Machine Translation: Alignment and Phrase-Based MT

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Outline of Lectures on MT

Today:

- Document, sentence and word alignment.
- Phrase-based MT as a tool.

Towards the end of semester:

- Multi-lingual (neural) MT.

Supplementary Materials

Videolectures & Wiki:

`http://mttalks.ufal.ms.mff.cuni.cz/`

Slides and Lectures from MT Marathon (see Programme):

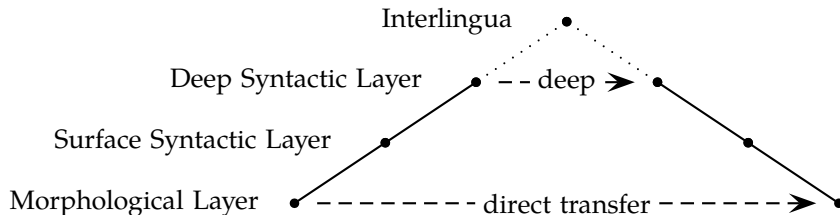`http://www.statmt.org/mtm15` and the neural `/mtm16`

Books:

- Ondřej Bojar: Čeština a strojový překlad. ÚFAL, 2012.
- Philipp Koehn: Statistical Machine Translation. Cambridge University Press, 2009.
  With some slides: `http://statmt.org/book/`
  NMT: `https://arxiv.org/pdf/1709.07809.pdf`

Approaches to Machine Translation

- The deeper analysis, the easier the transfer should be.
- A hypothetical interlingua captures pure meaning.

- Linguistically shallow (direct) methods need just parallel texts.
- ⇒ They can nicely serve as a tool for transfer.

A Classical Parallel Corpus

Another Classical One (1658)

Parallel Corpora

- Web is an immense resource.
- People keep crawling it over and over:
  - Bitextor: Esplà-Gomis and Forcada (2010)
  - `http://paracrawl.eu/releases.html` (2018)
- Good sources of (multi-)parallel corpora:
  - Corpus OPUS: `http://opus.nlpl.eu/`
  - WMT tasks data: `http://www.statmt.org/wmt19/`
  - University-specific corpora, e.g. UFAL released:
    - `http://ufal.mff.cuni.cz/czeng` (Czech-English)
    - `http://ufal.mff.cuni.cz/hindencorp` (Hindi-English)
    - `http://ufal.mff.cuni.cz/umc/`
      (Czech, Russian, Urdu, with English)

From Aligned Documents

In my dream , there was a sycamore growing out of the ruins of the sacristy , and I was told that , if I dug at the roots of the sycamore , I would find a hidden treasure . But I ' m not so stupid as to cross an entire desert just because of a recurrent dream . " And they disappeared . The boy stood up shakily , and looked once more at the Pyramids . " It is I who dared to do so , " said the boy . This man looked exactly the same , except that now the roles were reversed . " It is I who dared to do so , " he

अपने सपने में मुझे एक गुलर का पेड़ दिखाई देता था और मुझे लगता था कि अगर मैं उस गुलर की जड़ें खोद डालूं तो मुझे छिपा हुआ खजाना मिल जाएगा । मगर मैं तुम्हारी तरह इतना बेवकूफ नहीं हूं कि महज बार – बार आने वाले एक सपने के कारण पूरे रेगिस्तान को पार करूं । वे लोग , उसके बाद वहां से चले गए । लड़का लड़खड़ाता हुआ किसी तरह खड़ा हो गया ।<s>एक बार फिर उसने पिरामिडों को देखा । " यह जुर्रत मैंने की थी , " लड़के ने कहा ।<s>उसे सेंटियागो मातामोरोस कीं वह प्रतिमा याद आई जिसमें वह घोड़े पर सवार था और उसके घोड़े के खुरों में कितने ही नास्तिक कुचले हुए पड़े थे । यह घुड़सवार भी बिलकुल वैसा ही था । यह बात और थी कि इनके किरदार बदले हुए थे । " मैंने ही ऐसा करने का साहस किया था , " लड़के ने दोहराया और अपनी गर्दन तलवार का वार सहने के लिए झुका दी । ' ज़िंदगी ने भी हमेशा मेरे साथ अच्छा बर्ताव किया । '

