Concept Alignment for Multilingual Machine Translation

04.07.2021

Arianna Masciolini

Context

- GF is well suited for **domain-specific MT** systems, where precision is more important than coverage, as it provides strong guarantees of grammatical correctness

Context

- GF is well suited for **domain-specific MT** systems, where precision is more important than coverage, as it provides strong guarantees of grammatical correctness
- in such systems, **lexical exactness** is as important as grammaticality

Context

- GF is well suited for **domain-specific MT** systems, where precision is more important than coverage, as it provides strong guarantees of grammatical correctness
- in such systems, **lexical exactness** is as important as grammaticality
  - need for high-quality **translation lexica** preserving semantics *and* morphological correctness

The problem

- manually building a translation lexicon
  - is time consuming
  - requires significant linguistic knowledge
- desire to **automate** this process at least in part

The problem

- manually building a translation lexicon
  - is time consuming
  - requires significant linguistic knowledge
- desire to **automate** this process at least in part
  - possible when **example parallel data** are available

A parallel corpus

Alice thought she might as well wait, as she had nothing else to do, and perhaps after all it might tell her something worth hearing.

For some minutes it puffed away without speaking, but at last it unfolded its arms, took the hookah out of its mouth again, and said, 'So you think you're changed, do you?'

'I'm afraid I am, sir,' said Alice; 'I can't remember things as I used--and I don't keep the same size for ten minutes together!'

Alice pensò che poteva aspettare, perchè non aveva niente di meglio da fare, e perchè forse il Bruco avrebbe potuto dirle qualche cosa d'importante.

Per qualche istante il Bruco fumò in silenzio, finalmente sciolse le braccia, si tolse la pipa di bocca e disse: — E così, tu credi di essere cambiata?

— Ho paura di sì, signore, — rispose Alice. — Non posso ricordarmi le cose bene come una volta, e non rimango della stessa statura neppure per lo spazio di dieci minuti!

From Lewis Carroll, *Alice's adventures in Wonderland*. Parallel text at `paralleltext.io`

Alignment

Word alignment:

Alice thought she might as well wait, as she had nothing else to do, and perhaps after all it might tell her something worth hearing.

Alice pensò che poteva aspettare, perchè non aveva niente di meglio da fare, e perchè forse il Bruco avrebbe potuto dirle qualche cosa d'importante.

Alignment

Word alignment:

Alice thought she might as well wait, as she had nothing else to do, and perhaps after all it might tell her something worth hearing.

Alice pensò che poteva aspettare, perchè non aveva niente di meglio da fare, e perchè forse il Bruco avrebbe potuto dirle qualche cosa d'importante.

Phrase alignment:

Alice thought she might as well wait, as she had nothing else to do, and perhaps after all it might tell her something worth hearing.

Alice pensò che poteva aspettare, perchè non aveva niente di meglio da fare, e perchè forse il Bruco avrebbe potuto dirle qualche cosa d'importante.

Statistical approaches

Standard approaches are statistical (IBM models).

Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:

Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:
  - easy to use

Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:
  - easy to use
  - can handle noisy data

Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:
  - easy to use
  - can handle noisy data
  - fast on large corpora

Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:
  - easy to use
  - can handle noisy data
  - fast on large corpora
- **cons**:

Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:
  - easy to use
  - can handle noisy data
  - fast on large corpora
- **cons**:
  - *require* large amounts of raw data

Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:
  - easy to use
  - can handle noisy data
  - fast on large corpora
- **cons**:
  - *require* large amounts of raw data
  - correspondences between strings

Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:
  - easy to use
  - can handle noisy data
  - fast on large corpora
- **cons**:
  - *require* large amounts of raw data
  - correspondences between strings $\rightarrow$ no morphological info

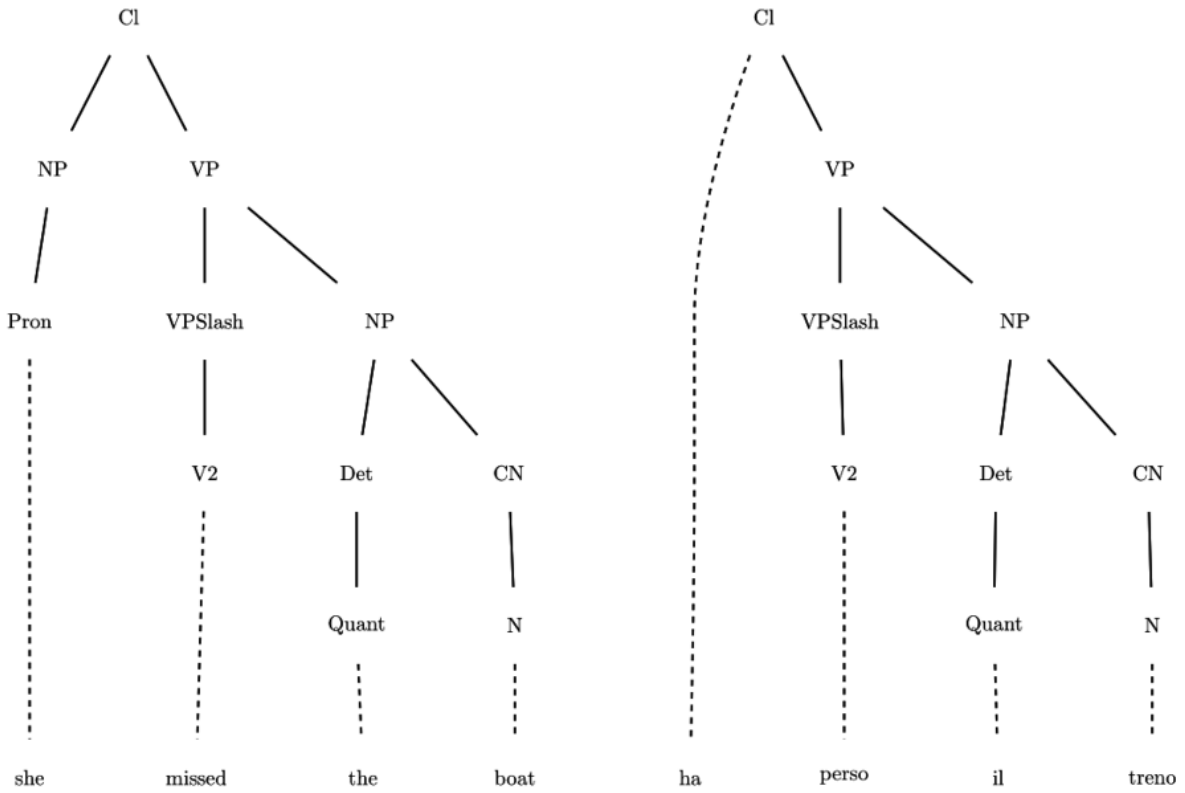
Statistical approaches

Standard approaches are statistical (IBM models).

