Constrained Recombination in an Example-based Machine Translation System

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Contents

1. The Framework
2. MT Systems
3. Experiments
4. Conclusions

Framework

Example-based Machine Translation

- Translation by analogy (Nagao, 1984).
- A (small) parallel aligned corpus is enough: database of examples.
- Three steps: matching, alignment and recombination.
- Several Approaches: linear, template-based, hybrid etc.

Template: *(...) gave (...) up* ↔ *(...) a abandonat (...)*

- Languages: Romanian, German, English
- Romanian as under-resourced language

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The Implemented MT Systems

1. $Lin - EBMT$
   - The EBMT baseline system
   - A linear EBMT system
2. $Lin - EBMT^{REC+}$
   - Extends $Lin - EBMT$
   - Hybrid system (linear + template-based)
   - Word-order constraints are used in the recombination step. The constraints are extracted from templates.

Lin – EBMT Matching

- Recursive approach
- Based on surface-forms
- Based on the longest common subsequence (LCS) algorithm (Bergroth et al, 2000)
- A token-index is used to reduce the matching space.

LCS Similarity (LCSS)

Given two strings - $s1$ and $s2$ - the LCSS measure is calculated as

$$LCSS(s1, s2) = LCSS_T(s1, s2) - P * noTG, \qquad (1)$$

where

$$LCSS_T(s1, s2) = \frac{Length(LCS(s1, s2))}{Length(s1)}, \qquad (2)$$

Example

Input s1 = "Saving **names and** phone **numbers** (Add name)"
Sentence in the corpus s2 = "Erasing **names and numbers**"
$LCS(s1, s2) =$ "*names and numbers*"
$LCSS(s1, s2) = \frac{3}{9} - 0.01 * 1 = 0.323.$

Lin – EBMT: Alignment

- Uses GIZA++ results and the longest TL aligned subsequence are used

LCS: ”*technical regulations standards*”
Alignments

- ”*technical - tehnice*” (position 8 in TL),
- ”*regulations - reglementările*” (position 7 in TL) and
- ”*standards - standarde*” (position 23 in TL)

We use further the sequences: ”*reglementările tehnice*” and ”*standarde*”.

Lin – EBMT: Recombination

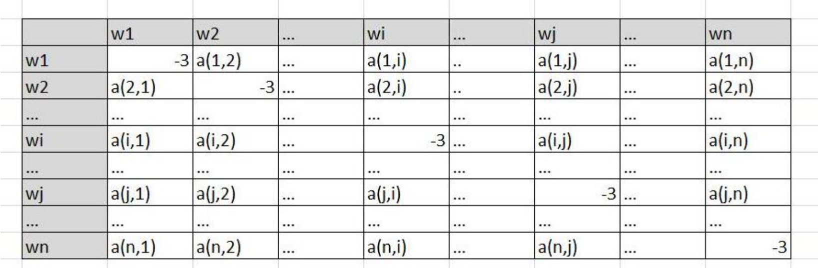
- Input the "*the bag of word sequences*" $\{w_1, w_2, ..., w_n\}$ provided by the alignment step
- The result is the needed translation.
- Uses a "**recombination matrix**"

The Recombination Matrix

Let $A = a(i, j)$ be the "*recombination matrix*". If the outcome of the alignment is n word-sequences $\{w_1, w_2, ..., w_n\}$ which form the output and are not necessarily different, with $w_i = w_{i_1} w_{i_2} ... w_{i_{last}}$, then A is a square matrix of order n that is defined as follows:

$$A = \begin{cases} -3, & \text{if } i = j; \\ -2, & \text{if } i <> j, \\ & w_{i_{last}} w_{j_1} \text{ is} \\ & \text{not in the} \\ & \text{corpus;} \\ \frac{2 * count(w_{i_{last}} w_{j_1})}{count(w_{i_{last}}) + count(w_{j_1})}, & \text{else.} \end{cases} \qquad (3)$$

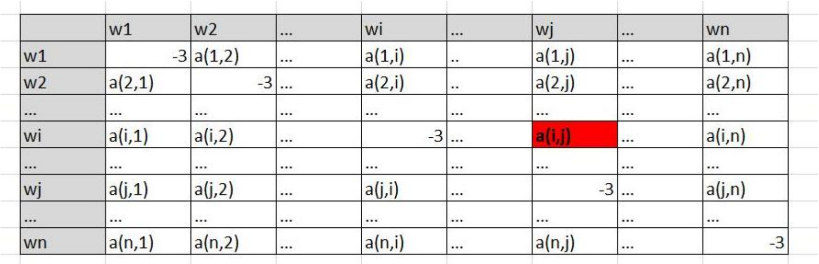
The Recombination Matrix - 2



	w1	w2	...	wi	...	wj	...	wn
w1	-3	a(1,2)	...	a(1,i)	..	a(1,j)	...	a(1,n)
w2	a(2,1)	-3	...	a(2,i)	..	a(2,j)	...	a(2,n)
...	...	...	...	...	...	...	...	...
wi	a(i,1)	a(i,2)	...	-3	...	a(i,j)	...	a(i,n)
...	...	...	...	...	...	...	...	...
wj	a(j,1)	a(j,2)	...	a(j,i)	...	-3	...	a(j,n)
...	...	...	...	...	...	...	...	...
wn	a(n,1)	a(n,2)	...	a(n,i)	...	a(n,j)	...	-3

