

DD2418 Language Engineering

2a: Syntax

Johan Boye, KTH

March 20, 2020

Levels of linguistic analysis

Words	Morphology, Phonology
Sentences	Syntax
Meaning	Semantics
Language use	Pragmatics

Formalizing syntax

We want an (automatic) procedure separating sequences of words that belong to the language from those who don't.

We'd like to identify *who* does *what when/how/to whom* .

- *who*: the subject
- *does*: the predicate
- *what/when/how/to whom* : the object, or adverbial, or complement

Despite the embattled prime minister's dramatic promise on Wednesday that she would hand over the keys to 10 Downing Street if her Tory colleagues backed the withdrawal agreement, parliament voted against it on Friday, by 344 to 286.

The Guardian, April 2, 2019

Who? parliament

Did? voted

What? against the withdrawal agreement

When? on Friday

How? by 344 to 286

Despite the embattled prime minister's dramatic promise on Wednesday that she would hand over the keys to 10 Downing Street if her Tory colleagues backed the withdrawal agreement, parliament voted against it on Friday, by 344 to 286.

The Guardian, April 2, 2019

- Who?** the embattled prime minister
- Did?** promised
- What?** to resign (to hand over the keys to 10 Downing Street)
- When?** on Wednesday
- How?** if her Tory colleagues backed the withdrawal agreement

Formalizing syntax

We'll have a look at two different formalisms:

- **Context-free grammars** (phrase-structure grammars), based on the notion of **constituent** or **phrase**
 - noun phrase, verb phrase, ...
- **Dependency structures**, based on the notion of **grammatical functions**
 - subject, predicate, complement, ...

Word classes and interchangeability

Words of the same class can often be substituted for each other (but there are also many exceptions).

- *There was a fly on the wall.*
- *There was a fear on the wall.*
- Syntactically correct although the meaning is unclear.

But also a group of words can have the same role.

Constituents

A **constituent** is a group of words acting as a unit.

E.g. a **noun phrase**:

- **Ideas** entered his brain.
- **An idea** entered his brain.
- **A brilliant idea** entered his brain.
- **A brilliant idea about prime numbers** entered his brain.
- **A brilliant idea about prime numbers that had struck him before several years earlier when he was working as a visiting professor in Paris** entered his brain.
- etc.

Context-free grammars (CFG)



Noam Chomsky introduced context-free grammars in 1956.

Recall that a CFG consists of

- A set of **terminal** symbols (words, in our case)
- A set of **non-terminal** symbols (constituents, in our case)
- A set of **rewrite rules** on the form

$$A \rightarrow \alpha$$

where α is a string of terminals and non-terminals.

Noun phrase

A **noun phrase** is a constituent where the head word is a **noun**, a **pronoun**, or a **proper name**.

$NP \rightarrow N$	Ideas
$NP \rightarrow P$	He
$NP \rightarrow PM$	John
$NP \rightarrow DET\ N$	An idea
$NP \rightarrow DET\ Adj\ N$	A great idea
$NP \rightarrow NP\ CConj\ NP$	A great idea and a bad idea
$NP \rightarrow DET\ Adj\ N\ PP$	A great idea about prime numbers
etc.	

where *PP* is a **prepositional phrase**.

Nominals

English (but not Swedish!) allows sequences of nouns. These are called **nominals**.

numbers

prime numbers

prime number theorem

prime number limit theorem

etc.

Nominal \rightarrow *N*

Nominal \rightarrow *Nominal N*

NP \rightarrow *Nominal*

Prepositional phrases

A **prepositional phrase** has a preposition as a head word.

$PP \rightarrow P\ NP$ about prime numbers

Verb phrases

$VP \rightarrow V$ run

$VP \rightarrow V NP$ run a business

$VP \rightarrow V NP PP$ run a business in Sweden

$VP \rightarrow V PP$ run for president

etc.

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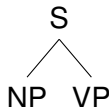
2b: Syntax trees

Johan Boye, KTH

Syntax trees

The phrase structure can be depicted in a **syntax tree** (or **parse tree**).

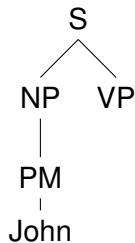
$S \rightarrow NP VP$
 $NP \rightarrow PM \mid Det N \mid Det N PP$
 $VP \rightarrow V NP \mid V NP PP$
 $PP \rightarrow P NP$
 $N \rightarrow pie \mid fridge$
 $V \rightarrow made$
 $P \rightarrow in$
 $Det \rightarrow the$
 $PM \rightarrow John$



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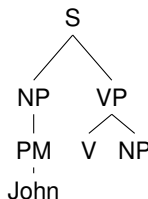
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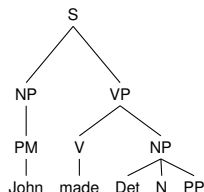
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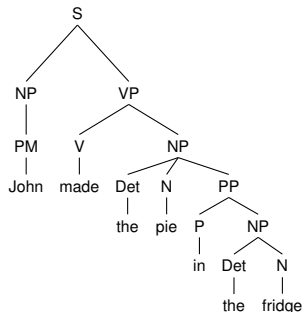
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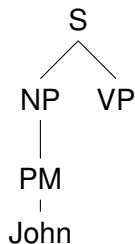
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Syntax trees

Suppose, at this point, we choose another rule.

