Tokenization and Word Segmentation

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Tokenization and Word Segmentation

- IMPORTANT because:
  - Training tokenization ≠ test tokenization
  - ⇒ accuracy goes down

- Not always trivial
- May interact with morphology

- May include normalization (character-level)
“María, I love you!” Juan exclaimed.

«¡María, te amo!», exclamó Juan.

- Classic tokenization:
  - Separate punctuation from words
  - Recognize certain clusters of symbols like “...”
  - Perhaps keep together things like user@mail.x.edu
Using Unicode Character Categories

- [https://perldoc.perl.org/perlunicode.html](https://perldoc.perl.org/perlunicode.html)

```perl
$text =~ s/\P/ $1 /g;
$text =~ s/\s+///;
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- Optionally recombine email addresses, URLs etc.
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```

- Optionally recombine email addresses, URLs etc.

Some problems

- haven’t (English; should be have n’t)
- instal · lació (Catalan; should be 1 token)
- single quote (punctuation) misspelled as acute accent (modifier letter)

- writing systems without spaces
Normalization

- Often part of tokenization

- Decimal comma to decimal point; separator of thousands
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  - Sometimes mistaken for ACUTE ACCENT, PRIME (math) etc.
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- English/ASCII punctuation in foreign writing systems
  - 「你看過《三國演義》嗎？」他問我。
  - “你看過‘三國演義’嗎?”他問我.
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- European/ASCII digits in Arabic, Devanagari etc.
  - ٠ ١ ٢ ٣ ٤ ٥ ٦ ٧ ٨ ٩ (Eastern Arabic)
  - ० १ २ ३ ४ ५ ६ ७ ८ ९ (Devanagari)
Let’s go to the sea.

Vámonos al mar. Vamos nos a el mar.

VERB? X NOUN PUNCT VERB PRON ADP DET NOUN PUNCT

- **Syntactic word** vs. orthographic word
- **Multi-word tokens**
- Two-level scheme:
  - Tokenization (low level, punctuation, concatenative)
  - Word segmentation (higher level, not necessarily concatenative)
Lexicalist hypothesis:
- Words (not morphemes) are the basic units in syntax
- Words enter in dependency relations
- Words are forms of lemmas and have morphological features

Orthographic vs. syntactic word
- Syntactically autonomous part of orthographic word
- Contractions ($al = a + el$)
- Clitics ($vámonos = vamos + nos$)
  - ¿A qué hora nos vamos mañana?
  - Nos despertamos a las cinco.
    "We wake up at five."
  - Nuestro guía nos despierta a las cinco.
    "Our guide wakes us up at five."
He abdicated in favour of his son Baudouin.

yatanāzalu can al-ʿarši li+ibni+hi būdūān
surrendered on the throne to son his Baudouin
VERB ADP NOUN ADP+NOUN+PRON PROPN
Segmentation as Part of Morphological Analysis

- Arabic
  - Enter "لاينة" (labnh)

- Sanskrit
  - Sanskrit Reader Companion: http://sanskrit.inria.fr/DICO/reader.fr.html
  - Select Input convention = Devanagari
  - Enter “सकलार्थशास्त्रसारं जगति समालोक्य विष्णुशर्मेदम्” (sakalārthaśāstrasāraṁ jagati samālokyaviṣṇuśarmedam)

- German compound splitting (unsupervised)
We are now in Valencia.

現在我們在瓦倫西亞。

Xiàn zài wǒ men zài wǎ lún xī yǎ.

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We are now in Valencia.
I went to the beauty salon of Kyōdō [, Beyond-R.]

経堂の美容室に行くてきました
Kyōdō no miyōshitsu ni ite kimashita

Kyōdō of beauty-salon to go will come was

Words in Japanese
I went to the beauty salon of Kyōdō [Beyond-R.]
I went to the beauty salon of Kyōdō [, Beyond-R.]

