НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
УНИВЕРСИТЕТ

Morphological modelling

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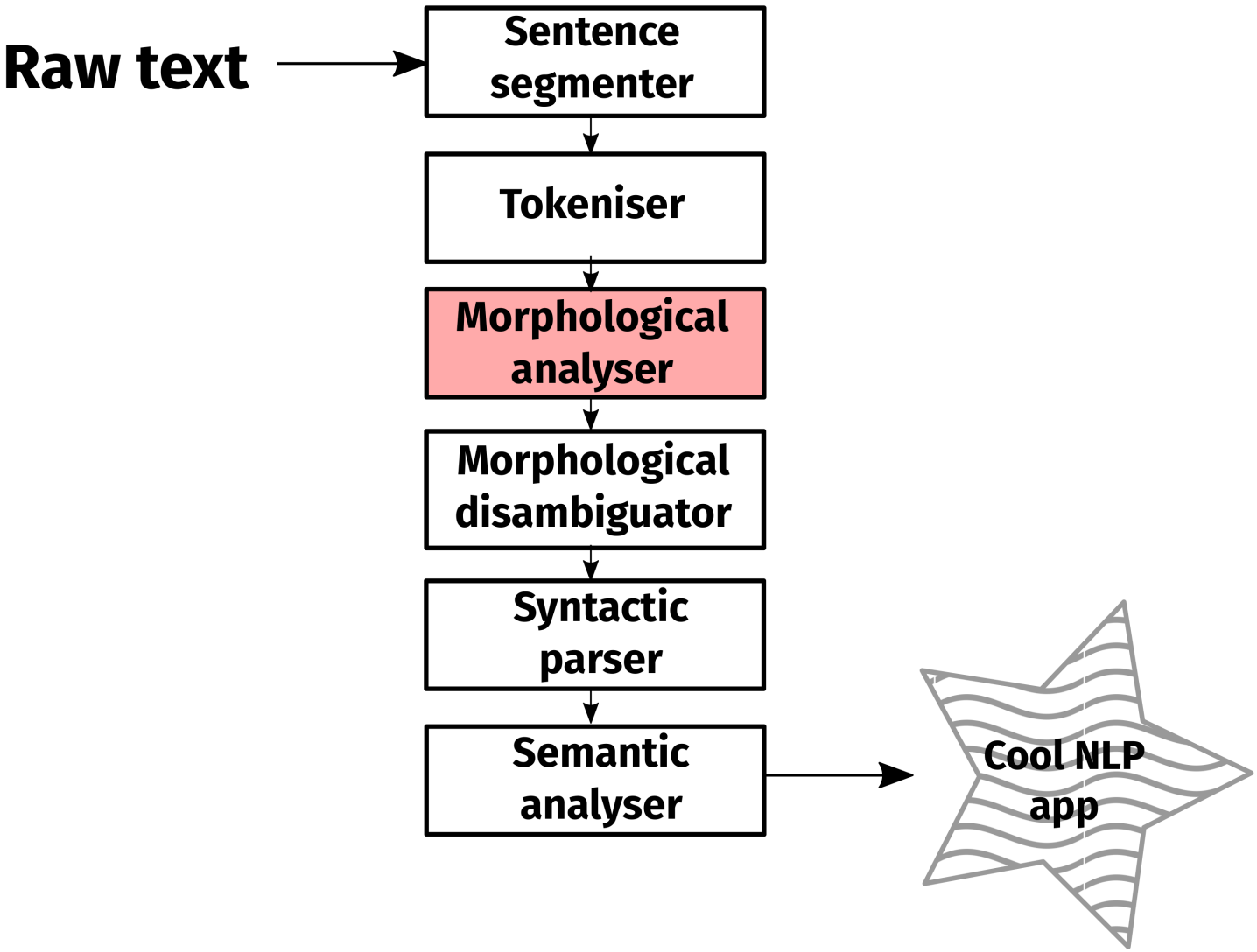
Pipeline


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

The story so far

В 1942—1945 годах профессором Г. С. Петровым и сотрудниками была разработана серия клеев БФ[1]. Советский учёный-химик Петров знаменит также «контактом Петрова» и работами в области химии и технологии карболита (бакелита, фенолформальдегидных пластмасс)[2].