We Want Sentence Alignment

In my dream , there was a sycamore growing out of the ruins of the sacristy , and I was told that , if I dug at the roots of the sycamore , I would find a hidden treasure .	अपने सपने में मुझे एक गुलर का पेड़ दिखाई देता था और मुझे लगता था कि अगर मैं उस गुलर की जड़ें खोद डालूँ, तो मुझे छिपा हुआ खजाना मिल जाएगा ।
But I ' m not so stupid as to cross an entire desert just because of a recurrent dream .	मगर मैं तुम्हारी तरह इतना बेवकूफ नहीं हूँ कि महज बार - बार आने वाले एक सपने के कारण पूरे रेगिस्तान को पार करूं ।
And they disappeared .	वे लोग , उसके बाद वहां से चले गए ।
The boy stood up shakily , and looked once more at the Pyramids .	लड़का लड़खड़ाता हुआ किसी तरह खड़ा हो गया । एक बार फिर उसने पिरामिडों को देखा ।
" It is I who dared to do so , " said the boy .	" यह नुरील मैं की थी , " लड़के ने कहा । उसे सेंटियागो माताबेरोस की वह प्रतिमा याद आई जिसमें वह घोड़े पर सवार था और उसके घोड़े के खुरों में किताने हो नास्तिक कुचले हुए पड़े थे ।
This man looked exactly the same , except that now the roles were reversed .	यह महुदखार भी बिलकुल वैसा ही था ।
" It is I who dared to do so , " he repeated , and he lowered his head to receive a blow from the sword .	यह बात और थी कि इनके किरदार बदले हुए थे । " मैंने ही ऐसा करने का साहस किया था , " लड़के ने दोहराया और अपनी गर्दन तलवार का वार सहने के लिए झुका दी ।
" Life was good to me , " the man said .	" जिंदगी ने भी हमेशा मेरे साथ अच्छा बर्ताव किया । "
" When you appeared in my dream , I felt that all my efforts had been rewarded , because my son ' s poems will be read by men for generations to come .	उस आदमी ने कहा , " जब आप मेरे सपने में आए थे , तो मुझे लगा कि मैंने अपने कर्मों का पुरस्कार पा लिया ... मेरे लिए इससे बढ़कर और क्या बात होगी कि मेरे बेटे की कविताएं युग - युगों तक पढ़ी जाएं ।
I don ' t want anything for myself .	नहीं , मुझे अपने लिए कुछ नहीं चाहिए ।
But any father would be proud of the fame achieved by one whom he had cared for as a child , and educated as he grew up .	कोई भी बाप उस इंसान की शोहरत सुनकर फूला नहीं समाएगा जिसे उसने अपनी गोद में खिलाया , पढ़ाया - लिखाया और पाल - पोसकर बड़ा किया हो ।
" We ' re two very different things . "	" हम दो अलग - अलग चीजें हैं । "
" That ' s not true , " the boy said .	" यह सही नहीं है । " लड़के ने कहा ,
" I learned the alchemist ' s secrets in my travels .	" यात्रा के दौरान मैंने औंगिधयान के रहस्यों को जाना है ।
I have inside me the winds , the deserts , the oceans , the stars , and everything created in the universe .	मेरे ही भीतर सब छिपा है — हवा , रेगिस्तान , समुद्र , तारे और वह सब कुछ जो ब्रह्माण्ड ने सर्जित किया है ।
We were all made by the same hand , and we have the same soul .	हम सबको उसी हाथ ने बनाया और हम सबकी आत्मा भी एक ही है ।
You ' ll learn to love the desert , and you ' ll get to know every one of the fifty thousand palms .	तुम्हें रेगिस्तान से प्यार करना आ जाएगा और उन पचास हजार खजूर के पेड़ों में तुम एक - एक को पहचानने लगोगे ।
You ' ll watch them as they grow , demonstrating how the world is always changing .	उन्हें बढ़ता हुआ देखकर तुम अनुभव करोगे कि कैसे हर क्षण दुनिया बदलती रहती है ।
And you ' ll get better and better at understanding omens , because the desert is the best teacher there is .	तुम शकुन पहचानने में बेहतर से बेहतर बनते जाओगे चूंकि इस मामले में रेगिस्तान से बढ़कर कोई अच्छा गुरु नहीं है ।
" Sometime during the second year , you ' ll remember about the treasure .	" फिर , किसी वक्त , दूसरे साल के दौरान तुम्हें खजाने की याद सताएगी ।
The omens will begin insistently to speak of it , and you ' ll try to ignore them .	शकुन चौगुन तुम्हें उसके बारे में बताना शुरू कर देंगे , मगर तुम उन्हें अनदेखा करना चाहोगे ।
But you know that I ' m not going to go to Mecca . Just as you know that you ' re not going to buy your sheep .	तुम अच्छी तरह से जानते हो , कि मैं मक्का नहीं जाने वाला हूँ ठीक उसी तरह जैसे कि तुम कोई भेड़ - वेड़ नहीं खरीदने वाले हो ! "
" Who told you that ? " asked the boy , startled .	" आपसे ऐसा किसने कहा ? " लड़के को आश्चर्य हुआ ।
" Maktub " said the old crystal merchant .	" मक्तूब ! " खिरस्टल - व्यापारी ने कहा ,
And he gave the boy his blessing .	कुछ पल खामोश रह कर , उसने लड़के को भरपूर आशीर्वाद दिया ।
The boy went to his room and packed his belongings .	कमरे में जाकर लड़के ने अपना सामान बांधा ।
They filled three sacks .	तीन बोरे भर गए ।
As he was leaving , he saw , in the corner of the room , his old shepherd ' s pouch .	बाहर जाते हुए उसने कमरे के एक कोने में , अपनी पुरानी थैली देखी ।
" I want to see the greatness of Allah , " the chief said , with respect .	" मैं अल्लाह की महानता देखना चाहता हूँ । " बड़े आदर के साथ मुखिया ने कहा ।
" I want to see how a man turns himself into the wind . "	" मैं देखना चाहता हूँ कि कैसे कोई आदमी खुद को हवा में बदलता है । "
But he made a mental note of the names of the two men who had expressed their fear .	मगर उसने अपने मन में उन दो सेनापतियों के नाम याद कर लिए जिन्होंने डर का इज़हार किया था ।

