

# Language Technology

<http://cs.lth.se/edan20/>  
Chapter 12: Constituent Parsing

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# Parsing

Possible parsing strategies are top-down or bottom-up

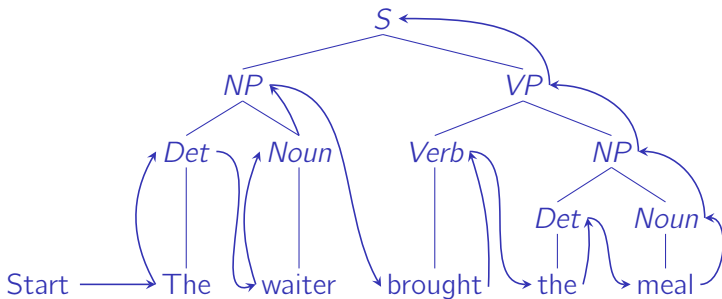
Prolog uses a top-down exploration and backtracks in case of error

Ambiguity can produce two or more possible parse trees

It is necessary to use probabilistic or symbolic techniques to rank parse trees



# Bottom-up Parsing



# Shift and Reduce

The shift and reduce algorithm implements bottom-up parsing.

Two input arguments: the list of words to parse and the parsing goal.

The algorithm gradually reduces words, parts of speech, and phrases until it reaches the parsing goal.

The algorithm consists of a loop of two steps:

- **Shift** a word from the phrase or sentence to parse onto a stack;
  - Apply a sequence of grammar rules to **reduce** elements of the stack
- until there is no more word in the list and the stack is reduced to the parsing goal.



# DCG Rules

## Nonterminal symbols

```
s --> np, vp.  
np --> det, noun.  
np --> np, pp.  
vp --> verb, np.  
vp --> verb, np, pp.  
pp --> prep, np.
```

## Terminal symbols

```
det --> [the].  
det --> [a].  
noun --> [waiter].  
noun --> [meal].  
noun --> [table].  
noun --> [day].  
verb --> [brought].  
prep --> [to].  
prep --> [of].
```



# Shift and Reduce in Action

It.	Stack	S/R	Word list
0			[the, waiter, brought, the, meal]
1	[the]	Shift	[waiter, brought, the, meal]
2	[det]	Reduce	[waiter, brought, the, meal]
3	[det, waiter]	Shift	[brought, the, meal]
4	[det, noun]	Reduce	[brought, the, meal]
5	[np]	Reduce	[brought, the, meal]
6	[np, brought]	Shift	[the, meal]
7	[np, v]	Reduce	[the, meal]
8	[np, v, the]	Shift	[meal]
9	[np, v, det]	Reduce	[meal]
10	[np, v, det, meal]	Shift	[]
11	[np, v, det, n]	Reduce	[]
12	[np, v, np]	Reduce	[]
13	[np, vp]	Reduce	[]
14	[s]	Reduce	[]



# Backtracking May be Inefficient

Example:

*The meal of the day*

np --> npx. npx --> det, noun.

np --> npx, pp.

pp --> prep, np.



