Context-Free Grammars

CS 485, Spring 2024

Applications of Natural Language Processing

https://people.cs.umass.edu/~brenocon/cs485_s24/

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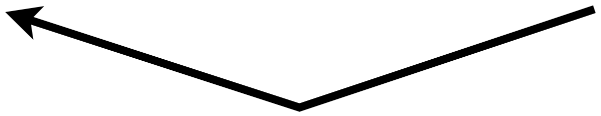
- *Do we have to make notes for every single text? Or just have one note encompassing everything? I am a little confused on that part.*

- Just makes notes on any of the texts where it makes sense to do so, in the "annotator notes" column referred to in 1.2 of the HW2 document. There are no requirements for the number of notes.
- The more informative your notes, the better a job you can do in Phase 2 when you (and separately, your groupmates) analyze the differences between annotators.

Syntax: how do words structurally combine to form sentences and meaning?

- Constituents
  - [the big dogs] chase cats
  - [colorless green clouds] chase cats

- Dependencies
  - The **dog** ← **chased** the cat.
  - My **dog**, who's getting old, **chased** the cat.



- Idea of a *grammar (G)*: global template for how sentences / utterances / phrases ***w*** are formed, via latent syntactic structure ***y***
  - Linguistics: what do G and P(w,y | G) look like?
  - Generation: score with, or sample from, P(w, y | G)
  - Parsing: predict P(y | w, G)

Syntax for NLP

- If we could predict syntactic structure from raw text (*parsing*), that could help with...
  - Language understanding: meaning formed from structure
  - Grammar checking
  - Preprocessing: Extract phrases and semantic relationships between words for features, viewing, etc.
- Provides a connection between the theory of *generative linguistics* and computational modeling of language
- Practically, accurate full sentence parsing is challenging....
  - ... but the same challenges exist for all NLP tasks/models/ systems

Is language context-free?

[Examples from Eisenstein (2017)]

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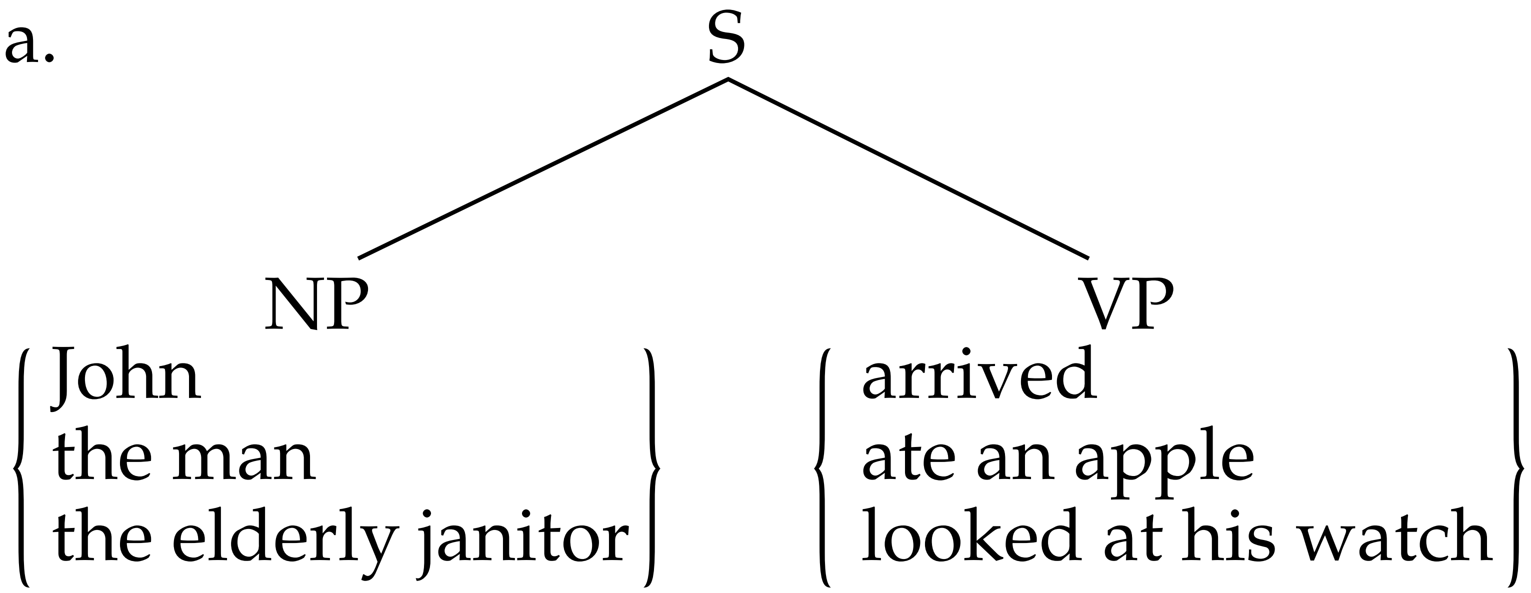
- Competence vs. Performance

