Syntax-based Concept Alignment for Machine Translation

04.07.2021

Arianna Masciolini

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.

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`

CA at different levels of abstraction

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.

CA at different levels of abstraction

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.

Subtasks

- **Concept Extraction**: identifying new concepts via linguistic comparison
- **Concept Propagation**: finding expressions corresponding to known concepts in a particular language

CA in translation

A human translator

CA in translation

A human translator

1. recognizes concepts in the text to translate

CA in translation

A human translator

1. recognizes concepts in the text to translate

CA in translation

A human translator

1. recognizes concepts in the text to translate
2. looks for ways to render them in the target language

CA in translation

A human translator

1. recognizes concepts in the text to translate
2. looks for ways to render them in the target language

A human translator

1. recognizes concepts in the text to translate
2. looks for ways to render them in the target language

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

Semantic compositionality

The meaning of a complex expression is determined by:

- the meanings of its components (lexical semantics)

Semantic compositionality

The meaning of a complex expression is determined by:

- the meanings of its components (lexical semantics)
- the way its components are combined with each other (syntax)

Semantic compositionality

The meaning of a complex expression is determined by:

- the meanings of its components (lexical semantics)
- the way its components are combined with each other (syntax)

Semantic compositionality

The meaning of a complex expression is determined by:

- the meanings of its components (lexical semantics)
- the way its components are combined with each other (syntax)

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

- the *translations* of its components (lexical semantics)

Semantic compositionality

The meaning of a complex expression is determined by:

- the meanings of its components (lexical semantics)
- the way its components are combined with each other (syntax)

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)
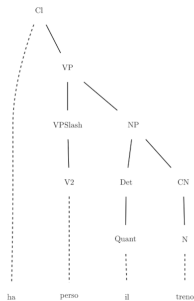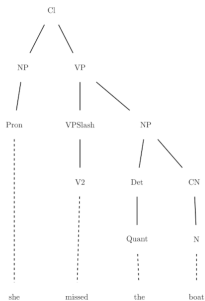
Issues:

Statistical approaches

Standard approaches to automation are statistical (IBM models)

Issues:

- "fixed" level of abstraction (generally either word or phrase alignment)
- correspondences are between strings
- need large amounts of raw data
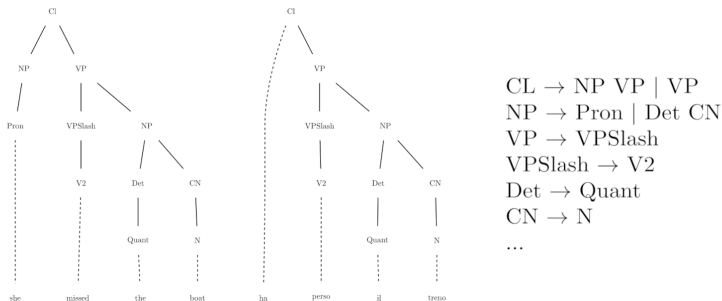
Syntax-based approaches

Alternative: tree-to-tree alignment

$$CL \rightarrow NP\ VP \mid VP$$
$$NP \rightarrow Pron \mid Det\ CN$$
$$VP \rightarrow VPSlash$$
$$VPSlash \rightarrow V2$$
$$Det \rightarrow Quant$$
$$CN \rightarrow N$$
...

Syntax-based approaches

Alternative: tree-to-tree alignment

$CL \rightarrow NP\ VP\ |\ VP$
$NP \rightarrow Pron\ |\ Det\ CN$
$VP \rightarrow VPSlash$
$VPSlash \rightarrow V2$
$Det \rightarrow Quant$
$CN \rightarrow N$
...

