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Depfix:

Automatic post-editing of phrase-based machine translation outputs

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Edinburgh SMT group meeting, 29th January 2014
Statistical Machine Translation

source sentence (English)

SMT system

target sentence (Czech)
Automatic Post-editing of SMT

source sentence (English)

SMT system

target sentence (Czech)

APE system

corrected target sentence (Czech)
input: target sentence (+ source sentence)

1. analysis
   - tokenization, lemmatization, tagging, word-alignment, parsing, deep-syntax induction

2. correction
   - a set of rules, e.g. noun-adjective agreement

3. generation
   - morphological generator

output: corrected target sentence
Analysis

- most important:
  - **lemma** + Czech fine-grained morphological **tag**
    - gender, number, case, person, tense, negation...
    - e.g. *pivem* (*beer* in instrumentative case)
    - \(\rightarrow pivo\text{ NNNS7-----A----} \)
  - **dependency tree**
    - tells us e.g. that the modifier *českým* (*Czech*) belongs to *pivem* (*beer*)
    - we use **MST parser adapted for parsing SMT outputs**
Correction

- usually edge-local
- morphological agreement of noun and adjective:
  - set **gender**, **number** and **case** of the **adjective**
    to **gender**, **number** and **case** of the **noun**

\[
\begin{align*}
\text{pivem} & \quad \text{pivo} \quad \text{Český} \\
& \quad \text{český} \quad \text{českým}
\end{align*}
\]
Generation

- morphological generator
  - lemma & tag → word form
  - e.g. český \texttt{AAMS7-}-\texttt{1A-} → českým

- Czech morphology is far from trivial
  - 2 numbers, 4 genders, 7 cases, various paradigms...
  - homonymous forms
    - \textit{piva} = sg gen / pl nom / pl acc / pl voc
  - variants
    - sg loc = pivu / pivě
Correction types (I)

- agreement
  - preposition – noun (case)
  - noun – adjective (gender, number, case)
  - subject – predicate (gender, number, person)
  - antecedent – relative pronoun (gender, number, case)
- minor errors
  - projection of tokenization
  - source-aware truecasing
  - vocalization of prepositions
Correction types (II)

- transfer of meaning to morphology
  - translation of possessives and “of” (genitive)
  - translation of passive voice and “by” (instrumentative)
  - subject (nominative)
  - verb tense
  - negation
- coarse translation of missing items
  - missing reflexive verbs
- analysis corrections (alignment, tags, trees)
Automatic evaluation (BLEU)

- **WMT10 (devel)**
  - Moses output: 15.66
  - After Depfix: 16.08

- **WMT11**
  - Moses output: 16.39
  - After Depfix: 16.61

- **WMT12**
  - Moses output: 13.81
  - After Depfix: 13.85

- **WMT13**
  - Moses output: 20.08
  - After Depfix: 20.02
## Automatic evaluation ($\Delta$ BLEU)

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<th>data/system</th>
<th>CU Bojar</th>
<th>CU TectoMT</th>
<th>CU Zeman</th>
<th>UEdin</th>
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<td>WMT10 (dev)</td>
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<td>+0.61</td>
<td>+0.78</td>
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<td>+0.07</td>
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<td>+0.34</td>
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<table>
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<td>+0.15</td>
<td>+0.37</td>
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</tbody>
</table>
Manual evaluation (WMT12)

- **changed sentences**
  - Improvement: 430 (58%)
  - Degradation: 152 (21%)
  - Indefinite: 157 (21%)

- **all sentences**
  - Improvement: 430 (32%)
  - Degradation: 152 (11%)
  - Indefinite: 157 (12%)
  - No change: 611 (45%)

IAA: 71% all, 93% impr./degr.
**Precision of rules (part of WMT12)**

\[
\text{precision} = \frac{|\text{improved}|}{|\text{improved}| + |\text{worsened}|}
\]

- **50% precision**
Impact of rules (part of WMT12)

Impact = $\frac{|modified|}{|all|}$

- 75% precision
- 60% precision
- 50% precision

5% impact

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Current & future work

- if we can write the rules manually...
  - ...can we also machine-learn them?
- currently running experiments
  - predict: gender, number, case (of modifier)
  - data: parallel corpus & its translation by Moses
  - decision trees / maximum entropy classifier
  - features (modifier, head & their source counterparts)
    - tag (split by category), dependency relation label, edge direction, number of modifiers, lemma
- preliminary positive results
Delving deeper...

