НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
УНИВЕРСИТЕТ

Dependency grammar and dependency parsing

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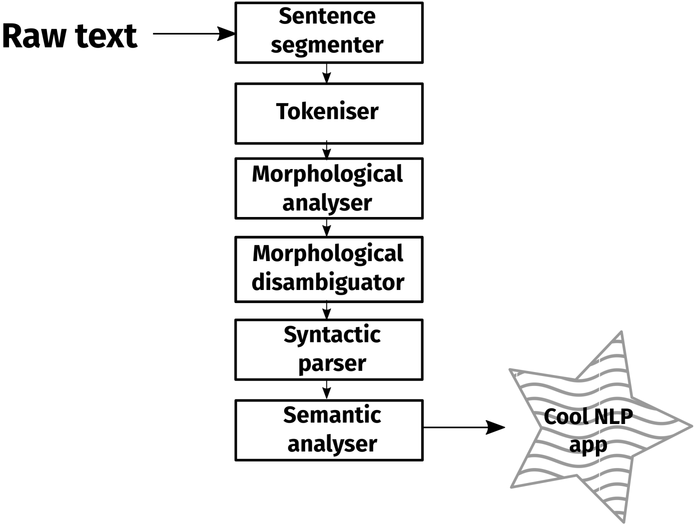
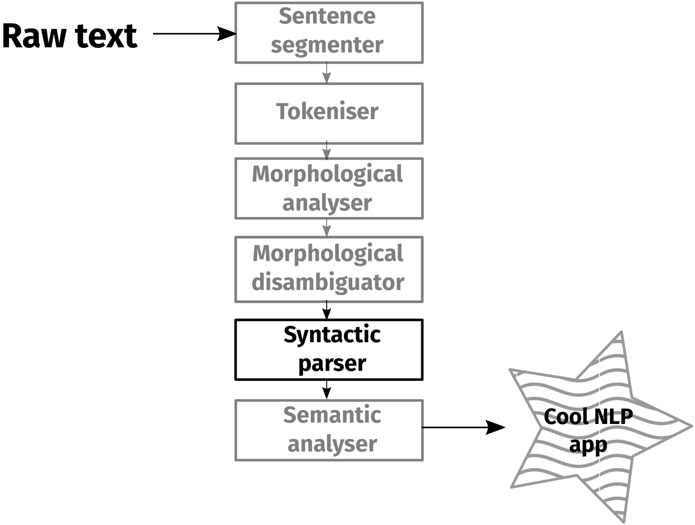
26 марта 2018 г.

Pipeline


Raw text
Sentence segmenter
Tokeniser
Morphological analyser
Morphological disambiguator
Syntactic parser
Semantic analyser
Cool NLP app

Pipeline



Raw text

Sentence segmenter

Tokeniser

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Syntactic parser

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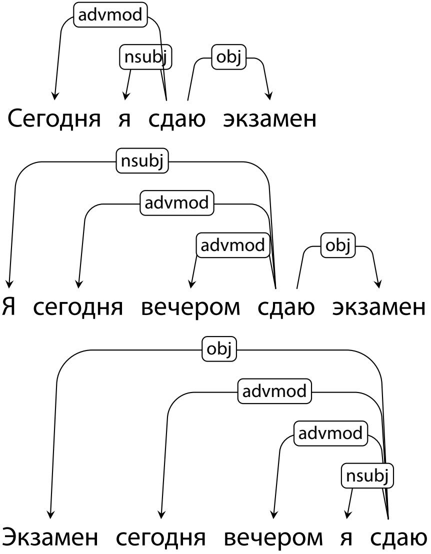
Cool NLP app

Motivating example

	Bigrams
Сегодня я сдаю экзамен	я сдаю, сдаю экзамен
Я сегодня вечером сдаю экзамен	вечером сдаю, сдаю экзамен
Экзамен сегодня вечером я сдаю	я сдаю, сдаю EOS