[Examples from Eisenstein (2017)]

Hierarchical view of syntax

- “a Sentence made of Noun Phrase followed by a Verb Phrase”

a.



S

NP

VP

{ John
the man
the elderly janitor }

{ arrived
ate an apple
looked at his watch }

b. S → NP VP (1)

[From Phillips (2003)]

Context-free grammars (CFG)

- A CFG is a 4-tuple:

  N a set of non-terminals
  Σ a set of terminals (distinct from N)
  R a set of productions, each of the form $A \rightarrow \beta$, where $A \in N$ and $\beta \in (\Sigma \cup N)^*$
  S a designated start symbol

Example: see handout!

- Derivation: a sequence of rewrite steps from S to a string (sequence of terminals, i.e. words)
- Yield: the final string (sentence)
- The parse tree or constituency tree corresponds to the rewrite steps that were used to derive the string

- A CFG is a "boolean language model"
  - A grammar (4-tuple) defines to a set of strings it could generate

Context-free grammars (CFG)

R: production rules typically split into two groups

Core grammar: 1 NT expands to >=1 NT

S	→	*NP VP*	I + want a morning flight
NP	→	*Pronoun*	I
	|	*Proper-Noun*	Los Angeles
	|	*Det Nominal*	a + flight
Nominal	→	*Nominal Noun*	morning + flight
	|	*Noun*	flights
VP	→	*Verb*	do
	|	*Verb NP*	want + a flight
	|	*Verb NP PP*	leave + Boston + in the morning
	|	*Verb PP*	leaving + on Thursday
PP	→	*Preposition NP*	from + Los Angeles

Lexicon: NT expands to a terminal

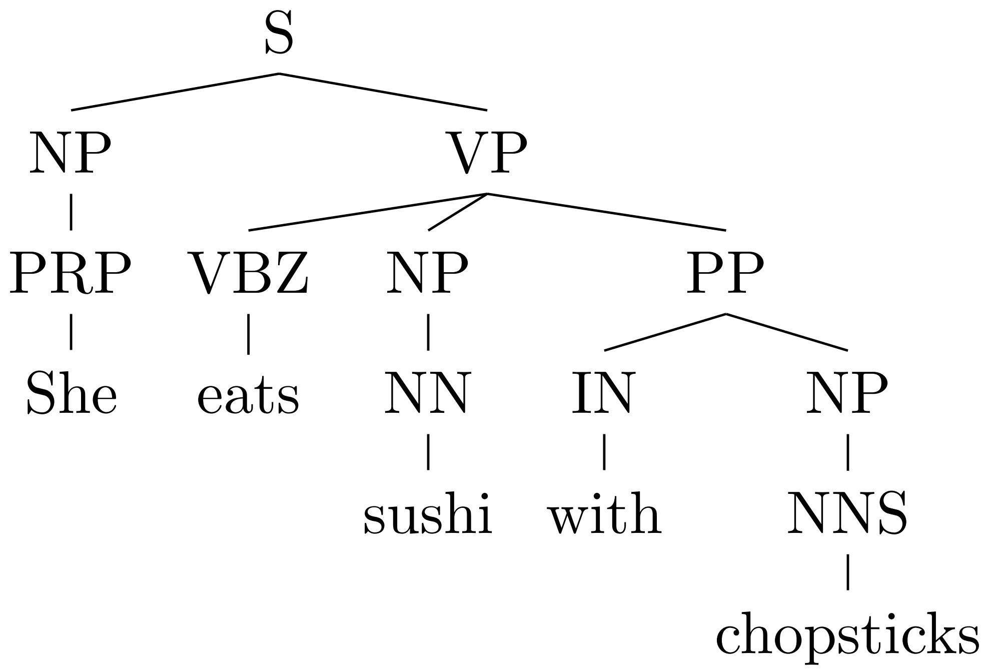
Noun	→	*flights* | *breeze* | *trip* | *morning* | …
Verb	→	*is* | *prefer* | *like* | *need* | *want* | *fly*
Adjective	→	*cheapest* | *non – stop* | *first* | *latest* | *other* | *direct* | …
Pronoun	→	*me* | *I* | *you* | *it* | …
Proper-Noun	→	*Alaska* | *Baltimore* | *Los Angeles* | *Chicago* | *United* | *American* | …
Determiner	→	*the* | *a* | *an* | *this* | *these* | *that* | …
Preposition	→	*from* | *to* | *on* | *near* | …
Conjunction	→	*and* | *or* | *but* | …

- Example: derivation from worksheet's grammar

- Why not?