- more corrections
  - an example of a cascade of corrections
  - correction of negation
  - correction of verb tense translation
- MSTperl parser
  - reimplementation of MST parser
  - adapted for parsing SMT outputs
Delving deeper...

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A cascade of corrections

- **Source:**
  - *All the winners received a diploma.*

- **Moses:**
  - *Všem výhercům obdržel diplom.*
  - *To all the winners he received a diploma.*

- **Depfix:**
  - *Všichni výherci obdrželi diplom.*
  - *All the winners received a diploma.*
Všem výhercům obdržel diplom.
Transfer of meaning: subject

a-tree
zone=en

received
Pred
VBD

winners
Sb
NNS

diploma
Obj
NN

All
Atr
PDT

the
AuxA
DT

a
AuxA
DT

obdržel
Pred
VpYSXRA

výhercům
Obj
NNMP3

diplom
Obj
NNIS1

Všem
Atr
PLXP3

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Transfer of meaning: subject

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Všem výherci obdržel diplom.
Noun-adjective agreement

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Agreement: gender, case (number)

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Všichni výherci obdržel diplom.
Subject-predicate agreement

The diagram illustrates subject-predicate agreement in English and Czech. In English, the subject "winners" is followed by the verb "received" and the object "diploma." In Czech, "výherci" (winners) is followed by "obdržel" (received) and "diplom" (diploma). The diagram highlights the agreement between the subject and the verb in both languages.
Agreement: gender, num (person)
Všichni výherci obdrželi diplom.
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Motivation

- **These are not actually errors.**
  - Moses: *Jsou to vlastně chyby.*
  - Gloss: *These are actually errors.*
  - Reference: *Nejsou to vlastně chyby.*

- **I would not cheat on you.**
  - Moses: *Já bych tě podváděl.*
  - Gloss: *I would cheat on you.*
  - Reference: *Já bych tě nepodváděl.*
Expressing negation

- default way in English: *not* token
  - *These are not* actually errors.
- default way in Czech: *ne-* prefix
  - *Nejsou to vlastně chyby.*
- hard for word-alignment
- hard for PB SMT
Actually, much more complex

- many ways to express negation (CS, EN)
  - negative particle (*not*), negative affix (*mis-*), *less*
  - negative preposition (*without*)...
  - lexical means (*not happy* ~ *sad*)
- differences between Czech and English
  - techniques based on word-alignment do badly
- the negation can be placed differently
  - usually it is the predicate heading the clause
    - but which part of it if it is multiword?
- but not always
Detecting the problem

- English clause seems to be negative
- Czech clause seems to be positive
Fixing the problem

- find a place to put the negation (clause head)
- negate it (using tag & morpho generator)
Deep syntactic analysis

- auxiliary nodes collapsed into values of attributes on parent nodes

- abstract from various ways of expressing negation (not, no, un-, in-,...)

are \[\rightarrow\] be, neg=1

not \[\rightarrow\] unpleasant \[\rightarrow\] pleasant, neg=1
Delving deeper...

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Verb tense translation

- analyze the source (English) verb
- analyze the target (Czech) verb
- if they do not seem to match, change CS tense:
  - EN future * → CS future
  - EN past *; present perfect → CS past
  - EN present * → CS present
- avoid hard cases
  - conditionals, reported speech...
English verbs analysis

- parsing the verb form
  - all VB* and MD modifiers of the main verb
  - occasionally checking other modifiers (to)
- normalize to forms of have, be and love
- other words mark something
  - modality (modals, have to, be (un)able to...)
  - future (will, going to – careful: was going to)
  - conditionality (would, should)
  - past (did)
English verbs analysis

(present is the default – can be overridden by markers such as did or will)