Sentence Alignment

Goal: Given a text in two languages, align sentences.
Assume: Sentences hardly ever reordered.

- Classical algorithm: Gale and Church (1993).
  - Based on similar character <u>length</u> of aligned sentences, no words examined.
  - Dynamic-programming search for the best alignment.
  - Allows 0 to 2 sentences in a group: 0-1, 1-0, 1-1, 2-1, 1-2, 2-2.
- Several algorithms for English-Czech evaluated by Rosen (2005).
  - Nearly perfect alignment possible by a combination of aligners.
- The "standard tool": Hunalign (Varga et al., 2005).
- Another option: Gargantua (Braune and Fraser, 2010).

Word Alignment

Goal: Given a sentence in two languages, align words (tokens).
State of the art: GIZA++ (Och and Ney, 2000):

- Unsupervised, only sentence-parallel texts needed.

- Word alignments formally restricted to a <u>function</u>:

$$\text{src token} \mapsto \text{tgt token or NULL}$$

- A cascade of models refining the probability distribution:
  - IBM1: only lexical probabilities: $P(ko\check{c}ka = cat)$
  - IBM3: adds fertility: 1 word generates several others
  - IBM4/HMM: to account for relative reordering
- Only many-to-one links created $\Rightarrow$ used twice, in both directions.

IBM Model 1

Lexical probabilities:

- Disregard the position of words in sentences.
- Estimated using Expectation-Maximization Loop.

More details available e.g. in MT Marathon slides:

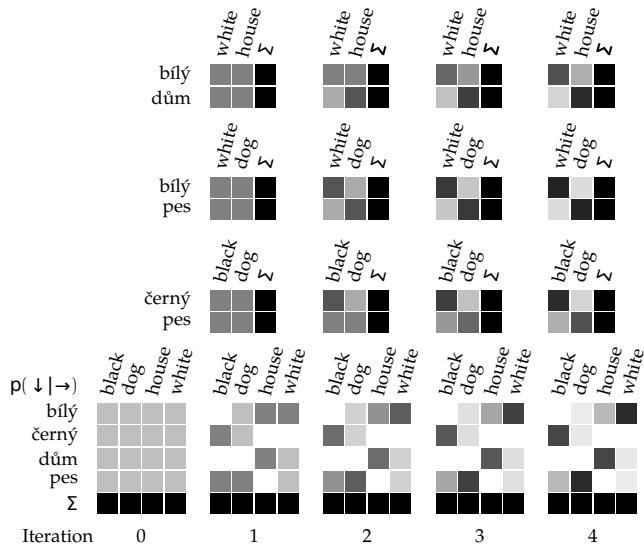- Aleš Tamchyna.

  http://www.statmt.org/mtm15
  $\rightarrow$ Programme $\rightarrow$ Tuesday Lecture

