НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ

Tokenisation and word segmentation

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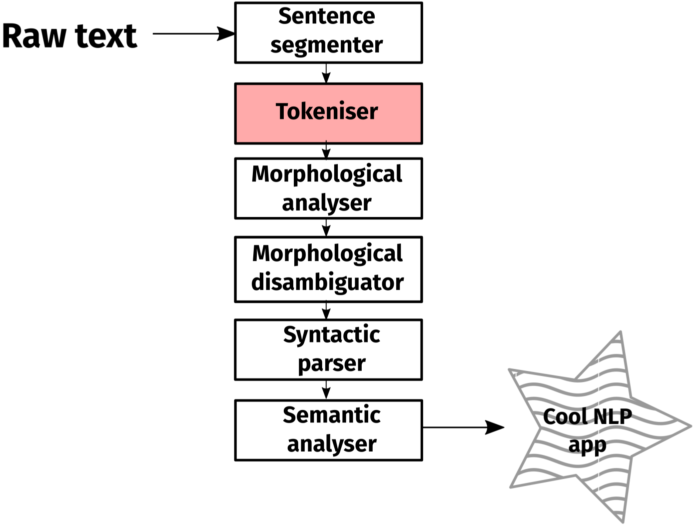
Pipeline


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

Token separators

ARMA·VIRVMQVE·CANO·TROIAE·QVI·PRIMVS·AB·ORIS
ITALIAM·FATO·PROFVGVS·LAVINIAQVE·VENIT
LITORA·MVLTVM·ILLE·ET·TERRIS·IACTATVS·ET·ALTO
VI·SVPERVM·SAEVAE·MEMOREM·IVNONIS·OB·IRAM

- Peoplecangenerallyreadsentencesevenifthereisnowhitespace, but:
  - The vast majority of languages use some kind of whitespace-based word/token separator

But what is a token?

Some questions:

- Multiword expressions
  - *только что* or *только·что* ?
- Named-entities
  - *Нижный Новгород* or *Нижный·Новгород* ?
- Numeral expressions
  - *150 000,0* or *150·000,0*

And how about abbreviations:

- *Гипотеза была выдвинута Каролем Борсуком в 1933 г.*
  - Is there one '.' here or two?
- *В 1933 г. гипотеза была выдвинута Каролем Борсуком.*
  - And here?

Clitics:

- Romance: *explicándoselo* [explicándo se lo], *j'ai* [j' ai]
- Germanic: *don't* [do n't], *I'm* [I 'm], *Nastya's* [Nastya 's]
- Slavic: *mógłbym* [mógł bym], *razumeću* [razume ću]
- Finnic: *voisiko* [voisi ko]
- Turkic: *чыгачакмы* [чыгачак мы]

Can be ambiguous:

- Nastya's cool → Nastya is
- Nastya's broke the record again → Nastya has
- Nastya's cat is cute → Nastya's

Is resolving this the job of a tokeniser ?

Tasks

The ideal tokenisation may depend on the task.[1]

- Russian–Arabic MT:
  - Split off clitics[2]
- Dependency parsing
- @@@
- @@@

[1] And also on the language (pair)!

[2] Zalmout and Habash (2017) “Optimizing Tokenization Choice for Machine Translation across Multiple Target Languages”

A simple approach

```
import sys, re

abbr = ['etc.', 'e.g.', 'i.e.']

def tokenise(line, abbr):
        line = re.sub(r'([\(\)"?:!;])', r' \g<1> ', line)
        line = re.sub(r'([^0-9]),', r'\g<1> ,', line)
        line = re.sub(r',([^0-9])', r', \g<1>', line)
        line = re.sub(r'  +', ' ', line[:-1])
        output = []
        for token in line.split(' '):
                if token[-1] == '.' and token not in abbr:
                        token = token[:-1] + ' .'

                output.append(token)

        return ' '.join(output)

line = sys.stdin.readline()

while line != '':
        print(tokenise(line.strip('\n'), abbr))
        line = sys.stdin.readline()
```

