Syntactic Analysis

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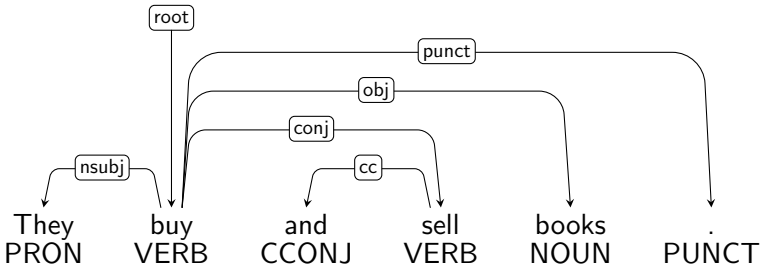
Syntactic Annotation

ID	FORM	LEMMA	POS	FEATS	HEAD	DEPREL
1	They	they	PRON	Case...	2	nsubj
2	buy	buy	VERB	Mood...	0	root
3	and	and	CCONJ	_	4	cc
4	sell	sell	VERB	Mood...	2	conj
5	books	book	NOUN	Number...	2	obj
6	.	.	PUNCT	_	2	punct

Dependency Tree



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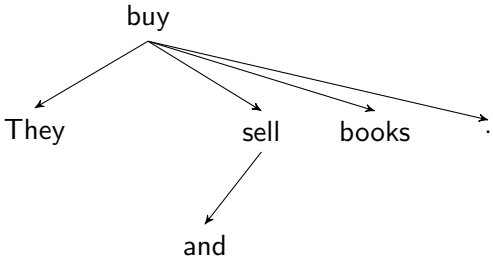

They buy and sell books.

Syntactic Annotation

ID	FORM	LEMMA	POS	FEATS	HEAD	DEPREL
1	Kupují	kupovat	VERB	Mood...	0	root
2	a	a	CCONJ	_	3	cc
3	prodávají	prodávat	VERB	Mood...	1	conj
4	knihy	kniha	NOUN	Case...	1	obj
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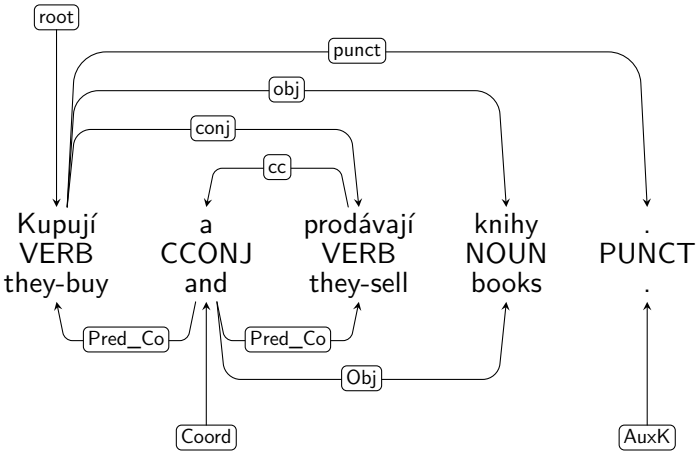
ID	FORM	LEMMA	XPOS	HEAD	DEPREL
1	Kupují	kupovat	VB-P---3P-AA---	2	Pred_Co
2	a	a	J^----------	0	Coord
3	prodávají	prodávat	VB-P---3P-AA---	2	Pred_Co
4	knihy	kniha	NNFP4-----A----	2	Obj
5	.	.	Z:----------	0	AuxK

Dependency Tree



Constituents vs. Dependencies

What Is (Surface) Syntax?