- Patrick Lambert (originally Philipp Koehn)

  http://lium3.univ-lemans.fr/mtmarathon2010/lectures/
  02-wordalignment.pdf

EM Loop in IBM1

Symmetrization for PBMT
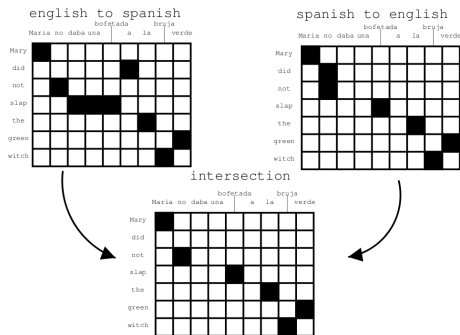
"Symmetrization" of two GIZA++ runs:

- intersection: high precision, too low recall.
- popular: gdfa (a heuristic between intersection and union).
- minimum-weight edge cover (Matusov et al., 2004).

Troubles with Word Alignment

- Humans have troubles aligning word for word.
  - Mismatch in alignments points 9–18%. (Bojar and Prokopová, 2006)

Top Problematic Words				Top Problematic Parts of Speech			
English		Czech		English		Czech	
361	to	319	,	679	IN	1348	N
259	the	271	se	519	DT	1283	V
159	of	146	v	510	NN	661	R
143	a	112	na	386	PRP	505	P
124	,	74	o	361	TO	448	Z
107	be	61	že	327	VB	398	A
99	it	55	.	310	JJ	280	D
95	that	47	a	245	RB	192	J

Partial Fix: "Possible" Alignments

Type 1: Language-specific function words omitted in the other language

[go over]

[Earth]

over   the   Earth

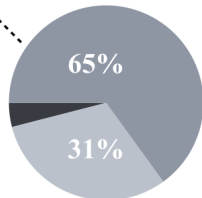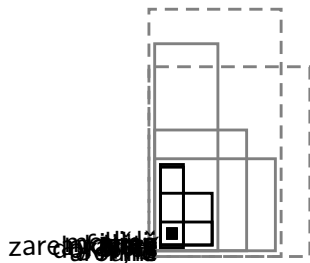**Type 2**: Role-equivalent pairs that are not lexical equivalents

[*passive marker*]

[discover]

was   discovered

Distribution over possible link types

65%

31%

Phrase-Based MT Overview

This time around	=	Nyní
they 're moving	=	zareagovaly
even	=	dokonce ještě
...	=	...
This time around, they 're moving	=	Nyní zareagovaly
even faster	=	dokonce ještě rychle
...	=	...

Phrase-based MT: choose such segmentation of input string and such phrase "replacements" to make the output sequence "coherent" (3-grams most probable).

1: Align Training Sentences

Nemám žádného psa.   Viděl kočku.

I have no dog.   He saw a cat.

Nemám žádného psa.

I have no dog.

Viděl kočku.

He saw a cat.

Nemám žádného psa.
I have no dog.

Viděl kočku.
He saw a cat.

New input: Nemám kočku.

Nemám žádného psa.
I have no dog.

Viděl kočku.
He saw a cat.

... I don't have cat.

New input: Nemám kočku.

Nemám žádného psa.

I have no dog.

Viděl kočku.

He saw a cat.

... I don't have cat.

New input: Nemám kočku.

I have

Nemám žádného psa.
I have no dog.

Viděl kočku.
He saw a cat.

... I don't have cat.

New input: Nemám kočku.
I have a cat.

Summary of MT Class 1

- Parallel corpora.
- Sentence alignment.
- Word alignment.
- Phrase-based MT.

Lab: Get GIZA and Moses Running

We will use Eman `http://ufal.mff.cuni.cz/eman`:

- to compile GIZA++ and Moses.
- (optionally) to actually train a PBMT system.

