Syntax-based Concept Alignment for Machine Translation

Master's thesis, A.Y. 2020-2021

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A first definition

Concept Alignment: the task of finding semantical correspondences between parts of multilingual parallel texts.

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.
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?'	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?
'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!'	— 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`

CA at different levels of abstraction

Word alignment:

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Phrase alignment:

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Subtasks

- **Concept Extraction**: identifying new concepts via linguistic comparison

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- **Concept Propagation**: finding expressions corresponding to known concepts in a particular language

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. . . same idea behind *compositional* Machine Translation.

Semantic compositionality

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The *translation* of a complex expression is given by:

- the *translations* of its components (lexical semantics)
- the way its components are combined with each other (syntax, taking cross-lingual divergences into account)

Statistical approaches

Standard approaches to automation are statistical (IBM models)

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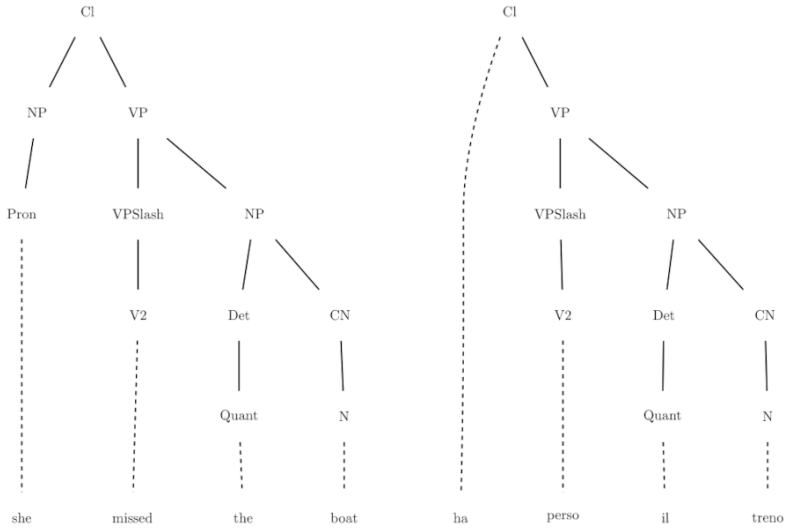
- need large amounts of raw data

Syntax-based approaches

Alternative: tree-to-tree alignment, generally based on constituency grammars.



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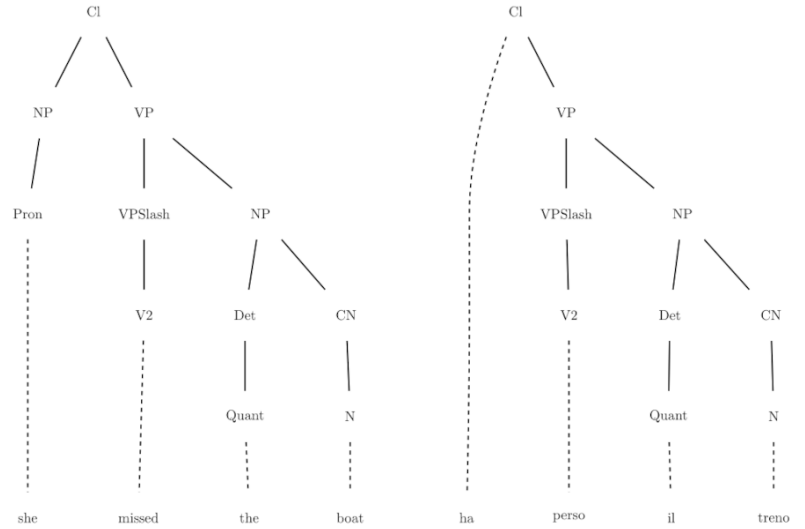