- ~~"fixed" level of abstraction~~ work at all levels of abstraction
- correspondences are between ~~strings~~ grammatical objects
- ~~need large amounts of raw data~~ work consistently well even on single *analyzed* sentence pairs

Syntax-based approaches: issues

1. grammars often defined independently, so not compatible each other
2. lack of robust parsers, while the quality of the analyses is crucial

Grammatical Framework

- formalism/programming language to write **multilingual grammars** → solves problem 1

Grammatical Framework

- formalism/programming language to write **multilingual grammars** → solves problem 1
  - one abstract syntax

Grammatical Framework

- formalism/programming language to write **multilingual grammars** → solves problem 1
  - one abstract syntax
  - multiple concrete syntaxes

Grammatical Framework

- formalism/programming language to write **multilingual grammars** → solves problem 1
  - one abstract syntax
  - multiple concrete syntaxes

Grammatical Framework

- formalism/programming language to write **multilingual grammars** → solves problem 1
  - one abstract syntax
  - multiple concrete syntaxes

- compilation-like approach to translation → good, grammaticality-preserving target language generation

SL string ⟶ **parsing** ⟶ AST ⟶ **linearization** ⟶ TL string
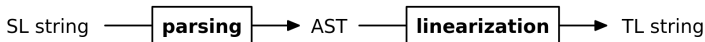
- but: problem 2 persist

Universal Dependencies

- framework for cross-linguistically consistent grammatical annotation → same "multilingual" approach as GF

Universal Dependencies

- framework for cross-linguistically consistent grammatical annotation → same "multilingual" approach as GF

Universal Dependencies

- framework for cross-linguistically consistent grammatical annotation → same "multilingual" approach as GF
- based on *dependency*, as opposed to constituency, relation

Universal Dependencies

- framework for cross-linguistically consistent grammatical annotation → same "multilingual" approach as GF
- based on *dependency*, as opposed to constituency, relation
  - **dependency**: word-to-word correspondence

Universal Dependencies

- framework for cross-linguistically consistent grammatical annotation → same "multilingual" approach as GF
- based on *dependency*, as opposed to constituency, relation
  - **dependency**: word-to-word correspondence
    - head

Universal Dependencies

- framework for cross-linguistically consistent grammatical annotation $\rightarrow$ same "multilingual" approach as GF
- based on *dependency*, as opposed to constituency, relation
  - **dependency**: word-to-word correspondence
    - head
    - dependent in some relation with the head

Universal Dependencies

- framework for cross-linguistically consistent grammatical annotation → same "multilingual" approach as GF
- based on *dependency*, as opposed to constituency, relation
  - **dependency**: word-to-word correspondence
    - head
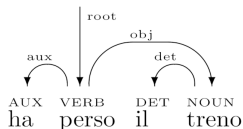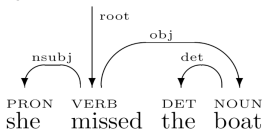   - dependent in some relation with the head

Universal Dependencies

- framework for cross-linguistically consistent grammatical annotation → same "multilingual" approach as GF
- based on *dependency*, as opposed to constituency, relation
  - **dependency**: word-to-word correspondence
    - head
    - dependent in some relation with the head

- easier target for a parser (e.g. UDPipe) → solves problem 2
- but: cannot be used for target language generation

Solution: UD + GF
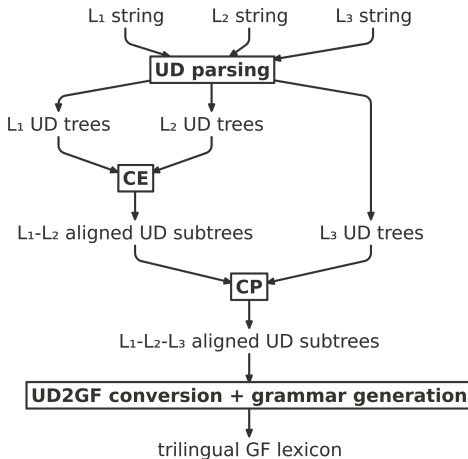
Concept Extraction

Representations of UD trees
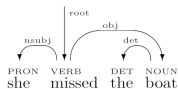

```
# text = she missed the boat
1 she she PRON _ _ 2 nsubj _ _
2 missed miss VERB _ _ 0 root _ _
3 the the DET _ _ 4 det _ _
4 boat boat NOUN _ _ 2 obj _
```

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

■ CoNNL-U is the standard format for 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 _ _
```

- CoNNL-U is the standard format for UD trees

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 _
```

