Last Class: Parsing Intro

1. Grammars and parsing

Today: Parsing Algorithms

1. Top-down and bottom-up parsing
2. Chart parsers
3. Bottom-up chart parsing

CFG's

A context free grammar consists of:

1. a set of non-terminal symbols N
2. a set of terminal symbols Σ (disjoint from N)
3. a set of productions, P, each of the form $A \rightarrow \alpha$, where A is a non-terminal and α is a string of symbols from the infinite set of strings $(\Sigma \cup N)^*$
4. a designated start symbol S

CFG example

CFG's are also called phrase-structure grammars.
Equivalent to Backus-Naur Form (BNF).

1. S → NP VP
2. VP → V NP
3. NP → NAME
4. NP → ART N
5. NAME → Beavis
6. V → ate
7. ART → the
8. N → cat

- CFG's are *powerful* enough to describe most of the structure in natural languages.
- CFG's are *restricted* enough so that efficient parsers can be built.

Derivations

- If the rule $A \rightarrow \beta \in P$, and α and γ are strings in the set $(\Sigma \cup N)^*$, then we say that $\alpha A \gamma$ **directly derives** $\alpha\beta\gamma$, or $\alpha A \gamma \Rightarrow \alpha\beta\gamma$
- Let $\alpha_1, \alpha_2, \ldots, \alpha_m$ be strings in $(\Sigma \cup N)^*$, $m > 1$, such that

$$\alpha_1 \Rightarrow \alpha_2, \alpha_2 \Rightarrow \alpha_3, \ldots, \alpha_{m-1} \Rightarrow \alpha_m,$$

then we say that α_1 **derives** α_m or $\alpha_1 \overset{*}{\Rightarrow} \alpha_m$

L_G

The language L_G generated by a grammar G is the set of strings composed of terminal symbols that can be derived from the designated start symbol S.

$L_G = \{w | w \in \Sigma^*, S \stackrel{*}{\Rightarrow} w\}$

Parsing: the problem of mapping from a string of words to its parse tree according to a grammar G.

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General Parsing Strategies

Grammar	Top-Down	Bottom-Up
1. S → NP VP	S → NP VP	→ NAME ate the cat
2. VP → V NP	→ NAME VP	→ NAME V the cat
3. NP → NAME	→ Beav VP	→ NAME V ART cat
4. NP → ART N	→ Beav V NP	→ NAME V ART N
5. NAME → Beavis	→ Beav ate NP	→ NP V ART N
6. V → ate	→ Beav ate ART N	→ NP V NP
7. ART → the	→ Beav ate the N	→ NP VP
8. N → cat	→ Beav ate the cat	→ S

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A Top-Down Parser

Input: CFG grammar, lexicon, sentence to parse
Output: yes/no

State of the parse: (*symbol list*, *position*)

$_1$ The $_2$ old $_3$ man $_4$ cried $_5$

start state: ((S) 1)

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Grammar and Lexicon

Grammar:

1. S → NP VP
2. NP → art n
3. NP → art adj n
4. VP → v
5. VP → v NP

Lexicon:
the: art
old: adj, n
man: n, v
cried: v

$_1$ The $_2$ old $_3$ man $_4$ cried $_5$

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Algorithm for a Top-Down Parser

$PSL \leftarrow$ (((S) 1))

1. *Check for failure.* If PSL is empty, return NO.
2. *Select the current state, C.* C $\leftarrow$ pop (PSL).
3. *Check for success.* If C = (() <final-position>), YES.
4. *Otherwise, generate the next possible states.*
   (a) $s_1 \leftarrow$ first-symbol(C)
   (b) If s_1 is a *lexical symbol* and next word can be in that class, create new state by removing s_1, updating the word position, and adding it to PSL. (I'll add to front.)
   (c) If s_1 is a *non-terminal*, generate a new state for each rule in the grammar that can rewrite s_1. Add all to PSL. (Add to front.)