$S \rightarrow NP VP$
 $NP \rightarrow PM \mid Det N \mid Det N PP$
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 $V \rightarrow made$
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Syntax trees

$S \rightarrow NP VP$

$NP \rightarrow PM \mid Det N \mid Det N PP$

$VP \rightarrow V NP \mid V NP PP$

$PP \rightarrow P NP$

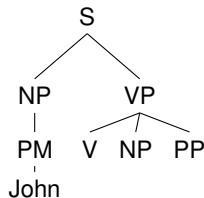
$N \rightarrow pie \mid fridge$

$V \rightarrow made$

$P \rightarrow in$

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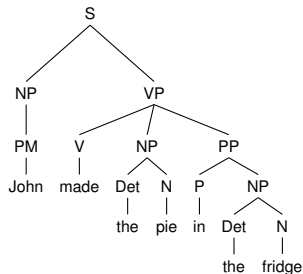
$PM \rightarrow John$



Syntax trees

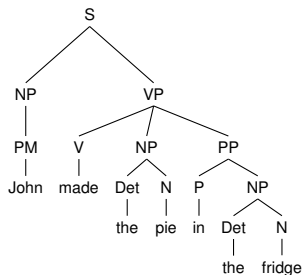
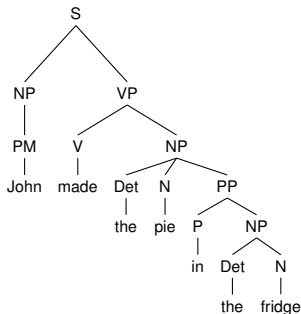
We could derive the same sentence, but in another way.

$S \rightarrow NP VP$
 $NP \rightarrow PM \mid Det N \mid Det N PP$
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 $PM \rightarrow John$



Ambiguity

This sentence has two different syntax trees, so it is **ambiguous**.



Exercise

Write syntax trees for the sentences

John bought a watch.

John bought a watch in pure gold.

John bought a watch in cash.

John bought a watch in pure gold in cash.

Invent the necessary grammar rules as you go along.

Use grammatically motivated constituents like NP, VP, etc.

Exercise

Write syntax trees for the sentences

John bought a watch.

John bought a watch in pure gold.

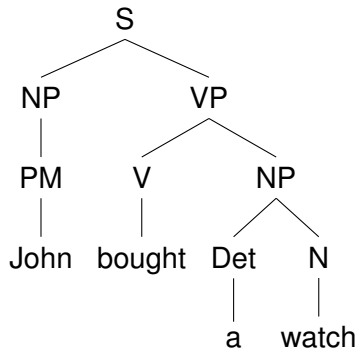
John bought a watch in cash.

John bought a watch in pure gold in cash.

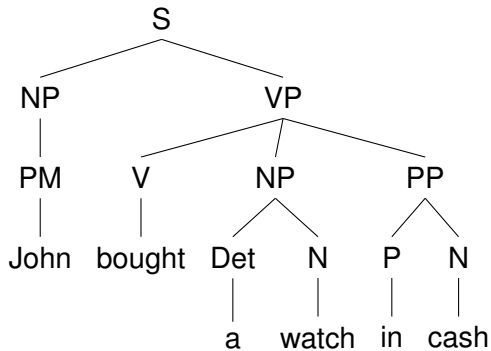
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Use grammatically motivated constituents like NP, VP, etc.