w_i, $1 \leq i \leq n$, is a sequence.

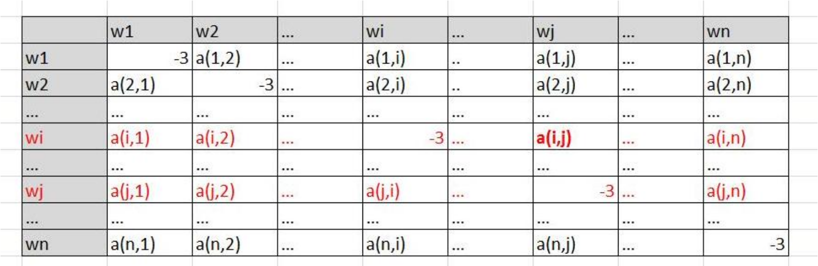
The Recombination Matrix - 2



	w1	w2	...	wi	...	wj	...	wn
w1	-3	a(1,2)	...	a(1,i)	..	a(1,j)	...	a(1,n)
w2	a(2,1)	-3	...	a(2,i)	..	a(2,j)	...	a(2,n)
...	...	...	...	...	...	...	...	...
wi	a(i,1)	a(i,2)	...	-3	...	**a(i,j)**	...	a(i,n)
...	...	...	...	...	...	...	...	...
wj	a(j,1)	a(j,2)	...	a(j,i)	...	-3	...	a(j,n)
...	...	...	...	...	...	...	...	...
wn	a(n,1)	a(n,2)	...	a(n,i)	...	a(n,j)	...	-3

w_i, $1 \leq i \leq n$, is a sequence.

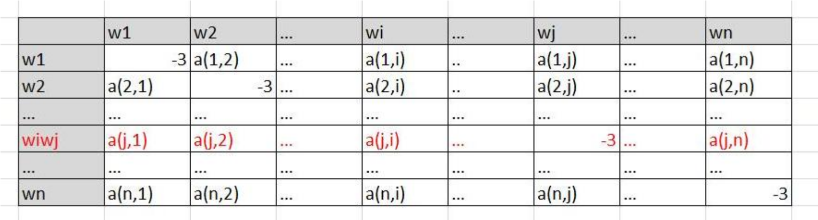
The Recombination Matrix - 2



	w1	w2	...	wi	...	wj	...	wn
w1	-3	a(1,2)	...	a(1,i)	..	a(1,j)	...	a(1,n)
w2	a(2,1)	-3	...	a(2,i)	..	a(2,j)	...	a(2,n)
...	...	...	...	...	...	...	...	...
wi	a(i,1)	a(i,2)	...	-3	...	**a(i,j)**	...	a(i,n)
...	...	...	...	...	...	...	...	...
wj	a(j,1)	a(j,2)	...	a(j,i)	...	-3	...	a(j,n)
...	...	...	...	...	...	...	...	...
wn	a(n,1)	a(n,2)	...	a(n,i)	...	a(n,j)	...	-3

w_i, $1 \leq i \leq n$, is a sequence.

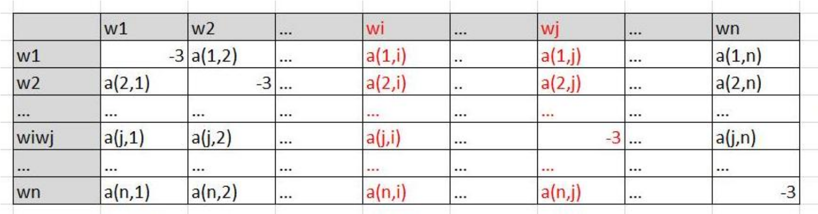
The Recombination Matrix - 2



	w1	w2	...	wi	...	wj	...	wn
w1	-3	a(1,2)	...	a(1,i)	..	a(1,j)	...	a(1,n)
w2	a(2,1)	-3	...	a(2,i)	..	a(2,j)	...	a(2,n)
...	...	...	...	...	...	...	...	...
wiwj	a(j,1)	a(j,2)	...	a(j,i)	...	-3	...	a(j,n)
...	...	...	...	...	...	...	...	...
wn	a(n,1)	a(n,2)	...	a(n,i)	...	a(n,j)	...	-3

w_i, $1 \leq i \leq n$, is a sequence.