- **pros**:
  - easy to use
  - can handle noisy data
  - fast on large corpora
- **cons**:
  - *require* large amounts of raw data
  - correspondences between strings $\rightarrow$ no morphological info
  - "fixed" level of abstraction (word or phrase)

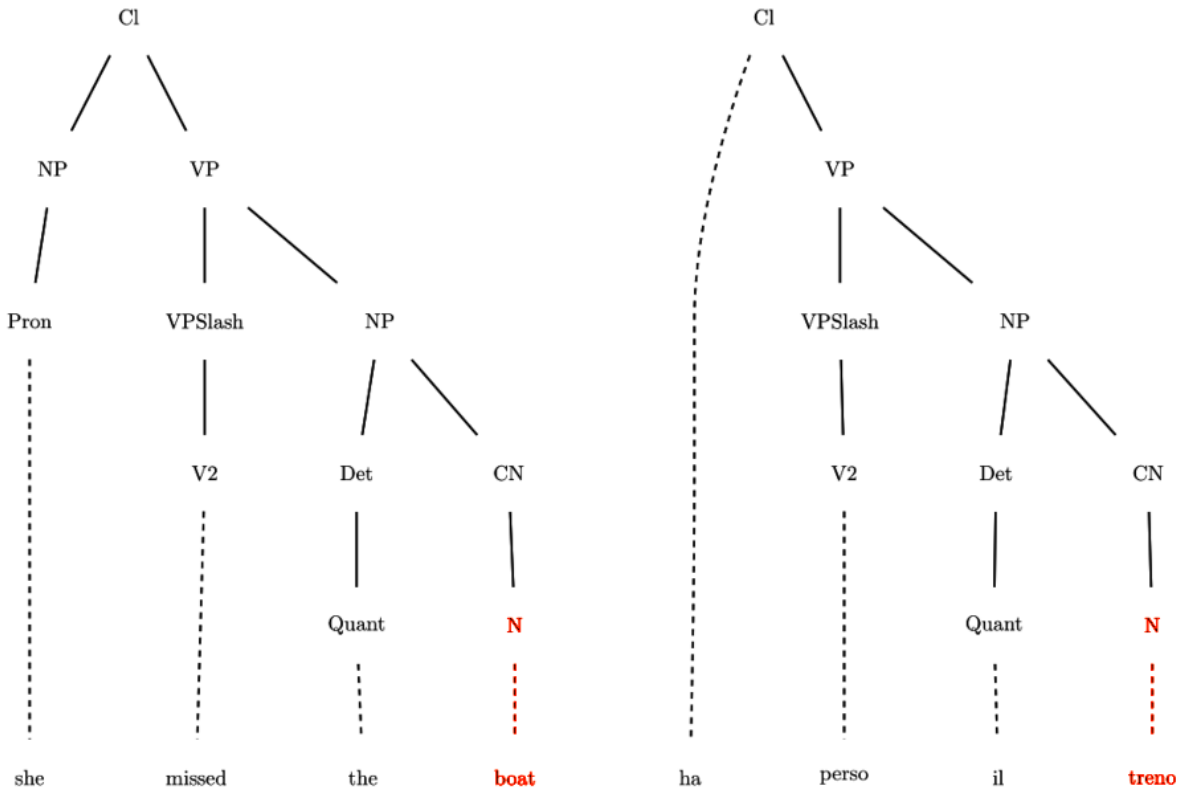
Syntax-based approaches I

Alternative: tree-to-tree alignment.