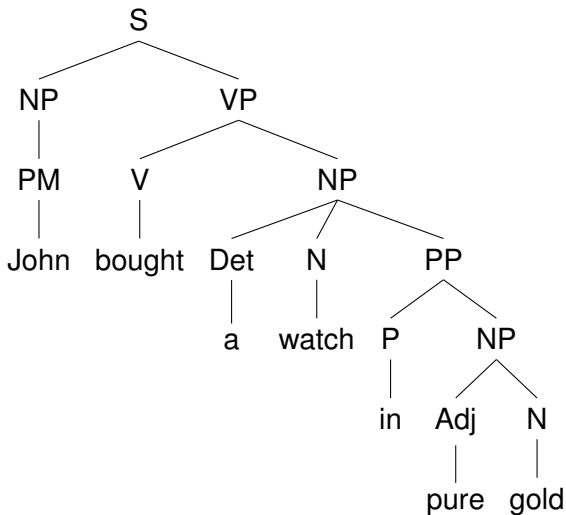
John bought a watch



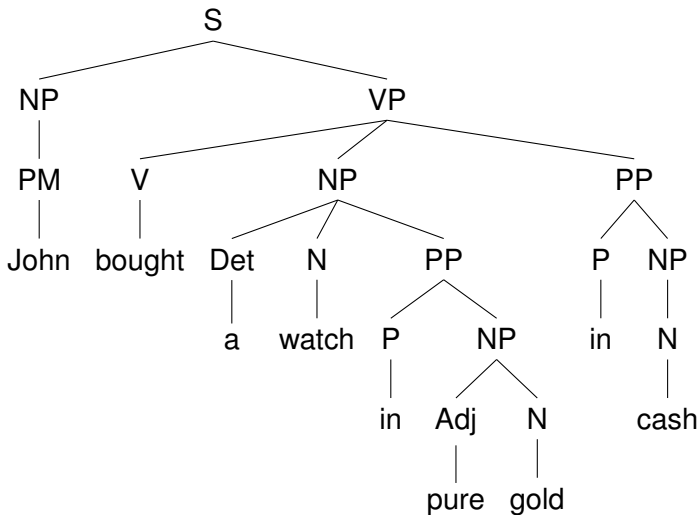
John bought a watch in cash



John bought a watch in pure gold



John bought a watch in pure gold in cash



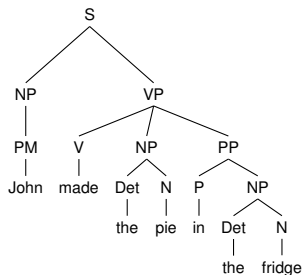
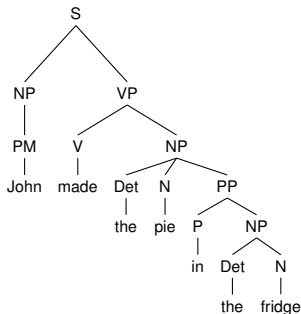
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2c: Ambiguity

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Ambiguity

This sentence has two different syntax trees, so it is **ambiguous**.



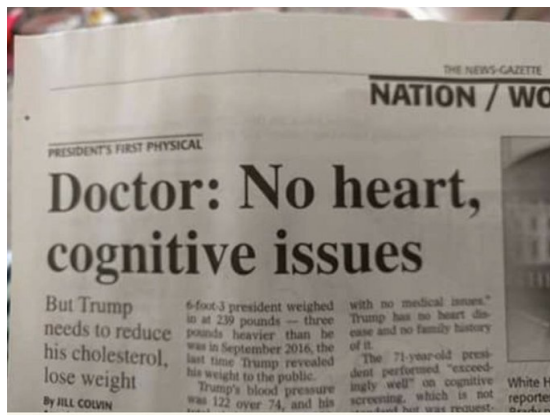
Prepositional attachment ambiguity

3 prepositional phrases give 5 analyses

- Put the block **[in the box on the table] in the kitchen**
- Put the block **[in the box] on the table in the kitchen**
- Put **[the block in the box] on the table** in the kitchen
- Put **[the block [in the box on the table]]** in the kitchen
- Put **[the block in the box] [on the table in the kitchen]**

Number of analyses grows as the Catalan numbers: 1, 2, 5, 14, 42, 132,...

Coordination ambiguity



The News Gazette, 2018

Modifier ambiguity

numbers, including some that featured a bucket and bells brigade of performers who beat big drums on buckets and trash cans with drums sticks and hammer mallets. PHOTO BY JENNIFER STULTZ

MENTORING DAY Students get first hand job experience

By Gale Rose
grose@pratttribune.com

Eager students invaded businesses all over Pratt Tuesday, October 24 as they looked for future job opportunities on Disability Mentoring Day.

The 97 students from 12 schools fanned out across Pratt and got first hand experience what it would be like to work at those 40 businesses. They asked questions and got some hands on experience with various operations.

Paola Luna of Pratt High School, Gina Patton of Kingman High School and America Fernandez of St. John chose the Main Street Small Animal Veterinarian Clinic for their business. Students got a tour of the facility, learned what happens in an examination, got to handle various animals and watched a snake eat a mouse.

Luna said she was interested in animal health and wanted to know more about caring for hurt animals. Patton likes all kinds of animals and said she learned a lot from the experience. Watching the snake eat the mouse impressed her the most.

Fernandez wants to become a veterinarian and enjoyed learning everything that veterinarians

SEE MENTORING, 6

ing Meyer
ty Commissioner

- Hospital Pharmacist for 41 years
- 4 years Commissioner for Pratt Planning and Zoning Board of Appeals
- 3 years Pratt City Commission
- Graduate of Pratt High School and KU School of Pharmacy
- Past Member and President of Civic Groups and Organizations
- Experience and Knowledge of Financial Responsibility and Budgeting
- Supports Family Values, Education, and Business Growth
- Common Sense Approach for the Sustained Progress of Pratt

12 SATURDAY, October 28, 2017 ■ The Pratt Tribune ■ www.pratttribune.com

Pratt Tribune, Oct 28, 2017

Time flies like an arrow.

Ambiguity

Time	flies	like	an	arrow
Noun	Verb	Prep	Det	Noun

Ambiguity

Time flies like an arrow

Noun Verb Prep Det Noun

Noun Noun Verb Det Noun

Ambiguity

Time	flies	like	an	arrow
Noun	Verb	Prep	Det	Noun
Noun	Noun	Verb	Det	Noun
Verb	Noun	Prep	Det	Noun

Ambiguity

Time	flies	like	an	arrow
Noun	Verb	Prep	Det	Noun
Noun	Noun	Verb	Det	Noun
Verb	Noun	Prep	Det	Noun
Verb	Noun	Conj	Det	Noun

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2d: Parsing

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Parsing strategies

Top-down

- Start at the root node, expand tree by matching left-hand side of rules.
- Derive a tree whose leaves match the input.
- We might use rules that could never match the input.
- Watch out for loops $VP \rightarrow VP PP$

Bottom-up

- Start at the leaves, build tree by matching right-hand side of rules.
- Derive a tree whose root is S .
- Builds structures that will never be used in the tree.