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

- 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)
  ```

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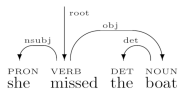
```
2 missed miss VERB _ _ 0 root _ _
  1 she she PRON _ _ 2 nsubj _ _
  4 boat boat NOUN _ _ 2 obj _
    3 the the DET _ _ 4 det _ _
```

- 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

```
# 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 _
```
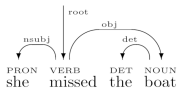
```
2 missed miss VERB _ _ 0 root _ _
  1 she she PRON _ _ 2 nsubj _ _
  4 boat boat NOUN _ _ 2 obj _
    3 the the DET _ _ 4 det _ _
```
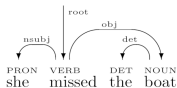
- CoNNL-U is the standard format for UD trees

- 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

Baseline

```
2 missed miss VERB _ _ 0 root _ _      2 perso perdere VERB  _ _ 0 root   _ _
  1 she she PRON _ _ 2 nsubj _ _          1 ha   avere AUX _ _   2 aux _ _
  4 boat boat NOUN _ _ 2 obj _            4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _             3 il   il   DET _ _ 4      det _ _
```

Baseline

```
2 missed miss VERB _ _ 0 root _ _          2 perso perdere VERB  _ _ 0 root   _ _
  1 she she PRON _ _ 2 nsubj _ _             1 ha   avere AUX _ _   2 aux _ _
  4 boat boat NOUN _ _ 2 obj _               4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _                3 il   il  DET _ _ 4       det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)

Baseline

```
2 missed miss VERB _ _ 0 root _ _          2 perso perdere VERB  _ _ 0 root  _ _
  1 she she PRON _ _ 2 nsubj _ _             1 ha  avere AUX _ _   2 aux _ _
  4 boat boat NOUN _ _ 2 obj _               4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _                3 il  il  DET _ _ 4     det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)

Baseline

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB  _ _ 0 root  _ _
  1 she she PRON _ _ 2 nsubj _ _           1 ha  avere AUX _ _   2 aux _ _
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)
2. pad the trees → perfectly aligned trees

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB  _ _ 0 root  _ _
  (dummy node replacing the aux)           1 ha  avere AUX _ _   2 aux _ _
  1 she she PRON _ _ 2 nsubj _ _           (dummy node replacing the nsubj)
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

Baseline

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB _ _ 0 root _ _
  1 she she PRON _ _ 2 nsubj _ _           1 ha  avere AUX _ _  2 aux _ _
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)
2. pad the trees → perfectly aligned trees

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB _ _ 0 root _ _
  (dummy node replacing the aux)           1 ha  avere AUX _ _  2 aux _ _
  1 she she PRON _ _ 2 nsubj _ _           (dummy node replacing the nsubj)
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

Baseline

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB  _ _ 0 root  _ _
  1 she she PRON _ _ 2 nsubj _ _           1 ha  avere AUX _ _  2 aux _ _
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)
2. pad the trees → perfectly aligned trees

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB  _ _ 0 root  _ _
  (dummy node replacing the aux)           1 ha  avere AUX _ _  2 aux _ _
  1 she she PRON _ _ 2 nsubj _ _           (dummy node replacing the nsubj)
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

3. extract alignments:

Baseline

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB  _ _ 0 root  _ _
  1 she she PRON _ _ 2 nsubj _ _           1 ha  avere AUX _ _   2 aux _ _
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)
2. pad the trees → perfectly aligned trees

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB  _ _ 0 root  _ _
  (dummy node replacing the aux)           1 ha  avere AUX _ _   2 aux _ _
  1 she she PRON _ _ 2 nsubj _ _           (dummy node replacing the nsubj)
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

3. extract alignments:

Baseline

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB  _ _ 0 root  _ _
  1 she she PRON _ _ 2 nsubj _ _           1 ha  avere AUX _ _   2 aux _ _
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)
2. pad the trees → perfectly aligned trees

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB  _ _ 0 root  _ _
  (dummy node replacing the aux)           1 ha  avere AUX _ _   2 aux _ _
  1 she she PRON _ _ 2 nsubj _ _           (dummy node replacing the nsubj)
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN  _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4      det _ _
```