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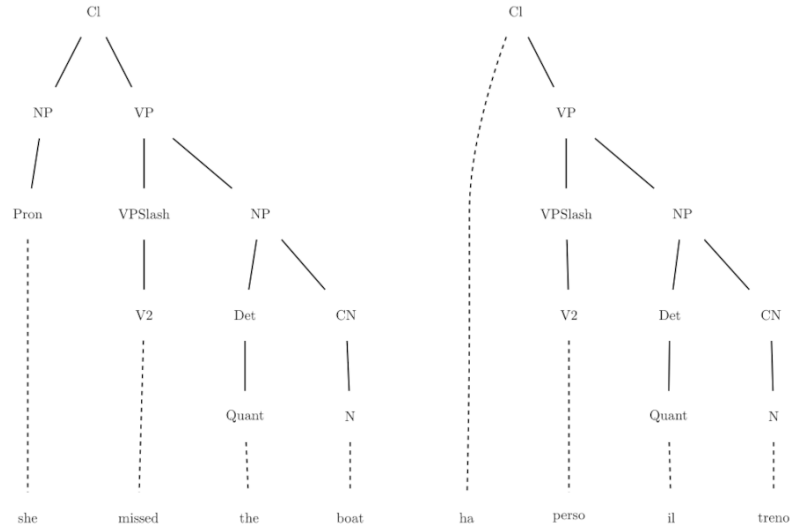

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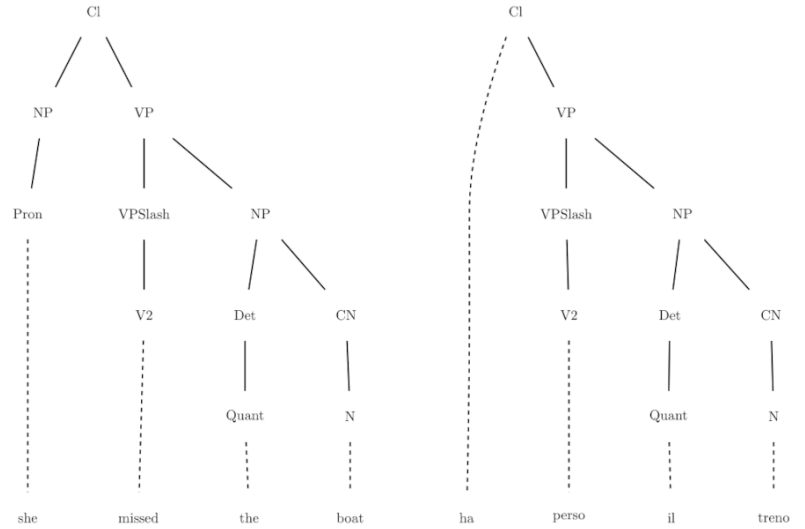

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- ~~need large amounts of raw data~~ work consistently well even on single *analyzed* sentence pairs

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2. lack of robust parsers, while the quality of the analyses is crucial

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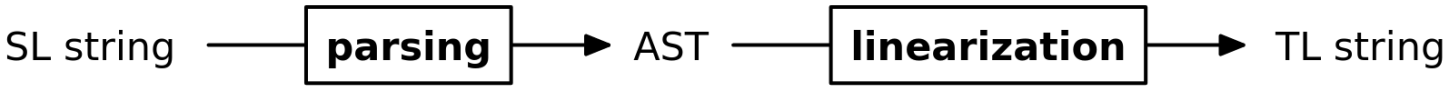

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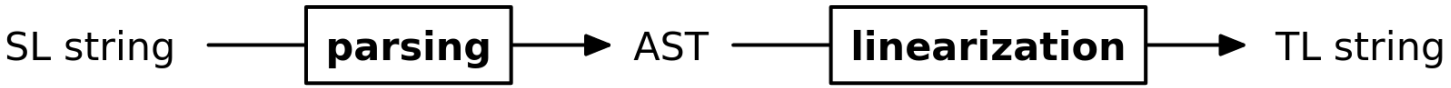

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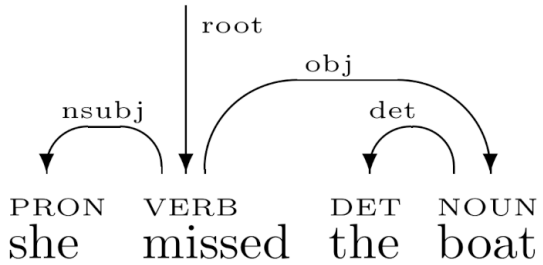