- Split off always-separating punctuation

A simple approach

```
import sys, re

abbr = ['etc.', 'e.g.', 'i.e.']

def tokenise(line, abbr):
        line = re.sub(r'([\(\)"?:!;])', r' \g<1> ', line)
        line = re.sub(r'([^0-9]),', r'\g<1> ,', line)
        line = re.sub(r',([^0-9])', r', \g<1>', line)
        line = re.sub(r'  +', ' ', line[:-1])
        output = []
        for token in line.split(' '):
                if token[-1] == '.' and token not in abbr:
                        token = token[:-1] + ' .'

                output.append(token)

        return ' '.join(output)

line = sys.stdin.readline()

while line != '':
        print(tokenise(line.strip('\n'), abbr))
        line = sys.stdin.readline()
```

- Split off commas not part of numeral expressions

A simple approach

```
import sys, re

abbr = ['etc.', 'e.g.', 'i.e.']

def tokenise(line, abbr):
        line = re.sub(r'([\(\)"?:!;])', r' \g<1> ', line)
        line = re.sub(r'([^0-9]),', r'\g<1> ,', line)
        line = re.sub(r',([^0-9])', r', \g<1>', line)
        line = re.sub(r'  +', ' ', line[:-1])
        output = []
        for token in line.split(' '):
                if token[-1] == '.' and token not in abbr:
                        token = token[:-1] + ' .'

                output.append(token)

        return ' '.join(output)

line = sys.stdin.readline()

while line != '':
        print(tokenise(line.strip('\n'), abbr))
        line = sys.stdin.readline()
```

- Collapse multiple spaces

A simple approach

```
import sys, re

abbr = ['etc.', 'e.g.', 'i.e.']

def tokenise(line, abbr):
        line = re.sub(r'([\(\)"?:!;])', r' \g<1> ', line)
        line = re.sub(r'([^0-9]),', r'\g<1> ,', line)
        line = re.sub(r',([^0-9])', r', \g<1>', line)
        line = re.sub(r'  +', ' ', line[:-1])
        output = []
        for token in line.split(' '):
                if token[-1] == '.' and token not in abbr:
                        token = token[:-1] + ' .'

                output.append(token)

        return ' '.join(output)

line = sys.stdin.readline()

while line != '':
        print(tokenise(line.strip('\n'), abbr))
        line = sys.stdin.readline()
```

- Split of full stops not part of abbreviations

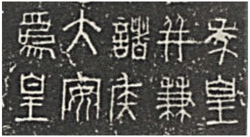
Caveats

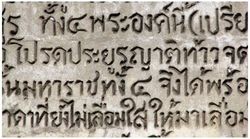
- Time and numeral expressions:
  - Let's meet at 17:45
- Proper names:
  - I'm surprised that Yahoo! are still solvent
  - Therapy? is one of the best bands from Northern Ireland
- Emoticons:
  - haters gonna hate ;____;

Machine-learning approaches

@@@

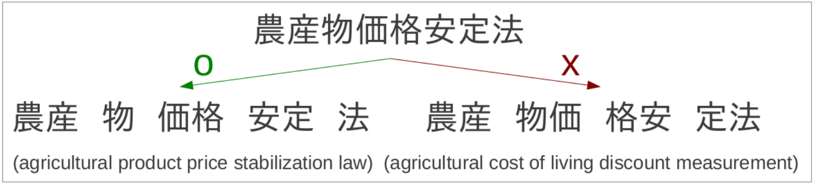
Space-free languages





- Some languages are written without spaces
- Tokenisation more difficult — space is a strong signal
- Issue of ambiguity — more than one possible interpretation
- A number of algorithms available

Ambiguity



- Many analyses for each sequence
- How do we choose the correct one(s) ?