3. extract alignments:
   - subtrees: ⟨*she missed the boat, ha perso il treno*⟩, ⟨*the boat, il treno*⟩, ⟨*the, il*⟩

Baseline

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB _ _ 0 root _ _
  1 she she PRON _ _ 2 nsubj _ _           1 ha  avere AUX _ _  2 aux _ _
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il il DET _ _ 4      det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)
2. pad the trees → perfectly aligned trees

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB _ _ 0 root _ _
  (dummy node replacing the aux)           1 ha  avere AUX _ _  2 aux _ _
  1 she she PRON _ _ 2 nsubj _ _           (dummy node replacing the nsubj)
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il il DET _ _ 4      det _ _
```

3. extract alignments:
   - subtrees: ⟨*she missed the boat, ha perso il treno*⟩, ⟨*the boat, il treno*⟩, ⟨*the, il*⟩

Baseline

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB _ _ 0 root _ _
  1 she she PRON _ _ 2 nsubj _ _           1 ha  avere AUX _ _  2 aux _ _
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4     det _ _
```

1. recursively sort trees based on the UD label of their root node (not needed in this case)
2. pad the trees → perfectly aligned trees

```
2 missed miss VERB _ _ 0 root _ _        2 perso perdere VERB _ _ 0 root _ _
  (dummy node replacing the aux)           1 ha  avere AUX _ _  2 aux _ _
  1 she she PRON _ _ 2 nsubj _ _           (dummy node replacing the nsubj)
  4 boat boat NOUN _ _ 2 obj _             4 treno treno NOUN _ _ 2 obj _ _
    3 the the DET _ _ 4 det _ _              3 il  il  DET _ _ 4     det _ _
```

3. extract alignments:
   - subtrees: ⟨*she missed the boat, ha perso il treno*⟩, ⟨*the boat, il treno*⟩, ⟨*the, il*⟩
   - heads: ⟨*missed, perso*⟩, ⟨*boat, treno*⟩

Multiple criteria

- **label matching** (original criterion): trees in matching context are aligned if they have the same UD label

Multiple criteria

- **label matching** (original criterion): trees in matching context are aligned if they have the same UD label

Multiple criteria

- **label matching** (original criterion): trees in matching context are aligned if they have the same UD label
- **POS-equivalence**: trees in matching context are aligned if they have the same multiset of POS tags of their *meaning-carrying* words

Multiple criteria

- **label matching** (original criterion): trees in matching context are aligned if they have the same UD label
- **POS-equivalence**: trees in matching context are aligned if they have the same multiset of POS tags of their *meaning-carrying* words
  - meaning-carrying words $\simeq$ content words

Multiple criteria

- **label matching** (original criterion): trees in matching context are aligned if they have the same UD label
- **POS-equivalence**: trees in matching context are aligned if they have the same multiset of POS tags of their *meaning-carrying* words
    - meaning-carrying words $\simeq$ content words

Multiple criteria

- **label matching** (original criterion): trees in matching context are aligned if they have the same UD label
- **POS-equivalence**: trees in matching context are aligned if they have the same multiset of POS tags of their *meaning-carrying* words
  - meaning-carrying words $\simeq$ content words
- **known alignment**: trees in matching context are aligned if an equivalent alignment is already known

Multiple criteria

- **label matching** (original criterion): trees in matching context are aligned if they have the same UD label
- **POS-equivalence**: trees in matching context are aligned if they have the same multiset of POS tags of their *meaning-carrying* words
    - meaning-carrying words $\simeq$ content words
- **known alignment**: trees in matching context are aligned if an equivalent alignment is already known
    - counting

Divergences

Divergence: systematic cross-linguistic distinction.

Divergences

Divergence: systematic cross-linguistic distinction.

- categorial

Divergences

Divergence: systematic cross-linguistic distinction.

- categorial
  - *Gioara listens **distractedly** VS Gioara lyssnar **distraherad***

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Divergences

Divergence: systematic cross-linguistic distinction.

