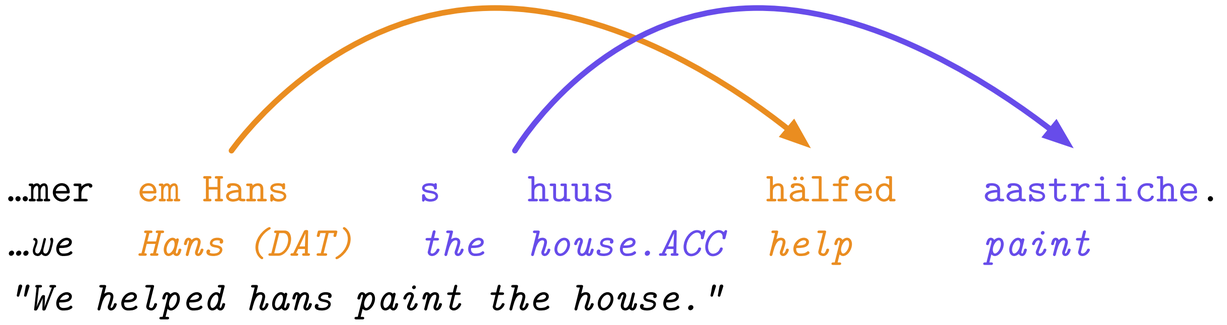
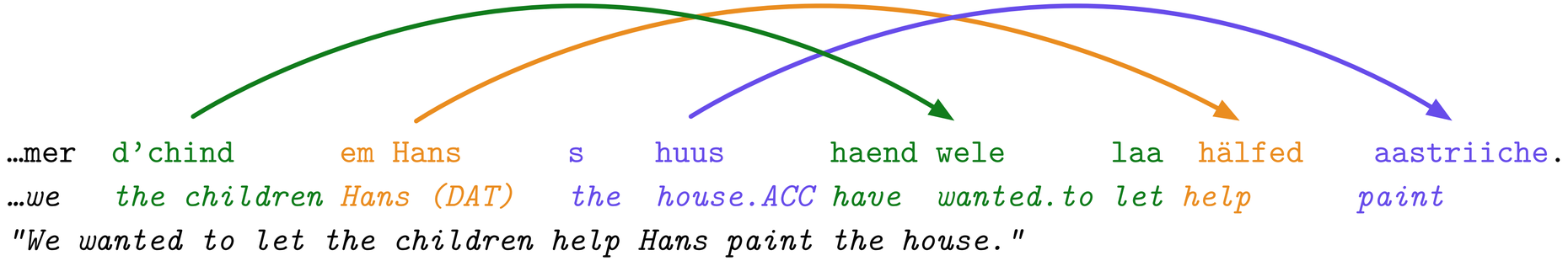
- …but do we need context-sensitivity?
  - Many articles have attempted to demonstrate we do
  - …many have failed.
- Solid proof for Swiss German: ***Cross-Serial Dependencies*** (Shieber, 1985)
  - $a^i b^j c^i d^j$



Context-Sensitive Example

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





What questions do you have?