Parsing and dynamic programming

The number of possible trees grows exponentially with sentence length.

A naive backtracking approach is too inefficient.

But alternative trees share subtrees, so we can use [dynamic programming](#).

- No work is repeated.
- Gives polynomial algorithm.
- Example: [CKY \(Cocke-Kasami-Younger\)](#)

Chomsky Normal Form

The CKY algorithm requires the grammar to be in **Chomsky Normal Form (CNF)**.

All rules have the form $A \rightarrow BC$ or $A \rightarrow \textit{word}$.

If the grammar is not in CNF, it has to be rewritten.

Chomsky Normal Form

Translation into CNF:

- $A \rightarrow B C D$ is replaced by

$$\begin{array}{l} A \rightarrow B X \\ X \rightarrow C D \end{array}$$

where X is a new symbol.

- $A \rightarrow B$ is replaced by

$$\begin{array}{l} A \rightarrow word_1 \\ \dots \\ A \rightarrow word_n \end{array}$$

where $word_1 \dots word_n$ are all the words derivable from B .

Chomsky Normal Form

Quiz: Translate into CNF:

$S \rightarrow NP VP$
 $NP \rightarrow NN \mid Det NN \mid Det NN PP$
 $VP \rightarrow V \mid V PP$
 $PP \rightarrow P NP$
 $NN \rightarrow girl \mid rain \mid coat$
 $V \rightarrow runs$
 $P \rightarrow in$
 $Det \rightarrow the$

$A \rightarrow BCD \Rightarrow$

$A \rightarrow BX$

$X \rightarrow CD$

where X is a new symbol.

$A \rightarrow B \Rightarrow$

$A \rightarrow word_1$

\dots

$A \rightarrow word_n$

where $word_1 \dots word_n$
are all the words derivable
from B .

Chomsky Normal Form

$S \rightarrow NP VP$

$NP \rightarrow Det N \mid Det X$

$X \rightarrow N PP$

$VP \rightarrow V PP$

$PP \rightarrow P NP$

$N \rightarrow girl \mid rain \mid coat$

$NP \rightarrow girl \mid rain \mid coat$

$V \rightarrow runs$

$VP \rightarrow runs$

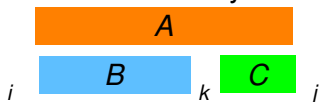
$P \rightarrow in$

$Det \rightarrow the$

CKY algorithm

$A \rightarrow BC$

- If there is an A somewhere in the input, then there has to be a B followed by a C



- If A extends from i to j , there must be a k , $i < k < j$, such that B extends from i to k , and C extends from k to j
- $_0$ the $_1$ girl $_2$ in $_3$ the $_4$ coat $_5$ runs $_6$
- PP covers $[2,5]$, $PP \rightarrow P NP$
- P covers $[2,3]$, NP covers $[3,5]$

CKY algorithm

Partial parses are represented in (half a) $N \times N$ table

- (N = length of input string)
- cell $[i, j]$ contains A if A covers i to j in the input string

		<i>j</i>				
		1	2	3	4	5
<i>i</i>	0	0-1	0-2	0-3	0-4	0-5
	1		1-2	1-3	1-4	1-5
	2			2-3	2-4	2-5
	3				3-4	3-5
	4					4-5

CKY algorithm

For A to cover $[i, j]$:

- $A \rightarrow BC$ is a rule in the grammar
- there is a B in $[i, k]$, and a C in $[k, j]$, for some $i < k < j$
- to apply $A \rightarrow BC$, look for a B in $[i, k]$, and a C in $[k, j]$

	j				
	1	2	3	4	5
0	0-1	0-2	0-3	0-4	0-5
1		1-2	1-3	1-4	1-5
2			2-3	2-4	2-5
3				3-4	3-5
4					4-5

CKY example

Example: Parse the sentence

$_0$ *giant* $_1$ *cuts* $_2$ *in* $_3$ *welfare*

given the grammar

$S \rightarrow NP VP$	$N \rightarrow giant$
$NP \rightarrow JJ NP$	$N \rightarrow cuts$
$NP \rightarrow NP PP$	$N \rightarrow welfare$
$NP \rightarrow N$	$V \rightarrow cuts$
$PP \rightarrow P NP$	$JJ \rightarrow giant$
$VP \rightarrow V PP$	$P \rightarrow in$

CKY example

First translate into Chomsky Normal Form:

- remove $NP \rightarrow N$
- add $NP \rightarrow giant \mid cuts \mid welfare$











$S \rightarrow NP VP$	$N \rightarrow giant$
$NP \rightarrow JJ NP$	$N \rightarrow cuts$
$NP \rightarrow NP PP$	$N \rightarrow welfare$
$NP \rightarrow giant$	$V \rightarrow cuts$
$NP \rightarrow cuts$	$JJ \rightarrow giant$
$NP \rightarrow welfare$	$P \rightarrow in$
$PP \rightarrow P NP$	$VP \rightarrow V PP$

CKY example

Now fill the table **left to right, bottom up**.