  S -> ADVP S

Ambiguity

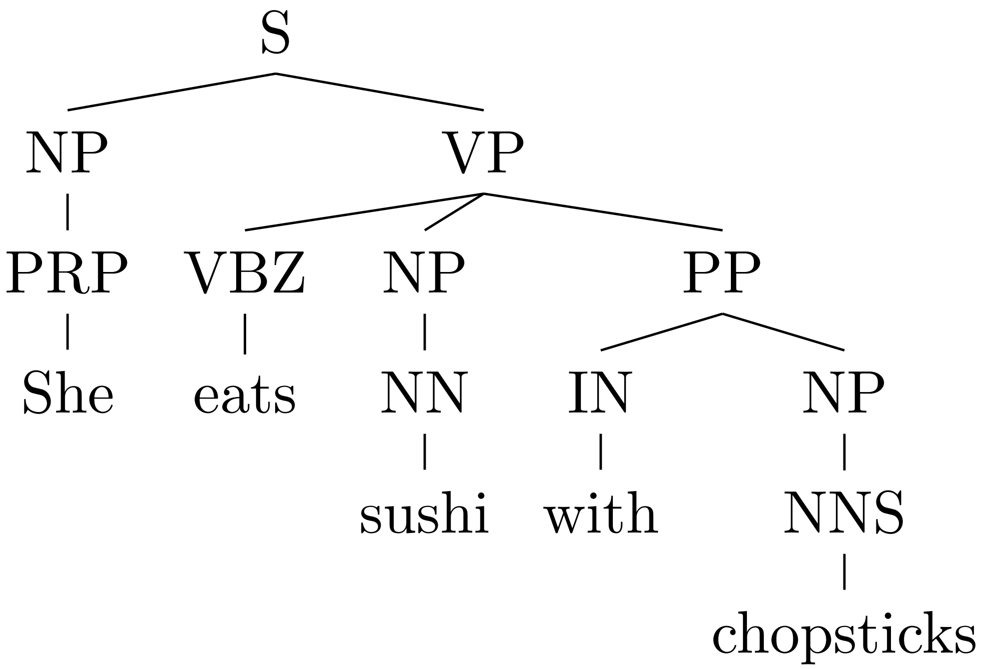


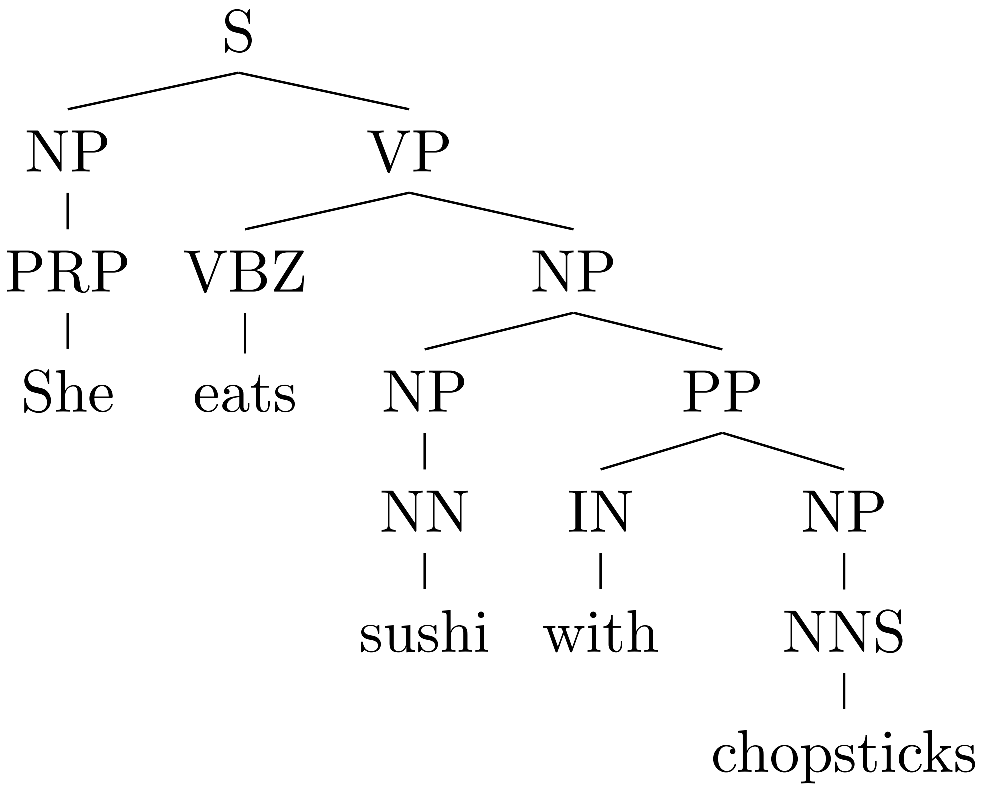
(S(NP(PRP *She*)(VP(VBZ *eats*)
(NP(NN *sushi*))
(PP(IN*with*)(NP(NNS *chopsticks*))))))