(because GIZA++ needs a patch and Moses needs some flags)
(eman itself may however also need something...)
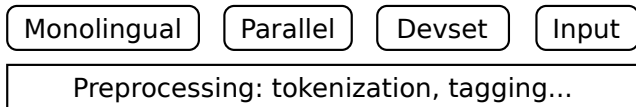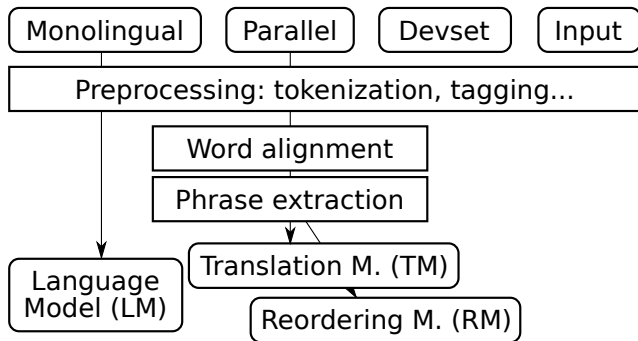
Bird's Eye View of PBMT
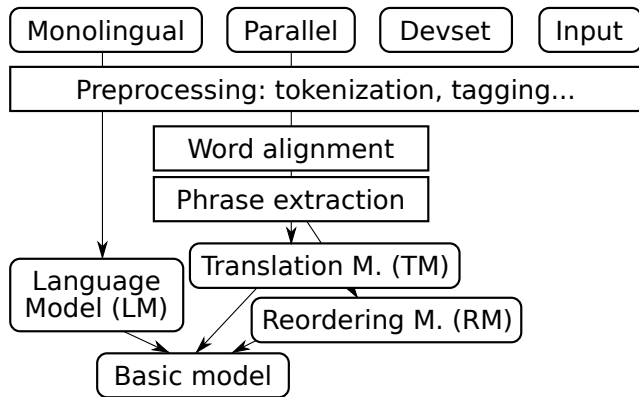
Monolingual | Parallel | Devset | Input

Bird's Eye View of PBMT

Monolingual	Parallel	Devset	Input

Preprocessing: tokenization, tagging...

Bird's Eye View of PBMT

Bird's Eye View of PBMT


```
┌──────────────┐ ┌──────────┐ ┌──────────┐ ┌────────┐
│ Monolingual  │ │ Parallel │ │  Devset  │ │ Input  │
└──────────────┘ └──────────┘ └──────────┘ └────────┘
┌─────────────────────────────────────────────────────┐
│       Preprocessing: tokenization, tagging...        │
└─────────────────────────────────────────────────────┘
              ┌──────────────────────────┐
              │      Word alignment      │
              └──────────────────────────┘
              ┌──────────────────────────┐
              │     Phrase extraction    │
              └──────────────────────────┘
┌──────────────┐ ┌──────────────────────────┐
│  Language    │ │   Translation M. (TM)    │
│ Model (LM)   │ └──────────────────────────┘
└──────────────┘      ┌──────────────────────────┐
                      │   Reordering M. (RM)     │
                      └──────────────────────────┘
              ┌──────────────────┐
              │   Basic model    │
              └──────────────────┘
```

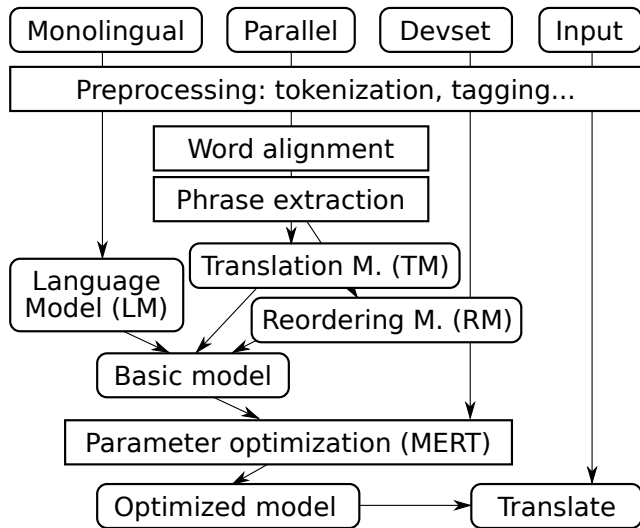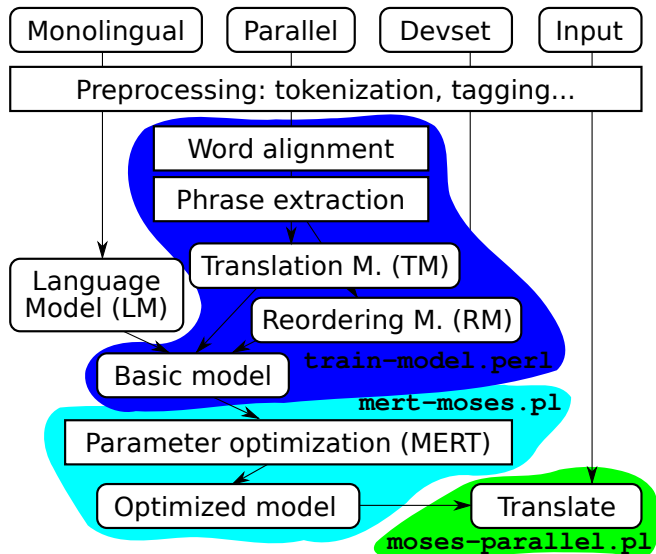# Bird's Eye View of PBMT
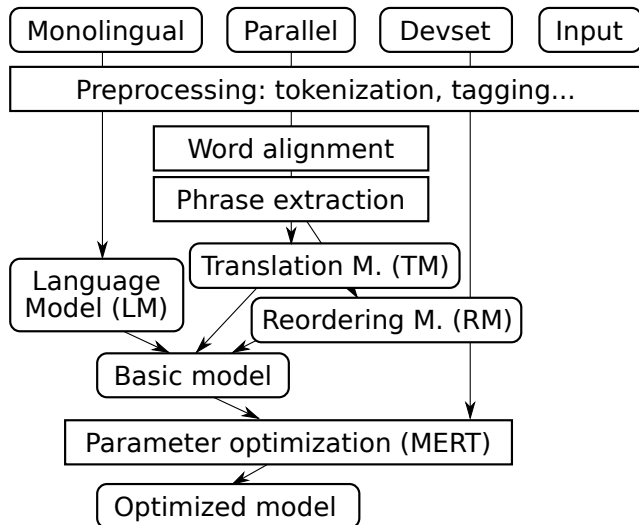
Bird's Eye View of PBMT