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

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like
  ⟨*Claudio eats a banana,Claudio mangia una banana*⟩

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like ⟨*Claudio eats a banana,Claudio mangia una banana*⟩
  - ⟨*eats, mangia*⟩

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like
  $\langle$ *Claudio eats a banana, Claudio mangia una banana* $\rangle$
  - $\langle$ *eats, mangia* $\rangle$
  - $\langle$ *banana, banana* $\rangle$

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like ⟨*Claudio eats a banana*,*Claudio mangia una banana*⟩
  - ⟨*eats, mangia*⟩
  - ⟨*banana, banana*⟩

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like
  ⟨*Claudio eats a banana*,*Claudio mangia una banana*⟩
  - ⟨*eats, mangia*⟩
  - ⟨*banana, banana*⟩
- many problematic cases

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like ⟨*Claudio eats a banana*,*Claudio mangia una banana*⟩
  - ⟨*eats, mangia*⟩
  - ⟨*banana, banana*⟩
- many problematic cases
  - some types of divergences → do not always align heads

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like ⟨*Claudio eats a banana*,*Claudio mangia una banana*⟩
  - ⟨*eats, mangia*⟩
  - ⟨*banana, banana*⟩
- many problematic cases
  - some types of divergences → do not always align heads

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like ⟨*Claudio eats a banana,Claudio mangia una banana*⟩
  - ⟨*eats, mangia*⟩
  - ⟨*banana, banana*⟩
- many problematic cases
  - some types of divergences → do not always align heads
  - compounds & head verbs with auxiliaries → enhanced head alignment

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like ⟨*Claudio eats a banana,Claudio mangia una banana*⟩
  - ⟨*eats, mangia*⟩
  - ⟨*banana, banana*⟩
- many problematic cases
  - some types of divergences → do not always align heads
  - compounds & head verbs with auxiliaries → enhanced head alignment
    - ⟨*many decisions were taken by Tommaso, många viktiga beslut togs av Tommaso*⟩ → ⟨*were taken, togs*⟩

Enhanced head alignment

- aligning head is extremely useful when alignment is perfect, like ⟨*Claudio eats a banana,Claudio mangia una banana*⟩
  - ⟨*eats, mangia*⟩
  - ⟨*banana, banana*⟩
- many problematic cases
  - some types of divergences → do not always align heads
  - compounds & head verbs with auxiliaries → enhanced head alignment
    - ⟨*many decisions were taken by Tommaso, många viktiga beslut togs av Tommaso*⟩ → ⟨*were taken, togs*⟩
    - ⟨*Giorgio took a course on machine learning techniques, Giorgio deltog i en kurs om maskininlärningstekniker*⟩ → ⟨*machine learning techniques, maskininlärningstekinker*⟩

Evaluation on PUD treebanks

Against the baseline

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

Evaluation on PUD treebanks

Against the baseline

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

Against `fast_align` (en-it)

	improved version	**`fast_align` (100)**	**`fast_align` (1000)**
distinct	716	1440	1435
correct	536 (74.86%)	410 (28.47%)	656 (45.71%)
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 (en-it, 798 sentences)	CSE (en-sv, 498 sentences)
distinct	352	529
correct	243 (69.03%)	368 (69.56%)
useful	229 (65.05%)	351 (66.35%)

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	352	529
correct	243 (69.03%)	368 (69.56%)
useful	229 (65.05%)	351 (66.35%)

Concept Propagation

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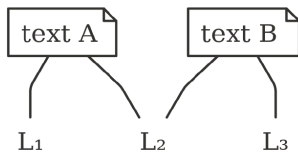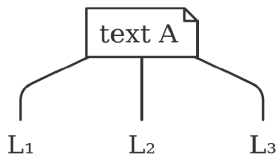
Two scenarios
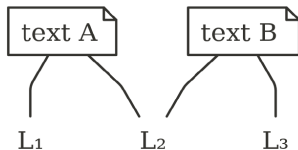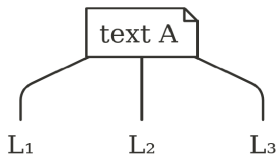
1. 3+ lingual parallel text
2. 2 bilingual parallel texts with one language in common

