Natural Language Processing

Lecture 1
Introduction to NLP
Methods of Morphological Analysis

Languages:

- Natural languages: *English*, *Chinese*, *Russian* etc.;
- Formal languages: *programming languages* etc.;
- Artificial languages: *Esperanto*, *Elvish languages* etc.

Natural Language Processing

Natural-language processing (**NLP**) is a field of computer science, artificial intelligence concerned with the interactions between computers and human (natural) languages.

- ***1950*** - Turing test
- ***1954*** - Georgetown experiment (Machine Translation)
- ***1970s*** - conceptual ontologies
- ***1980s*** - ***1990s*** - statistical revolution
- ***Currently*** - Deep Learning algorithms

Computer Linguistics Tasks:

1. Information Retrieval: *Google*, *Yahoo!*;
2. Information Extraction: *RCO Fact Extractor*;
3. Machine Translation: *PROMT*, *Google Translate*;
4. Automatic Text Summarization: *TextAnalyst*, *Extractor*, *Text Miner*;
5. Corpus Linguistics: *RusCorpora*, *OpenCorpora*;
6. Expert Systems: *IBM Watson*, *Wolfram Alfa*;
7. Question Answering Systems: *IBM Watson*, *Siri*;
8. Electronic dictionaries, thesaurus, onthology creation;
9. Optical Character Recognition: *Fine Reader*;
10. Automatic Speech Recognition: *plug-in in Google Chrome*;
11. Text-To-Speech: *Google Translate*

Stages to build NLP system:

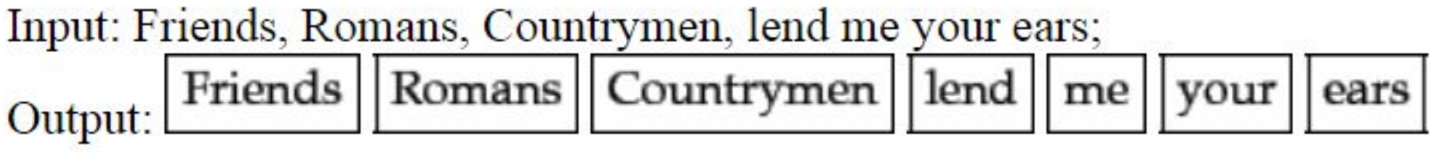
1. Analysis of graphemes (character level);
2. Morphological analysis (word level);
3. Fragmentational analysis (phrase level);
4. Syntax analysis (sentence level);
5. Semantic analysis (text level).

Discourse analysis - ?

Analysis of graphemes: Tokenization

Tokenization is words, digits, punctuation marks, formula etc. extraction from the text.

Tokens are elements extracted from the text.

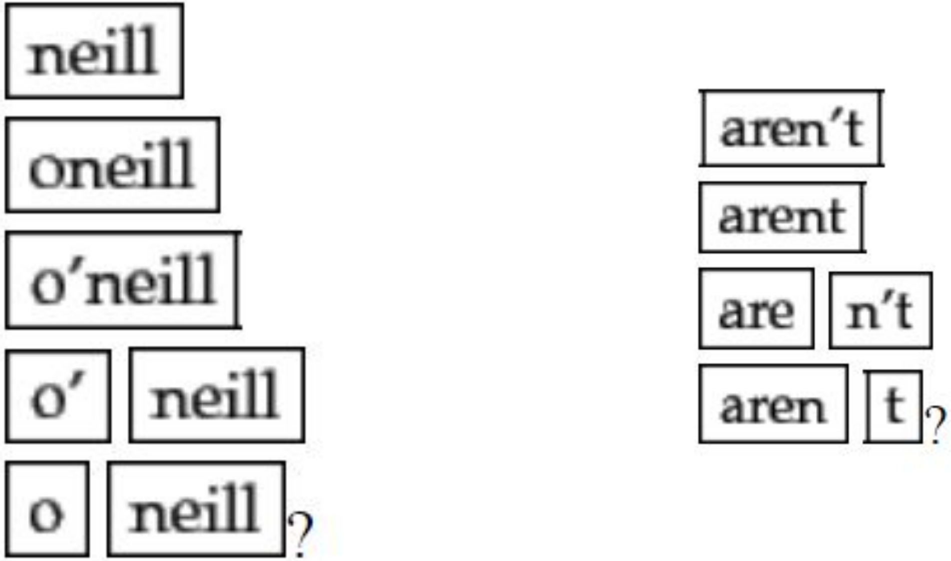


Input: Friends, Romans, Countrymen, lend me your ears;