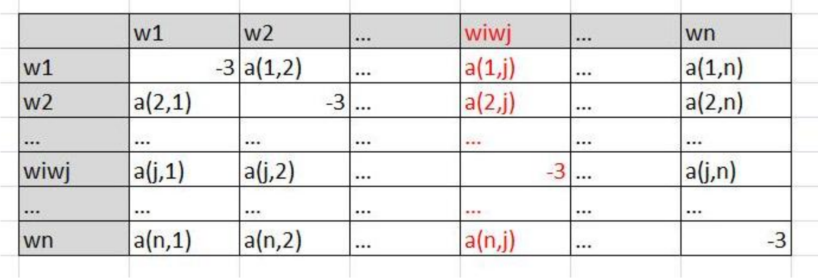
The Recombination Matrix - 2



	w1	w2	...	wi	...	wj	...	wn
w1	-3	a(1,2)	...	a(1,i)	..	a(1,j)	...	a(1,n)
w2	a(2,1)	-3	...	a(2,i)	..	a(2,j)	...	a(2,n)
...	...	...	...	...	...	...	...	...
wiwj	a(j,1)	a(j,2)	...	a(j,i)	...	-3	...	a(j,n)
...	...	...	...	...	...	...	...	...
wn	a(n,1)	a(n,2)	...	a(n,i)	...	a(n,j)	...	-3

w_i, $1 \leq i \leq n$, is a sequence.

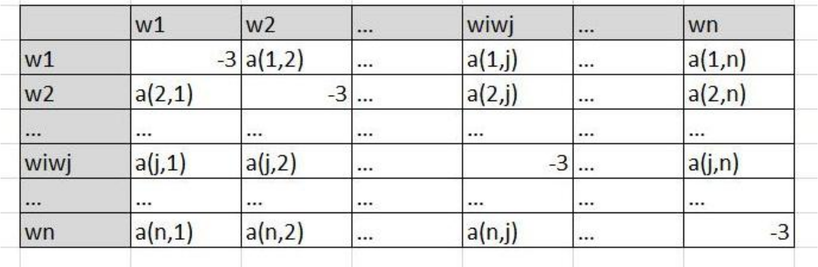
The Recombination Matrix - 2



	w1	w2	...	wiwj	...	wn
w1	-3	a(1,2)	...	a(1,j)	...	a(1,n)
w2	a(2,1)	-3	...	a(2,j)	...	a(2,n)
...	...	...	...	...	...	...
wiwj	a(j,1)	a(j,2)	...	-3	...	a(j,n)
...	...	...	...	...	...	...
wn	a(n,1)	a(n,2)	...	a(n,j)	...	-3

w_i, $1 \leq i \leq n$, is a sequence.

The Recombination Matrix - 2



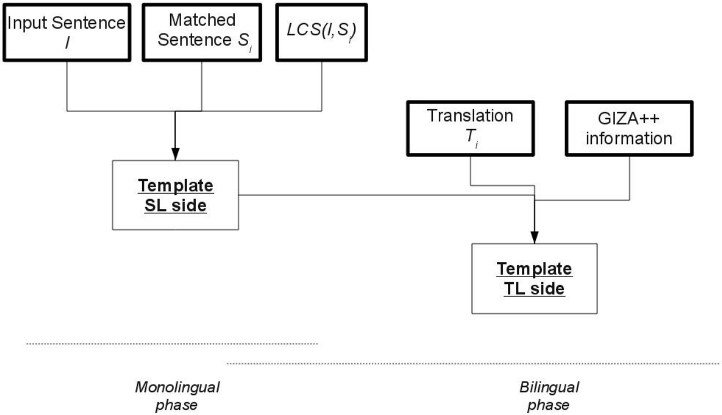
	w1	w2	...	wiwj	...	wn
w1	-3	a(1,2)	...	a(1,j)	...	a(1,n)
w2	a(2,1)	-3	...	a(2,j)	...	a(2,n)
...	...	...	...	...	...	...
wiwj	a(j,1)	a(j,2)	...	-3	...	a(j,n)
...	...	...	...	...	...	...
wn	a(n,1)	a(n,2)	...	a(n,j)	...	-3

w_i, $1 \leq i \leq n$, is a sequence.

$Lin - EBMT^{REC+}$

- Motivation: use the information which is lost in the recombination step of $Lin - EBMT$;
- Mixture of linear and template-based approach;
- Matching and alignment remain as in $Lin - EBMT$;
- Constraints are set on the values from the recombination matrix, by using information extracted from templates.