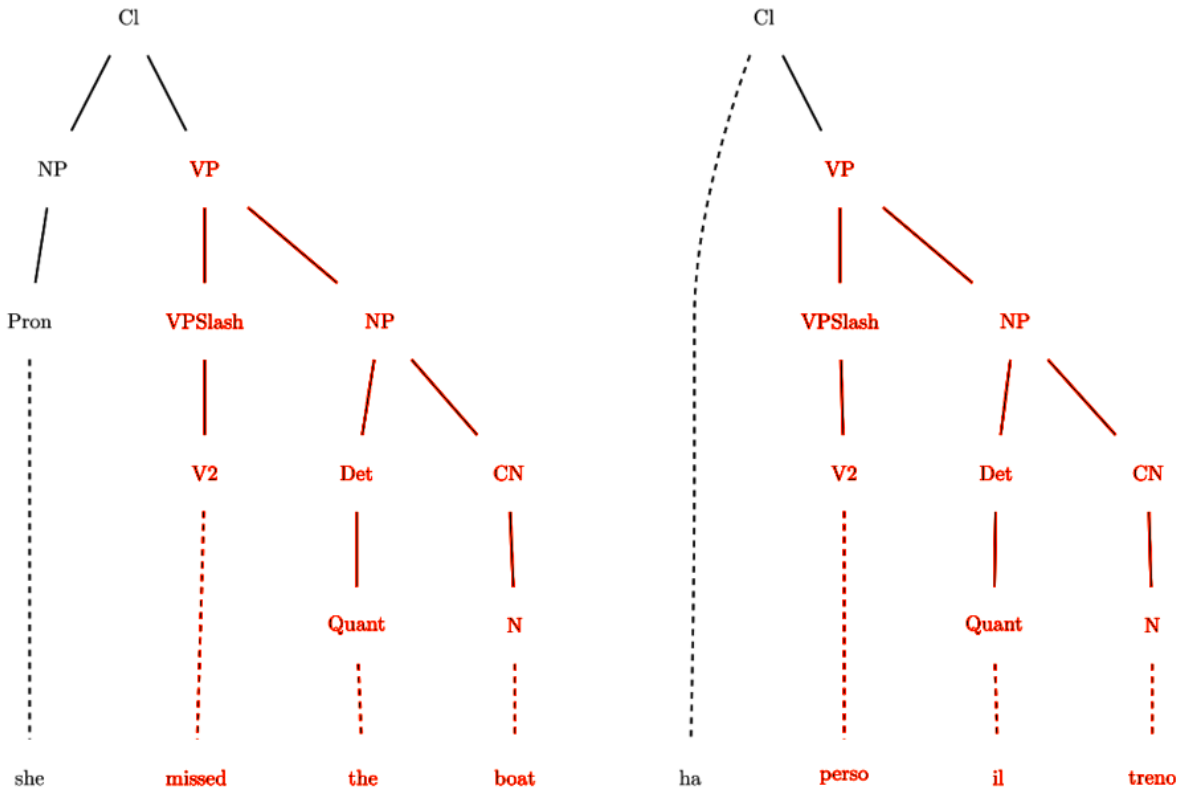
Syntax-based approaches II

Word alignment



Syntax-based approaches III

Phrase alignment



Comparison

statistical	**syntax-based**
require **large amounts of data**	work consistently well even on **individual sentence pairs**
works with **raw** data	requires the data to be **analyzed**
correspondences between **strings**	correspondences between **grammatical objects**
"fixed" level of abstraction (**word** or **phrase**)	all levels of abstraction $\rightarrow$ **concept** alignment

Why not just use GF?

- quality of the analysis is crucial
  - lack of robust GF parsers

Why not just use GF?

- quality of the analysis is crucial
  - lack of robust GF parsers
- dependency trees are an easier target for a parser
  - robust parsers such as UDPipe

Overview


parallel text
UD parsing
UD trees
concept alignment
UD subtrees
gf-ud ++
GF translation lexicon

Overview

1. parse parallel data to UD trees

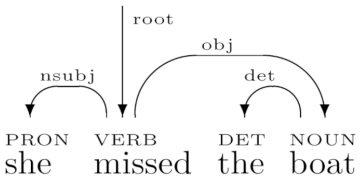
Overview

1. parse parallel data to UD trees
2. search for aligned UD subtrees

Overview

1. parse parallel data to UD trees
2. search for aligned UD subtrees
3. convert them to GF trees and then grammar rules

UD trees



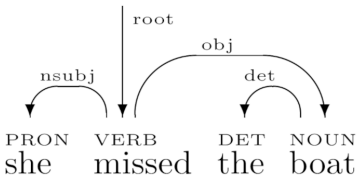

```
# text = she missed the boat
1 she she PRON _ _ 2 nsubj _ _
2 missed miss VERB _ _ 0 root _ _
3 the the DET _ _ 4 det _ _
4 boat boat NOUN _ _ 2 obj _
```

```
2 missed miss VERB _ _ 0 root _ _
  1 she she PRON _ _ 2 nsubj _ _
  4 boat boat NOUN _ _ 2 obj _
    3 the the DET _ _ 4 det _ _
```

Graphical, CoNNL-U and Rose Tree representation of the same UD tree.

- dependency-labelled links between words (head-dependent pairs)

UD trees



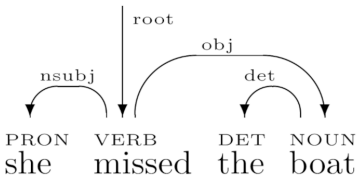

```
# text = she missed the boat
1 she she PRON _ _ 2 nsubj _ _
2 missed miss VERB _ _ 0 root _ _
3 the the DET _ _ 4 det _ _
4 boat boat NOUN _ _ 2 obj _
```

```
2 missed miss VERB _ _ 0 root _ _
  1 she she PRON _ _ 2 nsubj _ _
  4 boat boat NOUN _ _ 2 obj _
    3 the the DET _ _ 4 det _ _
```

Graphical, CoNNL-U and Rose Tree representation of the same UD tree.

- dependency-labelled links between words (head-dependent pairs)
- POS tags

UD trees




```
# text = she missed the boat
1 she she PRON _ _ 2 nsubj _ _
2 missed miss VERB _ _ 0 root _ _
3 the the DET _ _ 4 det _ _
4 boat boat NOUN _ _ 2 obj _
```

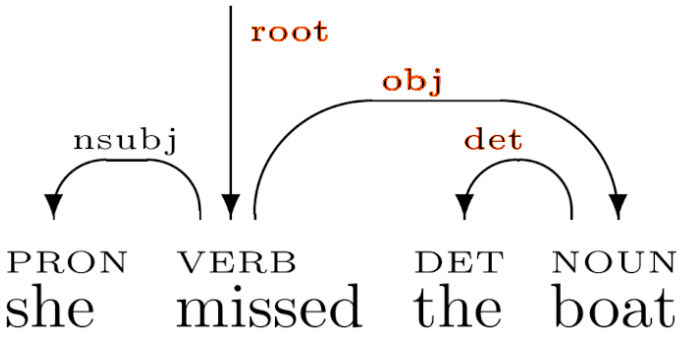
```
2 missed miss VERB _ _ 0 root _ _
  1 she she PRON _ _ 2 nsubj _ _
  4 boat boat NOUN _ _ 2 obj _
    3 the the DET _ _ 4 det _ _
```

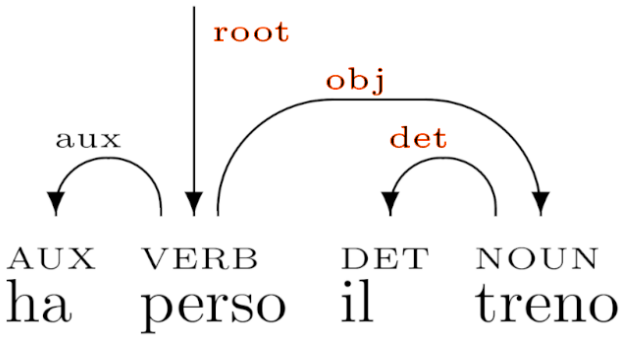
Graphical, CoNNL-U and Rose Tree representation of the same UD tree.