- 'love' => [ ],
- 'loved' => [ 'past' ],
- 'have loved' => [ 'perf' ],
- 'be loving' => [ 'cont' ],
- 'be loved' => [ 'pass' ],
- 'had loved' => [ 'past', 'perf' ],
- 'were loving' => [ 'past', 'cont' ],
- 'were loved' => [ 'past', 'pass' ],
- 'have been loving' => [ 'perf', 'cont' ],
- 'have been loved' => [ 'perf', 'pass' ],
- 'be being loved' => [ 'cont', 'pass' ],
- 'had been loving' => [ 'past', 'perf', 'cont' ],
- 'were being loved' => [ 'past', 'cont', 'pass' ],
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Delving deeper...

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MST parser

- Maximum Spanning Tree parser
- McDonald, Crammer, Pereira (2005)
  - Online large-margin training of dependency parsers
- McDonald, Pereira, Ribarov, Hajič (2006)
  - Non-projective dependency parsing using spanning tree algorithms
- discriminative, edge-local features
- MIRA learning algorithm
(1) Words and Tags

words = nodes

Rudolph  NNP  relaxes  VBZ
abroad   RB

root

#
(2) (Nearly) Complete Graph

all possible edges = directed edges

Rudolph NNP

# root

relaxes VBZ

abroad RB
(3) Assign Edge Weights

data weight = sum of edge features weights

Margin Infused Relaxed Algorithm (MIRA)
(4) Maximum Spanning Tree

non-projective trees: Chu-Liu-Edmonds algorithm

(projective trees: Eisner algorithm)
(5) Unlabeled Dependency Tree

dependency tree =
maximum
spanning tree

Rudolph
NNP

relaxes
VBZ

abroad
RB

root

dependency tree =
maximum
spanning tree
labels assigned by a second stage labeler
Parsing of SMT Outputs

- can be useful in many applications
  - automatic classification of translation errors
  - automatic correction of translation errors (Depfix)
  - multilingual question answering...

✔️ we have the source sentence available
  - Can we use it to help parsing?

❌ SMT outputs noisy (errors in fluency, grammar...)
  - parsers trained on gold standard treebanks
  - Can we adapt parser to noisy sentences?
MSTperl

- reimplementation of MST Parser in Perl
  - first-order, non-projective
- adapted for SMT outputs parsing
  - worsening the training data
  - adding parallel information
  - manually boosting feature weights
  - exploiting large-scale data
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Parser Training Data

- Prague Czech-English Dependency Treebank
  - parallel treebank
  - 50k sentences, 1.2M words
  - morphological tags, surface syntax, deep syntax
  - word alignment
Worsening the Treebank

- treebank used for training contains correct sentences
- SMT output is noisy
  - grammatical errors
  - incorrect word order
  - missing/superfluous words
  - …
- let's introduce similar errors into the treebank!
- so far, we have only tried inflection errors
Worsen (1): Apply SMT

- translate **English** side of PCEDT to **Czech**
  - by an SMT system (we used Moses)
- now we have e.g.:
  - **Gold English**
    - Rudolph's car is black.
  - **Gold Czech**
    - Rudolfovo _auto_ NEUT je černé NEUT.
  - **SMT Czech**
    - Rudolfova _auto_ NEUT je černý MASC.
Worsen (2): Align SMT to Gold

- **align SMT Czech to Gold Czech**
- **Monolingual Greedy Aligner**
  - alignment link score = linear combination of:
    - similarity of word forms (or lemmas)
    - similarity of morphological tags (fine-grained)
    - similarity of positions in the sentence
    - indication whether preceding/following words aligned
  - repeat: align best scoring pair until below threshold
  - no training: weights and threshold set manually
Worsen (3): Create Error Model

- for each tag:
  - estimate probabilities of SMT system using an incorrect tag instead of the correct tag (Maximum Likelihood Estimate)
- **Czech tagset:** fine-grained morphological tags
  - part-of-speech, gender, number, case, person, tense, voice...
  - 1500 different tags in training data
Worsen (3): Error Model

