

Context-Free Grammars

CS 485, Spring 2024

Applications of Natural Language Processing

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

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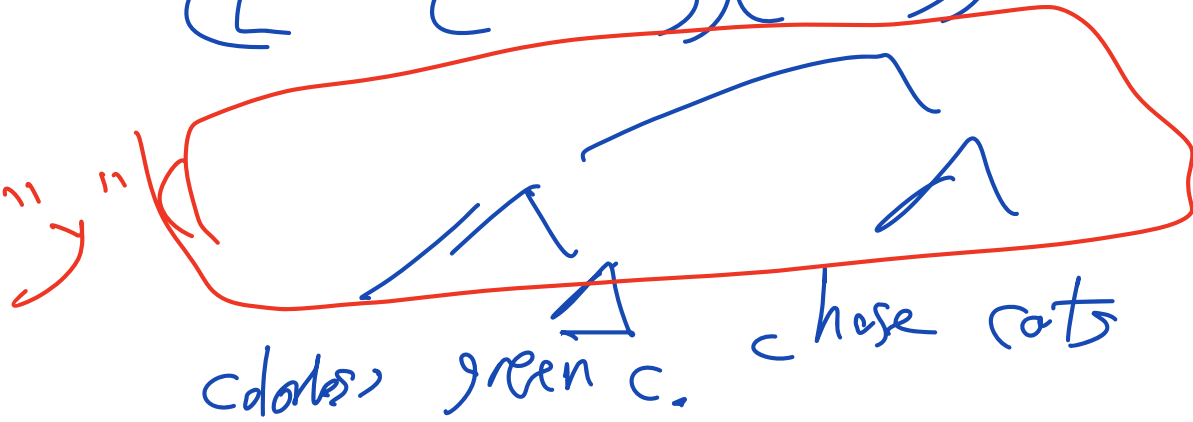
University of Massachusetts Amherst

- *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

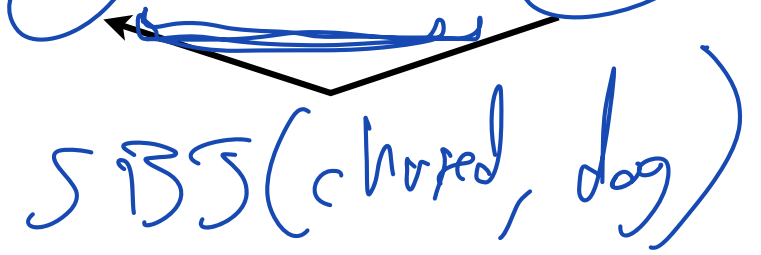
- [the big dogs] chase cats
- [colorless green clouds] chase cats



- Dependencies

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

"subject of verb"



- 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

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“0 or more times”



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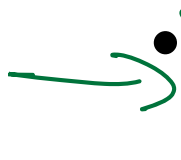
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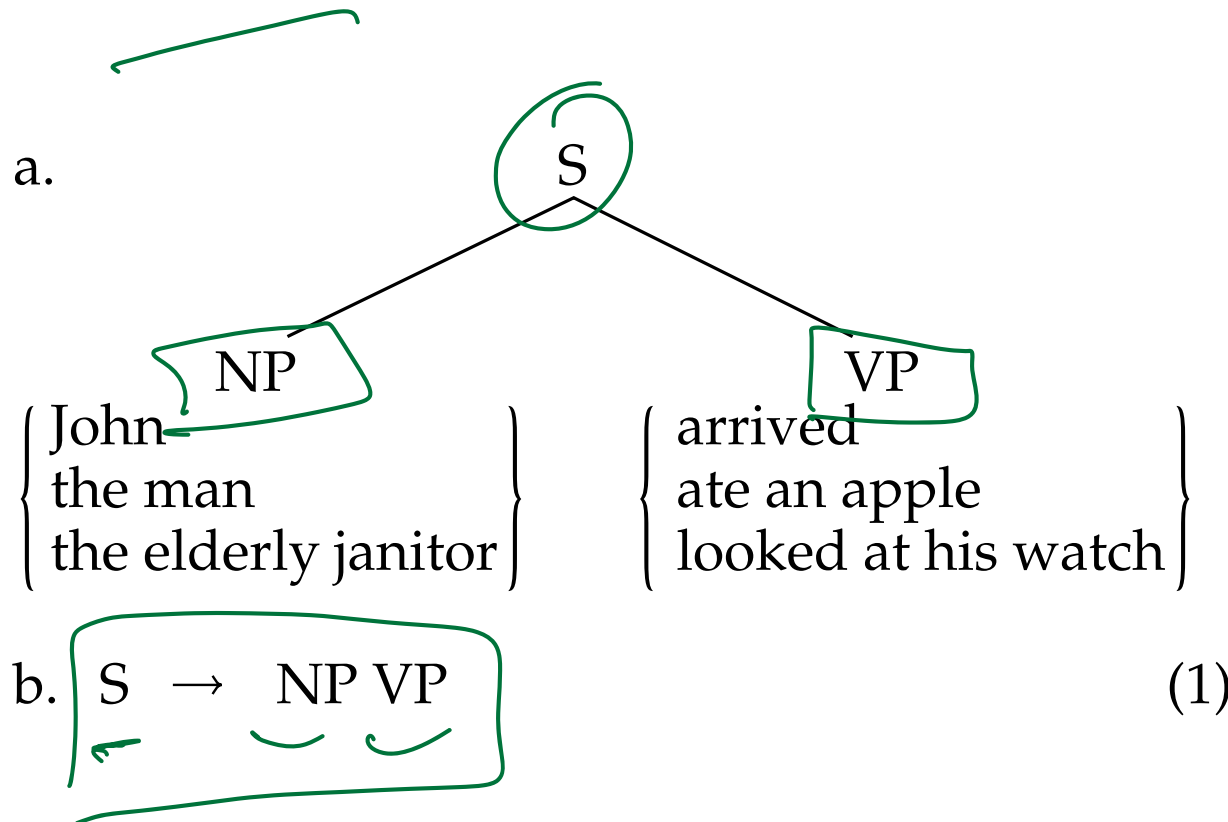
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lang = systematic + variable + structure