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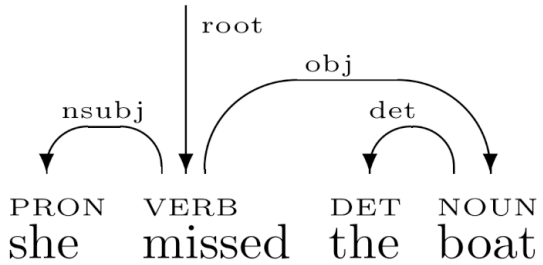

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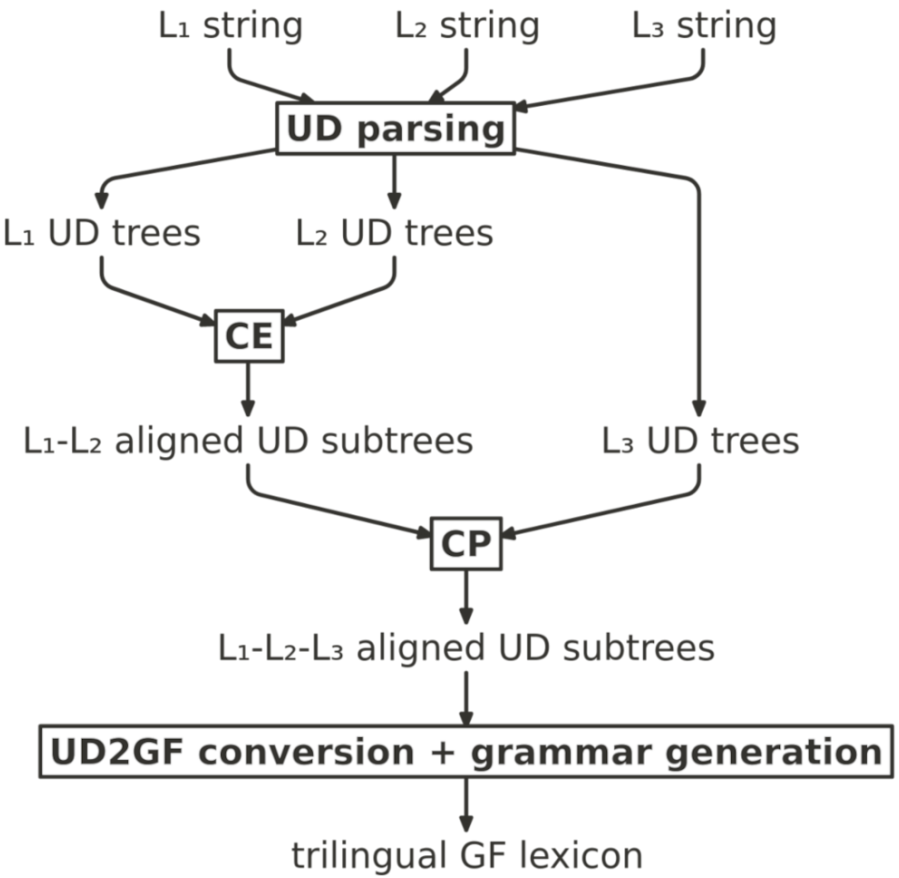
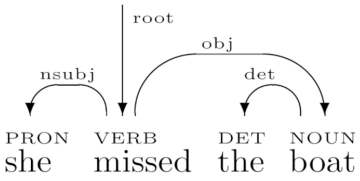
- but: cannot be used for target language generation

Solution: UD + GF



Concept Extraction

Representations of 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 _
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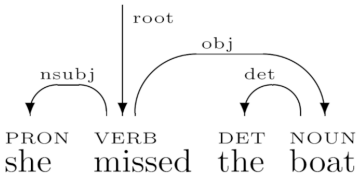


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- CoNNL-U is the standard format for UD trees
- internally to the CA module, they are represented as rose trees

```
data RTree n = RTree n [RTree n]
type UDTree = RTree UDWord
type Alignment = (UDTree,UDTree)
```