When a cell is considered, everything needed to fill that cell is already in the table.

Nice property: Analyses input from left to right, in one sweep.

giant	cuts	in	welfare
			
			
			
			

CKY example

$S \rightarrow NP VP$ $N \rightarrow giant$
 $NP \rightarrow JJ NP$ $N \rightarrow cuts$
 $NP \rightarrow NP PP$ $N \rightarrow welfare$
 $NP \rightarrow giant$ $V \rightarrow cuts$
 $NP \rightarrow cuts$ $JJ \rightarrow giant$
 $NP \rightarrow welfare$ $P \rightarrow in$
 $PP \rightarrow P NP$ $VP \rightarrow V PP$

giant	cuts	in	welfare
N NP JJ			
	N NP V		

CKY example

$S \rightarrow NP VP$	$N \rightarrow giant$
$NP \rightarrow JJ NP$	$N \rightarrow cuts$
$NP \rightarrow NP PP$	$N \rightarrow welfare$
$NP \rightarrow giant$	$V \rightarrow cuts$
$NP \rightarrow cuts$	$JJ \rightarrow giant$
$NP \rightarrow welfare$	$P \rightarrow in$
$PP \rightarrow P NP$	$VP \rightarrow V PP$

giant	cuts	in	welfare
$\begin{matrix} N NP \\ JJ \end{matrix}$	NP		
	$\begin{matrix} N NP \\ V \end{matrix}$		

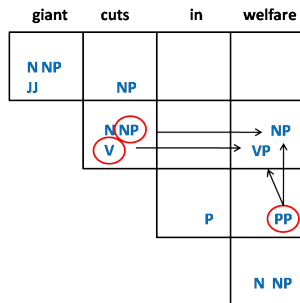
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$S \rightarrow NP VP$ $N \rightarrow giant$
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 $NP \rightarrow giant$ $V \rightarrow cuts$
 $NP \rightarrow cuts$ $JJ \rightarrow giant$
 $NP \rightarrow welfare$ $P \rightarrow in$
 $PP \rightarrow P NP$ $VP \rightarrow V PP$

giant	cuts	in	welfare
$N NP$ JJ	NP		
	$N NP$ V		
		P	PP
			$N NP$

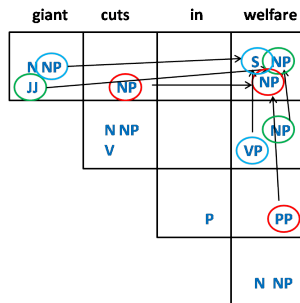
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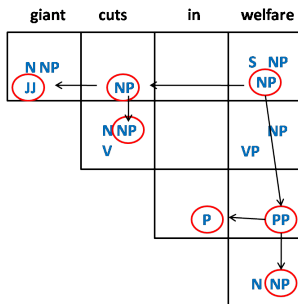


CKY example

$S \rightarrow NP VP$	$N \rightarrow giant$
$NP \rightarrow JJ NP$	$N \rightarrow cuts$
$NP \rightarrow NP PP$	$N \rightarrow welfare$
$NP \rightarrow giant$	$V \rightarrow cuts$
$NP \rightarrow cuts$	$JJ \rightarrow giant$
$NP \rightarrow welfare$	$P \rightarrow in$
$PP \rightarrow P NP$	$VP \rightarrow V PP$



Extracting trees from the CKY table



Summary so far

- Syntax can be described by means of **context-free grammars**
- Such grammars are **generative**
- **Syntax trees** describe the structure of sentences
- **Ambiguous** sentences have more than one tree
- By **parsing** (e.g. using the **CKY** algorithm), we can construct all trees for a given sentence (and grammar)

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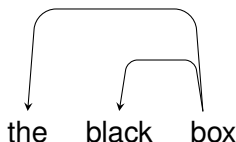
2e: Dependency syntax

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Dependency syntax

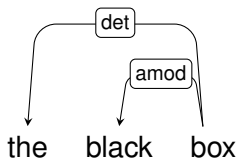
Dependency syntax provides an alternative view

- Binary relations (**dependencies**) between words
- A **head (governor)** word is related to its **modifiers (dependents)**
- The dependencies form a tree.



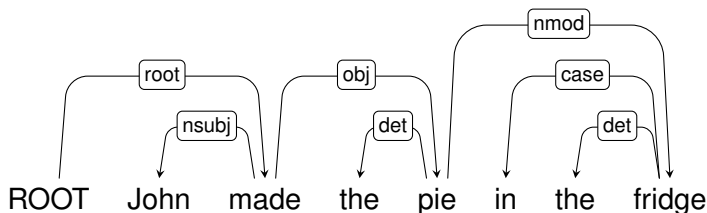
Dependency syntax

Usually the arcs are labeled with **grammatical functions**.