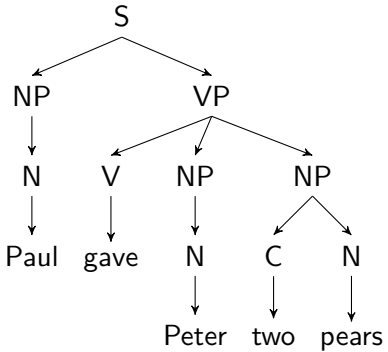
- Relations between sentence parts
- Sentence part = token (word, number, punctuation)
  - Advantages:
    - Token is easily recognizable
    - Unit of previous (morphological) level of processing
    - We do not restore elided (missing) constituents at this level
  - Drawbacks:
    - We must define relations for function words and punctuation
- Purpose:
  - Understand how meaning of words combines into meaning of sentence
  - Some theories also want to show how the sentence was generated

Syntactic Structure

- Different shapes in different theories
- Typically a hierarchical structure – tree
  - Phrasal (constituent) tree, parse tree
  - Dependency tree

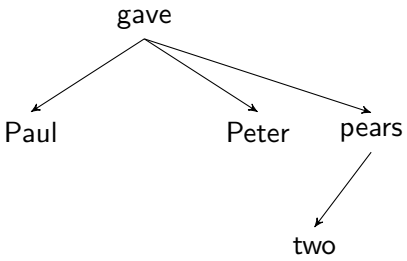
Constituent Tree

(S (NP (N Paul)) (VP (V gave) (NP (N Peter)) (NP (C two) (N pears))))



Dependency Tree

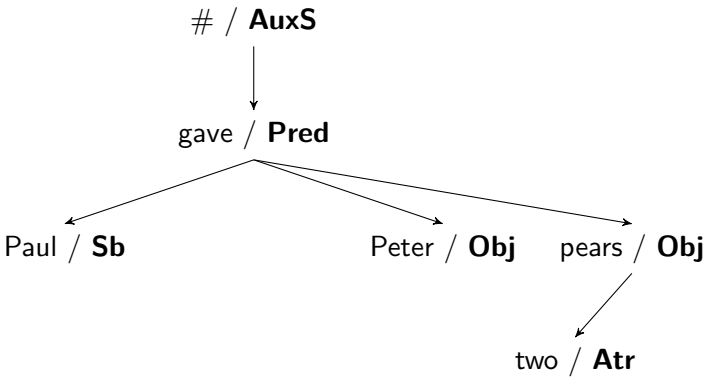
[gave,2] ([Paul,1], [Peter,3], [pears,5] ([two,4]))



Paul gave Peter two pears.

Dependency Tree with Labels

[#,0] ([gave,2] ([Paul,1], [Peter,3], [pears,5] ([two,4])), [.,6])



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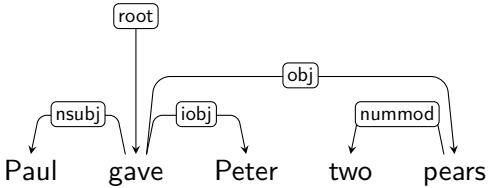
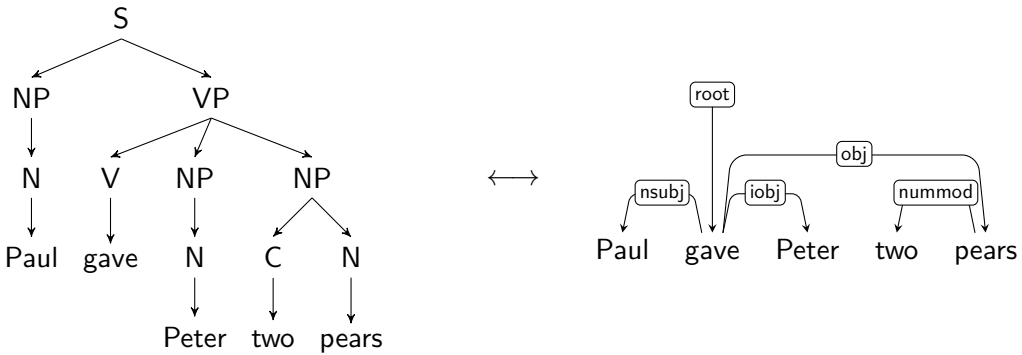


Constituents vs. Dependencies

- The two models are interconnected
- Sentence divided to phrases (constituents)
  - Recursive: phrases divided to smaller phrases
  - The smallest phrases are words
- There are dependencies (relations) between words (constituents)
  - Head of phrase = governing node, parent node
  - The other nodes are dependent nodes, children of the head