Hierarchical view of syntax

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



Context-free grammars (CFG)

- A CFG is a 4-tuple:

N a set of non-terminals

Σ a set of terminals (distinct from N) \rightarrow words

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: I NT expands to ≥ 1 NT

S	$\rightarrow NP VP$	I + want a morning flight
NP	\rightarrow <u>Pronoun</u>	I
	\rightarrow <u>Proper-Noun</u>	Los Angeles
	\rightarrow <u>Det Nominal</u>	a + flight
$Nominal$	\rightarrow <u>Nominal Noun</u>	morning + flight
	\rightarrow <u>Noun</u>	flights
VP	\rightarrow <u>Verb</u>	do
	\rightarrow <u>Verb NP</u>	want + a flight
	\rightarrow <u>Verb NP PP</u>	leave + Boston + in the morning
	\rightarrow <u>Verb PP</u>	leaving + on Thursday
PP	\rightarrow <u>Preposition NP</u>	from + Los Angeles

For day

Lexicon: NT expands to a terminal

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

$Noun \rightarrow flight$
 $Noun \rightarrow breeze$

...

- Example: derivation from worksheet's grammar

§.27:
§.31 → PRP

9.41

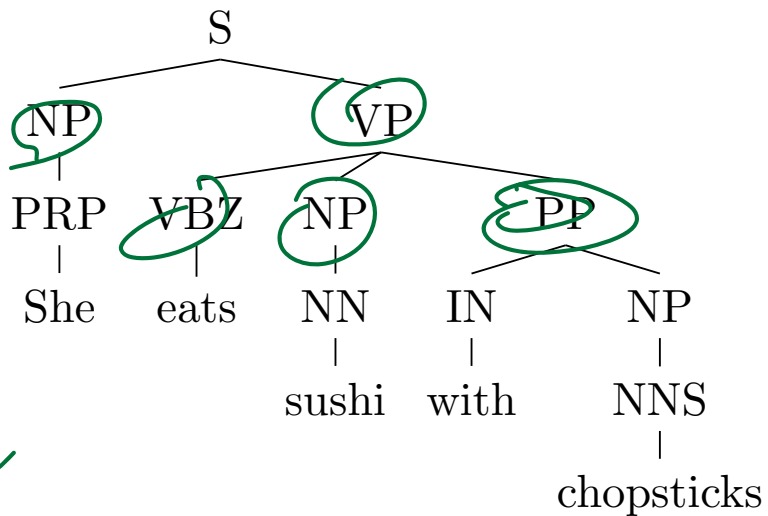
S	
NP	VP
└──┬──	VP
PRP	VP
it	VP
it	└──┬──
it	VBZ
it	└──┬──
it	snacks

S	
└──┬──	
NP	VP
PRP	VBZ
it	snacks

- Why not?