- Generalise over linear order
- Generalise long-distance

Motivating example



Bigrams

я сдаю, сдаю экзамен

Я сдаю, сдаю экзамен

я сдаю, сдаю экзамен

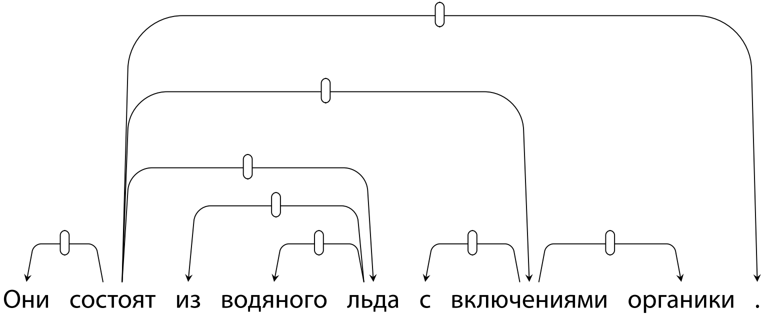
Dependency syntax

- Word based
- No non-terminals
- Words are linked by one-way binary relations
- Relations may be typed or untyped

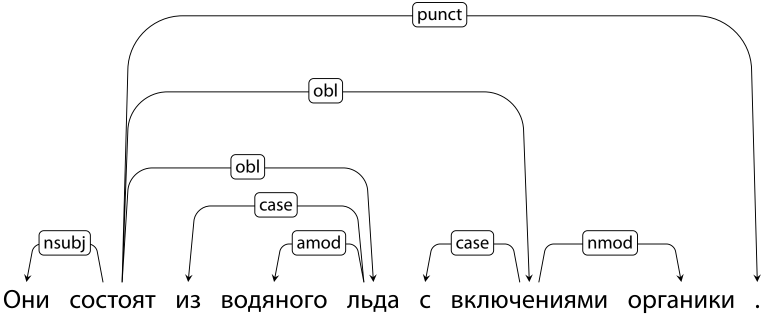
Dependency structure

Они состоят из водяного льда с включениями органики .

Dependency structure



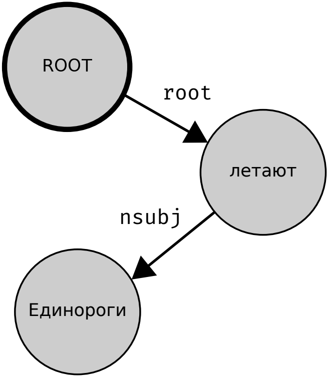
Dependency structure



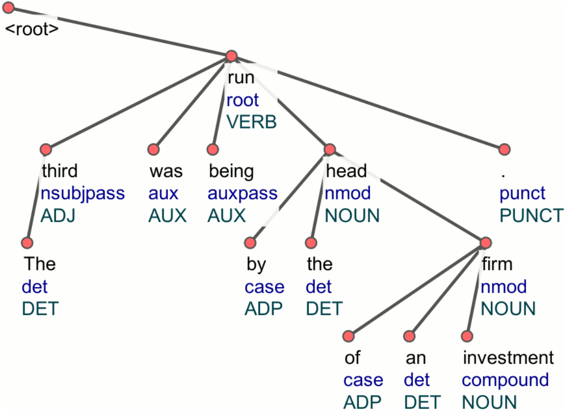
- Labels describe functional relations

Terminology

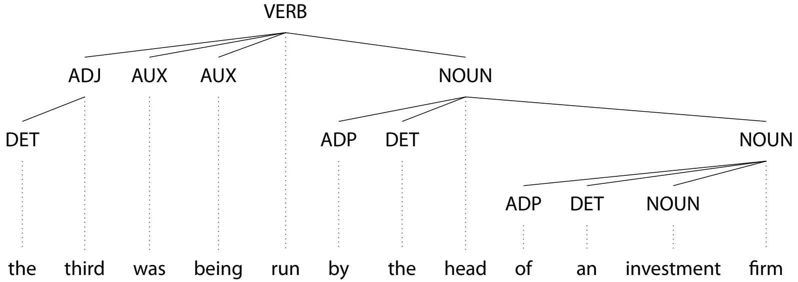
Superior	**Inferior**
Head	Dependent
Governor	Modifier
Regent	Subordinate
Mother	Daughter
Parent	Child



