# Forms Wanted: Training SMT on Monolingual Data

Ondřej Bojar, Aleš Tamchyna
bojar@ufal.mff.cuni.cz, a.tamchyna@gmail.com
Institute of Formal and Applied Linguistics
Faculty of Mathematics and Physics
Charles University, Prague

# Outline

- Targeting Czech.
  - Vocabulary sizes.
  - Source of the morphological explosion.
  - OOV rates.
  - Caveat: BLEU much less reliable.
- Failed: Factored attempts to generate forms on the fly.
- Promising: Two-Step Translation.
- Black Art: **Reverse Self-Training.**
- Summary.

# Vocabulary Sizes for en and cs

| WMT10 (Bojar and Kos, 2010) | Large | Small | Dev |
|---|---|---|---|
| Sentences | 7.5M | 126.1k | 2.5k |
| Czech Tokens | 79.2M | 2.6M | 55.8k |
| English Tokens | 89.1M | 2.9M | 49.9k |
| Czech Vocabulary | 923.1k | **138.7k** | 15.4k |
| English Vocabulary | 646.3k | **64.7k** | 9.4k |
| Czech Lemmas | 553.5k | 60.3k | 9.5k |
| English Lemmas | 611.4k | 53.8k | 7.7k |

| | Czech | English |
|---|---|---|
| Rich morphology | $\geq$ 4,000 tags possible | 50 used |
| | $\geq$ 2,300 tags seen | |
| Word order | free | rigid |

# Morphological Explosion in Czech

**(In)flective lang.**: many categories expressed in a single suffix:

- Czech nouns and adjectives: 7 cases, 4 genders, 3 numbers, . . .
- Czech verbs: gender, number, aspect (im/perfective), . . .

| I | saw | two | green | striped | cats | . |
|---|---|---|---|---|---|---|
| já | pila | dva | zelený | pruhovaný | kočky | . |
| | pily | dvě | zelená | pruhovaná | koček | |
| | . . . | dvou | zelené | pruhované | kočkám | |
| | viděl | dvěma | zelení | pruhovaní | kočkách | |
| | viděla | dvěmi | zeleného | pruhovaného | kočkami | |
| | . . . | | zelených | pruhovaných | | |
| | uviděl | | zelenému | pruhovanému | | |
| | uviděla | | zeleným | pruhovaným | | |
| | . . . | | zelenou | pruhovanou | | |
| | viděl jsem | | zelenými | pruhovanými | | |
| | viděla jsem | | . . . | . . . | | |

Wide margin for improvement: Standard BLEU ∼12% vs. lemmatized BLEU ∼21%

# OOV Rates

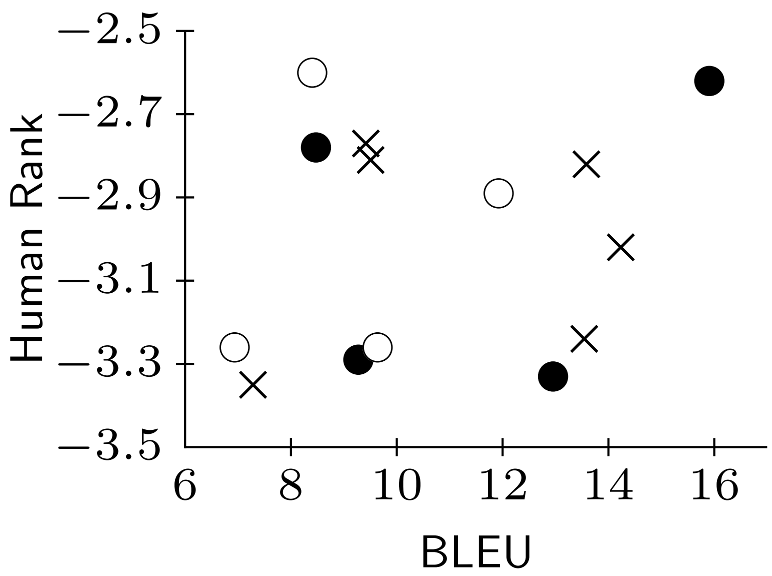
| Dataset (# Sents) | Language | n-grams Out of: Corpus Voc. 1 | 2 | Phrase-Table Voc. 1 | 2 |
|---|---|---|---|---|---|
| 7.5M | Czech | 2.2% | 30.5% | 3.9% | 44.1% |
| | English | 1.5% | 13.7% | 2.1% | 22.4% |
| | Czech + English input sent | 1.5% | 29.4% | 3.1% | 42.8% |
| 126k | Czech | 6.7% | 48.1% | 12.5% | 65.4% |
| | English | 3.6% | 28.1% | 6.3% | 45.4% |
| | Czech + English input sent | 5.2% | 46.6% | 10.6% | 63.7% |
| 126k | Czech lemmas | 4.1% | 36.3% | 5.8% | 52.6% |
| | English lemmas | 3.4% | 24.6% | 6.9% | 53.2% |
| | Czech + English input lemmas | 3.1% | 35.7% | 5.1% | 38.1% |