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Н. Я. История науки и техники. Пластмасса<!-- Заголовок добавлен ботом -->]{{Недоступная
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```

Overview

- Morphology: What is it? Why should we care?
- Modelling morphology: With finite-state machines
-

Morphology

What is morphology?

Morphology is:

« the branch of linguistics that studies patterns of word formation within and across languages, and attempts to formulate rules that model the knowledge of the speakers of those languages. »

This is a big field, here we are interested in practical models.

Why produce models?

English or Chinese:

- A full form list is a possibility
- Few or no inflectional forms
  - e.g. 5 forms per English verb {see, sees, saw, seen, seeing}

Other languages:

- Difficult or impossible to enumerate all forms
- Very productive inflection and derivation
  - Russian verbs: over 150 forms (maximally)
  - Turkish verbs: thousands of forms

Lexicon

A morphological lexicon consists of entries:

- Lemma: The citation form of a word (cf. headword)
- Stem: The part of a word affixes attach to
- Paradigm: A description of how the word inflects:

Affixes

Add additional meaning or change the meaning of a lexical stem:

- **Suffixes:** *hus* ‘house’ — *huset* ‘the house’
- **Prefixes:** *kjent* ‘known’ — *ukjent* ‘unknown’
- **Infixes:** *ktieb* ‘book’ — *kotba* ‘books’
- **Circumfixes:** *nagy* ‘big’ — *legnagyobb* ‘biggest’

Morphological processes

- **Inflection:** Inflectional morphemes carry grammatical information, such as number, case, tense, etc., but do not change the word category
- **Derivation:** Derivational morphemes change the basic semantic meaning of a word, and can also change word category.
- **Compounding:** A process where two or more words are joined together to form one, typically of the same category or supertype.
- **Clitics:** Syntactically independent word that functions phonologically as an affix of another word.
- **Incorporation:** Where a nominal (e.g. direct object) or adverbial is included into a verb form.

Inflection

Examples of inflection categories:

- **Case:**
  дом·у ‘house-LOC’, *ev·de* ‘house-LOC’, *talo·ssa* ‘house-INE’
- **Possession:**
  ev·im ‘house-1SG’, *talo·ni* ‘house-1SG’
- **Number:**
  дом·а ‘house-PL, *ev·ler* ‘house-PL’, *talo·t* ‘house-PL’
- **Tense, aspect, mood:**
  говори·ла ‘say-PAST.F, *söyle·di* ‘say-PAST’, *puhu·i* ‘say-PAST’
- **Comparison:**
  больш·е ‘big-COMP’, *пысăк·рах* ‘big-COMP’, *iso·mpi* ‘big-COMP’

In general: Change in meaning is regular.

Derivation

Examples of derivational affixes:

- Actor: *diş·çi* /tooth-er/ ‘dentist’
- State: *boş·luk* ‘emptiness’, *nycm·oma* ‘emptiness’
- Diminutive: *dog·gie*, *kedi·cik* /cat-DIM/ ‘kitten’

Can often be stacked:

- *temizlikçi* /temiz-lik-çi/ clean-ness-er = cleaner
- *поверхностный* /по-верх-ность-ный/ on-surface-ness-ly = superficial

Change in meaning may be irregular, compare:

- *cooker* /cook-er/ ‘machine that cooks’
- *cleaner* /clean-er/ ‘person who cleans’
- *looker* /look-er/ ‘person that looks good’

May be limited to particular stems.

Compounding

New words are formed from morphologically/syntactically independent words:

- This may be indicated in the writing system or not.
  - infrastruktuurontwikkelingsplan, or
  - infrastructure development plan
- tri-noun compounds, but different orthographical treatment

Note: a given compound word may be split different ways, or a given word may appear as a compound, but not be one:

- Freitag = Friday (not “Frei” + “tag” = free day)
- kulturforskeren = the ethnographer, and not
  - kultur+forskeren = “culture researcher”
  - kultur+forske+ren = “culture research clean”

Clitics

Clitics are syntactically separate words that are phonologically conditioned by another unit (word, phrase).