General algorithm

For each L_1-L_2 alignment:

General algorithm

For each L_1-L_2 alignment:

1. look for its L_2 member among all subtrees of the L_2 version of the text where it is to be propagated
2. if it is present, align the sentence it belongs to with its *TL* counterpart with the same procedure used for CE
3. if multiple candidate alignments are found, select the one with the closest depths

Caveats

- in step 1, irrelevant details of UD trees are to be ignored

Caveats

- in step 1, irrelevant details of UD trees are to be ignored
  - only consider word form, lemma, POS tag and dependency relation

Caveats

- in step 1, irrelevant details of UD trees are to be ignored
    - only consider word form, lemma, POS tag and dependency relation

Caveats

- in step 1, irrelevant details of UD trees are to be ignored
  - only consider word form, lemma, POS tag and dependency relation
- head alignments require special treatment as they are not composed of subtrees

	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

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 content 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%)
CP-introduced	33 (50%)	33 (54.09%)

- domain-specific concepts

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%)
CP-introduced	33 (50%)	33 (54.09%)

- domain-specific concepts

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%)
CP-introduced	33 (50%)	33 (54.09%)

- domain-specific concepts
    - ⟨skills, färdigheter, capacità⟩, ⟨exam, tentamen, prova⟩...

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%)
CP-introduced	33 (50%)	33 (54.09%)

- domain-specific concepts
  - ⟨skills, färdigheter, capacità⟩, ⟨exam, tentamen, prova⟩...

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%)
CP-introduced	33 (50%)	33 (54.09%)

- domain-specific concepts
  - ⟨skills, färdigheter, capacità⟩, ⟨exam, tentamen, prova⟩...
  - ⟨the aim of the course, syftet med kursen, l'obiettivo del corso⟩

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%)
CP-introduced	33 (50%)	33 (54.09%)

- domain-specific concepts
  - ⟨*skills, färdigheter, capacità*⟩, ⟨*exam, tentamen, prova*⟩...
  - ⟨*the aim of the course, syftet med kursen, l'obiettivo del corso*⟩

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%)
CP-introduced	33 (50%)	33 (54.09%)

- domain-specific concepts
  - ⟨*skills, färdigheter, capacità*⟩, ⟨*exam, tentamen, prova*⟩...
  - ⟨*the aim of the course, syftet med kursen, l'obiettivo del corso*⟩
  - an interesting error: ⟨*learning, inlärning, conoscere*⟩

MT experiments
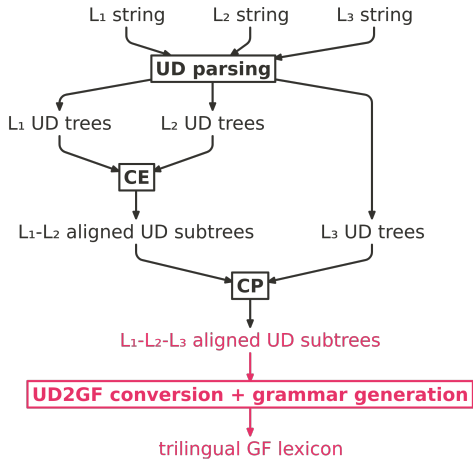
- UD alignment postprocessing:

- UD alignment postprocessing:

From UD to GF alignments

- UD alignment postprocessing:
  - normalization

From UD to GF alignments

- UD alignment postprocessing:
  - normalization

From UD to GF alignments

- UD alignment postprocessing:
  - normalization
  - selection based on size and usefulness

From UD to GF alignments

- UD alignment postprocessing:
  - normalization
  - selection based on size and usefulness

From UD to GF alignments

- UD alignment postprocessing:
  - normalization
  - selection based on size and usefulness
- conversion of UD trees into GF ASTs via `gf-ud`

From UD to GF alignments

- UD alignment postprocessing:
    - normalization
    - selection based on size and usefulness
- conversion of UD trees into GF ASTs via `gf-ud`
    - dependency configurations

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - requires: **extraction grammar**, **morphological dictionaries**

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - requires: **extraction grammar**, **morphological dictionaries**