経堂の

美容室に

行って

きました

経堂

美容室

行く

come

行く

going

去了

Kimashita

Kyōdō

to-beauty-salon

of-Kyōdō

PROPN

NOUN

VERB

Case=Gen

Case=Dat

VerbForm=Conv

VerbForm=Fin

Tense=Past

Polite=Form
All the concrete country roads are the result of...

Tất cả đường bê tông nội đồng là thành quả...

- Spaces delimit monosyllabic morphemes, not words.
- Multiple syllables without space occur in loanwords (*bê tông*).
- Spaces are allowed to occur word-internally in Vietnamese UD.
Il touche environ 100 000 sesterces par an.
Fixed Expressions

One syntactic word spans several orthographic words?

# text = Bin nach wie vor sehr zufrieden.
# text_en = I am still very satisfied.
1 Bin sein AUX ... 6 cop __ __
2 nach nach ADP ... 6 obl __ __
3 wie wie ADV ... 2 fixed __ __
4 vor vor ADP ... 2 fixed __ __
5 sehr sehr ADV ... 6 advmod __ __
6 zufrieden zufrieden ADJ ... 0 root __ SpaceAfter=No
7 . . PUNCT ... 6 obl __ __
One syntactic word spans several orthographic words?
*I am still very satisfied.*
Some corpora use the underscore character to glue MWEs together.

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- Durante la presentación del libro ”La_prosperidad_por_medio_de_la_investigación._La_investigación_básica_en_EEUU”, editado por la Comunidad_de_Madrid, el secretario general de la Confederación_Empresarial_de_Madrid-CEOE (CEIM), Alejandro_Couceiro, abogó por la formación de los investigadores en temas de innovación tecnológica.

- Lemmas?
- Tags?
Word Segmentation Summary

- When to split?
  - Only part of the token involved in a relation to something outside the token? Split!
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- Hard time finding POS tag? Split!

Border case? Keep orthographic words (if they exist).

Words with spaces
Vietnamese writing system
Very restricted set of exceptions (numbers)
Special relations elsewhere (fixed, compound)
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- Words with spaces
  - Vietnamese writing system
  - Very restricted set of exceptions (numbers)
  - Special relations elsewhere (fixed, compound)
# text = Vámonos al mar.
# text_en = Let's go to the sea.

<table>
<thead>
<tr>
<th>ID</th>
<th>FORM</th>
<th>LEMMA</th>
<th>UPOS</th>
<th>...</th>
<th>HEAD</th>
<th>_</th>
<th>MISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Vámonos</td>
<td>_</td>
<td>_</td>
<td>...</td>
<td>_</td>
<td>_</td>
<td>___</td>
</tr>
<tr>
<td>1</td>
<td>Vamos</td>
<td>ir</td>
<td>VERB</td>
<td>...</td>
<td>0</td>
<td>root</td>
<td>___</td>
</tr>
<tr>
<td>2</td>
<td>nos</td>
<td>nosotros</td>
<td>PRON</td>
<td>...</td>
<td>1</td>
<td>obj</td>
<td>___</td>
</tr>
<tr>
<td>3-4</td>
<td>al</td>
<td>_</td>
<td>_</td>
<td>...</td>
<td>_</td>
<td>_</td>
<td>___</td>
</tr>
<tr>
<td>3</td>
<td>a</td>
<td>a</td>
<td>ADP</td>
<td>...</td>
<td>5</td>
<td>case</td>
<td>___</td>
</tr>
<tr>
<td>4</td>
<td>el</td>
<td>el</td>
<td>DET</td>
<td>...</td>
<td>5</td>
<td>det</td>
<td>___</td>
</tr>
<tr>
<td>5</td>
<td>mar</td>
<td>mar</td>
<td>NOUN</td>
<td>...</td>
<td>1</td>
<td>obl</td>
<td>___ SpaceAfter=No</td>
</tr>
<tr>
<td>6</td>
<td>.</td>
<td>.</td>
<td>PUNCT</td>
<td>...</td>
<td>1</td>
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Vámonos al mar.

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Tokenization vs. Multi-word Tokens

- Parallelism among closely related languages
  - ca: informar-se sobre el patrimoni cultural
  - es: informarse sobre el patrimonio cultural