Phrase vs. Dependency Trees



Phrase vs. Dependency Trees

- Phrase trees
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  - May not mark the function of the constituent in the superordinate constituent

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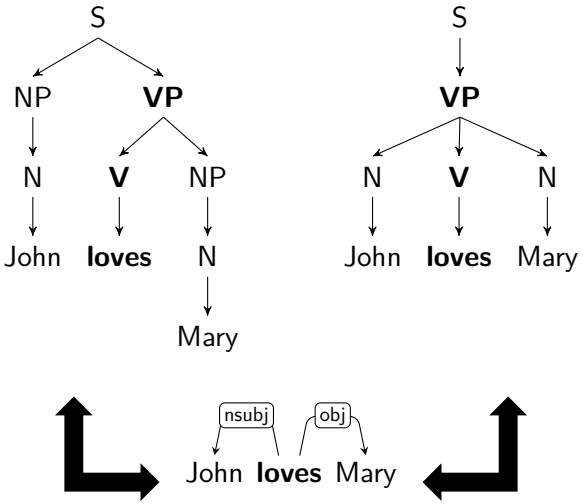
  - May not mark the function of the constituent in the superordinate constituent
- Dependency trees
  - Do not show nonterminals (phrase types)
    - Nor any other phrase-level features
  - Do not show "how the sentence is generated" (order, recursion, proximity of constituents)

Example


S
NP
VP
N
V
NP
John
loves
N
Mary
S
VP
N
V
N
John
loves
Mary
nsubj
obj
John
loves
Mary

Phrases, Their Types and Their Heads

Phrase Replaceability

- A phrase can be replaced by another phrase of the same type
- The sentence stays grammatical
- Specifically, a phrase can be replaced by its head
  - This is related to the generation of the sentence

- Phrases x, y, z can be immediate constituents of a larger phrase f only if they are related to each other. This is however a matter of the particular phrase structure grammar.

- Example sentence: *This is the man that I talked about.*
  - The part *man that I* is not a whole noun phrase.
  - Cannot replace it by another noun phrase, e.g., *man*:
  - **This is the man talked about.*

Phrase

- Sequence of immediate constituents (words or phrases)
- May be discontinuous in some languages
- Phrase types by their main word—head
  - Noun phrase: *the new **book** of my grandpa*
  - Adjectival phrase: *brand **new***
  - Adverbial phrase: *very **well***
  - Prepositional phrase: ***in** the classroom* (if preposition is considered the head—somewhat controversial (cannot replace whole phrase by preposition))
  - Verb phrase: *to **catch** a ball*

Noun Phrase

- A noun or a (substantive) pronoun is the head.
  - ***water***
  - *the* ***book***
  - *new* ***ideas***
  - *two* ***millions*** *of inhabitants*
  - *one small* ***village***
  - *the greatest price* ***movement*** *in one year since the World War II*
  - *operating* ***system*** *that, regardless of all efforts by our admin, crashes just too often*
  - ***he***
  - ***whoever***

Adjective Phrase

- An adjective or a determiner (attributive pronoun) is the head.
- Simple adjectives are very frequent, complex ADJPs are rare.
  - ***old***
  - *very* ***old***
  - *really very* ***old***
  - *five times* ***older*** *than the oldest elephant in our zoo*
  - ***sure*** *that he will arrive first*

Pronouns / Determiners

- (Substantive) pronouns: similar behavior as nouns
  - Personal pronouns *(I, you, they, oneself)*
  - Some demonstrative, interrogative, relative and negative pronouns *(who, what, somebody, something, everything, nothing)*
- Attributive pronouns (determiners): similar behavior as adjectives
  - Possessive pronouns in some languages *(my, your, his, whose)*
  - Articles *(the, a, an)*
  - Attributively used demonstrative, interrogative, relative and negative pronouns *(which, some, every, no)*

