Parsing: Phrase-Structure Grammars to Dependency Grammars

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Remember last time …

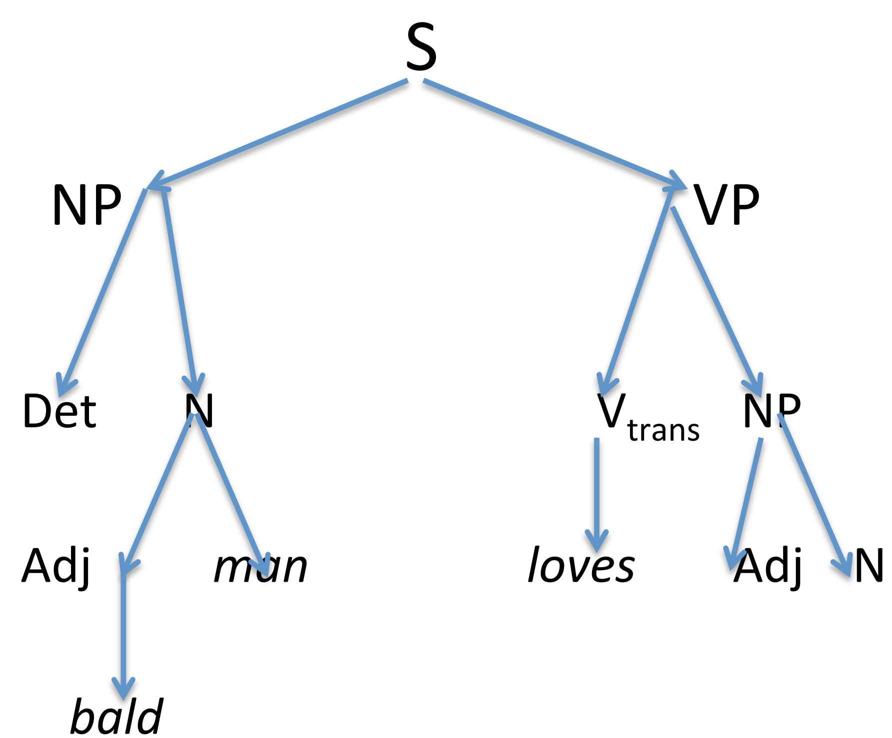
- **V x T**
- Where **V** is a complicated Vector Space
  - A Tensor Algebra
  - Which is where the semantics lives
- And **T?**
- **T** is a syntactic algebra of a certain sort, which one can think of as a way of representing a **phrase-structure grammar**
  - Kind of ….

In the Beginning, there was Chomsky

- Phrase-structure (rewrite) rules:
- Stated in terms of typed constituents
  - S → NP VP
  - NP → (Det) N
  - N → (AP) N (PP)
  - VP → V_{Trans} NP
- And a lexicon
  - N = {David, Roma, man …}
  - Adj = {bald, beautiful ….}
  - V_{Trans} = {loves, …}
  - Det = {a, the, …}
  - P = {in, from, of …}

Phrase Structure/Constituent Trees

The bald man loves beautiful Roma



The Chomsky Hierarchy: The General Set-up

- Finite set of production rules, whose left- and right-hand sides consist of sequences of symbols from
- Finite set of nonterminal symbols, including a distinguished element **S** (Sentence – the Start symbol)
- Finite set of terminal symbols (the lexicon/ vocabulary) – which might include a distinguished element ε, for the empty string

The Hierarchy: From Most to Least Restrictive

- Type-3 (finite-state) grammars:
  - Single nonterminal on left
  - Single terminal on right, possibly *followed* by a single nonterminal (right regular)
    - or --- exclusive "or"
  - Single terminal on right, possibly *preceded* by a single nonterminal (left regular)
  - **S** $\rightarrow$ ε, if **S** does not occur on right of any rule
- Generate *regular languages*
- Recognized/Decided by finite-state automata

Type-2 Grammars: Context-Free Grammars

- Single nonterminal on left
- String of terminal and/or nonterminals on right
- Generate context-free languages
- Recognized/decided by non-dterministic push-down automata