Output: Friends | Romans | Countrymen | lend | me | your | ears

Tokenization: tricky cases

Mr. O'Neill thinks that the boys' stories about Chile's capital aren't amusing.



neill

oneill

o’neill

o’ neill

o neill ?

aren’t

arent

are n’t

aren t ?

Tokenization: tricky cases

1. **Programming Languages**: C++, C#;
2. **Aircraft names**: B-52;
3. **Email addresses**: jblack@mail.yahoo.com;
4. **Web URLs**: http://stuff.big.com/new/specials.html;
5. **Numeric IP addresses**: 142.32.48.231;
6. **Package tracking numbers**: (1Z9999W99845399981)
7. and more...

Tokenization: hyphenation

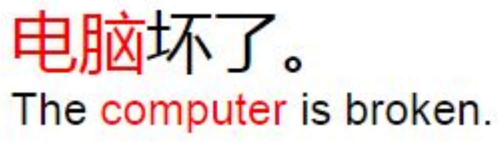
Example 1: *co-education*

Example 2: *Hewlett-Packard*

Example 3: *the hold-him-back-and-drag-him-away maneuver*

Tokenization: other languages

- French: *l'ensemble*, *donne-moi* ‘give me’;
- German: *Computerlinguistik* `computational linguistics'; *Lebensversicherungsgesellschaftsangestellter* `life insurance company employee'
- East Asian Languages (e.g., Chinese, Japanese, Korean, and Thai)



电脑坏了。

The computer is broken.

Analysis of graphemes: Segmentation

Segmentation is the retrieval of words boundaries in the text without spaces (e.g. Chinese or Japanese texts).

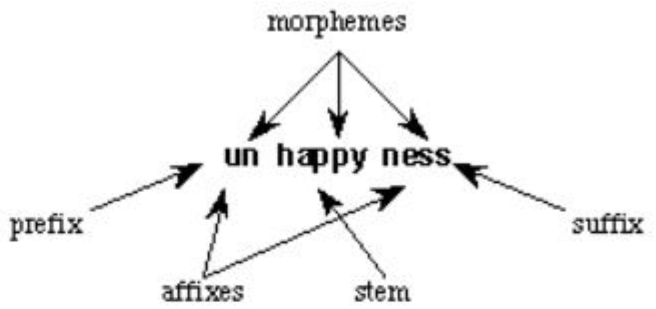
Example: *Itiseasytoreadtextwithoutspaces - It is easy to read text without spaces*

Morphological Analysis

Morphology

Morphology is the study of the structure and formation of words.

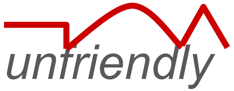
Its most important unit is the **morpheme**, which is defined as the "minimal unit of meaning".



Free morpheme can appear on its own
Bound morphemes have to be attached to a free morpheme

Morpheme is a minimal meaningful unit of a word.

Root is a morpheme with lexical meaning of a word.



unfriendly

Affix is a morpheme which modifies the lexical meaning of a word (e.g. prefix, suffix).