Numerals and Quantified Noun Phrases

- Slavic languages: not always clear what should be the head: the quantifier (number), or the counted noun?
  - Numeral inherits gender from counted noun.
  - Counted noun gets grammatical number from numeral (or in accord with it).
    - *jeden* ***muž*** "one man", *jedna* ***žena*** "one woman", *jedno* ***dítě*** "one child"
    - *dva* ***muži*** "two men", *dvě* ***ženy*** "two women", *dvě* ***děti*** "two children"
  - Numeral may govern the case of the counted noun.
    - ***pět*** *mužů* "five men" – noun in genitive, numeral in nominative, accusative, or vocative
  - Or both numeral and counted noun have case required by preposition or verb.
    - *pěti ženami* "five women" – instrumental case

Adverbial Phrase

- An adverb is the head.
- Simple adverbs are very frequent, complex ADVPs are rare.
  - ***quickly***
  - *much* ***more***
  - ***how***
  - ***louder*** *than you can imagine*
  - ***yesterday***

Prepositional (Postpositional) Phrase

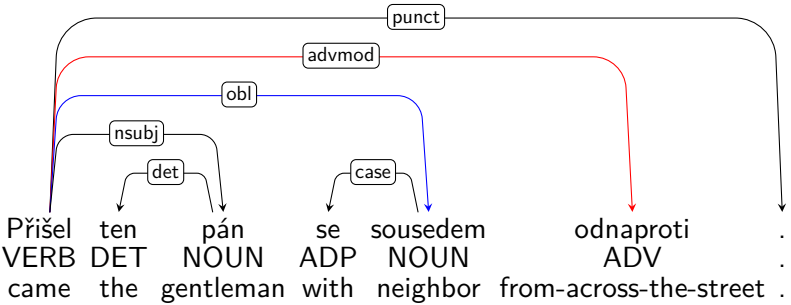
- Many theories: preposition is the head (it determines the case of the rest of the phrase)
- But we cannot replace the phrase by the preposition alone! (Nor can we replace it by the noun without the preposition.)
- PPs often have functions similar to adverbial phrases or noun phrases.
- Preposition in one language may correspond to case morphology in another language.
  - ***in*** *the city center*
  - ***in*** *January*
  - ***in*** *God*
  - ***around*** *five o'clock*
  - ***to*** *a better future*
  - *up* ***to*** *a situation where neither of them could back out*
  - *with respect* ***to*** *his nonage*

Ambiguity in Attachment of Prepositional Phrases

- Classic English example:
  - *I saw the man with a telescope.*
    1. "Viděl jsem muže dalekohledem."
    2. "Viděl jsem muže s dalekohledem."

Ambiguity in Attachment of Prepositional Phrases: Czech Example

Přišel ten pán se sousedem odnaproti. "The gentleman came with his neighbor from across the street."
(*Odnaproti* is an adverb arisen as a frozen PP: *od* + *naproti*.)



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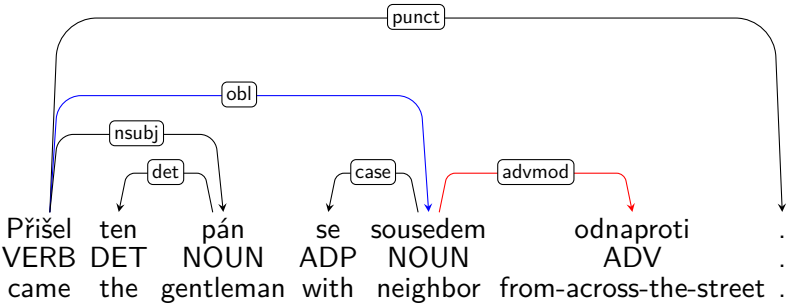

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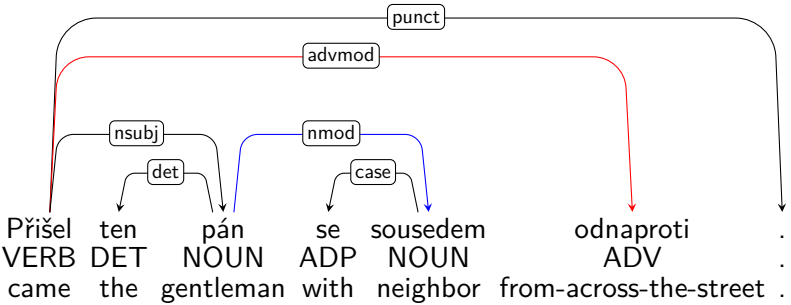