- dependency-labelled links between words (head-dependent pairs)
- POS tags
- ...

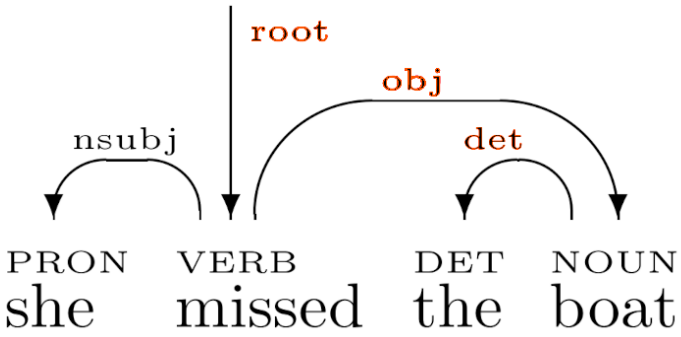
Extracting concepts

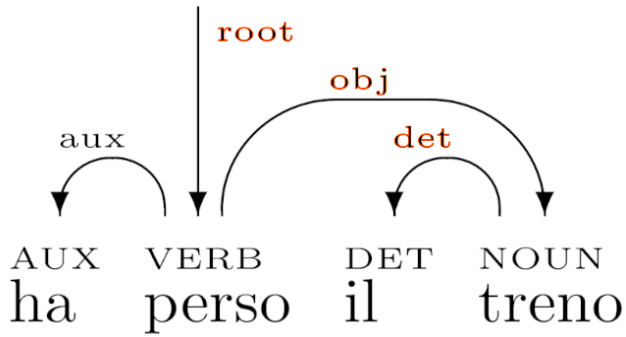
Matching dependency labels





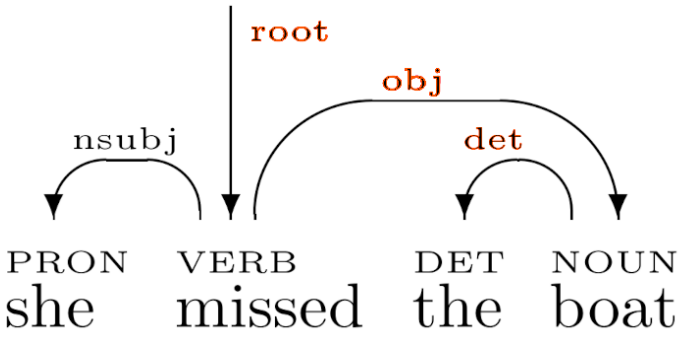
Matching dependency labels

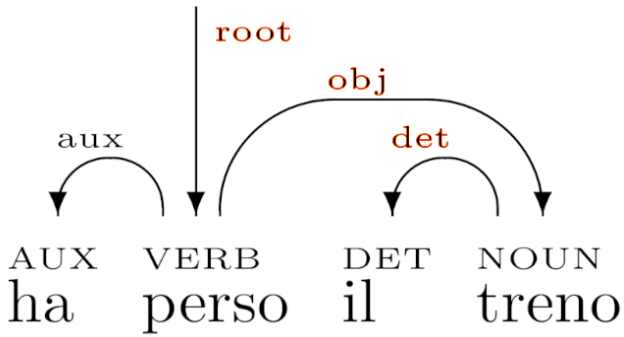




- $\langle$*she missed the boat, ha perso il treno*$\rangle$

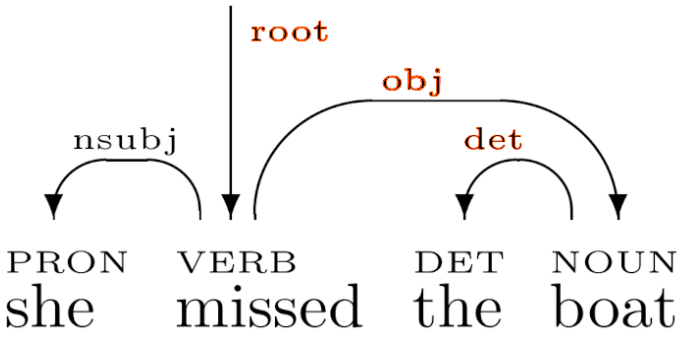
Matching dependency labels

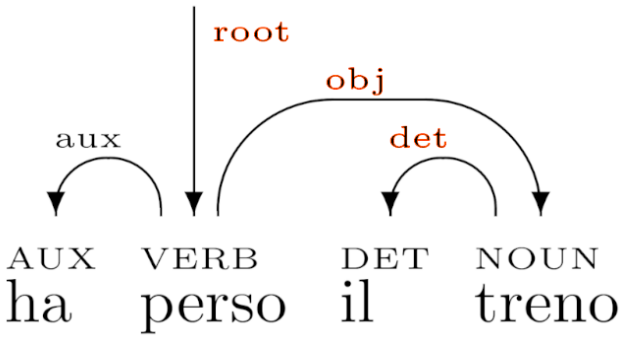




- $\langle$*she missed the boat, ha perso il treno*$\rangle$
- $\langle$*missed the boat, perso il treno*$\rangle$