- **Pronominal:**
  - Spanish: *me lo das* me it you.give ‘You give it to me’
  - Spanish: *dámelo!* give-me-it ‘Give it to me!’
- **Verb forms:**
  - Serbo-Croatian: *govorit ću* vs. *govoriću* ‘I will speak’
  - English: *I’m* ‘I am’, *gonna* ‘going to’
- **Other:**
  - Question words (e.g. Finnish *onko?* is-QST? ‘Is there?’)
  - Tense markers (e.g. Kurdish *-ê*)

Should these be tokenised prior to analysis?

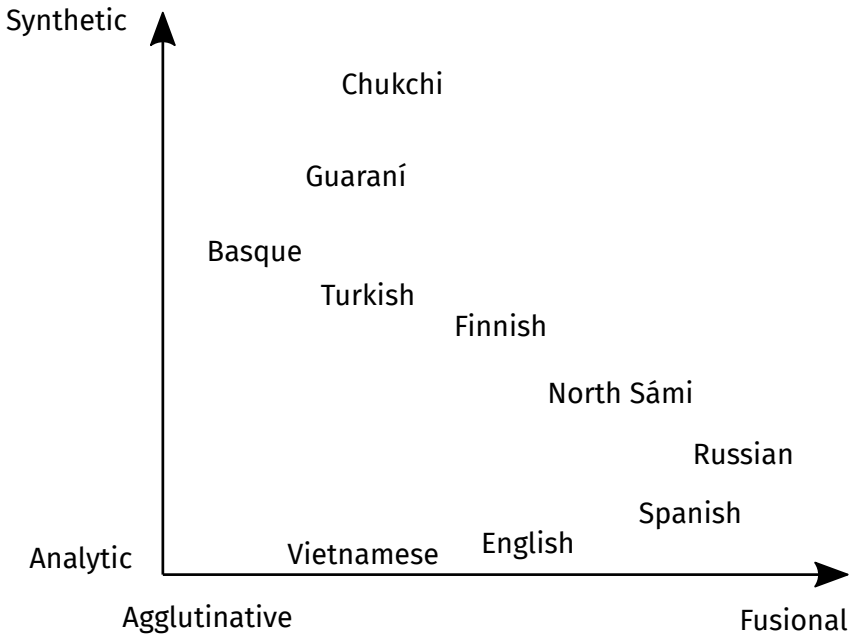
Incorporation

Гаӷорапэнратлэн Сыкваӈаӄай рэмкык
"Cıkwaŋaqaj chased after the reindeer in the other encampment."

га-ӷора-пэнр-ат-лэн	Сыкваӈаӄай	рэмк-ык
PERF-reindeer-chase-S3SG	Cıkwaŋaqaj	folk-LOC

- Syntactically determined (not lexically!)
- Can be valency changing, e.g.
  - DOBJ + V.TR $\rightarrow$ V.INTR
- ...

Morphological typology



- Analytic—Synthetic:
  - Morphemes per word
- Agglutinative—Fusional:
  - Meanings per morpheme

Modelling

Analysis and generation

Analysis:

студента → {студент<n><m><aa><sg><gen>,
студент<n><m><aa><sg><acc>}

Generation:

студент<n><m><aa><sg><gen> → студента

Morphotactics

How morphemes can be combined:

- студентом, играющийся, played, evlerde
- *омстудент, *ющийсяигра, *edplay, *deevler

Morphophonology

The changes that happen when morphemes are combined:

- работа + ы $\rightarrow$ работы
- fox + s $\rightarrow$ foxes
- огонёк + и $\rightarrow$ огоньки