- Significant vocabulary loss during phrase extraction:
  - e.g. 2.2%→3.9% for 7.5M Czech.
- OOV of Czech forms ∼twice as bad as in English, cf. the reds.
- OOV of Czech lemmas lower than in English, see the greens.

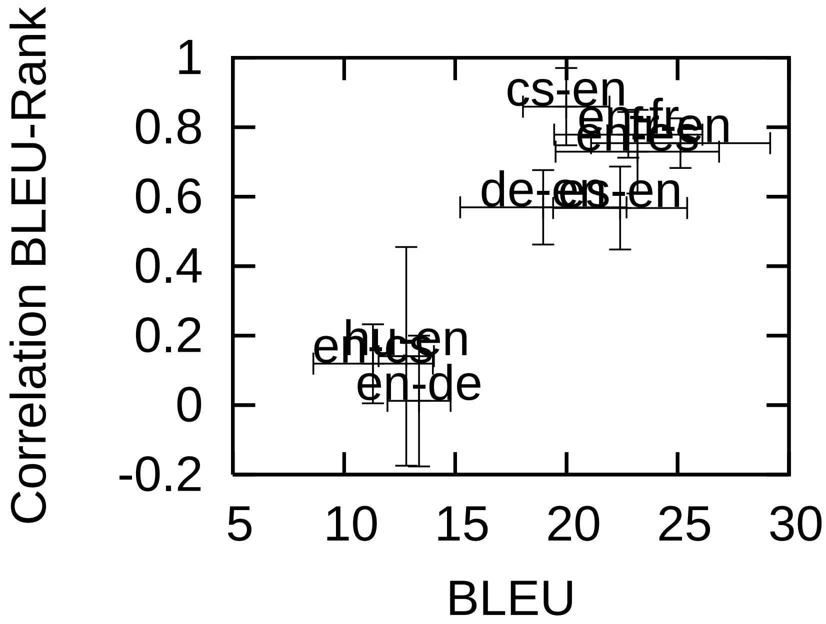
# Side Note: BLEU vs. Human Rank

- Large vocabulary impedes the performance of BLEU.

En→Cs Systems — WMT08, WMT09




Various Language Pairs — WMT08, WMT09, MetricsMATR




⇒ BLEU does not correlate with human rank <u>if below</u> ∼20.

# Reason 1: Focus on Forms

| | |
|---|---|
| SRC | Prague Stock Market falls to minus by the end of the trading day |
| REF | pražská burza se ke konci obchodování propadla do minusu |
| cu-bojar | praha stock market klesne k minus na <u>konci</u> obchodního dne |
| pctrans | praha trh cenných papírů padá minus <u>do</u> konce obchodního dne |

- Only a single unigram in each hyp. confirmed by the reference.
- Large chunks of hypotheses are not compared at all.

| | | | | |
|---|---|---|---|---|
| Confirmed by Reference | Yes | Yes | No | No |
| Contains Errors | Yes | No | Yes | No |
| Running words | 6.34% | 36.93% | 22.33% | **34.40%** |

# Reason 2: Sequences Overvalued

BLEU overly sensitive to sequences:

- Gives credit for 1, 3, 5 and 8 four-, three-, bi- and unigrams,
- Two of three serious errors not noticed,

  ⇒ Quality of cu-bojar overestimated.

| | |
|---|---|
| SRC | Congress yields: US government can pump 700 billion dollars into banks |
| REF | kongres ustoupil : vláda usa může do bank napumpovat 700 miliard dolarů |
| cu-bojar | kongres výnosy : vláda usa může čerpadlo 700 miliard dolarů v bankách |
| pctrans | kongres vynáší : us vláda může čerpat 700 miliardu dolarů do bank |

⇒ Bojar et al. (2010) use SemPOS, a coarse metric that correlates better with humans for Czech and English.