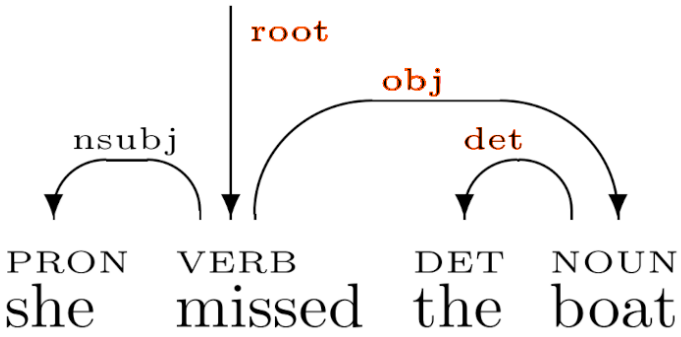
Matching dependency labels

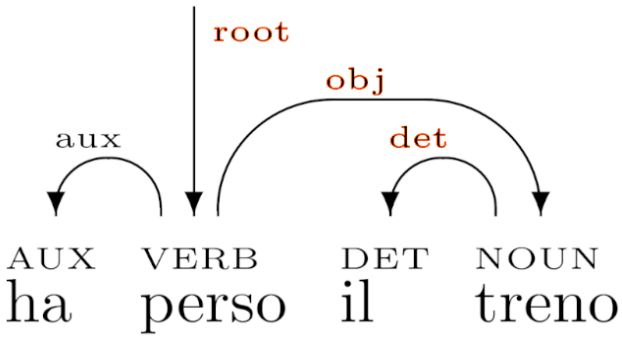




- $\langle$*she missed the boat, ha perso il treno*$\rangle$
- $\langle$*missed the boat, perso il treno*$\rangle$
- *$\langle$*the boat, il treno*$\rangle$

Matching dependency labels





- $\langle$*she missed the boat, ha perso il treno*$\rangle$
- $\langle$*missed the boat, perso il treno*$\rangle$
- *$\langle$*the boat, il treno*$\rangle$
- $\langle$*the, il*$\rangle$

Aligning heads of maching trees

- $\langle \textit{the boat}, \textit{il treno} \rangle$

Aligning heads of maching trees

- $\langle \textit{the boat}, \textit{il treno} \rangle \rightarrow \langle \textit{boat}, \textit{treno} \rangle$

Aligning heads of maching trees

- $\langle \textit{the boat}, \textit{il treno} \rangle \rightarrow \langle \textit{boat}, \textit{treno} \rangle$
- $\langle \textit{missed the boat}, \textit{perso il treno} \rangle$

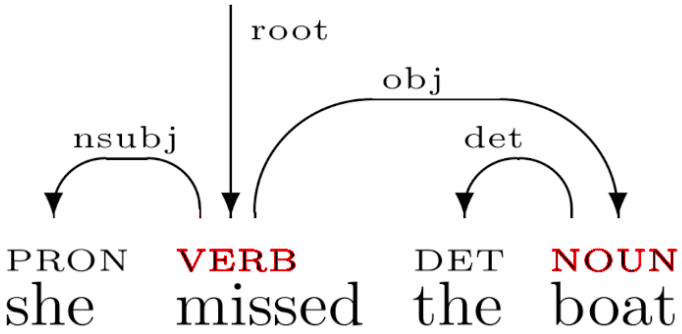
Aligning heads of maching trees

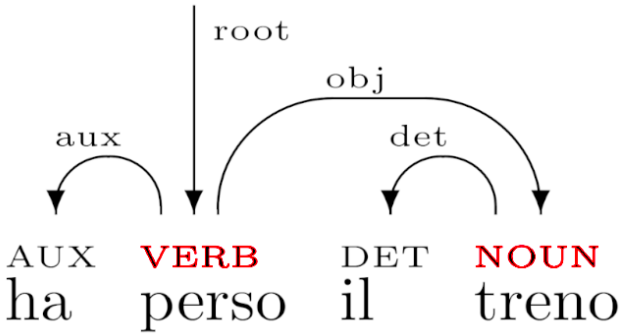
- $\langle \textit{the boat}, \textit{il treno} \rangle \rightarrow \langle \textit{boat}, \textit{treno} \rangle$
- $\langle \textit{missed the boat}, \textit{perso il treno} \rangle \rightarrow \langle \textit{missed}, \textit{ha perso} \rangle$

Aligning heads of maching trees

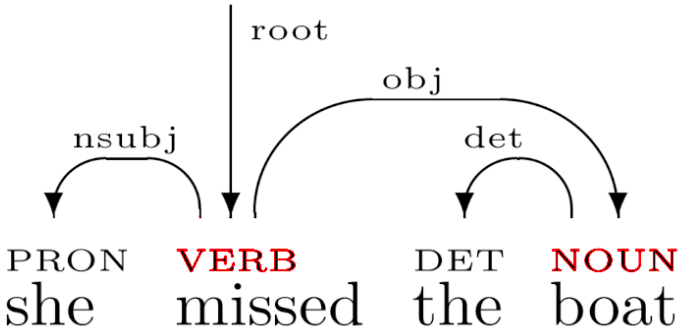
- $\langle \textit{the boat}, \textit{il treno} \rangle \rightarrow \langle \textit{boat}, \textit{treno} \rangle$
- $\langle \textit{missed the boat}, \textit{perso il treno} \rangle \rightarrow \langle \textit{missed}, \textit{ha perso} \rangle$ (including the auxiliary)