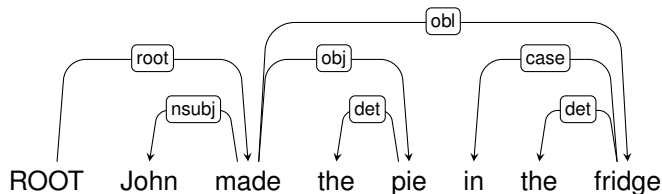
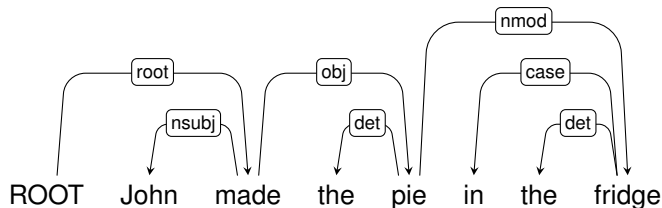


Dependency syntax

- The root of the tree of a whole sentence is almost always the main verb.
- Often a ROOT node is added (so every word is the child of some node).



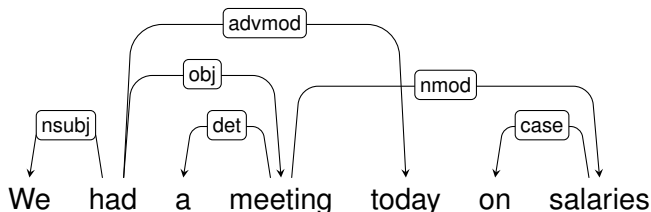
Dependency syntax



Projectivity

A tree is **projective** if no edges cross.

In English, most sensible sentences and phrases are projective. Some exceptions:



Universal dependencies

Where do the labels (nsubj, obj, det, ...) come from?

The **Universal Dependencies** initiative provides a common set of part-of-speech tags, morphological features, and dependency relations.

	Nominals	Clauses	Modifier words	Function Words
Core arguments	<u>nsubj</u> <u>obj</u> <u>iobj</u>	<u>csubj</u> <u>ccomp</u> <u>xcomp</u>		
Non-core dependents	<u>obl</u> <u>vocative</u> <u>expl</u> <u>dislocated</u>	<u>advcl</u>	<u>advmod</u> * <u>discourse</u>	<u>aux</u> <u>cop</u> <u>mark</u>
Nominal dependents	<u>nmod</u> <u>appos</u> <u>nummod</u>	<u>acl</u>	<u>amod</u>	<u>det</u> <u>clf</u> <u>case</u>
Coordination	MWE	Loose	Special	Other
<u>conj</u> <u>cc</u>	<u>fixed</u> <u>flat</u> <u>compound</u>	<u>list</u> <u>parataxis</u>	<u>orphan</u> <u>goeswith</u> <u>reparandum</u>	<u>punct</u> <u>root</u> <u>dep</u>

Treebanks and annotated data

A **treebank** is a corpus in which each sentence has exactly one parse tree.

- Manual annotation by linguists
- Provides frequency information: How often are various relations/rules used?
- Reusability: Many parsers, part-of-speech taggers can be built upon it
- Provides a way to evaluate systems.

The Universal Dependencies website provides links to treebanks in many languages, using the same tags and relations.

Dependency parsing

Parsing can be done using dynamic programming ([Eisner's algorithm](#)).

- This will give all parse trees of a given sentence in $O(n^3)$ time
- Much like the CKY algorithm for context-free grammars

However, much more popular (and more efficient) is to use [transition-based parsing](#)

- Greedy, deterministic algorithm
- Returns a single, projective, tree
- By using statistics from a treebank, the returned tree is most often (but not always) the “best” tree (the most probable interpretation of the sentence)

Transition-based dependency parsing

A **parser configuration** consists of:

- the **buffer**, initially containing the token ROOT + all the words of the sentence
- the **stack**, initially empty
- the **(partial) dependency tree** being constructed, initially containing all the words but no arcs.

The goal is to reach a **final** configuration, in which:

- the buffer is empty
- the stack only contains ROOT
- the tree is complete (there is an arc to every word)

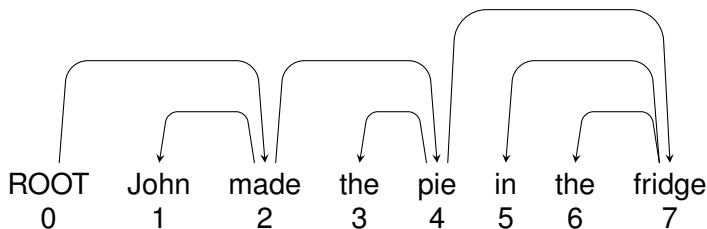
Transition-based dependency parsing

Three possible transitions:

- **shift (SH)**: take the next word from the buffer, and push it onto the stack
- **left arc (LA)**: create an arc from the topmost word to the second topmost word on the stack, then remove the second topmost word
- **right arc (RA)**: create an arc from the second topmost word to the topmost word on the stack, then remove the topmost word

Representing dependency trees

Unlabeled trees can be represented by a list of head positions.



node	0	1	2	3	4	5	6	7
head	0	2	0	4	2	7	7	4

Transition-based parsing example

ROOT	John	made	the	pie	in	the	fridge
0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0

