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)
Tokenization and Word Segmentation

- Issues of orthography of individual languages
- Issues caused by design decisions of individual corpora
- We will refer to the Universal Dependencies project (UD; https://universaldependencies.org/); more info in following weeks
- Due to limited time, we will probably skip some slides at the end
“María, I love you!” Juan exclaimed.

«¡María, te amo!», exclamó Juan.

X  PRON  X  VERB  X

« ¡María , te amo! » ,

PUNCT PUNCT PROPN PUNCT PRON VERB PUNCT PUNCT PUNCT PUNCT

▶ 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{P}/ $1 /g;
$text =~ s/^\s+//;
$text =~ s/\s+$//;
$text =~ s/\p{P}/ $1 /g;

Optionally recombine email addresses, URLs etc.
```
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```

▶ $text =~ s/(\pP)/ $1 /g;
▶ 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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- \TeX-like ASCII directed quotes ` ` and ' ' and hyphens -- and ---
- 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.

▶ Syntactic word vs. orthographic word
▶ Multi-word tokens
▶ Two-level scheme:
  ▶ Tokenization (low level, punctuation, concatenative)
  ▶ Word segmentation (higher level, not necessarily concatenative)
Word Segmentation

- Orthographic vs. syntactic word
  - Syntactically autonomous part of orthographic word
  - Contractions ($al = a + el$)
  - Clitics ($vámonos = vamos + nos$)
    - ¿A qué hora $nos$ vamos mañana?
      “What time do we leave tomorrow?”
    - *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 ʿan al-ʿarši li+ibni+hi būdūān
surrendered on the throne to son his Baudouin
Segmentation as Part of Morphological Analysis

- **Arabic**
  - Select **Resolve**
  - Enter "ﻻﺑﻨﻪ" (labnh)

- **Sanskrit**
  - Sanskrit Reader Companion: [https://sanskrit.inria.fr/DICO/reader.fr.html](https://sanskrit.inria.fr/DICO/reader.fr.html)
  - Select Input convention = Devanagari
  - Enter “सकलार्थाशास्त्रसारं जगति समालोक्य विष्णुशमेदम्” (sakalārthaśāstrasāram jagati samālokyaviṣṇuśarmedam)

- **German compound splitting (unsupervised)**
  - Not split in Universal Dependencies
We are now in Valencia.

現在我們在瓦倫西亞。
Xiàn zài wǒ men zài wǎ lún xī yǎ.
We are now in Valencia.

現在 我們 在 瓦倫西亞 。
Xiànzài wǒmen zài Wǎlúnxīyǎ 。
Now we in Valencia .

ADV PRON ADP PROPN PUNCT
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た
Kyōdō of beauty-salon to going came
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

来る

of-Kyōdō
to-beauty-salon

PROPN

NOUN

VERB

VERB

Case=Gen

Case=Dat

VerbForm=Conv

VerbForm=Fin

Tense=Past

Polite=Form
Vietnamese: Words with Spaces

All the concrete country roads are the result of...

Tất cả đường bê tông nội đồng là thành quả ...
All road concrete country is achievement ...

PRON NOUN NOUN NOUN AUX NOUN PUNCT

- 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.
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 | ___ | ___ |
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*I am still very satisfied.*

```
Am after like before very satisfied .
Bin nach wie vor sehr zufrieden .
```
Some corpora use the underscore character to glue MWEs together.

*I am still very satisfied.*
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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?
When to split?

- Only part of the token involved in a relation to something outside the token? Split!
- Hard time finding POS tag? Split!
- Hard time finding dependency relation? Don’t split!
- Or not hard time but the relation would be compound, flat, fixed or goeswith.
- 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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Word Segmentation Summary

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▶ Words with spaces
  ▶ Vietnamese writing system
  ▶ Very restricted set of exceptions (numbers)
  ▶ Special relations elsewhere (fixed, compound)
Recoverability: CoNLL-U Format

```plaintext
# 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>
<td>punct</td>
<td>_ _</td>
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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’únic 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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- Boundary between two letters? Typically high level.
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▶ Boundary between two letters? Typically high level.
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▶ Non-concatenative? High level!
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  But: reference corpora (linguistic research) may want to hide them.
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Possibilities:
- Typo not involving word boundary
  - FORM = annotation; LEMMA = annotation; FEATS: Typo=Yes; MISC: Correct=annotation
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- Wrongly split word:

- Wrongly merged words: thecar
  - Fix tokenization (i.e. two lines); first line MISC: SpaceAfter=No | CorrectSpaceAfter=Yes
  - Sentence segmentation can be affected, too!
Errors in Underlying Text

- Wrong morphology: the cars is produced in Detroit
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  - Not like normal typo (the car iss produced...)

Tokenization and Word Segmentation
Wrong morphology: *the cars is produced in Detroit*
- Not like normal typo (*the car iss produced...*)
- Not obvious what is correct
  - *the car is*
  - *the cars are*
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- FORM = *cars*; FEATS: **Number=Plur; MISC: Correct=car | CorrectNumber=Sing**
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- 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
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

- Align system-output tokens to gold tokens

*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.

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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