  - `UDWord` represents a line of a CoNNL-u file
  - alignments are pairs of ud trees

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   - heads:$\langle$*missed,perso*$\rangle$, $\langle$*boat,treno*$\rangle$

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  - meaning-carrying words $\simeq$ content words
- **known alignment**: trees in matching context are aligned if an equivalent alignment is already known
  - counting

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  - *Gioara listens* ***distractedly*** VS *Gioara lyssnar* ***distraherad***
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- thematic
  - ***Yana*** *likes* ***books*** VS ***A Yana*** *piacciono* ***i libri***

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- many problematic cases
  - some types of divergences $\rightarrow$ do not always align heads
  - compounds & head verbs with auxiliaries $\rightarrow$ enhanced head alignment
    - $\langle$*many decisions were taken by Tommaso,många viktiga beslut togs av Tommaso*$\rangle$ $\rightarrow$ $\langle$*were taken,togs*$\rangle$
    - $\langle$*Giorgio took a course on machine learning techniques,Giorgio deltog i en kurs om maskininlärningstekniker*$\rangle$ $\rightarrow$ $\langle$*machine learning techniques,maskininlärningstekinker*$\rangle$

Evaluation on PUD treebanks

Against the baseline

	baseline		improved version	
	en-it	**en-sv**	**en-it**	**en-sv**
distinct alignments	1097	1257	1198	1314
correct (+ and =)	830 (58.12%)	995 (79.15%)	964 (80.46%)	1105 (84.03%)
correct and useful (+)	776 (54.34%)	976 (77.64%)	896 (74.79%)	1082 (82.28%)

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Against `fast_align`

	our system	`fast_align` 100	`fast_align` 1000
distinct alignments	716	1440	1435
correct	536 (74.86%)	410 (28.47%)	656 (45.71%)
correct and useful	491 (68.57%)	371 (25.76%)	590 (41.11%)

Evaluation on "raw" data

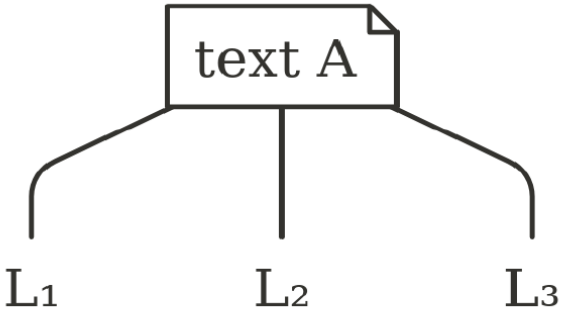
Data: sentence-aligned Computer Science course plans

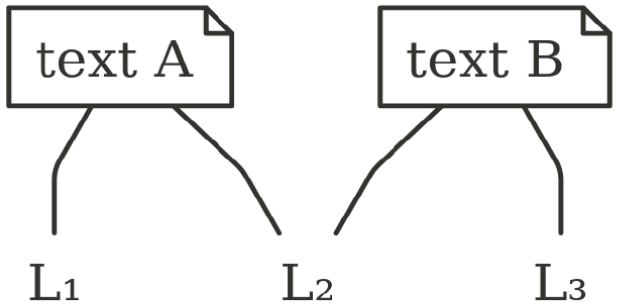
- CSE (GU/Chalmers)
- DMI (UniPG)

	DMI (en-it, 798 sentences)	**CSE (en-sv, 498 sentences)**
distinct alignments	352	529
correct (+ and =)	243 (69.03%)	368 (69.56%)
correct and useful (+)	229 (65.05%)	351 (66.35%)