STACK

ROOT John made the pie in the fridge

BUFFER

Next move: SH

Transition-based parsing example

ROOT	John	made	the	pie	in	the	fridge
0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0

STACK

	ROOT
--	------

BUFFER

John made the pie in the fridge

Next move: SH

Transition-based parsing example

ROOT	John	made	the	pie	in	the	fridge
0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0

ROOT John

STACK

made the pie in the fridge

BUFFER

Next move: SH

Transition-based parsing example

ROOT	John	made	the	pie	in	the	fridge
0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0

ROOT John made

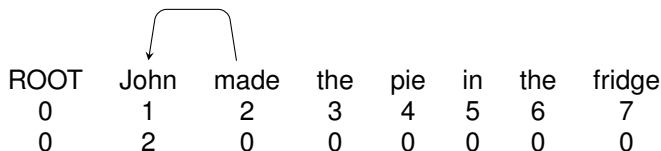
STACK

the pie in the fridge

BUFFER

Next move: LA

Transition-based parsing example



STACK

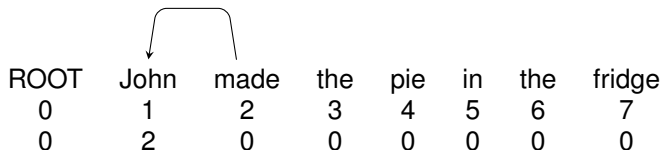
ROOT made

BUFFER

the pie in the fridge

Next move: SH

Transition-based parsing example

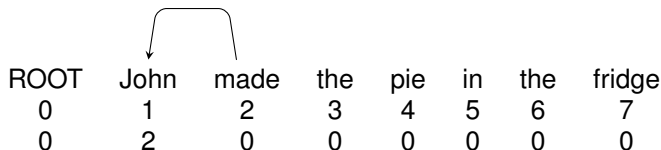


ROOT made the
STACK

pie in the fridge
BUFFER

Next move: SH

Transition-based parsing example



ROOT made the pie

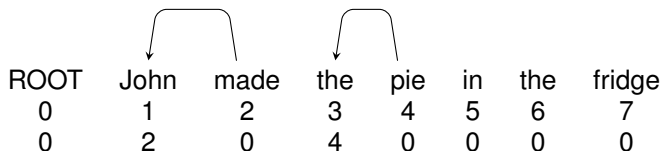
STACK

in the fridge

BUFFER

Next move: LA

Transition-based parsing example

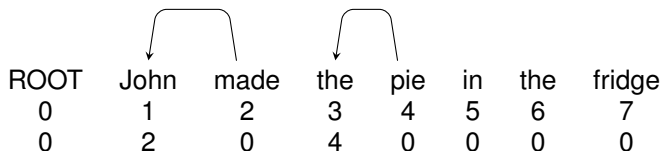


STACK
ROOT made pie

BUFFER
in the fridge

Next move: SH

Transition-based parsing example

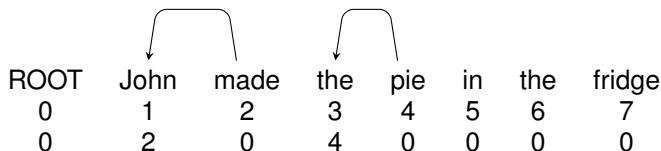


STACK
ROOT made pie in

BUFFER
the fridge

Next move: SH

Transition-based parsing example



ROOT made pie in the

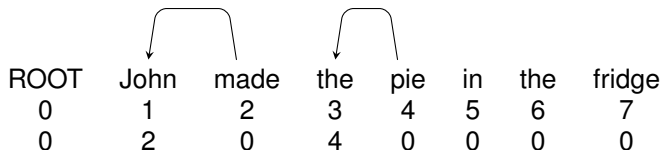
STACK

fridge

BUFFER

Next move: SH

Transition-based parsing example



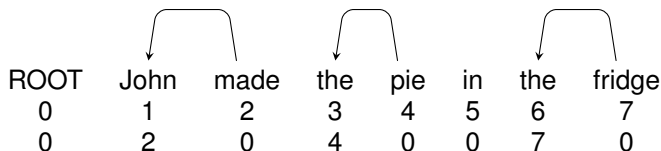
ROOT made pie in the fridge

STACK

BUFFER

Next move: LA

Transition-based parsing example



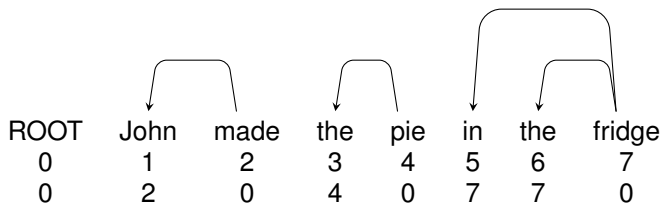
ROOT made pie in fridge

STACK

BUFFER

Next move: LA

Transition-based parsing example



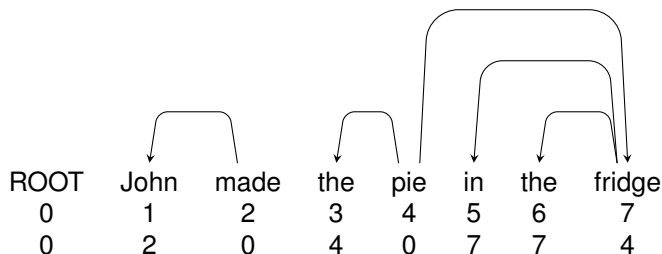
ROOT made pie fridge

STACK

BUFFER

Next move: RA

Transition-based parsing example

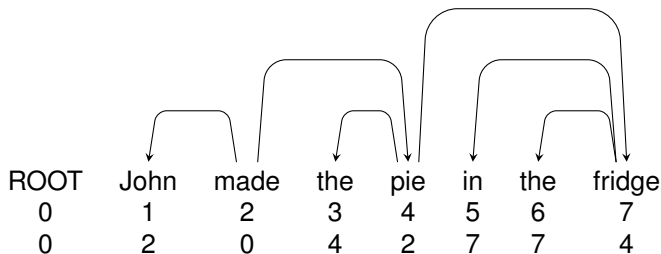