- Adjective, Masculine, Plural, Instrumental case (AAMP7), e.g. *lingvistickými* (linguistic)
  - 0.2 Adjective, Masculine, Singular, Nominative case
    - e.g. *lingvistický*
  - 0.1 Adjective, Masculine, Plural, Nominative case
    - e.g. *lingvističtí*
  - 0.1 Adjective, Neuter, Singular, Accusative case
    - e.g. *lingvistické*

- ... altogether 2000 such change rules
Worsen (4): Apply Error Model

- take Gold Czech
- for each word:
  - assign a new tag randomly sampled according to Tag Error Model
  - generate a new word form
    - rule-based generator, generates even unseen forms
    - new_form = generate_form(lemma, tag) || old_form
- → get Worsened Czech
- use resulting Gold English-Worsened Czech parallel treebank to train the parser
- reimplementation of MST Parser in Perl
  - first-order, non-projective
- adapted for SMT outputs parsing
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- manually boosting feature weights
- exploiting large-scale data
Parallel Features

- word alignment (using GIZA++)
- additional features (if aligned node exists):
  - aligned tag (NNS, VBD...)
  - aligned dependency label (Subject, Attribute...)
  - aligned edge existence (0/1)
Parallel Features Example
MSTperl

- reimplementation of MST Parser in Perl
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  - exploiting large-scale data
Manually boosting feature weights

- **aligned edge existence** is the key feature here
- observation: since the worsening is probably too mild, its weight is too low
  - edge exists: -0.57
  - edge does not exist: -0.83
  - missing aligned node(s): -0.67
Manually boosting feature weights

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- observation: since the worsening is probably too mild, its weight is too low
  - edge exists: -0.57
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  - missing aligned node(s): -0.67
- experiment: manually increase its weight
  - edge exists: -0.25
Manually boosting feature weights

- **aligned edge existence** is the key feature here
- observation: since the worsening is probably too mild, its weight is too low
  - edge exists: -0.57
  - edge does not exist: -0.83
  - missing aligned node(s): -0.67
- experiment: manually increase its weight
  - edge exists: -0.25
- success – manual changing of weights feasible
MSTperl

- reimplemention of MST Parser in Perl
  - first-order, non-projective
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  - worsening the training data
  - adding parallel information
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  - exploiting large-scale data
Exploiting large-scale data

- exploiting large-scale parsed data (CzEng)
  to provide additional lexical features
- lexical features are important for the parser
- CzEng has 10 times more word types (lemmas)
  than PCEDT (400k vs. 40k)
- training the parser on whole CzEng infeasible
- new feature: pointwise mutual information

\[
PMI'(parent, child) = \log \frac{\text{count}([parent, child])}{\text{count}([parent, *]) \cdot \text{count}([*, child])}
\]
Direct Evaluation: by Inspection

- manual inspection of several parse trees
  - comparing baseline and adapted parser outputs
- examples of improvements:
  - subject identification even if not in nominative case
  - adjective-noun dependence identification even if agreement violated (gender, number, case)
- hard to do reliably
  - trying to find a correct parse tree for an (often) incorrect sentence – not well defined
Indirect Evaluation: in Depfix

- run Depfix with
  - baseline 1: the original McDonald's MST parser
  - baseline 2: basic MSTperl (without the adaptations)
  - adapted MSTperl
- manual evaluation of adapted MSTperl versus the two baseline parsers
  - how many sentences come out better from Depfix using adapted MSTperl than from Depfix using a baseline parser
Indirect Evaluation: in Depfix

- **improvements** and **deteriorations** in Depfix:
  - adapted MSTperl vs original McDonald's MST Parser
  - adapted MSTperl vs basic MSTperl

![Pie charts showing the comparison of adapted MSTperl vs original and basic MSTperl.]
Conclusion

- automatic post-editing of SMT is possible
  - “easy” with using linguistic analysis and generation
  - adapting the parser for SMT outputs also helps
- rule-based system for English→Czech
  - achieves improvements across SMT systems
- machine-learned system (now English→Czech)
  - could learn more fine-grained rules
  - could be easily extended to other languages (if we have analysis and generation)
Thank you for your attention

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For this presentation and other information, please visit:

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