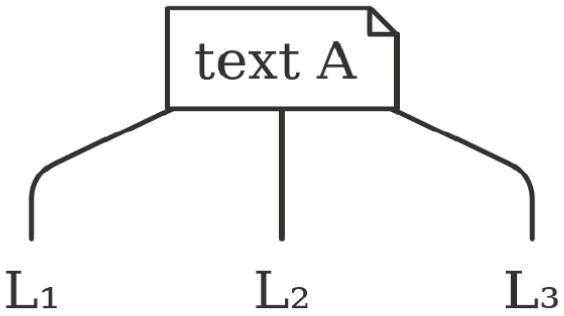
Concept Propagation

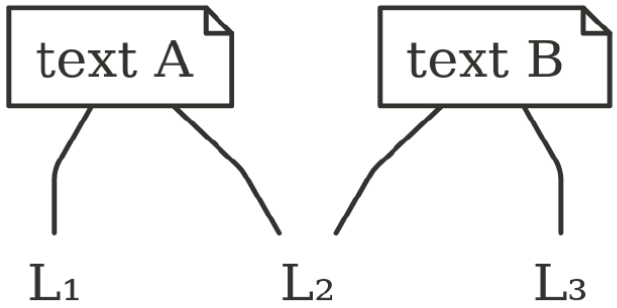
Two scenarios





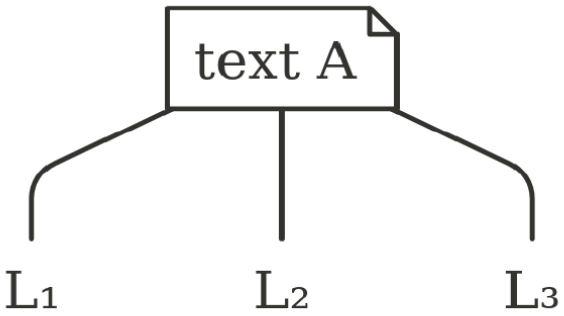
Two scenarios

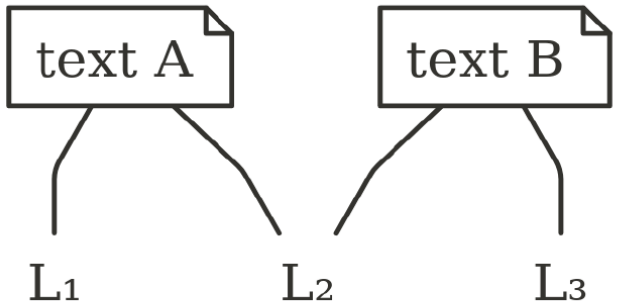




1. 3+ lingual parallel text

Two scenarios





1. 3+ lingual parallel text
2. 2 bilingual parallel texts with one language in common

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- head alignments require special treatment as they are not composed of subtrees

Evaluation: scenario 1

	en-sv	it-sv
propagated	1019 (85.05%)	979 (84.64%)
tot. errors	133 (13.05%)	187 (19.1%)
CP-introduced	75 (56.39%)	84 (44.91%)

- PUD treebanks
- the vast majority of concepts is propagated

Evaluation: scenario 2

Texts in different domains (subsets of PUD treebanks)

	en-it-sv	it-en-sv	en-sv-it	sv-en-it	it-sv-en	sv-it-en
extracted	638	638	687	687	608	608
propagated	92 (14.42%)	92 (14.42%)	98 (14.26%)	84 (12.22%)	101 (16.61%)	87 (14.37%)
tot. errors	46 (50%)	21 (22.82%)	42 (42.85%)	24 (28.57%)	21 (20.79%)	28 (32.18%)
CP-introduced	33 (71.73%)	11 (52.38%)	21 (50%)	12 (50%)	12 (57.14%)	21 (75%)

- mostly function words and very common function words

Evaluation: scenario 2

Texts in the same domain (course plans corpora)