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Example

Current state	Backup states	
1. ((S) 1)		
2. ((NP VP) 1)		
3. ((art n VP) 1)	((art adj n VP) 1)	
4. ((n VP) 2)	((art adj n VP) 1)	
5. ((VP) 3)	((art adj n VP) 1)	
6. ((v) 3)	((v NP) 3) ((art adj n VP) 1)	
7. (() 4)	((v NP) 3) ((art adj n VP) 1)	Backtrack

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8. ((v NP) 3)	((art adj n VP) 1)	leads to backtracking
...		
9. ((art adj n VP) 1)		
10. ((adj n VP) 2)		
11. ((n VP) 3)		
12. ((VP) 4)		
13. ((v) 4)	((v NP) 4)	
14. (() 5)	((v NP) 4)	
YES		

DONE!

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Problems with the Top-Down Parser

1. Only judges grammaticality.
2. Stops when it finds a single derivation.
3. No semantic knowledge employed.
4. No way to rank the derivations.
5. Problems with left-recursive rules.
6. Problems with ungrammatical sentences.

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Efficient Parsing

The top-down parser is terribly inefficient.

Have the first year Phd students in the computer science department take the Q-exam.

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Chart Parsers

chart: data structure that stores partial results of the parsing process in such a way that they can be reused. The chart for an n-word sentence consists of:

- $n + 1$ **vertices**
- a number of **edges** that connect vertices

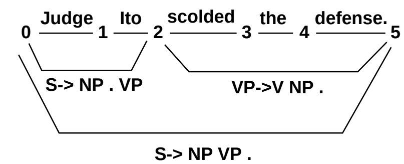

Chart Parsing: The General Idea

The process of parsing an n-word sentence consists of forming a chart with $n + 1$ vertices and adding edges to the chart one at a time.

- Goal: To produce a complete edge that spans from vertex 0 to n and is of category S.
- There is no backtracking.
- Everything that is put in the chart stays there.
- Chart contains all information needed to create parse tree.

Bottom-UP Chart Parsing Algorithm

Do until there is no input left:

1. If the agenda is empty, get next word from the input, look up word categories, add to agenda (as constituent spanning two postions).
2. Select a constituent from the agenda: constituent C from p_1 to p_2.
3. Insert C into the chart from position p_1 to p_2.
4. For each rule in the grammar of form $X \rightarrow C\ X_1 \ldots X_n$, add an active edge of form $X \rightarrow C \circ X_1 \ldots X_n$ from p_1 to p_2.

5. Extend existing edges that are looking for a C.
   (a) For any active edge of form $X \to X_1 \ldots \circ C X_n$ from p_0 to p_1, add a new active edge $X \to X_1 \ldots C \circ X_n$ from p_0 to p_2.
   (b) For any active edge of form $X \to X_1 \ldots X_n \circ C$ from p_0 to p_1, add a new (completed) constituent of type X from p_0 to p_2 to the agenda.

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Grammar and Lexicon

Grammar:

1. S → NP VP
2. NP → ART N
3. NP → ART ADJ N
4. VP → V NP

Lexicon:

the: ART

old: ADJ, N

man: N, V

boat: N

Sentence: $_1$ The $_2$ old $_3$ man $_4$ the $_5$ boat $_6$

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Example

[See .ppt slides]

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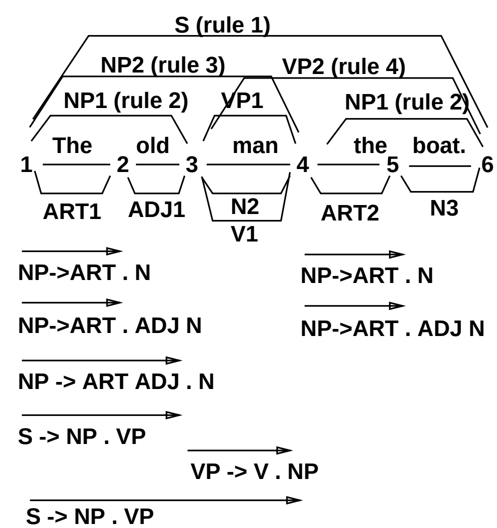

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Bottom-up Chart Parser

Is it any less naive than the top-down parser?

1. Only judges grammaticality.[fixed]
2. Stops when it finds a single derivation.[fixed]
3. No semantic knowledge employed.
4. No way to rank the derivations.
5. Problems with ungrammatical sentences.[better]
6. Terribly inefficient.