  - en: learn about cultural heritage

- ca: L’única que veig és => L’ únic que veig és
- en: don’t => do n’t

- No strict guidelines for tokenization (yet)
  - UD English: non-stop, post-war: single-word tokens
  - UD Czech: non-stop would be split to three tokens
  - Abbreviations: etc.
    - End of sentence...
Tokenization vs. Multi-word Tokens Summary

- Punctuation involved? Low level!
  - Exceptions: Spanish-Catalan parallelism.
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- Non-concatenative? High level!
Errors in Underlying Text

- We do not want to hide errors (learning robust parsers!)
  - But: reference corpora (linguistic research) may want to hide them.

- Typo not involving word boundary
  - FORM = annotation
  - LEMMA = annotation
  - FEATURES = Typo=Yes; MISC: Correct=annotation

- Wrongly split word: annoration

- Wrongly merged words: thecar

- Fix tokenization (i.e. two lines); first line MISC: SpaceAfter=No | CorrectSpaceAfter=Yes

- Sentence segmentation can be affected, too!
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- Wrong morphology: *the cars is produced in Detroit*

  - FORM = cars; FEATURES: Number=Plur; MISC: Correct=car | CorrectNumber=Sing
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- Suggestion: select which word to fix, e.g. *cars* to *car*
- FORM = *cars*; FEATS: Number=Plur; MISC: Correct=car | CorrectNumber=Sing
- cs: *viděl moři* “he saw the sea”
  - Should be *moře*
  - Would be Case=Acc (disambiguated from Case=Acc,Gen,Nom,Voc)
  - This form is Case=Dat,Loc (but which one?)
- *cestoval k moři* “he traveled to the sea” Case=Dat
- *plavil se po moři* “he sailed the sea” Case=Loc
Tokenization Alignment

- If you need to match two different tokenizations
- Use case: evaluation of end-to-end parsing systems
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- Normalization involved? Bad luck...
  - Normalization rules needed
  - Or: Longest common subsequence (LCS) algorithm
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- Otherwise easy
  - Non-whitespace character offsets
Evaluation Metrics

- Align system-output tokens to gold tokens

*Al-Zaman*: *American forces killed Shaikh Abdullah al-Ani, the preacher at the mosque in the town of Qaim, near the Syrian border.*

**GOLD:**  
*Al-Zaman*: American forces killed Shaikh

**OFFSET:**  0-1  2  3-7  8  9-16  17-22  23-28  29-34

- All characters except for whitespace match => easy align!

**SYSTEM:** *Al-Zaman*: American forces killed Shaikh

**OFFSET:**  0-7  8  9-16  17-22  23-28  29-34
Evaluation Metrics

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Die Kosten sind definitiv auch im Rahmen.

GOLD:  Die Kosten sind definitiv auch im Rahmen .
SPLIT:  Die Kosten sind definitiv auch in dem Rahmen .
OFFSET:  0-2  3-8  9-12  13-21  22-25  26-27  28-33  34

- Corresponding but not identical spans?
- Find longest common subsequence

SYSTEM: Kosten sind definitiv auch im Rahmen .
SPLIT: Kosten sind de finitiv auch im Rahmen .
OFFSET:  3-8  9-12  13-21  22-25  26-27  28-33  34
Evaluation Metrics

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*Die Kosten sind definitiv auch im Rahmen.*

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**OFFSET:** 0-2 3-8 9-12 13-21 22-25 26-27 28-33 34

- Corresponding but not identical spans?
- Find longest common subsequence

**SYSTEM:** auch im Rahmen .
**SPLIT:** auch in einem , dem alle zustimmen , Rahmen .
**OFFSET:** 22-25 26-27 28-33 34