Bird's Eye View of PBMT

Get Eman, GIZA and Moses

At Student machines, ÚFAL machines, or your laptop:

1. "Install" eman in your home directory:

   ```
   git clone https://redmine.ms.mff.cuni.cz/ufal-smt/eman.git
   ```

2. Make sure eman is in your PATH: Bad things happen if not.

   ```
   export PATH=$HOME/eman/bin/:$PATH
   echo "export PATH=$HOME/eman/bin/:\$PATH" >> ~/.bashrc
   ```

3. Get our SMT Playground (with all the seeds):

   ```
   git clone \
   https://redmine.ms.mff.cuni.cz/ufal-smt/playground.git
   ```

Possibly Fix Perl Dependencies

1. Set up a local Perl repository.

   `http://stackoverflow.com/questions/2980297`

   Copy & paste code from the first answer, just replace `.profile` with `.bashrc`

2. Install the required package:

   `cpanm YAML::XS`

3. Confirm that eman runs:

   `eman --man`

Start Compiling Moses

In eman's philosophy, software is just data.

- Binaries should be compiled in timestamped step dirs.
- ...so we know the exact code that was used.

Compile Moses and GIZA++ (all on one line!):

```
BJAMARGS=" link=shared --no-xmlrpc-c
           --max-kenlm-order=12 -a "
  eman init --start mosesgiza
```

✎ Examine the newly created step dir s.mosesgiza.*.

Where is the compilation log?
(Moses+GIZA compilation takes ∼8min.)

Use GIZA++

It's easier to run GIZA using my wrapper:

https://raw.githubusercontent.com/ufal/qtleap/master/cuni_train/bin/gizawrapper.pl

1. Download gizawrapper, chmod 755.
2. Download a parallel corpus of your choice.
   - From OPUS.
   - In "moses" format, which probably means already tokenized.
   - It should have ∼0.1M sentence pairs.
   - Amharic (am) – English (en) Tanzil corpus is a good choice.
3. Run gizawrapper + symal (takes ∼20 min on Am-En):

```
./gizawrapper.pl \
  --bindir=/PATH/TO/playground/s.mosesgiza.????????.2018????-????/bin/ \
  am-en/Tanzil.am-en.am \
  am-en/Tanzil.am-en.?? \
  --dirsym=left,right,int,union | gzip > am-en.ali.gz
```

Observe the Alignment

1. Get my alignment viewer alitextview:

2. Render the alignment on text console:

```
paste am-en/Tanzil.am-en.am am-en/Tanzil.am-en.en \
      <(zcat am-en.ali.gz ) | cut -f 1,2,5 \
      | ./alitextview.pl | less
```

Improve the Alignment

1. Alignment needs large data.
2. If you don't have it, you need to make statistics denser. Here we lowercase and "stem" (chop words to 4 characters):

```
for f in Tanzil.am-en.??; do
  cat $f | ../playground/scripts/lowercase.pl \
  | ../playground/scripts/stem_factor.pl \
  > $f.lcstem4
done
```

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