Tokenization and Word Segmentation

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Tokenization and Word Segmentation

- IMPORTANT because:
  - Training tokenization $\neq$ test tokenization
  - $\Rightarrow$ 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

Tokenization

"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

- 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

```
$text =~ s/(\pP)/ $1 /g;
$text =~ s/^\s+//;
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  - $text =~ s/(\pP)/ $1 /g;
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- 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

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- European/ASCII digits in Arabic, Devanagari etc.
  - 0 1 2 3 4 5 6 7 8 9 (Western Arabic/European)
  - ٠ ١ ٢ ٣ ٤ ٥ ٦ ٧ ٨ ٩ (Eastern Arabic)
  - ० १ २ ३ ४ ५ ६ ७ ८ ९ (Devanagari)

Word Segmentation

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)

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."

Contractions in Arabic

He abdicated in favour of his son Baudouin.

يتنازل	عن	العرش	لابنه	بودوان
yatanāzalu	**ᶜan**	**al-ᶜarši**	**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
  - ElixirFM: `http://lindat.mff.cuni.cz/services/elixirfm/run.php`
  - Select **Resolve**
  - Enter "لابنه" *(labnh)*
- Sanskrit
  - Sanskrit Reader Companion: `https://sanskrit.inria.fr/DICO/reader.fr.html`
  - Select Input convention = Devanagari
  - Enter "सकलार्थशास्त्रसारं जगति समालोक्य विष्णुशर्मेदम्" *(sakalārthaśāstrasāraṁ jagati samālokya viṣṇuśarmedam)*
- German compound splitting (unsupervised)
  - Not split in Universal Dependencies

Chinese Word Segmentation

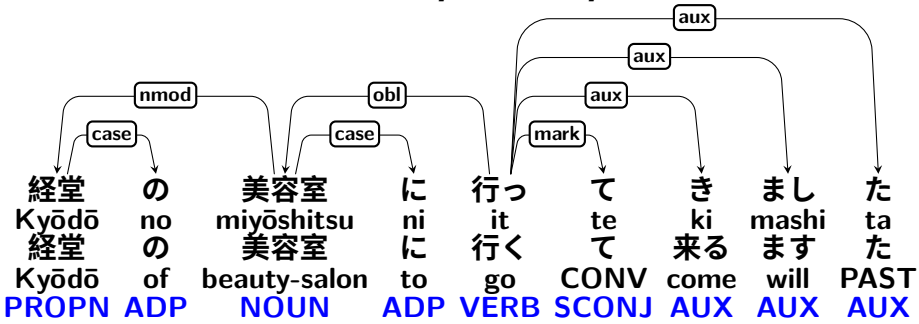
We are now in Valencia.

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

Words in Japanese

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



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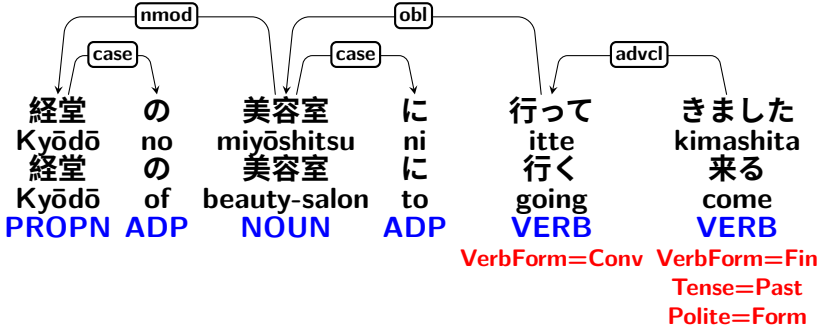

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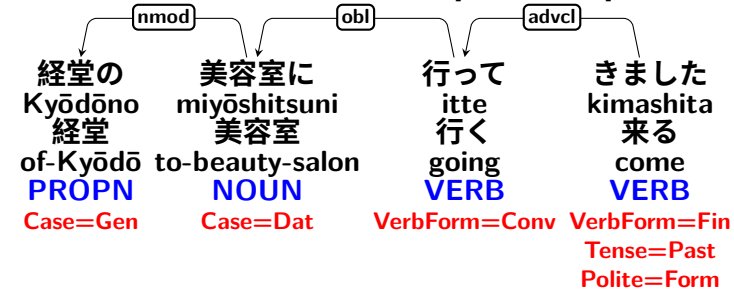

Vietnamese: Words with Spaces

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

Tất cả	đường	bêtông	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 *(bêtông)*.
- Spaces are allowed to occur word-internally in Vietnamese UD.

Numbers with Spaces

text = Il touche environ 100 000 sesterces par an.

1	Il	il	PRON	...	2	nsubj	_ _
2	touche	toucher	VERB	...	0	root	_ _
3	environ	environ	ADV	...	4	advmod	_ _
4	100 000	100 000	NUM	...	5	nummod	_ _
5	sesterces	sesterce	NOUN	...	2	obj	_ _
6	par	par	ADP	...	7	case	_ _
7	an	an	NOUN	...	2	obl	_ SpaceAfter=No
8	.	.	PUNCT	...	2	punct	_ _

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      _ _
```