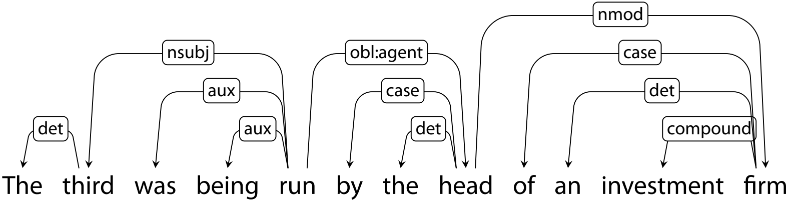
Notational variants



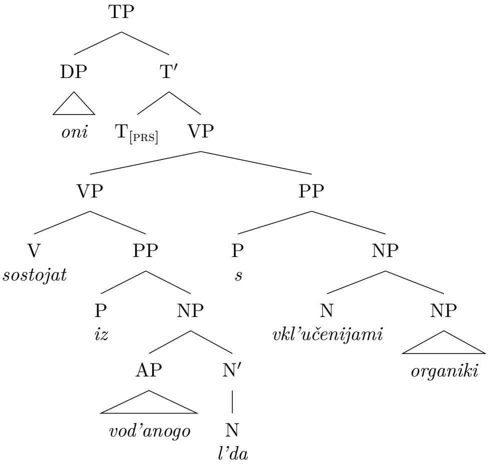
Notational variants



Notational variants



Phrase structure



Comparison

Dependency structures explicitly represent:

- head–dependent relations (directed arcs)
- functional categories (arc labels)

Phrase structures explicitly represent:

- phrases (non-terminal nodes)
- structural categories (non-terminal labels)

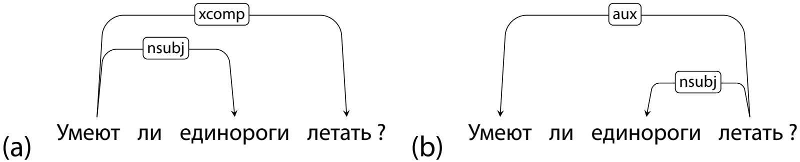
Heads and dependents

- Criteria for a syntactic relation between a head H and a dependent D in a construction C (Zwicky, 1985)[1]
  1. *H* determines the syntactic category of *C*; *H* can replace *C*
  2. *H* determines the semantic category of *C*; *D* specifies *H*
  3. *H* is obligatory, *D* may be optional
  4. *H* selects *D* and determines optionality of *D*
  5. The form of *D* depends on *H* (agreement or government)
  6. Linear position of *D* is specified with reference to *H*
- An issue:
  - Syntactic (and morphological) versus semantic criteria

[1] Zwicky, A. (1985) "Heads"*Journal of Linguistics*, 21:1–29

Some fuzzy cases

- **Complex verb groups** (auxiliary–main verb)
- Subordinate clauses (complementiser–verb)
- Coordination (coordinator–conjuncts)
- Adpositional phrases (adposition–nominal)
- Punctuation



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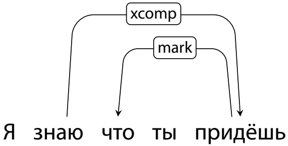
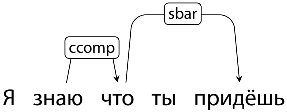
(a)



(b)



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- **Coordination** (coordinator–conjuncts)
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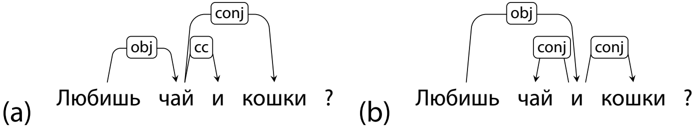
- Punctuation



Some fuzzy cases

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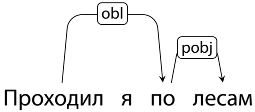
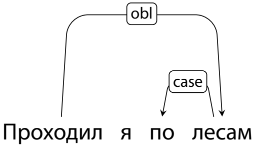
(a)



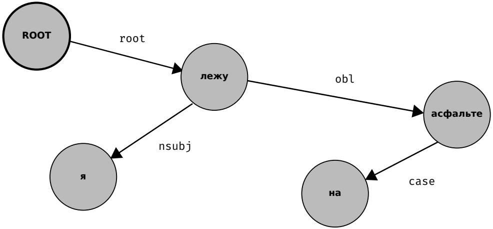
(b)



Some fuzzy cases

- Complex verb groups (auxiliary–main verb)
- Subordinate clauses (complementiser–verb)
- Coordination (coordinator–conjuncts)
- Adpositional phrases (adposition–nominal)
- **Punctuation**