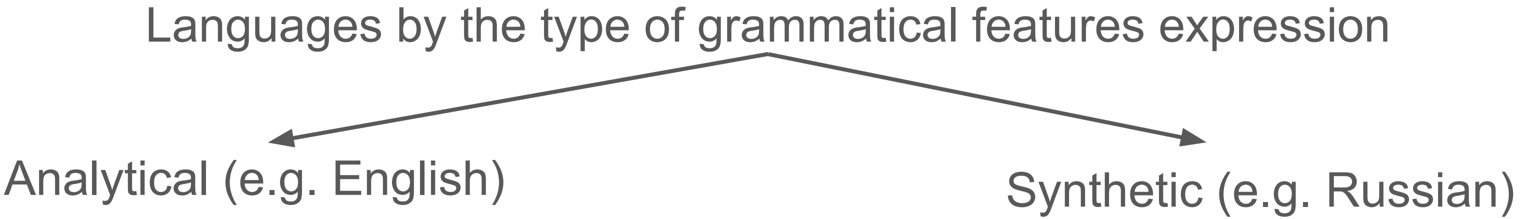
Allomorph is some complementary **morphs** (the phonetic realization of morpheme), which manifest a morpheme in its different morphological or phonological environments.

Lexemes: *illegal*, *impatient*, *irregular*, *inconsiderate*

Allomorphs: *il*, *im*, *ir*, *in* Morpheme: *in*

Paradigm is a list of all word forms.

Paradigm for verb *to be*: *am*, *is*, *are*, *was*, *were*, *will*



Languages by the type of grammatical features expression

Analytical (e.g. English)

Synthetic (e.g. Russian)

Index of synthesis = M / W,
M - number of morphs in text;
W - number of words in text.

For analytical languages index < 2.0 (e.g. for English 1.68)

For synthetic languages index 2.0 - 3.0 (e.g. for Russian 2.33 - 2.45)

Languages by the type of morphological structure

- **Isolating** languages: isolated morphemes as a word (e.g. *Chinese*);
- **Agglutinative** languages: a lot of affixes in word, each affix has its own meaning (e.g. *Turkish*);
- **Inflectional** languages: affixes are homonymous (e.g. *Russian*)

Isolating languages (e.g. Mandarin Chinese)

Transliterated sentence: *gou bú ài chi qingcài*

may be literally translated as: *dog not like eat vegetable*

Depending on the context, it can mean any of the four following sentences:

- *the dog did not like to eat vegetables*
- *the dogs do not like to eat vegetables*
- *the dogs did not like to eat vegetables*
- *dogs do not like to eat vegetables*

Agglutinative languages (e.g. Turkish)

- *ler* = plural
- *i* = possessive (e.g. *his*, *her*, *its*)
- *den* = ablative (e.g. a grammatical "case" ending showing a source, e.g. *from a house*)
    - ev: house
    - evler: houses
    - evi: his/her house
    - evleri: his/her houses, their houses
    - evden: from the house
    - evlerden: from the houses
    - evinden: from his/her house
    - evlerinden: from his/her houses, from their houses

Inflecting languages (e.g. Latin)

amo = I love

Ending *o* is used to express the meanings:

- first person ("*I*" or "*we*"),
- singular,
- present tense,
- and also other meanings.

Stemming is the process of reducing inflected words to their word stem or root (the stem need not be identical to morphological root of the word): *‘stems’*, *‘stemmer’*, *‘stemming’*, *‘stemmed’* → *‘stem’ .*

Lemmatization is the process of getting the base form of the word: *‘tables’* → *‘table’*, *‘written’* → *‘write’*.

Tagging a wordform with its grammems: *‘table’*: [Noun, sing]; *‘book’*: [Noun, sing], [Verb, 1/2 person, sing/plur, Pr.Simple] / [Verb, 3 person, plur, Pr.Simple].

Paradigm derivation is the process of derivation all word forms from the base form.

Morphological analyzers

- **Dictionary-based**: using a table (a dictionary), which contains mapping from set of words on set of lemmas. For Russian Zaliznyak’s dictionary is used. Downside: it is impossible to get information for word if the dictionary does not contain it.
- **Analytical**: using a set of rules for morphological transformations. Don’t cope with all morphological tasks, but good for stemming, lemmatization and getting paradigm.