# The Structure of a Chart

A chart is a data structure that avoids backtracking

It uses classical grammar rules

It is a graph (DAG) where nodes are intervals between words

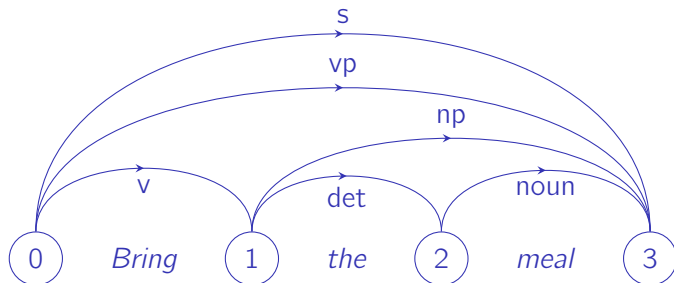
① *Bring* ② *the* ③ *meal* ④

① *The* ② *meal* ③ *of* ④ *the* ⑤ *day* ⑥



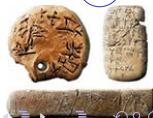
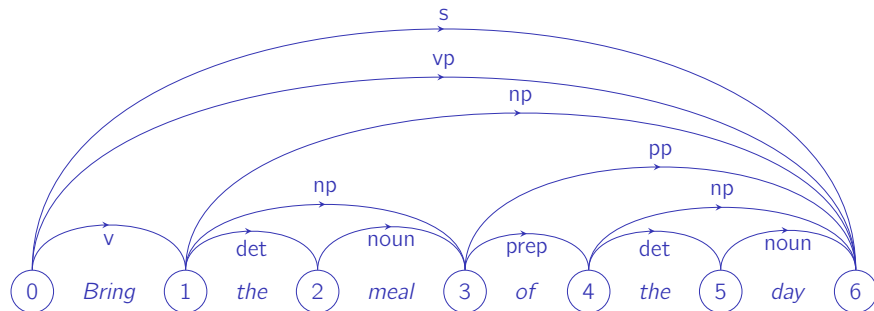


# Parsing with a Chart



# Charts Contain Alternative Parses

We can view rules  $vp \rightarrow v, np$  and  $vp \rightarrow v, np, pp$  in the chart



# The Active Chart

The active chart stores constituents being parsed and marks the rules accordingly.

The rule:

`np --> det noun •`

is a completely parsed noun phrase: a determiner and a noun.

The arc is said to be inactive

The rules below are said to be active:

`np --> det • noun`    A determiner has been found

`np --> • det noun`    We are seeking a noun phrase



# The Earley Algorithm

Complexity of  $O(N^3)$

Three modules: the predictor, the scanner, and the completer.

They use phrase-structure rules as:

`start --> • np`

`np --> det, noun.`

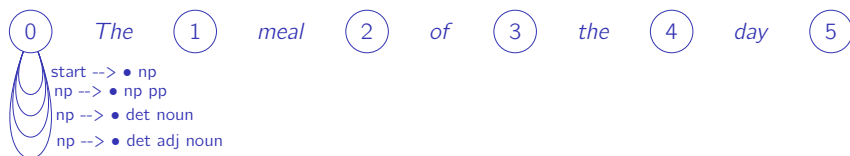
`np --> det, adj, noun.`

`np --> np, pp.`

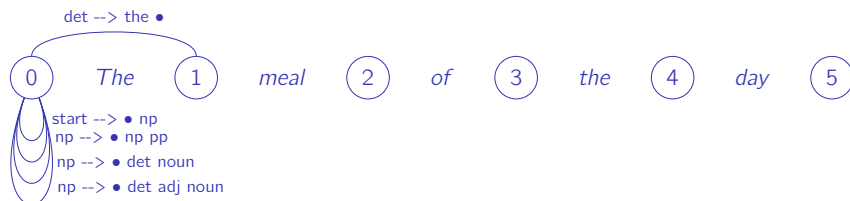
`pp --> prep, np.`



# The Predictor



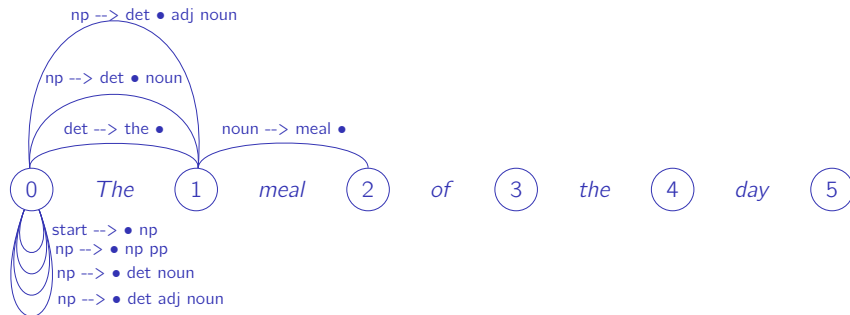
# The Scanner



# The Completer

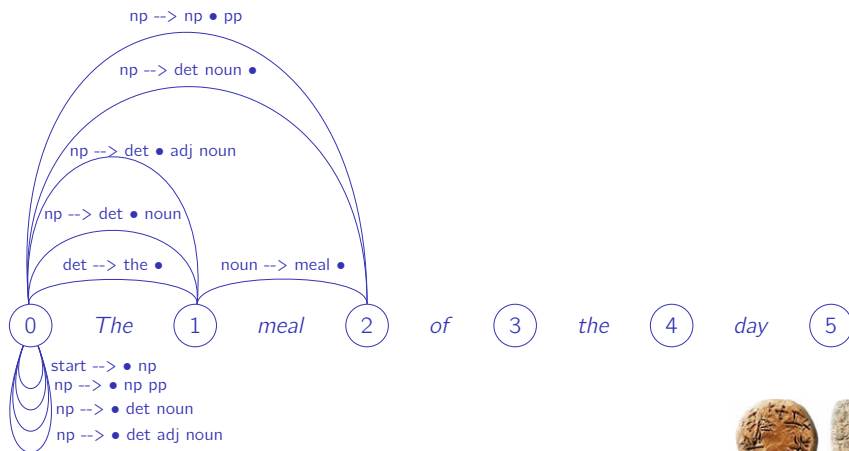


# The Next Steps (I)





# The Next Steps (II)



# The Prolog Database

Module	New chart entries
	Position 0
start predictor	arc(start, ['.', np], 0, 0) arc(np, [., d, n], 0, 0), arc(np, [., d, a, n], 0, 0), arc(np, [., np, pp], 0, 0)
	Position 1
scanner completer predictor	arc(d, [the, .], 0, 1) arc(np, [d, ., a, n], 0, 1), arc(np, [d, ., n], 0, 1) []
	Position 2
scanner completer completer predictor	arc(n, [meal, .], 1, 2) arc(np, [d, n, .], 0, 2) arc(np, [np, ., pp], 0, 2), arc(start, [np, .], 0, 2) arc(pp, [., prep, np], 2, 2)



# The Prolog Database

	Position 3
scanner	<code>arc(pre, [of, .], 2, 3)</code>
completer	<code>arc(pp, [pre, ., np], 2, 3)</code>
predictor	<code>arc(np, [., d, n], 3, 3), arc(np, [., d, a, n], 3, 3), arc(np, [., np, pp], 3, 3)</code>
	Position 4
scanner	<code>arc(d, [the, .], 3, 4)</code>
completer	<code>arc(np, [d, ., a, n], 3, 4), arc(np, [d, ., n], 3, 4)</code>
predictor	<code>[]</code>
	Position 5
scanner	<code>arc(n, [day, .], 4, 5)</code>
completer	<code>arc(np, [d, n, .], 3, 5)</code>
completer	<code>arc(np, [np, ., pp], 3, 5), arc(pp, [pre, np, .], 2, 5)</code>
completer	<code>arc(np, [np, pp, .], 0, 5)</code>
completer	<code>arc(np, [np, ., pp], 0, 5), arc(start, [np, .], 0, 5)</code>



# Probabilistic Context-Free Grammars

$$P(T, S) = \prod_{rule(i) \text{ producing } T} P(rule(i)).$$

where

$$P(lhs \rightarrow rhs_i | lhs) = \frac{Count(lhs \rightarrow rhs_i)}{\sum_j Count(lhs \rightarrow rhs_j)}.$$



# An Example of PCFG

Rules	$P$	Rules	$P$
s --> np vp	0.8	det --> the	1.0
s --> vp	0.2	noun --> waiter	0.4
np --> det noun	0.3	noun --> meal	0.3
np --> det adj noun	0.2	noun --> day	0.3
np --> pronoun	0.3	verb --> bring	0.4
np --> np pp	0.2	verb --> slept	0.2
vp --> v np	0.6	verb --> brought	0.4
vp --> v np pp	0.1	pronoun --> he	1.0
vp --> v pp	0.2	prep --> of	0.6
vp --> v	0.1	prep --> to	0.4
pp --> prep np	1.0	adj --> big	1.0



# Parse Trees of *Bring the meal of the day*

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## Parse trees

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T1: `vp(verb(bring),  
      np(np(det(the), noun(meal)),  
          pp(prep(of), np(det(the), noun(day))))))`