Dependency graphs



A dependency graph, *G*

- a set of *V* nodes, $V = \{0, 1, 2, 3, 4\}$
- a set of *A* arcs, $A = \{0 \rightarrow 2, 2 \rightarrow 1, 2 \rightarrow 4, 4 \rightarrow 3\}$
- a linear precedence order $<$ on *V*

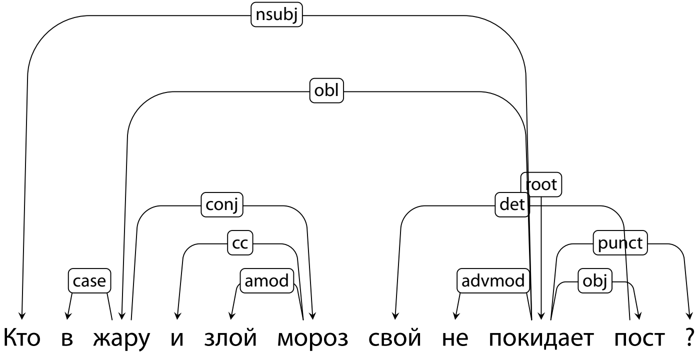
Labelled graphs:

- Nodes in *V* are labelled with word forms (and annotation)
- Arcs in *A* are labelled with dependency types

Conditions

- **Connectedness**: The syntactic structure must be complete, every word must be covered by the structure
- **Acyclicity**: The structure must be hierarchical, no cycles,
- **Single-headedness**: Each word must have at most one head

Projectivity



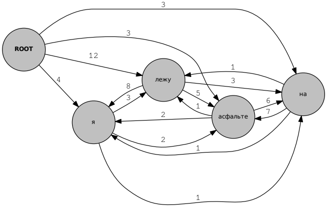
- Projectivity = no crossing arcs
- Non-projective → more complex to parse

Parsing methods

Transition-based

...

Graph-based



Transition-based

General idea

Components

Data structures:

- Stack:
  - Starts as containing only the ROOT
- Buffer
  - Starts as containing the full sentence
- Arcs
  - Starts as empty

Operations:

- SHIFT: Take the word on top of the buffer and put it on the stack
- LEFT-ARC: Make the word at the top of the stack the head of the word below it
  - Then remove the word at the top
- RIGHT-ARC: Make the word second from top the head of the word above it
  - Then remove the second from top word

Example

ROOT   Мы   пошли   домой

Stack	**Buffer**
ROOT	Мы пошли домой

Example

SHIFT

ROOT Мы пошли домой

Stack	**Buffer**
ROOT Мы	пошли домой

Example

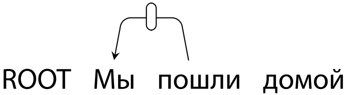
SHIFT

ROOT Мы пошли домой

Stack	**Buffer**
ROOT Мы пошли	домой

Example

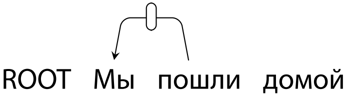
LEFT-ARC



Stack	**Buffer**
ROOT пошли	домой

Example

SHIFT

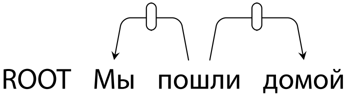


ROOT Мы пошли домой

Stack	Buffer
ROOT пошли домой	

Example

RIGHT-ARC

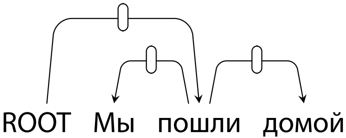


Stack **Buffer**

ROOT пошли

Example

RIGHT-ARC



Stack	**Buffer**
ROOT	

Configurations

A **configuration** is a snapshot of the state of the parser at a given time.

- A stack: Representing the word(s) currently being processed
- A buffer: Representing the remaining words
- A set of arcs representing a (partial) tree

We can conceive parsing as transitioning from one configuration to another via an operation.

Oracle

How do we get the sequence of operations?