Running example

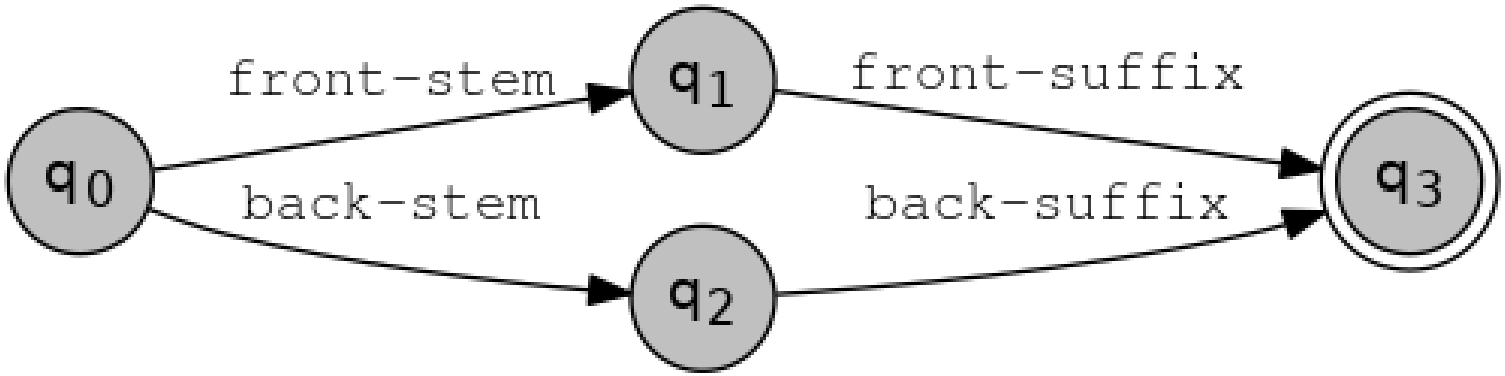
Let's take the Turkish words *ev* 'house', *kız* 'girl':

	Singular	**Plural**
Nominative	ev, kız	ev-ler, kız-lar
Accusative	ev-i, kız-ı	ev-ler-i, kız-lar-ı
Genitive	ev-in, kız-ın	ev-ler-in, kız-lar-ın
Dative	ev-e, kız-a	ev-ler-e, kız-lar-a
Locative	ev-de, kız-da	ev-ler-de, kız-lar-da
Ablative	ev-den, kız-dan	ev-ler-den, kız-lar-dan

Suffixes are different according to front and back vowels.

Finite-state morphology

We can represent these as a finite-state automaton:



Where the labels would mean:

- `front-stem`: the front stems (e.g. *ev*)
- `back-stem`: the back stems (e.g. *kız*)
- `front-suffix`: the front suffixes (e.g. *-de*)
- `back-suffix`: the back suffixes (e.g. *-da*)

Lexicon format: `lexc`

```
Multichar_Symbols

%<n%> %<nom%> %<loc%>

LEXICON Root

front-stem ;
back-stem ;

LEXICON front-suffix

%<n%>%<nom%>: # ;
%<n%>%<loc%>:de # ;

LEXICON back-suffix

%<n%>%<nom%>: # ;
%<n%>%<loc%>:da # ;

LEXICON front-stem

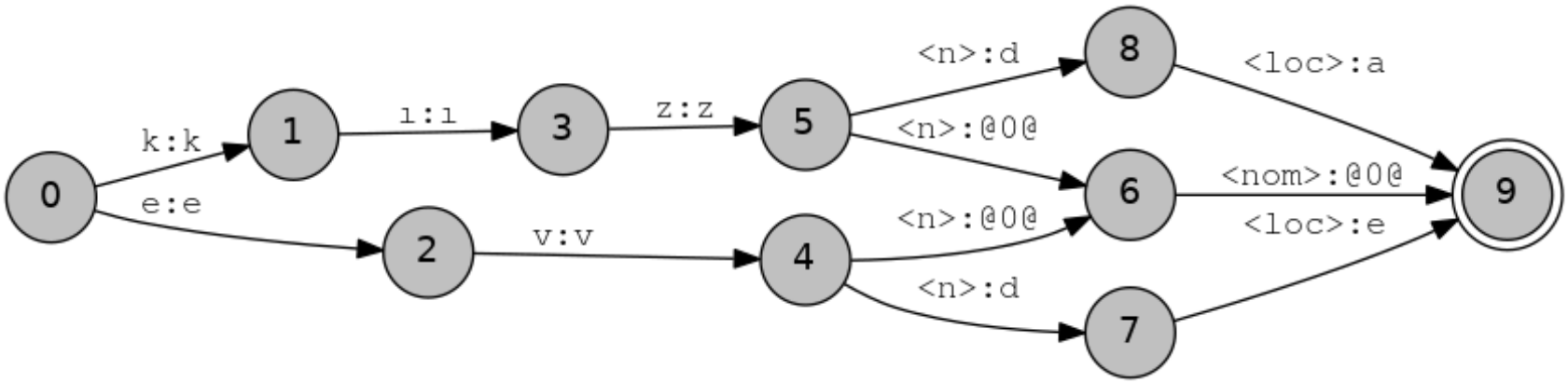
ev:ev front-suffix ; ! "house"

LEXICON back-stem

kız:kız back-suffix ; ! "girl"
```