Type-1 Grammars: Context-Sensitive Grammars

- $\alpha A\beta \dashrightarrow \alpha\gamma\beta$: A a nonterminal, α, β, γ strings of nonterminals and/or terminals
- α and β may be empty, but not γ
- $S \rightarrow \varepsilon$, if S does not occur on right of any rule
- Generates the set of context-sensitive languages
- Recognized/decided by linear bounded automaton: nondeterministic Turing machine is tape-length is bounded by some constant times length of input

Type-0 Grammars: Unrestricted

- No restrictions (What a surprise!)
- Generate all languages recognizable by a Turing machine, so
- All recursively enumerable languages
- Includes languages where membership is undecidable – r.e., but not recursive
  - Can't always tell in a finite computation when some string that isn't in the language isn't in the language

And English (Italian, etc., etc.,…) ?

- What type? For an empirically adequate grammar
  - Mildly context-sensitive
  - Huh?
  - Just beyond context-free, but nowhere near the full power of context-sensitive grammars
  - Hard to define precisely (or easily) in terms of the form of the grammars in the form of standard production rules
- How many nonterminals needed?
  - Who knows?

Phrase Structure Parsing

- Structural decomposition of a sentence – given as a sequence of words
- Into constituents or *brackets*
- Generally applicable data structure: nested trees
- Enormous Amount of Ambiguity
  - Even small grammars (10 rules) + tiny lexicons generate 100’s of parses per sentence

Syntactic Ambiguities

- impractical design requirements
- plastic cup holder
- David cleaned the dishes from dinner
- David cleaned the dishes with detergent
- David cleaned the dishes in his tuxedo
- David cleaned the dishes in the sink
- David cooked the beans in the pot in the stove with handles
- Visiting relatives can be boring
- Changing schedules frequently confused customers
- The chicken is ready to eat
- The lawyer is rich enough to sue
- Small rats and mice can squeeze through cracks in the walls
- Etc., etc., etc.

Hand-written Broad Coverage CFGs

- ARE IMPOSSIBLE!!
- Well, … They're very, very big
- Very hard to add to, edit, maintain
- Can generate millions of parses for average-length sentences
- And still don't have broad enough coverage
- As a species, they are *almost* extinct

(Probabilistic) CFGs

- A CFG as a 4-tuple <*N, T, S, R*>
  - *N:* set of nonterminals
    - Phrasal categories: S, NP, VP, AdjP, etc.
    - POS (pre-terminals): N, V, Adj, etc.
  - *T*: set of terminals (lexicon)
  - *S*: distinguished nonterminal **start** symbol
    - Sometimes another special nonterminal is used , e.g., **ROOT**
  - *R*: the set of (cfg) rules or productions
- A PCFG adds: A top-down production probability per rule
  - Where: $X \rightarrow Y_1\ Y_2 \ldots Y_n \in R$, $Prob(Y_1\ Y_2 \ldots Y_n \mid X)$

Unsupervised Learning of PCFG's

- Significant efforts begin in the early '90's
  - Carroll and Charniak ('92); Pereira and Schabes ('92); Brill ('93); Stolcke and Omohundro ('94)
- Penn Treebank (early 90's) as a crucial resource
  - Large corpus (bank?) of trees: of phrase-structure analyses of English sentences
  - Very carefully trained annotators
  - Demand for high inter-annotator agreement (>> 90%)