Graphics by Graham Neubig (NAIST)

(A tale of) two algorithms

Maxmatch:

- Rule-based algorithm
  - Requires some kind of dictionary — from wordlist or corpus

Graph-based:

- Statistical algorithm
  - Requires pre-segmented corpus

Maxmatch algorithm

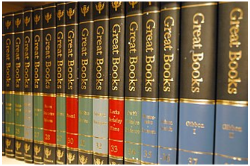
```
function MAXMATCH(sentence, dictionary) returns word sequence W

    if sentence is empty
        return empty list
    for i ← length(sentence) downto 1
        firstword = first i chars of sentence
        remainder = rest of sentence
        if InDictionary(firstword, dictionary)
            return list(firstword, MaxMatch(remainder,dictionary) )

    # no word was found, so make a one-character word
    firstword = first char of sentence
    remainder = rest of sentence
    return list(firstword, MaxMatch(remainder,dictionary) )
```

- Start at beginning of string
- Iteratively look up the longest word in the dictionary
- If no word is found, output a single character

Caveats

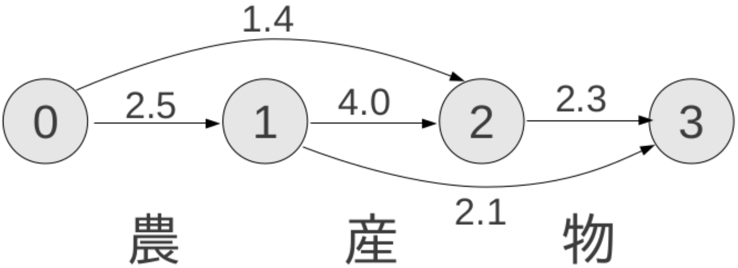



wecanonlyseeashortdistanceahead
we canon l y see ash ort distance ahead

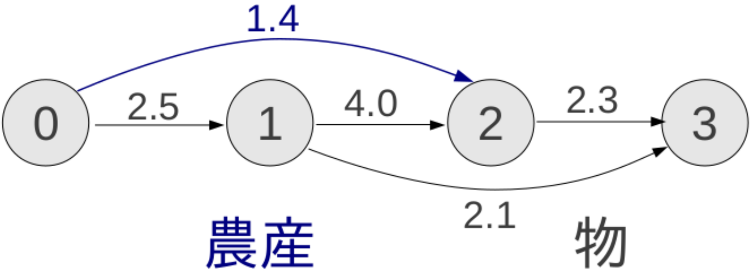
– Alan Turing

- Works pretty well for some languages (e.g. Chinese)
- Not so great for others
- Why? Length of words

A graph-based approach

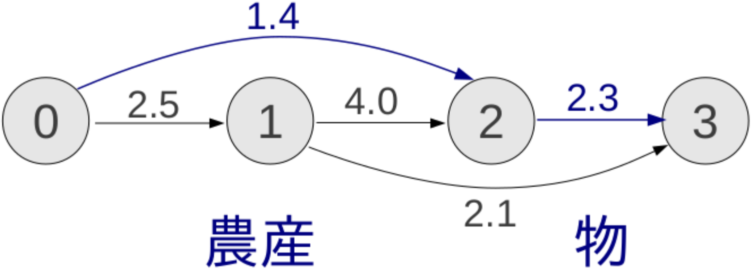


A graph-based approach



- Each edge is a word (segmentation decision)
- Each edge weight is a unigram probability

A graph-based approach



- Each path is a segmentation
- The path weight is the unigram probability of the sentence