- Tags: Symbols that show grammatical information
- Continuation class: Sets of morphemes
- Next continuation: Shows where to go next
- #: End of string
- Comment string: Indicated with **!**

Representing the lexicon



- Q = Set of N states = $\{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$
- Σ = Input alphabet = $\{$a, d, e, k, ı, v, z, @0@$\}$
- Δ = Output alphabet = $\{$e, k, ı, v, z, $<$ n $>$, $<$ nom $>$, $<$ loc $>\}$
- $q_0 \in Q$ = A single start state = 0
- $F \subseteq Q$ = A set of final states = $\{9\}$
- $\delta(q, w)$ = A transition function from a state $q \in Q$ and a string $w \in \Sigma^*$ to a set of states in Q

Archiphonemes

We can simplify the morphotactics by using **archiphonemes**:

- Archiphonemes stand in for underspecified surface symbols
- e.g. underlying %{A%} can be surface *a* or *e*

Example:

```
Multichar_Symbols

%<n%> %<nom%> %<loc%> %{A%}

LEXICON Root

stems ;

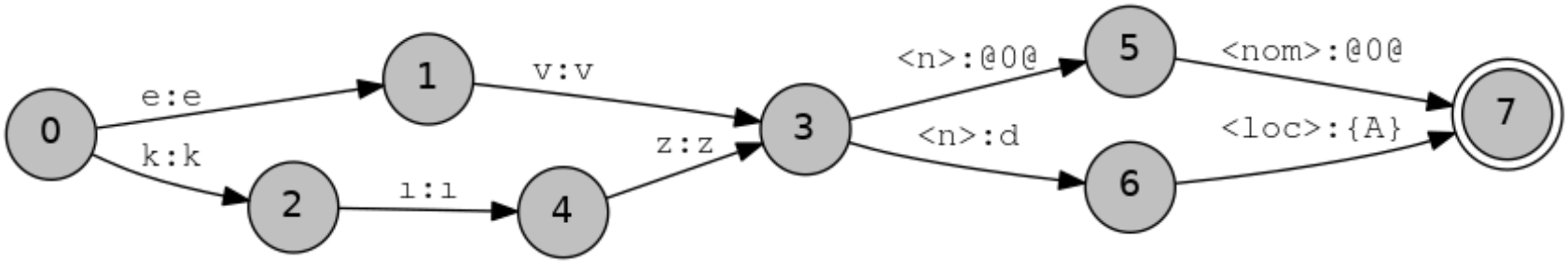
LEXICON suffix

%<n%>%<nom%>: # ;
%<n%>%<loc%>:d%{A%} # ;

LEXICON stems

ev:ev suffix ; ! "house"
kɪz:kɪz suffix ; ! "girl"
```

Archiphonemes/2



- 50% reduction in code length (15 lines $\rightarrow$ 10 lines)
- 20% reduction in number of states (9 states $\rightarrow$ 7 states)

Two-level rules

```
evd{A}:evde
evd{A}:evda
kɪzd{A}:kɪzde
kɪzd{A}:kɪzda
```

[apply rules]