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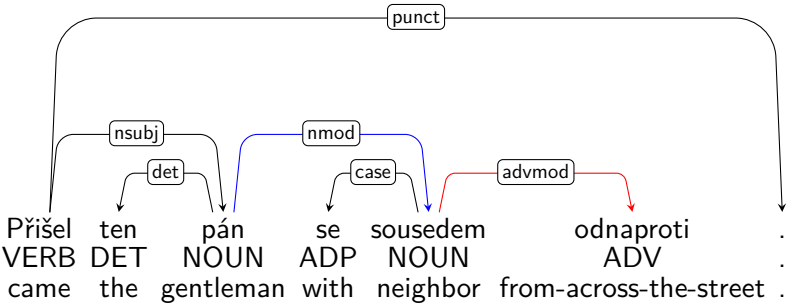


Prepositional Phrase Attachment Ambiguity: Corpus Example

- *V letech 1991 – 1993 jsem absolvovala kurzy řízení a marketingu na Collège Bart v kanadském Québecu.*
- "In years 1991 – 1993 I attended classes of management and marketing at Collège Bart in Canadian Québec."

(A Czech sentence from the Prague Dependency Treebank.)

Prepositional Phrase Attachment Ambiguity: Corpus Example

- *In years 1991 – 1993 I attended classes of management and marketing at Collège Bart in Canadian Québec.*
  - *attended at Collège Bart*
  - *classes at Collège Bart*
  - *management and marketing at Collège Bart*
  - *marketing at Collège Bart*
  - *Collège Bart in Québec*
  - *marketing in Québec*
  - *management and marketing in Québec*
  - *classes in Québec*
  - *attended in Québec*

Prepositional Phrase Attachment Ambiguity: Corpus Example

- *In years 1991 – 1993 I attended classes of management and marketing at Collège Bart in Canadian Québec.*
  - *attended (classes (of (management and marketing))) (at Collège Bart)*
  - *attended (classes (of (management and marketing)) (at Collège Bart))*
  - *attended (classes (of (management and marketing) (at Collège Bart)))*
  - *attended (classes (of (management and (marketing (at Collège Bart)))))*
  - *... ((at Collège Bart) (in Québec))*
    - Is Collège Bart in Québec or Québec in Collège Bart?

Prepositional Phrase Attachment Ambiguity: News Example

- *říjnové jednání OSN o klimatických změnách v Kodani* (Události ČT, 27.2.2009)
- "October UNO summit about climatic changes in Copenhagen" (Czech TV news, 2009-02-27)

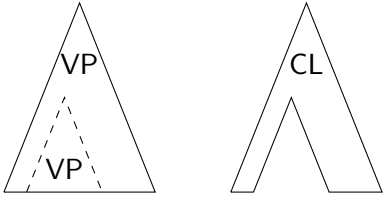
- Question:
  Were there climatic changes in Copenhagen?

Verb Phrase

- The repertory depends on the rules for analytical verb forms and varies greatly across languages.
  - *it rains*
  - *he could at all sight Mr. President*
  - *why we got wet so much*
  - *Go!*
  - *he has been transported to the hospital on Sunday*
  - *it began to rain*
  - *the law prohibits smoking in this room*
  - *give Mary the beads that we brought from the vacation in Morocco*
  - *the file could not be opened*

Clause

- One predicate together with its arguments and modifiers, e.g.:
  - *John loves Mary.*
  - *... that you are right.*
- Not recursive ⇒ not necessarily the same as a verb phrase (VP).
  - Nested phrases are part of the superordinate phrase.
  - Nested clauses are not parts of the main ('matrix') clause.