Lovins’ algorithm (Lovins, 1968)

- 294 endings are defined;
- 29 conditions for removing one of the endings;
- 35 rules of wordform transformation after the ending removing

Example: ‘*nationally*’ → ‘*nat*’. Two endings can be removed: ‘*ationally*’ and ‘*ionally*’. But the first can’t be removed because of the restriction: stem should be longer than 3 characters.

Downside: the algorithm requires linguists for rules and exceptions creating.

Porter’s algorithm (Porter, 1980)

Rule: <*condition*>, <*ending*> → <*new ending*>

Contains ~ 60 rules, each of them is applied to the input wordform.

Example:

(*m* > 0) *eed* → *ee*   *agreed* → *agree*

Algorithm of Paice&Husk (Paice/Husk, 1990)

Table of rules for ending transformations (removing or replacement).

Rule contains:

- inverted ending;
- integrity mark “*” (optional);
- length of the removing ending (including 0);
- string with length > 1, which has to be added (optional);
- symbols ‘>’ (switching to the pointed entry) or ‘.’ (stopping).

Example: “*nois4j*>”

Comparison

Original sentence	*Such an analysis can reveal features that are not easily visible from the variations in the individual genes.*
Lovins’ algorithm	*Such an analysis can reve featur that ar not eas vis from th vari in th individu gen*
Porter’s algorithm	*Such an analysi can reveal featur that ar not easili visibl from the variat in the individu gene.*
Algorithm of Paice&Husk	*Such an analysis can rev feat that are not easy vis from the vary in the individ gen*

Metrics for algorithm performance

- Under-stemming index;
- Over-stemming index;
- Words number belonging to the same paradigm;
- Coefficient of the index compression;
- Modified Hamming distance

Under-stemming index - % analyzed wordforms, for which the same stem has to be produced, but different stems were produced.

Over-stemming index - % analyzed wordforms, for which different stems have to produced, but the same stem was produced.

Both metrics require annotated text corpora

Words number belonging to the same paradigm

$$\mathbf{MVC = N / S},$$

N - number of distinctive word usage before the algorithm performance,

S - number of distinctive stems produced by the algorithm

Coefficient of the index compression

Shows the difference between distinctive stems collection and distinctive wordforms collection:

$$\mathbf{ICF} = (\mathbf{N} - \mathbf{S}) / \mathbf{N},$$

N - number of distinctive word usage before the algorithm performance,

S - number of distinctive stems produced by the algorithm

Modified Hamming distance

Hamming distance is the number of positions where two strings (sequences) with equal length are different.

For strings with different lengths modified Hamming distance is used:

$$\mathbf{MHD = HD\ (1, P) + (Q - P)},$$

HD (1, P) - Hamming distance for the first **P** characters of the analyzed strings (**P** < **Q**).

Example:

Algorithm output: ‘*parties*’ → ‘*party*’

MHD (*party*, *parties*) = 1 + 2 = 3, **HD** (1, P) = 1, **P** = 5

Why does morphology matter?

- Information retrieval:
  - A query for ***phones*** should match both ***phone*** and ***phones***
- Language modeling:
  - If we have seen ***scrutinize***, we can predict ***scrutinized***
- Machine translation:
  - Swedish ***bilen*** corresponds to English ***the car***
- etc.

Morphological analyzers

- **Morphology software for English**: https://aclweb.org/aclwiki/Morphology_software_for_English
- **AOT**: http://aot.ru/technology.html
- **PyMorphy**: *documentation*: http://pymorphy.readthedocs.io/en/v0.5.6/index.html , *code*: https://github.com/kmike/pymorphy2
- **TreeTagger**: http://www.cis.uni-muenchen.de/~schmid/tools/TreeTagger/
- **MyStem**: https://tech.yandex.ru/mystem/
- more: https://nlpub.ru/%D0%9E%D0%B1%D1%80%D0%B0%D0%B1%D0%BE%D1%82%D0%BA%D0%B0_%D1%82%D0%B5%D0%BA%D1%81%D1%82%D0%B0

Thank you for your attention!