# Factored Phrase-Based MT

- Both input and output words can have more factors.

  **Mapping steps** ($\rightarrow$)

  Translate (phrases of) source factors to target factors.

  two green $\rightarrow$ dvě zelené

  **Generation steps** ($\downarrow$)

  Generate target factors from target factors.

  dvě $\rightarrow$ *fem*-*nom*; dva $\rightarrow$ *masc*-*nom*

  $\Rightarrow$ To ensure "vertical" coherence.

  **Target-side language models** (+LM)

  Applicable to various target-side factors.

  p(dvě kočkách) $<$ p(dvě kočky); p(*fem*-*nom* *masc*-*nom*) $<$ p(*fem*-*nom* *fem*-*nom*)

  $\Rightarrow$ To ensure "horizontal" coherence.

| src | tgt | |
|---|---|---|
| $f_1 \rightarrow$ | $e_1$ | +LM |
| $f_2$ | $e_2$ | |

(Koehn and Hoang, 2007)

# Translation Scenarios

Vanilla

| English | | Czech | |
|---|---|---|---|
| form | → | form | +LM |
| lemma | | lemma | |
| morphology | | morphology | |

Translate+Check (T+C)

| English | | Czech | |
|---|---|---|---|
| form | → | form | +LM |
| lemma | | lemma | |
| morphology | | morphology | +LM |

Translate+2·Check (T+C+C)

| English | | Czech | |
|---|---|---|---|
| form | → | form | +LM |
| lemma | | lemma | +LM |
| morphology | | morphology | +LM |

2·Translate+Generate (T+T+G)

| English | | Czech | |
|---|---|---|---|
| form | | form | +LM |
| lemma | → | lemma | +LM |
| morphology | → | morphology | +LM |

# Factored Attempts (WMT09)

| Sents | System | BLEU | NIST | Sent/min |
|---|---|---|---|---|
| 2.2M | Vanilla | **14.24** | **5.175** | 12.0 |
| 2.2M | T+C | 13.86 | 5.110 | 2.6 |
| 84k | T+C+C&T+T+G | 10.01 | 4.360 | 4.0 |
| 84k | Vanilla MERT | 10.52 | 4.506 | – |
| 84k | Vanilla even weights | 08.01 | 3.911 | – |

- In WMT08, T+C was still the effort (Bojar and Hajič, 2008).
- In WMT09, our computers could handle 7-grams of forms.
  $\Rightarrow$ No gain from T+C.
- T+T+G too big to fit and explodes the search space.
  $\Rightarrow$ Worse than Vanilla trained on the same dataset.

# T+T+G Failure Explained

- Factored models are "**synchronous**", i.e. Moses:
  1. Generates fully instantiated "translation options".
  2. Appends translation options to extend "partial hypothesis".
  3. Applies LM to see how well the option fits the previous words.
- There are too many possible combinations of lemma+tag.

⇒ Less promising ones must be pruned.

! Pruned <u>before</u> the linear context is available.

- Hieu Hoang wasted a year on trying asynchronous factors.
  – Pruning hard to design (no clear comparison for partial translation options).
- In a completely different decoder Bojar et al. (2009) use "delayed factors".
  – The final value generated only after the full hypothesis is ready.

# Two-Step Attempts (WMT10) 1/2

1. English → lemmatized Czech
   - meaning-bearing morphology preserved
   - max phrase len 10, distortion limit 6
   - large target-side (lemmatized LM)
2. Lemmatized Czech → Czech
   - trained on much more data
   - max phrase len 1, monotone

| | | | |
|---|---|---|---|
| **Src** | after a sharp drop | | |
| **Mid** | po+6 | ASA1.prudký | NSA-.pokles |
| **Gloss** | *after+voc* | *adj+sg...sharp* | *noun+sg...drop* |
| **Out** | po | prudkém | poklesu |