Coordination

- There is no real head ⇒ difficult to capture in dependency trees.
- The coordinate phrases (conjuncts) are usually of the same type.
  - *chickens, hens, rabbits, cats* ***and*** *dogs*
  - *new* ***or*** *even newer*
  - *quickly* ***and*** *finely*
  - *he came to the conclusion that there is no point in hiding any more,* ***so*** *we might hear him here today*
  - *in the house* ***or*** *outside*
  - *to* ***and*** *from Prague*
  - ***either*** *now* ***or*** *later*
  - *not only on Monday* ***and*** *on Wednesday* ***but*** *also tomorrow* ***or*** *the day after tomorrow*
  - *veni****,*** *vidi****,*** *vici*

Ellipsis

- A phrase omitted from the (surface form of the) sentence although it is present in the underlying meaning (deep structure).
- Often in dialogues: the elided information is known from context.
  - *Whom did you see there? — Peter.* (missing verb)
- Also often in coordination:
  - *Czech and German researchers discussed...* It probably means *Czech researchers and German researchers discussed.* Unlikely that each researcher was Czech and German at the same time.
  - *The Penguins are leading 4:0, while the Colorado Avalanches only 3:2.* (missing verb in the second part)
- Systemic elision of subject pronouns in pro-drop languages (it is marked on the verb).
  - *Sedím.* "(I) sit."

Dependency Parsing

Dependency Parsing

- Automatically assign a dependency tree to a sentence.
- Machine-learning: manually annotated "gold standard" data needed!

- **Chart** (Eisner, CKY)
  - $O(n^3)$
  - Produces only projective parses
    (if x directly depends on y, all words between x and y transitively depend on y)

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- **Graph-based** (MST)
  - $O(n^2)$
  - Can produce projective and nonprojective parses

Transition-Based Parsers: Malt

- Nivre et al., *Natural Language Engineering* 2007
- `http://maltparser.org/`
- Based on *transitions* from one configuration to another
- Configuration:
  - Input buffer (words of the sentence, left-to-right)
  - Stack
  - Output tree (words, edges, labels)
- Transitions:
  - `Shift`: move word from buffer to stack
  - `Larc`: connect two topmost stack words (higher is parent)
  - `Rarc`: connect two topmost stack words (lower is parent)

Malt Parser

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- Training: decompose the training tree to a sequence of transitions
  - Sometimes more than one possibility
    - Various learning strategies: e.g. create dependencies eagerly, as soon as possible
- The oracle learns based on the features of the configuration
  - E.g. word, lemma, POS, case, number...
    - n^{th} word from the top of the stack
    - k^{th} word remaining in the buffer
    - particular node in output tree part created so far

Malt Parser

- Machine learning responsible for training, here the Support Vector Machines (SVM)
  - Classifier. Input vectors: values of all features of the current configuration
  - In addition, during training there is the output value, i.e. action identifier (`shift` / `larc` / `rarc`)
  - The trained oracle (SVM) tells the output value during parsing
- Training on the whole PDT may take weeks!
  - Complexity $O(n^2)$ where n is number of training examples
  - Over 3 million training examples can be extracted from PDT
- Parsing comparatively faster ($\sim$ 1 sentence / second) and can be parallelized

Example of Malt Parsing

STACK	BUFFER
ROOT	Pavel dal Petrovi dvě hrušky .

Pavel	dal	Petrovi	dvě	hrušky	.	
Pavel	gave	Petr	two	pears	.	

Example of Malt Parsing

STACK		BUFFER
ROOT		Pavel dal Petrovi dvě hrušky .

SHIFT

Pavel dal Petrovi dvě hrušky .
Pavel gave Petr two pears .

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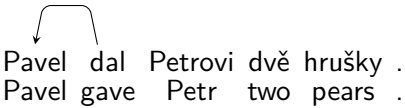
STACK		BUFFER
ROOT Pavel **dal**		Petrovi dvě hrušky .

LARC



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STACK		BUFFER
ROOT dal		Petrovi dvě hrušky .

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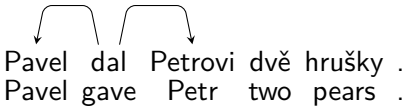
Example of Malt Parsing

STACK		BUFFER
ROOT **dal** Petrovi		dvě hrušky .