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - requires: **extraction grammar**, **morphological dictionaries**
- grammar generating simple sentences, limited variation:

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - requires: **extraction grammar**, **morphological dictionaries**
- grammar generating simple sentences, limited variation:
  - *the sentence is simple*

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - requires: **extraction grammar**, **morphological dictionaries**
- grammar generating simple sentences, limited variation:
  - *the sentence is simple*
  - *a sentence is simple*

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - requires: **extraction grammar**, **morphological dictionaries**
- grammar generating simple sentences, limited variation:
  - *the sentence is simple*
  - *a sentence is simple*
  - *sentences are simple*

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - 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*

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - 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*

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - 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*

From alignments to a grammar

- aligned ASTs used to automatically generate a GF translation lexicon
- again via one of `gf-ud`'s modules
  - 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*

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*

Extending the grammar

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

- *this sentence isn't simple*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*
- *this sentence was simple*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*
- *this sentence was simple*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*
- *this sentence was simple*
- *this sentence will be simple*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*
- *this sentence was simple*
- *this sentence will be simple*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*
- *this sentence was simple*
- *this sentence will be simple*
- *this sentence is simpler than that sentence*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*
- *this sentence was simple*
- *this sentence will be simple*
- *this sentence is simpler than that sentence*

Extending the grammar

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

- *this sentence isn't simple*
- *is this sentence simple?*
- *this sentence was simple*
- *this sentence will be simple*
- *this sentence is simpler than that sentence*

Combining variations:

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

Evaluation: strategy

- small course plans corpora $\rightarrow$ 2 bilingual lexica instead of a trilingual one

Evaluation: strategy

- small course plans corpora $\rightarrow$ 2 bilingual lexica instead of a trilingual one

Evaluation: strategy

- small course plans corpora → 2 bilingual lexica instead of a trilingual one
- still small lexica + parsing issues → sentences to translate generated in the GF shell

Evaluation: strategy

- small course plans corpora $\rightarrow$ 2 bilingual lexica instead of a trilingual one
- still small lexica + parsing issues $\rightarrow$ sentences to translate generated in the GF shell
  - partly arbitrary lexical and grammatical variations on a set of semantically plausible sentences

Evaluation: strategy

- small course plans corpora → 2 bilingual lexica instead of a trilingual one
- still small lexica + parsing issues → sentences to translate generated in the GF shell
  - partly arbitrary lexical and grammatical variations on a set of semantically plausible sentences

Evaluation: strategy

- small course plans corpora $\rightarrow$ 2 bilingual lexica instead of a trilingual one
- still small lexica + parsing issues $\rightarrow$ sentences to translate generated in the GF shell
  - partly arbitrary lexical and grammatical variations on a set of semantically plausible sentences
- metric: BLEU scores

Evaluation: strategy

- small course plans corpora → 2 bilingual lexica instead of a trilingual one
- still small lexica + parsing issues → sentences to translate generated in the GF shell
  - partly arbitrary lexical and grammatical variations on a set of semantically plausible sentences
- metric: BLEU scores

Evaluation: strategy

- small course plans corpora $\rightarrow$ 2 bilingual lexica instead of a trilingual one
- still small lexica + parsing issues $\rightarrow$ sentences to translate generated in the GF shell
  - partly arbitrary lexical and grammatical variations on a set of semantically plausible sentences
- metric: BLEU scores
- reference translations obtained by manual postprocessing of the automatic ones

Evaluation: strategy

- small course plans corpora $\rightarrow$ 2 bilingual lexica instead of a trilingual one
- still small lexica + parsing issues $\rightarrow$ sentences to translate generated in the GF shell
  - partly arbitrary lexical and grammatical variations on a set of semantically plausible sentences
- metric: BLEU scores
- 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
BLEU-1 to 2	70.6	74.3
BLEU-1	79.33	80.99

- max score:

Evaluation: results

	DMI (en-it)	CSE (en-sv)
BLEU-1 to 4	55.4	61.27
BLEU-1 to 3	62.75	67.77
BLEU-1 to 2	70.6	74.3
BLEU-1	79.33	80.99

- max score:
  - ⟨*the library provides useful textbooks, la biblioteca fornisce libri utili*⟩