Deterministic algorithm:

- LEFT-ARC: Configuration has arc from the top of stack to the word below
- RIGHT-ARC: Configuration has arc from the of the stack to the first word in the input buffer
  - In addition: The dependent must have no dependents of its own
- SHIFT: All other cases

Oracle

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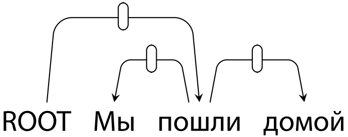
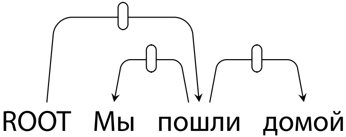
Parsing with an oracle



Stack	**Buffer**
ROOT	Мы пошли домой

- Is there an arc from the first word in the buffer to the top of the stack?
  - (Мы, ROOT)
- Is there an arc from the top of the stack to the first word in the buffer?
  - (ROOT, Мы)
- → then SHIFT

Parsing with an oracle

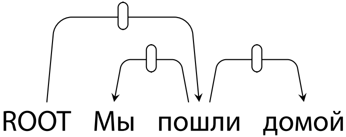


ROOT Мы пошли домой

Stack	Buffer
ROOT Мы	пошли домой

- Is there an arc from the first word in the buffer to the top of the stack?
    - (пошли, Мы) — YES, LEFT-ARC
- Is there an arc from the top of the stack to the first word in the buffer?
    - (Мы, пошли)

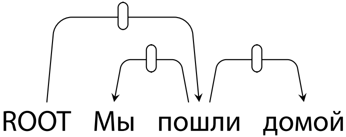
Parsing with an oracle



Stack	Buffer
ROOT	пошли домой

- Is there an arc from the first word in the buffer to the top of the stack?
  - (пошли, ROOT)
- Is there an arc from the top of the stack to the first word in the buffer?
  - (ROOT, пошли) – YES, but *пошли* still has dependents
- → then SHIFT

Parsing with an oracle



ROOT Мы пошли домой

Stack	Buffer
ROOT пошли	домой

- Is there an arc from the first word in the buffer to the top of the stack?
  - (домой, пошли)
- Is there an arc from the top of the stack to the first word in the buffer?
  - (пошли, домой) – YES, and *домой* has no dependents
  - → RIGHT-ARC

Training data

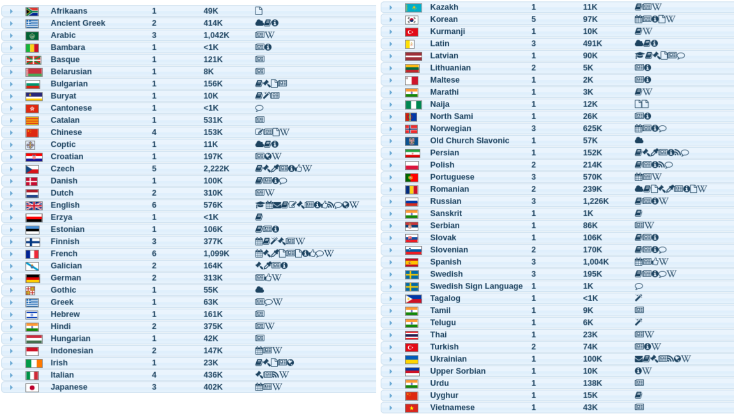
The “only” training data required is a treebank.

- Collection of sentences annotated for dependency structure
- Universal dependencies: 67 languages, 100s of treebanks

Data trains a classifier to predict a transition from a configuration.