	sv-en-it	**it-en-sv**
extracted	1950	1823
propagated	205 (10.51%)	200 (10.97%)
tot. errors	66 (32.19%)	61 (30.5%)
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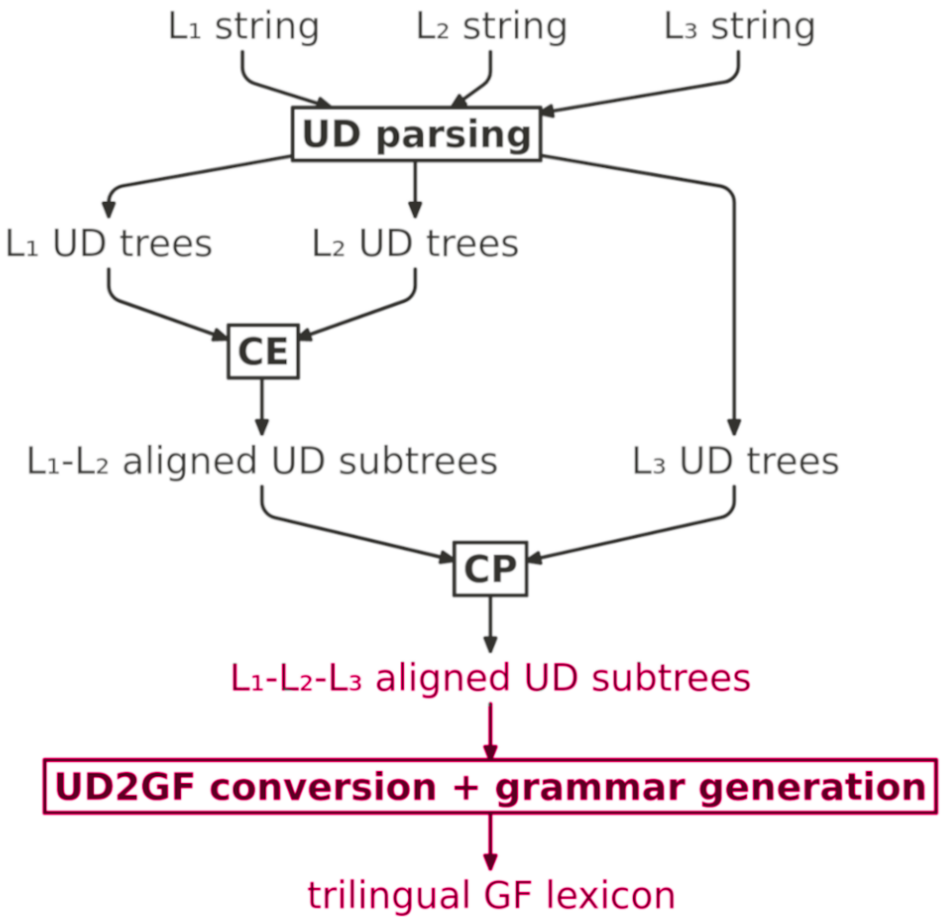
  - an interesting error: ⟨*learning, inlärning, conoscere*⟩

MT experiments

What's left


L1 string
L2 string
L3 string
UD parsing
L1 UD trees
L2 UD trees
CE
L1-L2 aligned UD subtrees
L3 UD trees
CP
L1-L2-L3 aligned UD subtrees
UD2GF conversion + grammar generation
trilingual GF lexicon

From UD to GF alignments

- UD alignment postprocessing:

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- conversion of UD trees into GF ASTs via `gf-ud`
  - dependency configurations

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  - requires: **extraction grammar**, **morphological dictionaries**
- grammar generating simple sentences, limited variation:
  - *the sentence is simple*
  - *a sentence is simple*
  - *sentences are simple*
  - *these sentences are simple*
  - *this sentence is an example*
  - *this short sentence is simple*
  - *this sentence of the text is simple*

Extending the grammar

Easy to add RGL categories and functions to allow more variation:

Extending the grammar

Easy to add RGL categories and functions to allow more variation:

- *this sentence isn't simple*

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Combining variations:

- *won't these short sentences be simpler than that long sentence?*

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- reference translations obtained by manual postprocessing of the automatic ones
  - avoid low scores due to different but equally valid lexical choices

Evaluation: results

	DMI (en-it)	CSE (en-sv)
BLEU-1 to 4	55.4	61.27
BLEU-1 to 3	62.75	67.77
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- max score:
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- most errors are semantical, but 10% of the translation to Italian and 6% of those to Swedish only contain grammatical errors

Conclusions and future work

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- evaluation
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  - in a simple rule-based MT system

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