T2: `vp(verb(bring),  
      np(np(det(the), noun(meal))),  
      pp(prep(of), np(det(the), noun(day))))`

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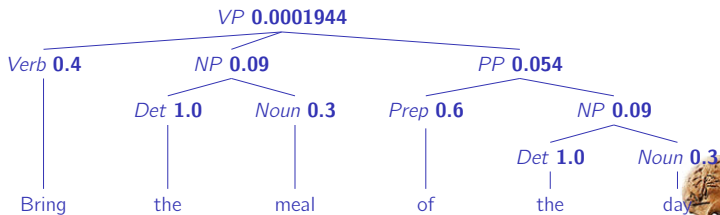
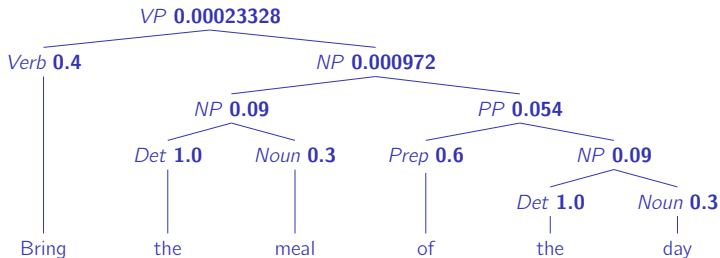
# Computing the Probabilities

$$\begin{aligned}
 &P(T_1, \text{Bring the meal of the day}) = \\
 &P(vp \rightarrow v, np) \times P(v \rightarrow \text{Bring}) \times P(np \rightarrow np, pp) \times \\
 &P(np \rightarrow det, noun) \times P(det \rightarrow the) \times P(noun \rightarrow meal) \times \\
 &P(pp \rightarrow prep, np) \times P(pre \rightarrow of) \times P(np \rightarrow det, noun) \times \\
 &P(det \rightarrow the) \times P(noun \rightarrow day) = \\
 &0.6 \times 0.4 \times 0.2 \times 0.3 \times 1.0 \times 0.3 \times 1.0 \times 0.6 \times 0.3 \times 1.0 \times 0.3 = 0.00023328,
 \end{aligned}$$

$$\begin{aligned}
 &P(T_2, \text{Bring the meal of the day}) = \\
 &P(vp \rightarrow v, np, pp) \times P(v \rightarrow \text{Bring}) \times P(np \rightarrow det, noun) \times \\
 &P(det \rightarrow the) \times P(noun \rightarrow meal) \times P(pp \rightarrow prep, np) \times P(pre \rightarrow of) \times \\
 &P(np \rightarrow det, noun) \times P(det \rightarrow the) \times P(noun \rightarrow day) = \\
 &0.1 \times 0.4 \times 0.3 \times 1.0 \times 0.3 \times 1.0 \times 0.6 \times 0.3 \times 1.0 \times 0.3 = 0.0001944
 \end{aligned}$$



# Computing the Probabilities





# PCF Grammars Ignore Lexical Preferences

$$\begin{aligned}\frac{P(T_1|\text{Bring the meal of the day})}{P(T_2|\text{Bring the meal of the day})} &= \frac{P(T_1|\text{Bring the meal to the table})}{P(T_2|\text{Bring the meal to the table})}, \\ &= \frac{P(vp \rightarrow v, np) \times P(np \rightarrow np, pp)}{P(vp \rightarrow v, np, pp)}\end{aligned}$$

PCF grammars do not take into account the lexicon and the attachment preferences of *of* and *to*.



# Parser Evaluation

## Constituent parsing

$$\text{Recall} = \frac{\text{Number of correct constituents generated by the parser}}{\text{Number of constituents in the manually bracketed corpus}}$$

$$\text{Precision} = \frac{\text{Number of correct constituents generated by the parser}}{\text{Total number of constituents generated by the parser}}$$

Bracketing	Crossing brackets
( ((bring) (the meal)) (of the day))	(        ) (        )
((bring) ((the meal) (of the day)))	(        ) (        )