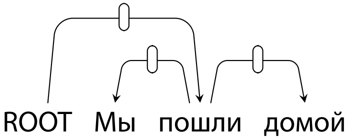
Training data

http://universaldependencies.org



Afrikaans	1	49K
Ancient Greek	2	414K
Arabic	3	1,042K
Bambara	1	<1K
Basque	1	121K
Belarusian	1	8K
Bulgarian	1	156K
Buryat	1	10K
Cantonese	1	<1K
Catalan	1	531K
Chinese	4	153K
Coptic	1	11K
Croatian	1	197K
Czech	5	2,222K
Danish	1	100K
Dutch	2	310K
English	6	576K
Erzya	1	<1K
Estonian	1	106K
Finnish	3	377K
French	6	1,099K
Galician	2	164K
German	2	313K
Gothic	1	55K
Greek	1	63K
Hebrew	1	161K
Hindi	2	375K
Hungarian	1	42K
Indonesian	2	147K
Irish	1	23K
Italian	4	436K
Japanese	3	402K
Kazakh	1	11K
Korean	5	97K
Kurmanji	1	10K
Latin	3	491K
Latvian	1	90K
Lithuanian	2	5K
Maltese	1	2K
Marathi	1	3K
Naija	1	12K
North Sami	1	26K
Norwegian	3	625K
Old Church Slavonic	1	57K
Persian	1	152K
Polish	2	214K
Portuguese	3	570K
Romanian	2	239K
Russian	3	1,226K
Sanskrit	1	1K
Serbian	1	86K
Slovak	1	106K
Slovenian	2	170K
Spanish	3	1,004K
Swedish	3	195K
Swedish Sign Language	1	1K
Tagalog	1	<1K
Tamil	1	9K
Telugu	1	6K
Thai	1	23K
Turkish	2	74K
Ukrainian	1	100K
Upper Sorbian	1	10K
Urdu	1	138K
Uyghur	1	15K
Vietnamese	1	43K

Features



Stack	Buffer
ROOT пошли	домой

Features indexed by address (in stack or buffer) and attribute name.

Traditional:

- (Stack[0], Form) = пошли
- (Buffer[0], Form) = домой
- (Stack[0], UPOS) = VERB
- (Stack[1], Form) = ROOT

Can return NULL.

Indicator:

- Combinations of such features, e.g.
  - (Stack[0], Form) = пошли & (Buffer[0], UPOS) = ADP

Features begone!

Instead of all of those features, what do people do nowadays?

- Use embeddings
    - For words, POS tags, characters, features etc.

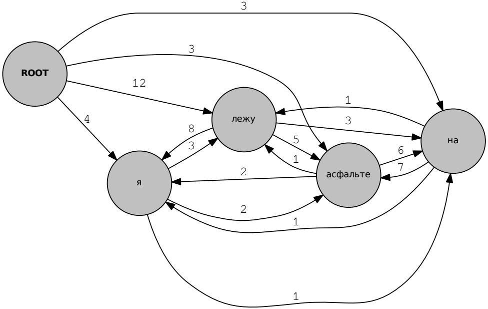
Why? Defining features is easy enough, but defining all those indicator features is tiresome.

Extensions

- **Labelled parsing**: Instead of having three transitions, the LEFT-ARC and RIGHT-ARC transitions are expanded for the number of labels,
    - e.g. LEFT-ARC$_{\text{nsubj}}$
- **Non-projective parsing**: Add an extra transition which “swaps” adjacent nodes

Graph-based

Basic model



- Represent sentence as directed graph
- Score every edge
- Running the spanning tree algorithm

Compared to transition based

Scoring

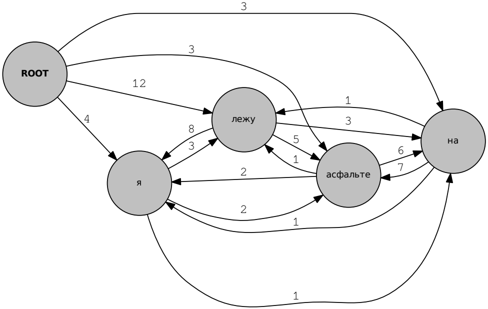
Where do the scores come from ?

- ...

Maximum spanning tree

- Higher score
- Contains all nodes
- Each node has at most one incoming edge
- Originates from a single, predefined root