Treebank Sentences

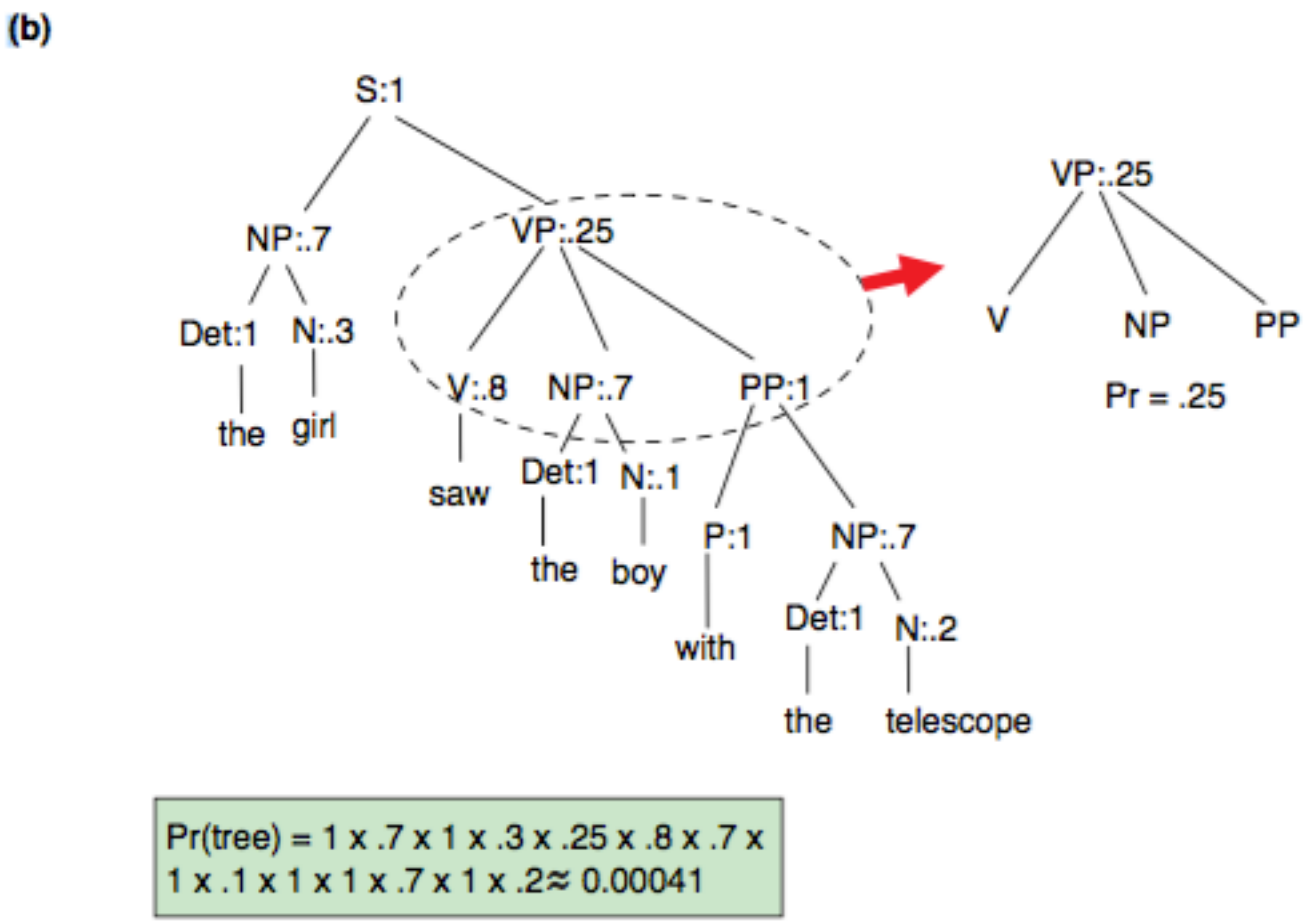
```
( (S (NP-SBJ The move)
     (VP followed
         (NP (NP a round)
             (PP of
                 (NP (NP similar increases)
                     (PP by
                         (NP other lenders))
                     (PP against
                         (NP Arizona real estate loans)))))
         ,
         (S-ADV (NP-SBJ *)
                (VP reflecting
                    (NP (NP a continuing decline)
                        (PP-LOC in
                                (NP that market))))))
     .))
```

A Simple(!!) PCFG

(a)