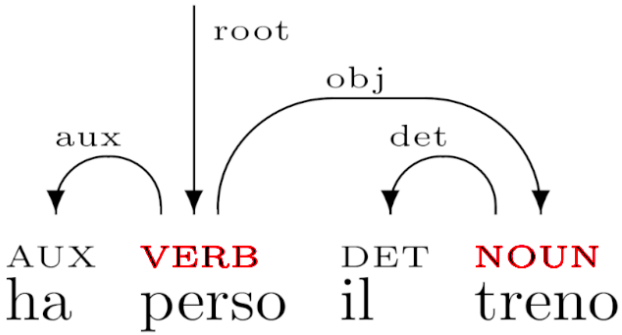
Using POS tags





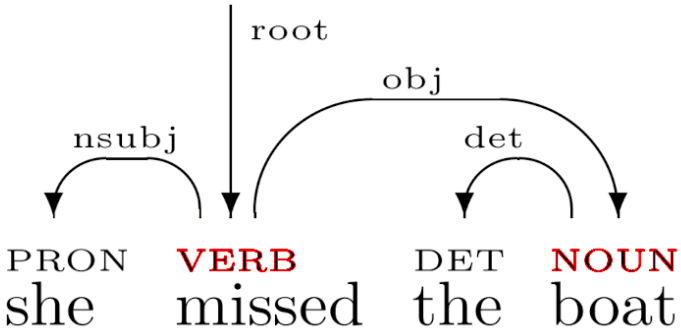
Using POS tags

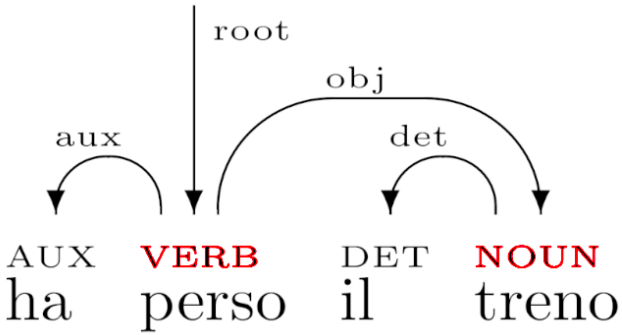




- more reliable **ignoring function words**

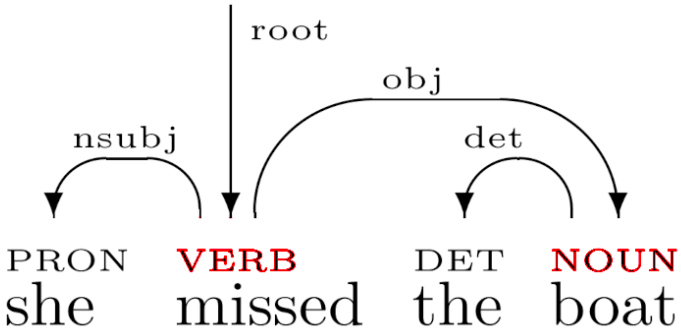
Using POS tags

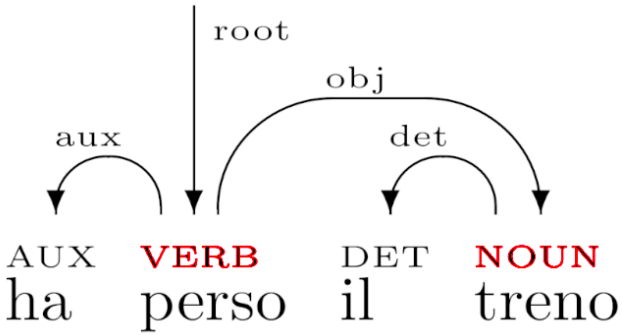




- more reliable **ignoring function words**
- in this case, basically same results as when matching labels

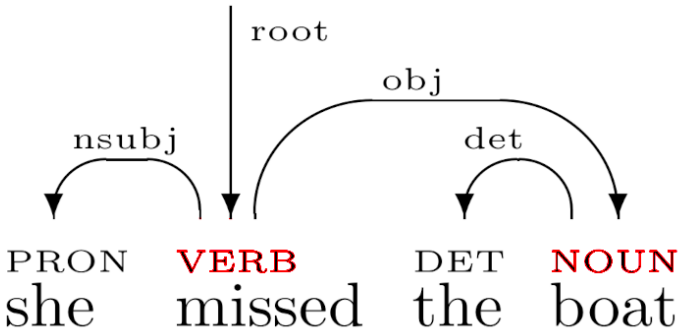
Using POS tags

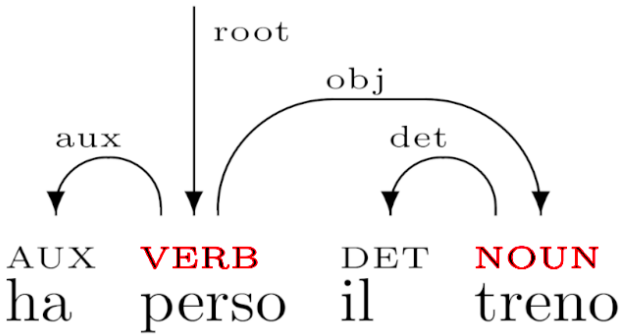




- more reliable **ignoring function words**
- in this case, basically same results as when matching labels
- can increase recall when labels do not coincide

Using POS tags





- more reliable **ignoring function words**
- in this case, basically same results as when matching labels
- can increase recall when labels do not coincide
- can increase precision if used **in conjuncion with labels**

Translation divergences

Divergence: systematic cross-linguistic distinction.

Translation divergences

Divergence: systematic cross-linguistic distinction.

- categorial
  - ⟨*Gioara listens* ***distractedly***, *Gioara lyssnar* ***distraherad***⟩
  - ⟨*Herbert completed his* ***doctoral*** *thesis*, *Herbert ha completato la sua tesi* ***di dottorato***⟩

Translation divergences

Divergence: systematic cross-linguistic distinction.

- categorial
  - ⟨*Gioara listens* ***distractedly***, *Gioara lyssnar* ***distraherad***⟩
  - ⟨*Herbert completed his* ***doctoral*** *thesis*, *Herbert ha completato la sua tesi* ***di dottorato***⟩
- conflational
  - ⟨*Filippo is interested in* ***game development***, *Filippo är intresserad av* ***spelutveckling***⟩

Translation divergences

Divergence: systematic cross-linguistic distinction.

- categorial
  - ⟨*Gioara listens* ***distractedly***, *Gioara lyssnar* ***distraherad***⟩
  - ⟨*Herbert completed his* ***doctoral*** *thesis*, *Herbert ha completato la sua tesi* ***di dottorato***⟩
- conflational
  - ⟨*Filippo is interested in* ***game development***, *Filippo är intresserad av* ***spelutveckling***⟩
- structural
  - ⟨*I called* ***Francesco***, *Ho telefonato* ***a Francesco***⟩

Translation divergences

Divergence: systematic cross-linguistic distinction.