RARC



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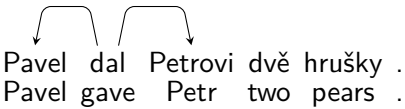

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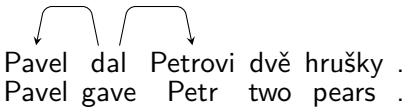

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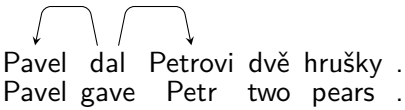

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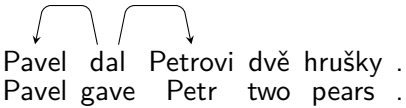
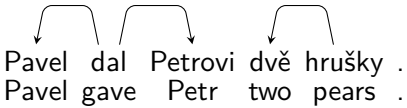
STACK		BUFFER
ROOT dal dvě hrušky		.



Example of Malt Parsing

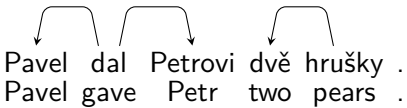
STACK		BUFFER
ROOT dal dvě **hrušky**		.

LARC



Example of Malt Parsing

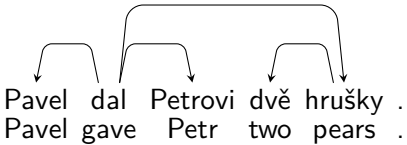
STACK		BUFFER
ROOT dal hrušky		.



Example of Malt Parsing

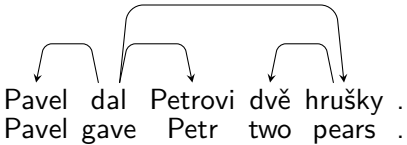
STACK		BUFFER
ROOT **dal** hrušky		.

RARC



Example of Malt Parsing

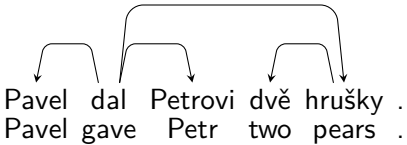
STACK	BUFFER
ROOT dal	.



Example of Malt Parsing

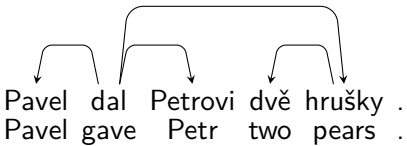
STACK	BUFFER
ROOT dal	.

SHIFT



Example of Malt Parsing

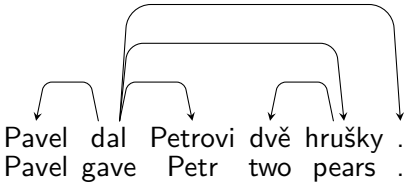
STACK	BUFFER
ROOT dal .	



Example of Malt Parsing

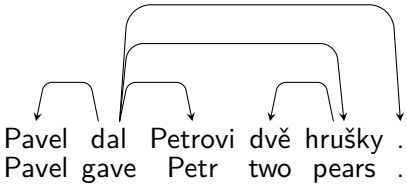
STACK	BUFFER
ROOT **dal** .	

RARC



Example of Malt Parsing

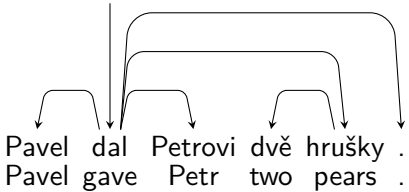
STACK		BUFFER
ROOT dal		



Example of Malt Parsing

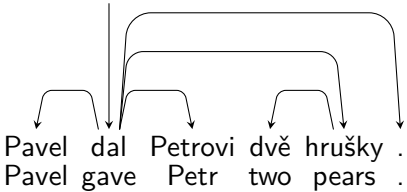
STACK		BUFFER
ROOT dal		

RARC



Example of Malt Parsing

STACK		BUFFER
ROOT		



So Far Only Projective Trees

- It can be proven that the above transition system is
  - **correct**
    - resulting graph is always a tree (connected, cycle-free)

- There are extensions that can produce non-projective trees
- Non-projective constructions occur in natural languages but they are rare

So Far Only Projective Trees

- It can be proven that the above transition system is
  - **correct**
    - resulting graph is always a tree (connected, cycle-free)
  - **complete** for the set of projective trees
    - every projective tree can be expressed as a sequence of transitions
- There are extensions that can produce non-projective trees
- Non-projective constructions occur in natural languages but they are rare