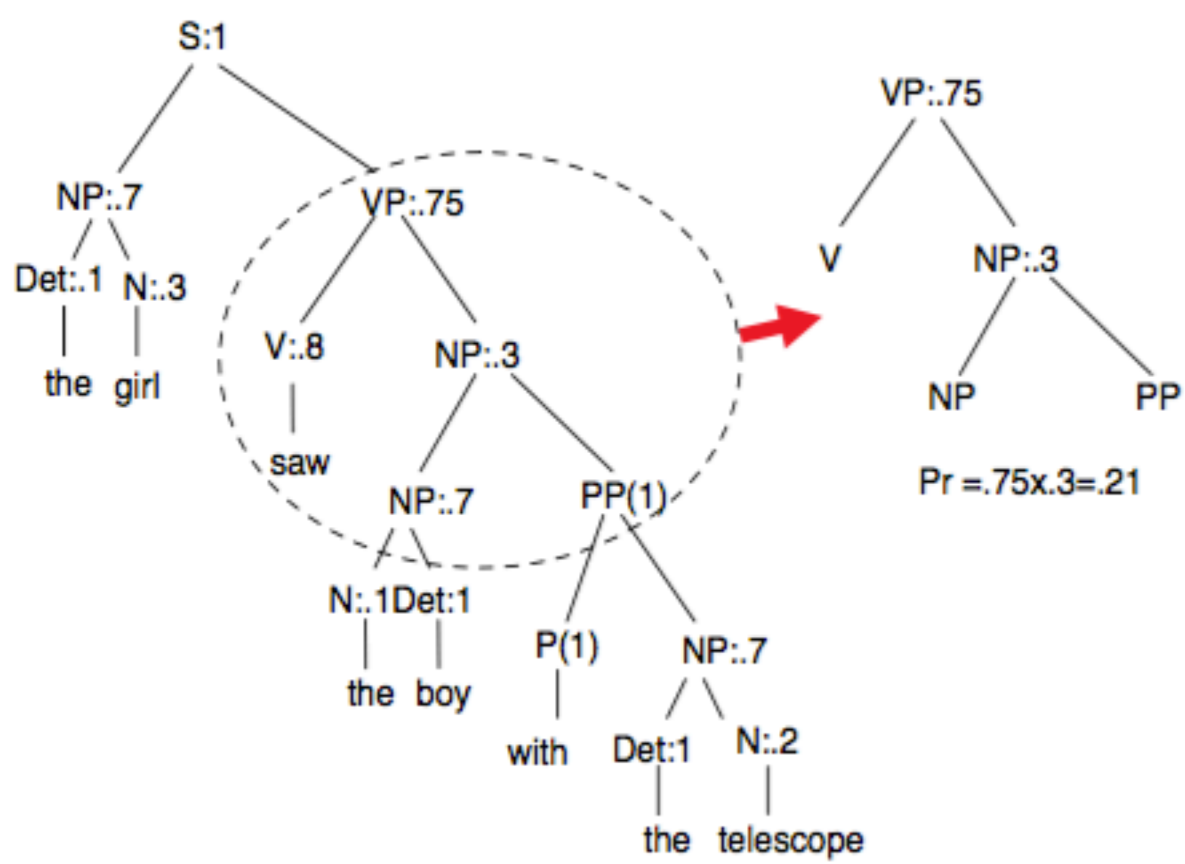
S→ NP VP	(1)	V→ saw	(.8)	N→ cat	(.1)
VP → V NP	(.75)	V → prodded	(.2	Det → the	(1)
VP → V NP PP	(.25)	N → telescope	(.2)	P → with	(1)
NP → Det Noun	(.7)	N → stick	(.3)		
NP → NP PP	(.3)	N → girl	(.3)		
PP → P NP	(1)	N → boy	(.1)		

A Parse of
"The girl saw the boy with the telescope."



Yet Another Parse

(c)



Pr(tree) = 1 x .7 x 1 x .3 x .75 x .8 x .3 x .7 x 1 x .1 x 1 x 1 x .7 x 1 x .2 ≈ 0.00037

Unsupervised Learning of Dependency Grammar

- Production Rules for DGs:
  - Same set of nonterminals and terminals as PSG's
    - SO, depends in a minor way on which PSG you're dealing with
    - Note: **ROOT** usually replaces **S** as distinguished start symbol
  - X → XY or X → YX
  - And that's it: all dependencies are binary
  - Often in learning there are no lexical items; the terminals are, e.g., POS tags or word-class labels
  - No big dependency-annotated corpus for English … yet.