- categorial
  - ⟨*Gioara listens* ***distractedly***, *Gioara lyssnar* ***distraherad***⟩
  - ⟨*Herbert completed his* ***doctoral*** *thesis*, *Herbert ha completato la sua tesi* ***di dottorato***⟩
- conflational
  - ⟨*Filippo is interested in* ***game development***, *Filippo är intresserad av* ***spelutveckling***⟩
- structural
  - ⟨*I called* ***Francesco***, *Ho telefonato* ***a Francesco***⟩
- head swapping
  - ⟨*Anna* ***usually*** *goes for walks*, *Anna* ***brukar*** *promenera*⟩

Translation divergences

Divergence: systematic cross-linguistic distinction.

- categorial
  - ⟨*Gioara listens* ***distractedly***, *Gioara lyssnar* ***distraherad***⟩
  - ⟨*Herbert completed his* ***doctoral*** *thesis*, *Herbert ha completato la sua tesi* ***di dottorato***⟩
- conflational
  - ⟨*Filippo is interested in* ***game development***, *Filippo är intresserad av* ***spelutveckling***⟩
- structural
  - ⟨*I called* ***Francesco***, *Ho telefonato* ***a Francesco***⟩
- head swapping
  - ⟨*Anna* ***usually*** *goes for walks*, *Anna* ***brukar*** *promenera*⟩
- thematic
  - ⟨***Yana*** *likes* ***books***, ***A Yana*** *piacciono* ***i libri***⟩

Reusing known alignments

- allows using CA in conjunction with statistical tools

Reusing known alignments

- allows using CA in conjunction with statistical tools
- iterative application

Searching for specific patterns

- `gf-ud` pattern matching allows looking for specific syntactic patterns

Searching for specific patterns

- `gf-ud` pattern matching allows looking for specific syntactic patterns
- possible generalization via pattern replacement

Searching for specific patterns

- `gf-ud` pattern matching allows looking for specific syntactic patterns
- possible generalization via pattern replacement

Example predication patterns:

- ⟨*[subj] missed [obj]*,*[subj] ha perso [obj]*⟩
- ⟨*[subj] told [iobj] [obj]*,*[subj] berättade [obj] för [obl]*⟩

Propagating concepts to a new language

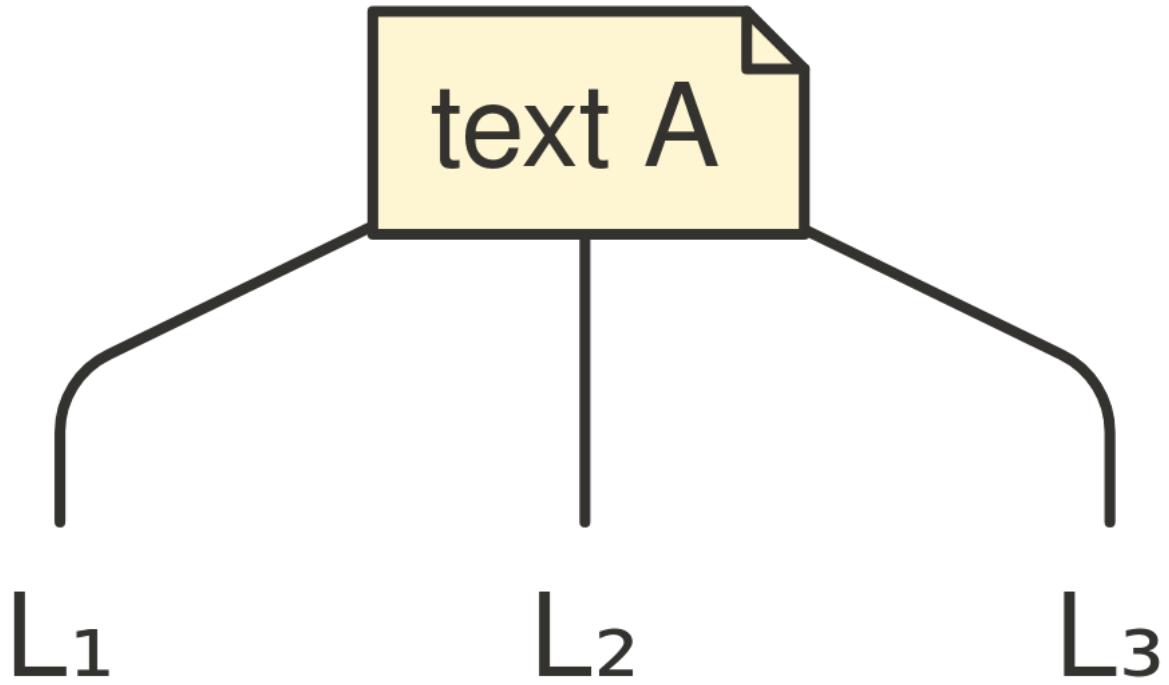
Concept Propagation

- So far, we focused on how to identify correspondences in bilingual parallel texts (***Concept Extraction***)