- All useful grammars are *ambiguous*: multiple derivations with same yield
- [Parse tree representations: Nested parens *or* non-terminal spans]

[Examples from Eisenstein (2017)]

Ambiguity





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[Examples from Eisenstein (2017)]

Constituents

- Constituent tree/parse is one representation of sentence's syntax. What should be considered a constituent, or constituents of the same category?
  - Movement tests
  - Substitution tests
  - Coordination tests

- Simple grammar of English
  - Must balance *overgeneration* versus *undergeneration*
  - Noun phrases
  - NP modification: adjectives, PPs
  - Verb phrases
  - Coordination
  - etc...
- Better coverage: machine-learned grammars, if you have a treebank (labeled dataset)

Is language context-free?

- CFGs nicely explain nesting and agreement (if you stuff grammatical features into the non-terminals)
  - *The* ***processor has*** *10 million times fewer transistors on it than todays typical micro-processors,* ***runs*** *much more slowly, and* ***operates*** *at five times the voltage...*
  - $$\begin{aligned} S &\rightarrow NN\ \ VP \\ VP &\rightarrow VP3S \mid VPN3S \mid \ldots \\ VP3S &\rightarrow VP3S, VP3S, \text{ and } VP3S \mid VBZ \mid VBZ\ NP \mid \ldots \end{aligned}$$

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- Real sentences have massively ambiguous syntax!

Attachment ambiguity *we eat sushi with chopsticks, I shot an elephant in my pajamas.*

Modifier scope *southern food store*

Particle versus preposition *The puppy tore up the staircase.*

Complement structure *The tourists objected to the guide that they couldn't hear.*

Coordination scope *"I see," said the blind man, as he picked up the hammer and saw.*

Multiple gap constructions *The chicken is ready to eat*

Penn Treebank

```
( (S
    (NP-SBJ (NNP General) (NNP Electric) (NNP Co.) )
    (VP (VBD said)
      (SBAR (-NONE- 0)
        (S
          (NP-SBJ (PRP it) )
          (VP (VBD signed)
            (NP
              (NP (DT a) (NN contract) )
              (PP (-NONE- *ICH*-3) ))
            (PP (IN with)
              (NP
                (NP (DT the) (NNS developers) )
                (PP (IN of)
                  (NP (DT the) (NNP Ocean) (NNP State) (NNP Power) (NN project) ))))
            (PP-3 (IN for)
              (NP
                (NP (DT the) (JJ second) (NN phase) )
                (PP (IN of)
                  (NP
                    (NP (DT an) (JJ independent)
                      (ADJP
                        (QP ($ $) (CD 400) (CD million) )
                        (-NONE- *U*) )
                      (NN power) (NN plant) )
                    (, ,)
                    (SBAR
                      (WHNP-2 (WDT which) )
                      (S
                        (NP-SBJ-1 (-NONE- *T*-2) )
                        (VP (VBZ is)
                          (VP (VBG being)
                            (VP (VBN built)
                              (NP (-NONE- *-1) )
                              (PP-LOC (IN in)
                                (NP
                                  (NP (NNP Burrillville) )
                                  (, ,)
                                  (NP (NNP R.I) ))))))))))))))))
```

- stopped here 10/17