STACK ROOT made pie

BUFFER

Next move: RA

Transition-based parsing example

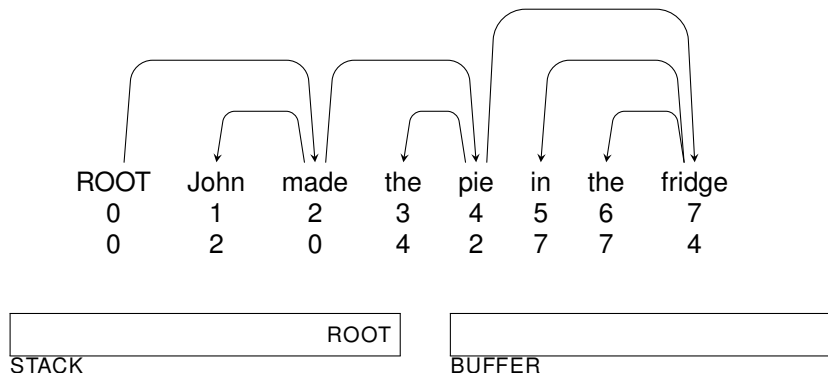


STACK
ROOT made

BUFFER

Next move: RA

Transition-based parsing example



Terminal state

Arc-standard algorithm

The algorithm we just looked at is called the **arc-standard** algorithm.

- possible moves are SH, LA, RA.
- in every parser configuration, one move needs to be selected
- algorithm is greedy, choices can not be undone
- we need an **oracle** to choose the correct action

Creating an oracle

An automatic oracle can be trained through machine learning.

We need a data material to use a training set:

- data points are parser configurations, with associated correct moves

Given such a training set, we can train a classifier:

- 3 classes: SH, LA, RA for unlabeled trees
- For labeled trees (with n labels) we would have $2n + 1$ classes: n LA moves, n RA moves, and 1 SH move.

The moves can be extracted from treebanks with correct dependency trees.

Determining the correct move

ROOT	John	made	the	pie	in	the	fridge
0	1	2	3	4	5	6	7
0							
0	2	0	4	2	7	7	4

STACK

BUFFER

Next move: SH

Determining the correct move

ROOT	John	made	the	pie	in	the	fridge
0	1	2	3	4	5	6	7
0							
0	2	0	4	2	7	7	4

STACK ROOT John

made the pie in the fridge
BUFFER

Next move: SH

Determining the correct move


ROOT	John	made	the	pie	in	the	fridge
0	1	2	3	4	5	6	7
0							
0	2	0	4	2	7	7	4

STACK ROOT John made

BUFFER the pie in the fridge

Next move: LA

Determining the correct move



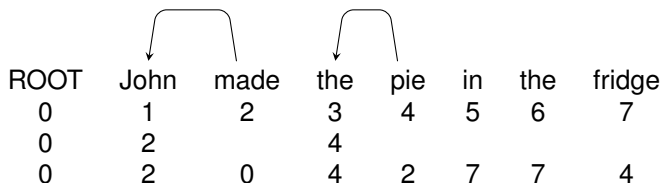
ROOT	John	made	the	pie	in	the	fridge
0	1	2	3	4	5	6	7
0	2						
0	2	0	4	2	7	7	4

STACK ROOT made

the pie in the fridge
BUFFER

Next move: SH

Determining the correct move



ROOT made pie

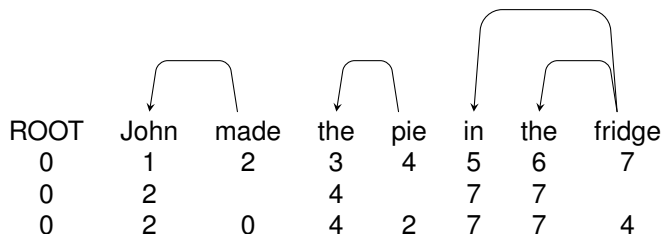
STACK

in the fridge

BUFFER

Next move: SH

Determining the correct move



STACK ROOT made pie fridge

BUFFER

Next move: RA

Extracted datapoints

An example of a datapoint:

- Stack: ROOT made pie
- Buffer: in the fridge
- Correct move: SH