→

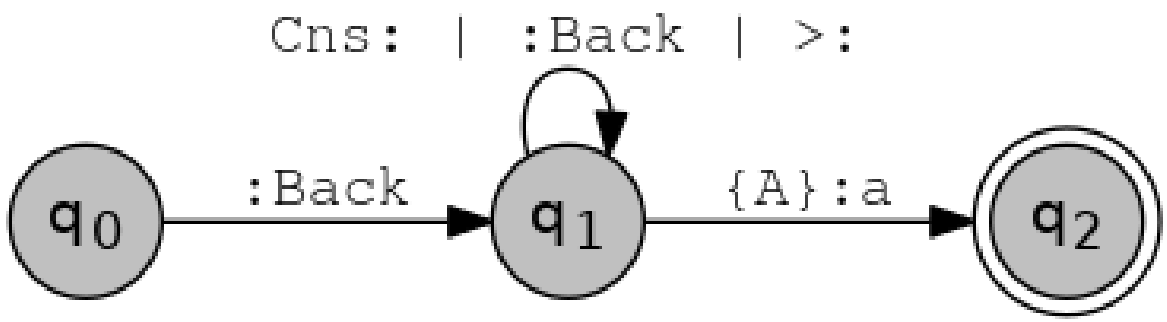
```
evd{A}:evde
kɪzd{A}:kɪzda
```

- First expand all possible forms, then
- Constraints on possible symbol pairs

Rule example: Vowel harmony

```
"Vowel harmony for archiphoneme {A}"
%{A%}:a <=> :Back [ Cns: | :Back | %>: ]* _ ;
```

- Symbol pair: The symbol pair to constraint
- Rule operator: The type of constraint
- Rule context: The context where the rule should apply
- Rule centre: Where the symbol pair is found in the context



Rule operators

	Positive Reading	*Negative Reading*
`a:b <=> l _ r ;`	1. If the symbol pair a:b appears, it must be in the context l _ r. 2. If lexical a appears in the context l _ r, then it must be be realized on the surface as b.	1. If the symbol pair a:b appears outside the context l _ r, FAIL. 2. If lexical a appears in the context l _ r and is realized as anything other than b, FAIL.
`a:b => l _ r ;`	If the symbol pair a:b appears, it must be in the context l _ r.	If the symbol pair a:b appears outside the context l _ r, FAIL.
`a:b <= l _ r ;`	If lexical a appears in the context l _ r, it must be realized on the surface as b.	If lexical a appears in the context l _ r and is realized as anything other than b, FAIL.
`a:b /<= l _ r ;`	Lexical a is never realized as b in the context l _ r .	If lexical a is realized as b in the context l _ r, FAIL.

Table 1.1: **twolc** Rule Operator Semantics

From `twolc.pdf` page 22

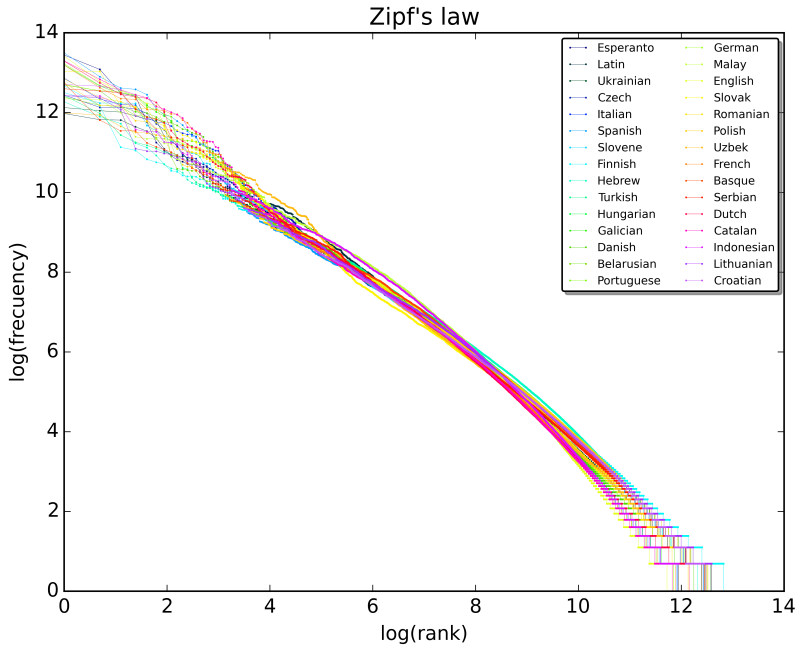
Rule application

- Rules are applied in parallel
- Every pair must be accepted by all rules

Example

Development

Development guidelines



Take frequency into account, of:

- Stems
- Morphemes
- Phonological rules

Applications

What we have not covered

- Templatic morphology:
- Machine learning approaches:
- Rewrite rules:

Practical

Go through the following practical:

`https://ftyers.github.io/2017-КЛ_МКЛ/hfst.html`

This will take you through all of the main steps to build a transducer.