Evaluation: results

	DMI (en-it)	CSE (en-sv)
BLEU-1 to 4	55.4	61.27
BLEU-1 to 3	62.75	67.77
BLEU-1 to 2	70.6	74.3
BLEU-1	79.33	80.99

- max score:
  - ⟨*the library provides useful textbooks, la biblioteca fornisce libri utili*⟩
  - ⟨*this lab is more difficult than the exam, den här laborationen är svårare än tentamen*⟩

Evaluation: results

	DMI (en-it)	CSE (en-sv)
BLEU-1 to 4	55.4	61.27
BLEU-1 to 3	62.75	67.77
BLEU-1 to 2	70.6	74.3
BLEU-1	79.33	80.99

- max score:
  - ⟨*the library provides useful textbooks, la biblioteca fornisce libri utili*⟩
  - ⟨*this lab is more difficult than the exam, den här laborationen är svårare än tentamen*⟩

Evaluation: results

	DMI (en-it)	CSE (en-sv)
BLEU-1 to 4	55.4	61.27
BLEU-1 to 3	62.75	67.77
BLEU-1 to 2	70.6	74.3
BLEU-1	79.33	80.99

- max score:
  - ⟨*the library provides useful textbooks, la biblioteca fornisce libri utili*⟩
  - ⟨*this lab is more difficult than the exam, den här laborationen är svårare än tentamen*⟩
- min score:

Evaluation: results

	DMI (en-it)	CSE (en-sv)
BLEU-1 to 4	55.4	61.27
BLEU-1 to 3	62.75	67.77
BLEU-1 to 2	70.6	74.3
BLEU-1	79.33	80.99

- max score:
  - ⟨*the library provides useful textbooks, la biblioteca fornisce libri utili*⟩
  - ⟨*this lab is more difficult than the exam, den här laborationen är svårare än tentamen*⟩
- min score:
  - ⟨*the test is oral, la prova è dura*⟩

Evaluation: results

	DMI (en-it)	CSE (en-sv)
BLEU-1 to 4	55.4	61.27
BLEU-1 to 3	62.75	67.77
BLEU-1 to 2	70.6	74.3
BLEU-1	79.33	80.99

- max score:
  - ⟨*the library provides useful textbooks, la biblioteca fornisce libri utili*⟩
  - ⟨*this lab is more difficult than the exam, den här laborationen är svårare än tentamen*⟩
- min score:
  - ⟨*the test is oral, la prova è dura*⟩

Evaluation: results

	DMI (en-it)	CSE (en-sv)
BLEU-1 to 4	55.4	61.27
BLEU-1 to 3	62.75	67.77
BLEU-1 to 2	70.6	74.3
BLEU-1	79.33	80.99

- max score:
  - ⟨*the library provides useful textbooks, la biblioteca fornisce libri utili*⟩
  - ⟨*this lab is more difficult than the exam, den här laborationen är svårare än tentamen*⟩
- min score:
  - ⟨*the test is oral, la prova è dura*⟩
- 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

Conclusions

- developed a syntax-based CA module

Conclusions

- developed a syntax-based CA module
  - Haskell library + easy to use and configure executables + evaluation and translation scripts

Conclusions

- developed a syntax-based CA module
  - Haskell library + easy to use and configure executables + evaluation and translation scripts

Conclusions

- developed a syntax-based CA module
  - Haskell library + easy to use and configure executables + evaluation and translation scripts
- evaluation

Conclusions

- developed a syntax-based CA module
  - Haskell library + easy to use and configure executables + evaluation and translation scripts
- evaluation
  - against a baseline algorithm and a standard statistical tool

Conclusions

- developed a syntax-based CA module
  - Haskell library + easy to use and configure executables + evaluation and translation scripts
- evaluation
  - against a baseline algorithm and a standard statistical tool
  - in a simple rule-based MT system

Future work

- integration with statistical alignment techniques
- verb phrases alignment
- iterative CA
- optimization of CP for multilingual corpora (scenario 1)
- generalization of CE to n languages
- stricter and language pair-specific criteria
- better alignment selection