Dense graph

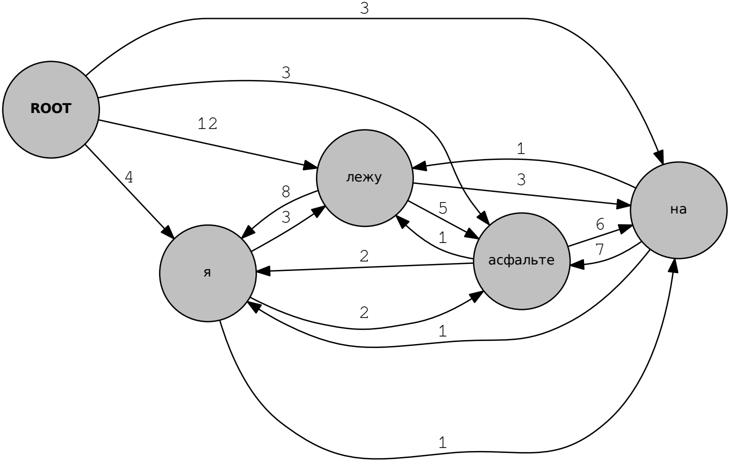


- Links between all nodes
- Except the root

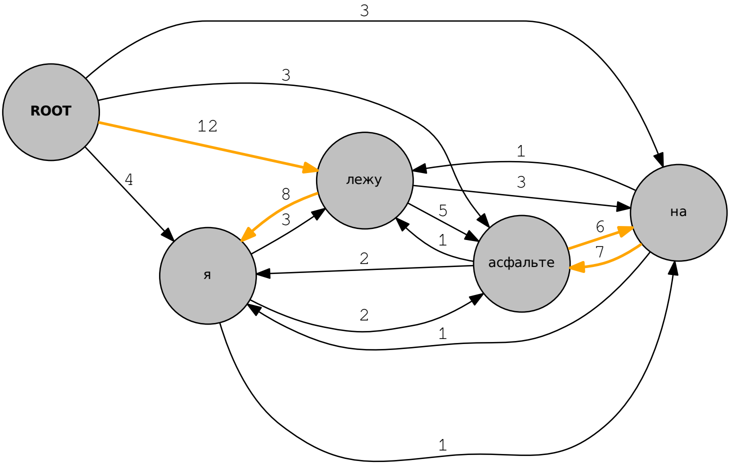
Chu-Liu-Edmonds

- For each node in the graph
  - pick the incoming arc with the highest weight.
  - if this makes a tree → it's the MST
- Otherwise:
  - For each cycle
    - contract the cycle
    - find the incoming arc with highest weight
    - remove incompatible arcs in the cycle
  - repeat

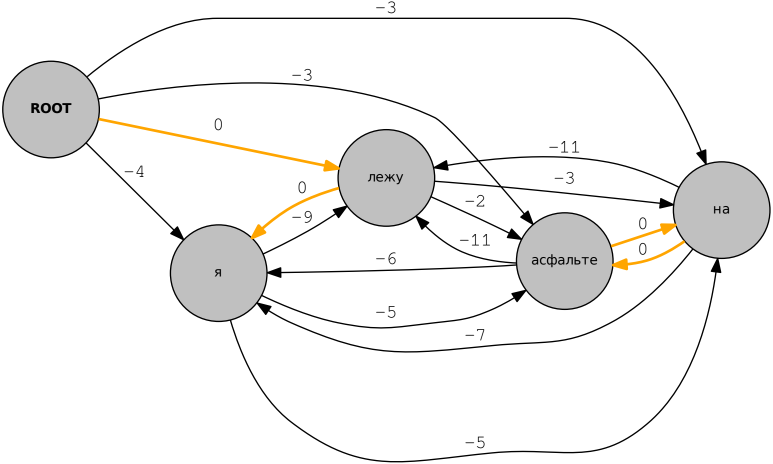
Example



Example



Example



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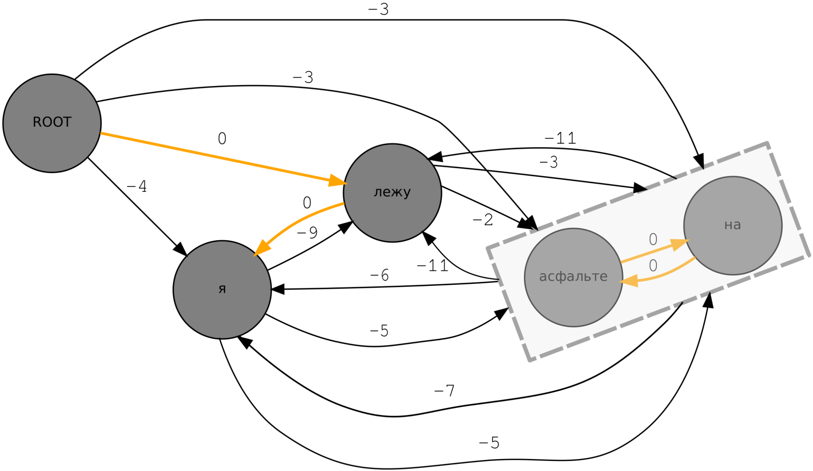