Fixed Expressions

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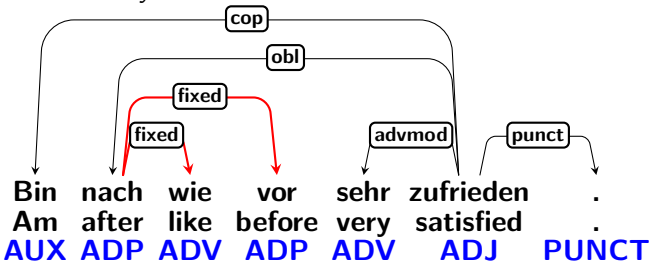

Multi-Word Expressions outside UD

Some corpora use the underscore character to glue MWEs together.

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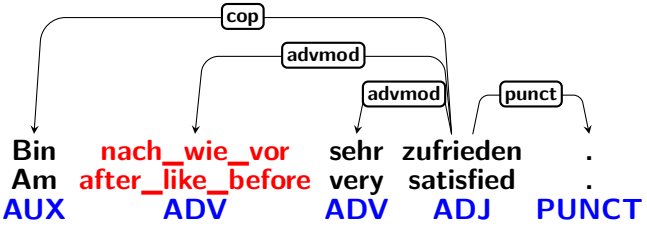

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- Durante la presentación del libro " La_prosperidad_por_medio_de_la_investigación_._La_investigación_básica_en_EEUU " , editado por la Comunidad_de_Madrid , el secretario general de la Confederación_Empresarial_de_Madrid-CEOE (CEIM) , Alejandro_Couceiro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

- Lemmas?
- Tags?

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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

text = Vámonos al mar.
text_en = Let's go to the sea.

ID	FORM	LEMMA	UPOS	...	HEAD		_ MISC
1-2	Vámonos	_	_	...	_	_	_ _
1	Vamos	ir	VERB	...	0	root	_ _
2	nos	nosotros	PRON	...	1	obj	_ _
3-4	al	_	_	...	_	_	_ _
3	a	a	ADP	...	5	case	_ _
4	el	el	DET	...	5	det	_ _
5	mar	mar	NOUN	...	1	obl	_ SpaceAfter=No
6	.	.	PUNCT	...	1	punct	_ _

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3-4	al	_	_	...	_	_	_ _
3	a	a	ADP	...	5	case	_ _
4	el	el	DET	...	5	det	_ _
5-6	**mar.**	**_**	**_**	**...**	**_**	**_**	**_ _**
5	mar	mar	NOUN	...	1	obl	_ _
6	.	.	PUNCT	...	1	punct	_ _

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...

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- Boundary between two letters? Typically high level.
  - Exceptions: Chinese, Japanese.
- Non-concatenative? High level!

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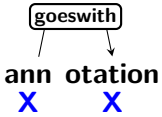

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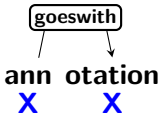

- Wrongly split word:
- Wrongly merged words: *thecar*
  - Fix tokenization (i.e. two lines); first line MISC: **SpaceAfter=No | CorrectSpaceAfter=Yes**
  - **Sentence segmentation can be affected, too!**

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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**

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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!

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Die Kosten sind definitiv auch im Rahmen.

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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**

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- Find longest common subsequence

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SPLIT:	**auch**	**in einem , dem alle zustimmen ,**	**Rahmen**	**.**
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