S -> ADVP S

Ambiguity

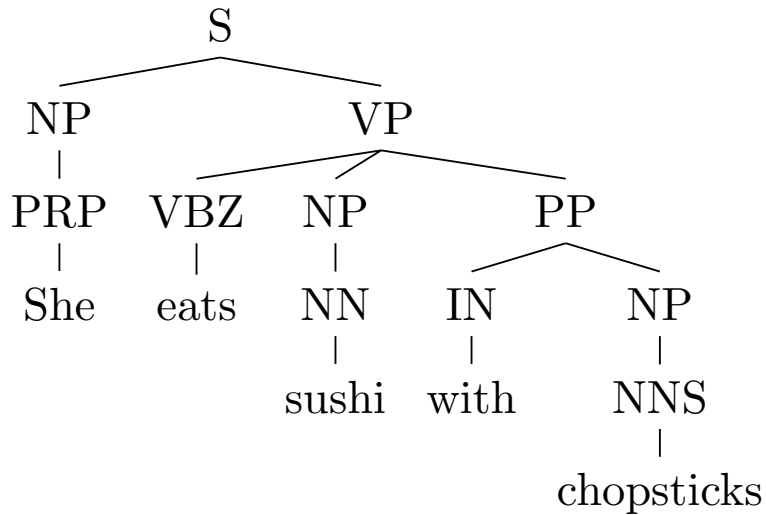


(S(NP(PRPP She))(VP(VBZ eats)
(NP(NN sushi))
(PP(IN with)(NP(NNS chopsticks))))))

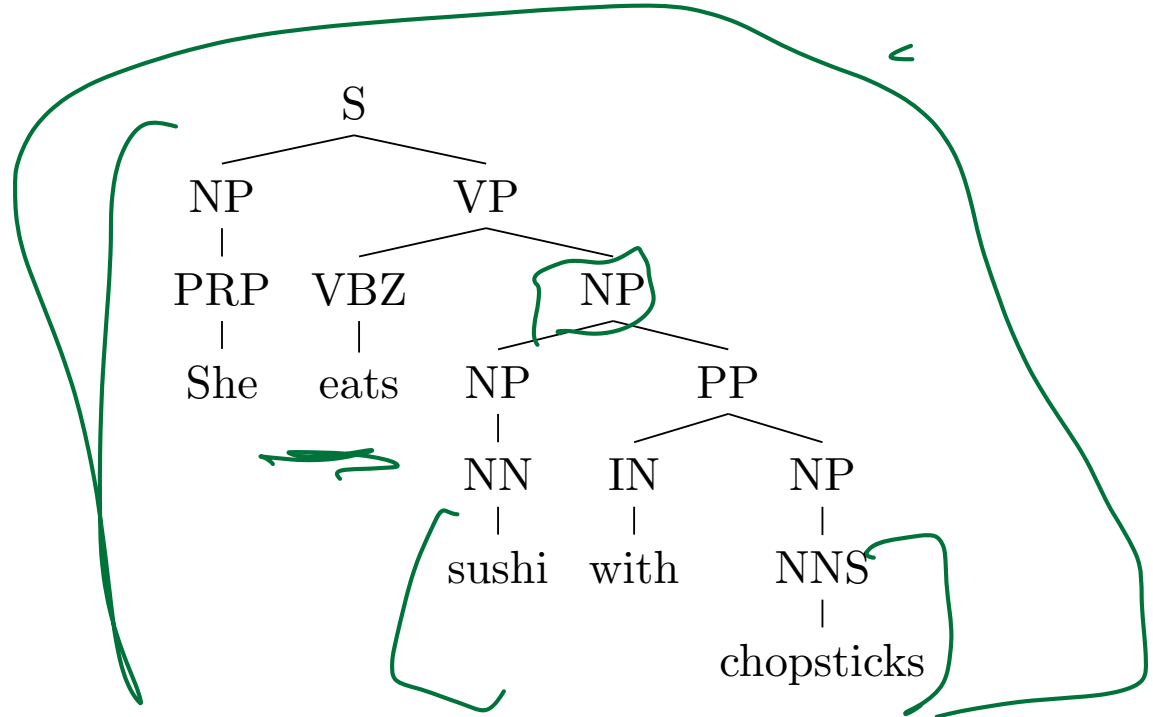
- All useful grammars are *ambiguous*: multiple derivations with same yield
- [Parse tree representations: Nested parens or non-terminal spans]

Ambiguity

WRONG!



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



(S(NP(PRIP She))(VP(VBZ eats)
 [NP(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]

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 today's typical micro-processors, runs much more slowly, and operates at five times the voltage...*
- - $S \rightarrow NN VP$
 - $VP \rightarrow VP3S \mid VPN3S \mid \dots$
 - $VP3S \rightarrow VP3S, VP3S, \text{ and } VP3S \mid VBZ \mid VBZ NP \mid \dots$

- **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) ))))))))))))))))
          (, ,)
          (NP (NNP R.I) ))))))))))))))))
    )
  )
)

```

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