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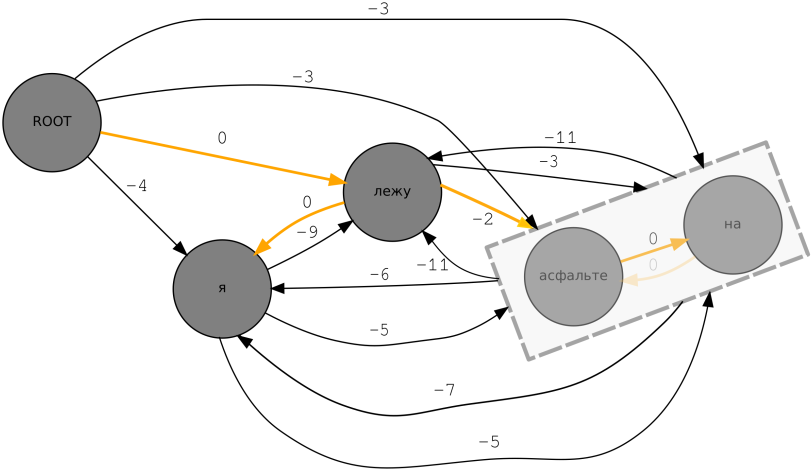

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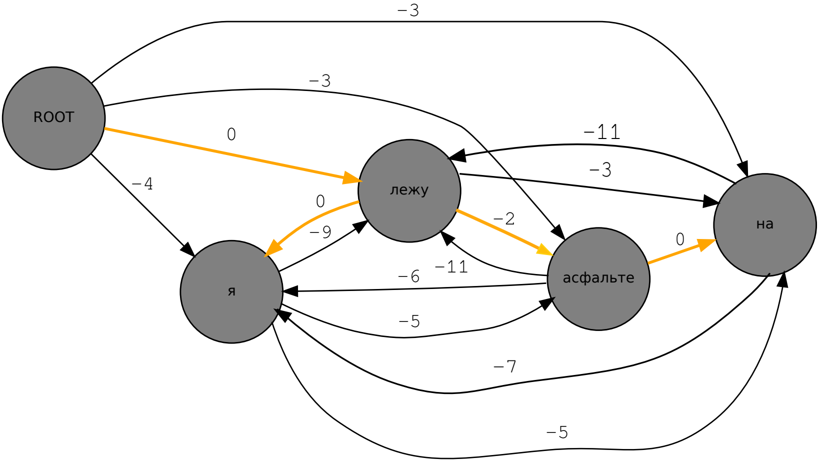
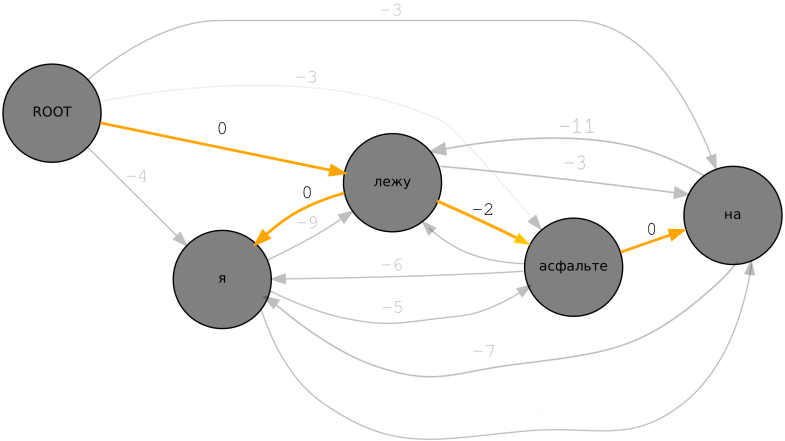


Example



Parsers

Modern:

- UDPipe http://github.com/ufal/udpipe
- SyntaxNet https://github.com/tensorflow/models/tree/master/research/syntaxnet
- BiST https://github.com/elikip/bist-parser
  - Both MST and transition variants
- Stanford Parser https://nlp.stanford.edu/software/nndep.html

Historical:

- MaltParser
- MSTParser

Evaluation

Simple evaluation:

- Unlabelled attachment score, **UAS**: correct heads/total heads
- Labelled attachment score, **LAS**: (correct heads+labels)/total heads

Shared tasks

CoNLL 2018

Practical

Ace the exam!