Language model

$P($ 農産 物 価格 安定 法 $) = 4.12 * 10^{-23}$

$P($ 農産 物価 格安 定法 $) = 3.53 * 10^{-24}$

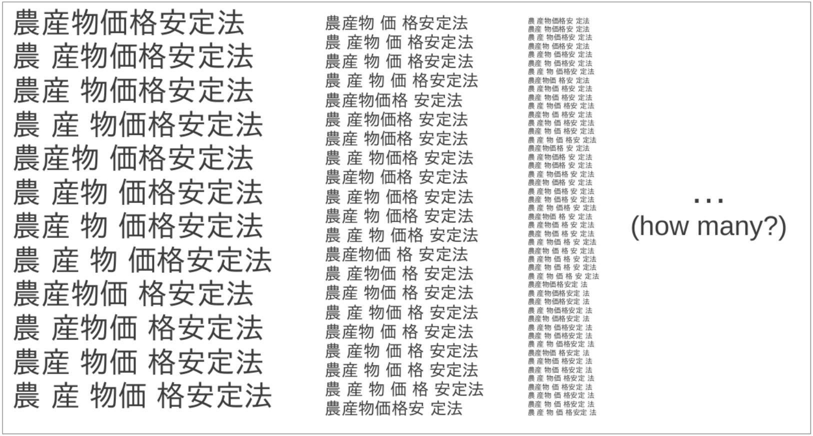
$P($ 農産 物 価 格安 定法 $) = 6.53 * 10^{-25}$

$P($ 農産 物 価格 安 定法 $) = 6.53 * 10^{-27}$

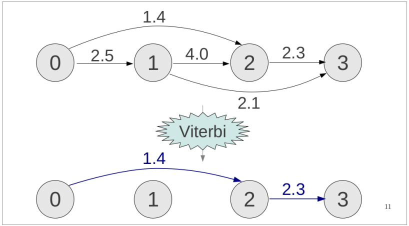
...

- Language model to choose sequence with highest probability
- Requires an existing tokenised corpus
- Maximum likelihood estimation (MLE):
    - Probability of a word: frequency / number of tokens in corpus

Combinatorial explosion



Finding the best segmentation



Viterbi algorithm:

- Forward step:
  - Search the graph left-to-right, picking the highest prob arc at each step,
  - leaving a pointer to the previously visited node
- Backward step:
  - Follow the pointers back to read off the path

[Algorithm covered in Lecture 3 *Morphological disambiguation*.]

Unknown words

What to do with out-of-vocabulary (OOV) items?

Smoothing:

- Add-one smoothing[3], basically just add 1 to every count
  - Assigns too much probability mass to unknown words
- Use the Good-Turing method (see Manning and Schütze, p.212)

[3] If you do this, avoid a man called Ken Church.

A note on encodings

Watch out for characters other than space (U+0020):

- Non-breaking spaces (U+2060, U+FEFF, …)
- Soft-hyphen (U+00AD)
- En quad (U+2000)
- En space (U+2002)

Plus 20 or so other characters.

Formats

Extra-spaces format:

```
Крайняя западная точка расположена в районе Фленсбурга (9°10′ в.д.).
```

↓

```
Крайняя западная точка расположена в районе Фленсбурга ( 9°10′ в.д. ) .
```

- Widely used
- Basically just add in (extra) spaces to indicate tokenisation
- Easy to process
- Loses original text

Formats

CoNLL-U:

```
# text = Крайняя западная точка расположена в районе Фленсбурга (9°10′ в.д.).
1    Крайняя       _  _  _  _  _  _  _  _
2    западная      _  _  _  _  _  _  _  _
3    точка         _  _  _  _  _  _  _  _
4    расположена   _  _  _  _  _  _  _  _
5    в             _  _  _  _  _  _  _  _
6    районе        _  _  _  _  _  _  _  _
7    Фленсбурга    _  _  _  _  _  _  _  _
8    (             _  _  _  _  _  _  _  SpaceAfter=No
9    9°10′         _  _  _  _  _  _  _  _
10   в.д.          _  _  _  _  _  _  _  SpaceAfter=No
11   )             _  _  _  _  _  _  _  SpaceAfter=No
12   .             _  _  _  _  _  _  _  _
```

- More complex to process
- Original text can be reconstructed
- universaldependencies.org/format.html

Evaluation

Most common evaluation method is Word Error Rate (WER):

- Number of edits divided by number of tokens in the reference
  - Edits: insertions (I), deletions (D), substitutions (S)
- Implemented with Levenshtein distance

wecanonlyseeashortdistanceahead

```
REF: we can   only   see a   short distance ahead
HYP: we canon l    y see ash ort   distance ahead
EVA:    S     S    I     S   S
```

WER: $\frac{5}{8} = 62.5\%$

Practical

Implement the `maxmatch` algorithm and test it on Japanese:

- Extract surface form dictionary from the training corpus
- Run the algorithm with the dictionary on the test corpus
- Write script to calculate WER for the segmentation.
  - Feel free to use a library or existing code for this

https://github.com/UniversalDependencies/UD_Japanese-GSD