# Two-Step Attempts (WMT10) 2/2

| Training Sents | | Vanilla | | Two-Step | | Diff |
|---|---|---|---|---|---|---|
| Parallel | Mono | BLEU | SemPOS | BLEU | SemPOS | B.S. |
| 126k | 126k | 10.28±0.40 | 29.92 | 10.38±0.38 | 30.01 | $\nearrow\nearrow$ |
| 126k | 13M | 12.50±0.44 | 31.01 | 12.29±0.47 | 31.40 | $\searrow\nearrow$ |
| 7.5M | 13M | 14.17±0.51 | 33.07 | 14.06±0.49 | 32.57 | $\searrow\searrow$ |

Manual micro-evaluation of $\searrow\nearrow$, i.e. 12.50±0.44 vs. 12.29±0.47:

| | Two- -Step | Both Fine | Both Wrong | Vanilla | Total |
|---|---|---|---|---|---|
| Two-Step | **23** | 4 | 8 | - | **35** |
| Both Fine | 7 | 14 | 17 | 5 | 43 |
| Both Wrong | 8 | 1 | 28 | 2 | 39 |
| Vanilla | - | 3 | 7 | **23** | 33 |
| Total | **38** | 22 | 60 | 30 | 150 |

- Each annotator weakly prefers Two-step
  – but they don't agree on individual sentences.

# Reverse Self-Training

Goal: Learn from monolingual data to produce new target-side word forms in correct contexts.

| | Source English | | Target Czech |
|---|---|---|---|
| Para 126k | a cat chased. . . | = | **kočka** honila. . . |
| | | | *kočka honit. . . (lem.)* |
| | I saw a cat | = | viděl jsem **kočku** |
| | | | *vidět být kočka (lem.)* |
| Mono 2M | ? | | četl jsem o **kočce** |
| | | | *číst být o kočka (lem.)* |
| | | | Use reverse translation |
| | I read about a cat | $\leftarrow$ | backed-off by lemmas. |

$\Rightarrow$ New phrase learned: “about a cat” = “o **kočce**”.

# The Back-off to Lemmas

- The key distinction from self-training used for domain adaptation (Bertoldi and Federico, 2009; Ueffing et al., 2007).
- We use simply "alternative decoding paths" in Moses:

| Czech | English | |
|---|---|---|
| form → | form | +LM |

or

| Czech | English | |
|---|---|---|
| lemma → | form | +LM |

  – We even don't correct the bug that phrases available only in one of the tables score better than phrases scored by both paths.
- Other languages (e.g. Turkish, German) need different back-off techniques:
  – Split German compounds.
  – Separate and allow to ignore Turkish morphology.
  $\Rightarrow$ See the talks by Chris Dyer and Marcello Federico.

# Mixing Para+Mono

**Simple concatenation (denoted ".").**

- Just append the baseline parallel and the monolingual texts.

**Interpolated in MERT (denoted "+").**

- Separate weight for the LM trained on the monolingual data.
- Separate five weights for the phrase table extracted from the monolingual data.

# Results

| BLEU | TM | LM | Manual |
|---|---|---|---|
| 10.56±0.39 | para | para | |
| 10.70±0.40 | mono | mono | |
| 10.98±0.38 | mono | para+mono | |
| 11.06±0.40 | mono | para.mono | |
| 12.20±0.40 | para | para+mono | |
| **12.24±0.44** | para | para.mono | baseline |
| 12.27±0.41 | para.mono | para+mono | |
| 12.33±0.43 | para.mono | para.mono | 29 over 19 better |
| **12.65±0.42** | para+mono | para.mono | 35 over 27 better |

- For LM, interpolation ("+") usually beats concat. (".").
  - Here domains match exactly ⇒ no gain.
- Reverse self-training works (TM "+") for en→cs small data.
- 2M monolingual (alone!) make a reasonable baseline (10.70±0.40).

# Summary

- Czech is an interesting target language for MT.

  `http://ufal.mff.cuni.cz/czeng`

  8 million parallel sents (~90 milion words per lang.)
- BLEU unreliable if below 20.
- Naive factored setup to generate unseen forms fails.
  - Search space explodes.
- Two-step approach (translate to lemmas first) promising.
  - Future: pass lattice between step 1 and 2.
  - Future: better model for step 2 (see Alex Fraser's talk).
- Reverse-self training works on small datasets.
  - Future: test on larger dataset.
  - Future: back-off for the reverse step in other languages.

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