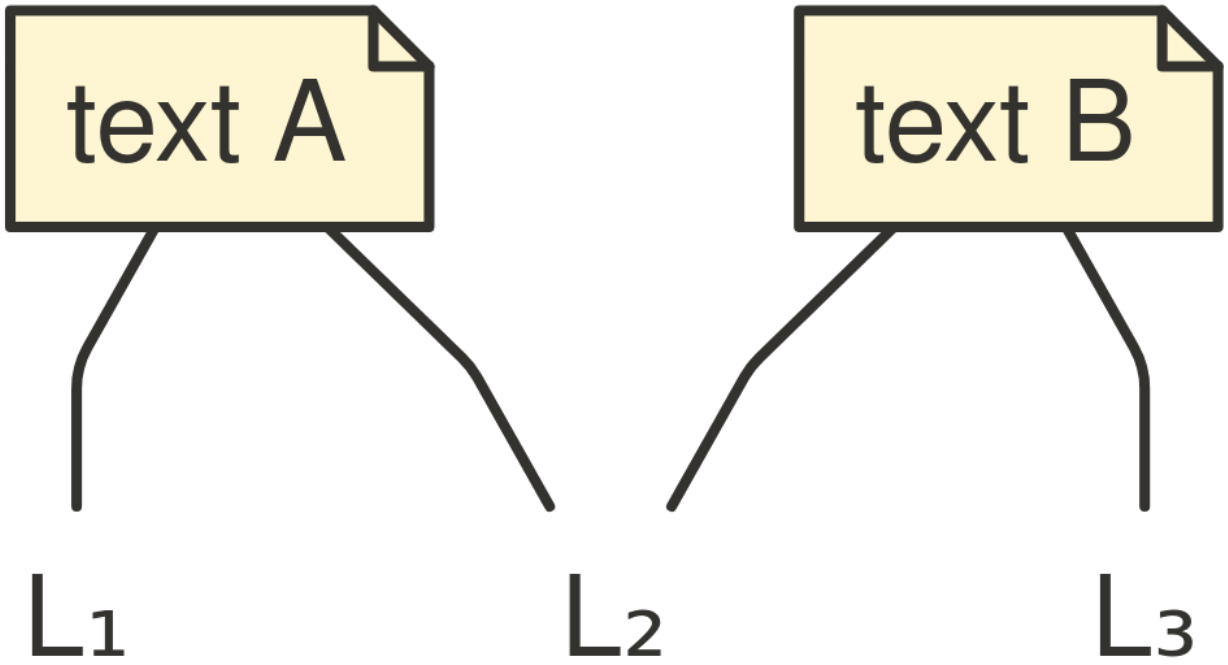
Concept Propagation

- So far, we focused on how to identify correspondences in bilingual parallel texts (***Concept Extraction***)
- what happens when we need to handle a third language?
  - ***Concept Propagation***: finding expression corresponding to a known concept in a new language

Scenario 1



Scenario 2



Generating grammar rules

Requirements

- aligned UD trees

Requirements

- aligned UD trees
- morphological dictionaries

Requirements

- aligned UD trees
- morphological dictionaries
- extraction grammar

Morphological dictionaries

Purely morphological unilingual dictionaries.

Morphological dictionaries

Purely morphological unilingual dictionaries.

Example:

```
...
lin morphologic_A =
  mkAMost "morphologic" "morphologicly" ;
lin morphological_A =
  mkAMost "morphological" "morphologically" ;
lin morphology_N =
  mkN "morphology" "morphologies" ;
...
```

Extraction grammar

Defines the syntactic categories and functions to build lexical entries.

Extraction grammar

Defines the syntactic categories and functions to build lexical entries.

Example (prepositional NPs):

```
PrepNP : Prep -> NP -> PP # case head
```

Lexical rules

Abstract:

```
fun in_the_field__inom_området_PP : PP ;
```

Lexical rules

Abstract:

```
fun in_the_field__inom_området_PP : PP ;
```

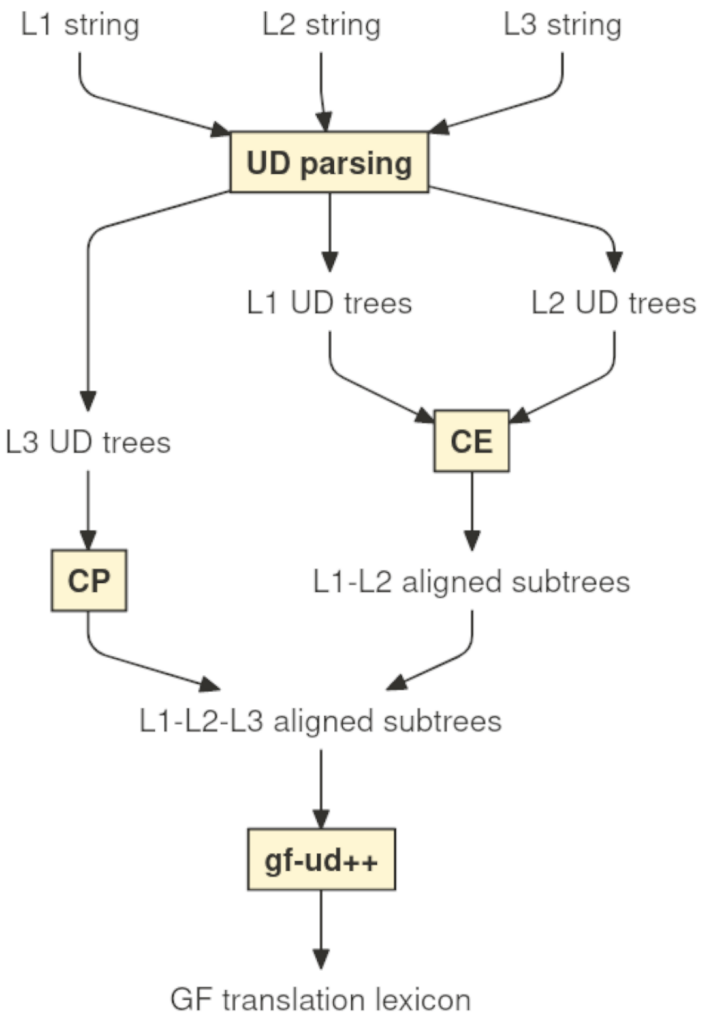
English concrete:

```
lin in_the_field__inom_område_PP =
  PrepNP in_Prep (DetCN the_Det (UseN field_N))
```

Refining the generated lexicon

- interactive selection
- CoNNL-U synoptic viewer

Detailed view



Summary

- concept extraction (UD)

Summary

- concept extraction (UD)
- concept propagation (UD)

Summary

- concept extraction (UD)
- concept propagation (UD)
- GF lexicon generation

Summary

- concept extraction (UD)
- concept propagation (UD)
- GF lexicon generation
- postprocessing tools

Questions?