Template Extraction



$$((TF_{SL})^*(VAR_{SL})^*)^*TF_{SL}((TF_{SL})^*(VAR_{SL})^*)^* \leftrightarrow ((TF_{TL})^*(VAR_{TL})^*)^*$$

Template-Example

The input

press and hold clear to delete the characters more quickly .

Matched sentence and alignment

pentru a sterge simultan toate **caracterele** cand scrieti un mesaj , apasati optiuni si selectati stergeti textul .

to delete all **the characters** at once when writing a message press options and select clear text .

Template-Example

The input

press and hold clear to delete the characters more quickly .

Template

to&&1&& **delete&&2&&** VAR3 **the&&4&&** **characters&&5&&** VAR6 NOALIGN7 VAR8_18 .&&19&& ↔ **pentru&&1&&** **a&&1&&** **sterge&&2&&** VAR6 VAR3 **caracterele&&5&&** VAR8_18 .&&19&&

Constraints

1. **The First-Word-Constraint (C.1)**: A constraint C.1 refers to the first word of the output.
2. **TLSide-Template-Constraint (C.2)**: the C.2 constraints are deduced only from the TL side of each of the templates extracted.
3. **Whole-Template-Constraint (C.3)**: the C.3 constraints are extracted considering each of the templates, together with the input sentence, and the alignment information.

The result: a set $C = \{(word_i, word_j)\}$ of constraints: The sequence $word_i word_j$ is not allowed.

C.1 Constraints

The input

to delete the characters more quickly press and hold clear.

Template

to&&1&& **delete&&2&&** VAR3 **the&&4&&**
characters&&5&& VAR6 NOALIGN7 VAR8_18 **.&&19&&**
↔ **pentru&&1&&** **a&&1&&** **sterge&&2&&** VAR6 VAR3
caracterele&&5&& VAR8_18 **.&&19&&**

C.2 Constraints

Template

to&&1&& **delete&&2&&** VAR3 **the&&4&&** **characters&&5&&** VAR6 NOALIGN7 VAR8_18 **.&&19&&** ↔ **pentru&&1&&** **a&&1&&** **sterge&&2&&** VAR6 VAR3 **caracterele&&5&&** VAR8_18 **.&&19&&**

New Recombination Matrix

$$A = \begin{cases} -3, & \text{if } i = j; \\ -2, & \text{if } i <> j, \\ & w_{i_{last}} w_{j_1} \text{ is not in} \\ & \text{the corpus or} \\ & (w_{i_{last}} w_{j_1}) \in C; \\ \frac{2 * count(w_{i_{last}} w_{j_1})}{count(w_{i_{last}}) + count(w_{j_1})}, & \text{else.} \end{cases} \quad (4)$$

Another Recombination Matrix

$$A = \begin{cases} -3, & \text{if } i = j; \\ -1, & \text{if } i <> j, \\ & w_{i_{last}} w_{j_1} \text{ is not in} \\ & \text{the corpus;} \\ -2, & (w_{i_{last}} w_{j_1}) \in C; \\ \frac{2 * count(w_{i_{last}} w_{j_1})}{count(w_{i_{last}}) + count(w_{j_1})}, & \text{else.} \end{cases} \tag{5}$$

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1. The Framework
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The Experimental Settings

- 2 EBMT systems: $Lin - EBMT$, $Lin - EBMT^{REC+}$
- 2 language pairs, both directions of translations: English-Romanian, German-Romanian
- 1 corpus: RoGER

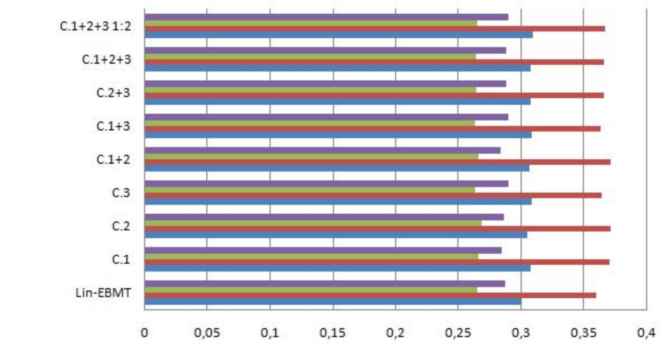
The Corpus: RoGER

- Developed between 2005 and 2006, at the University of Hamburg, NatS, together with Natalia Eliţa
- Romanian, German, English, Russian
- Manual of an electronic device
- 2333 sentences, between 25K and 27K words
- Manually verified
- No diacritics, some data replaced with meta-notations

Experimental Setting

- Training: 2200 sentences, approx 27 K items, 13 words the average sentence length
- Test: 133 sentences, approx 1.6 K items, 12.3 words the average sentence length

BLEU (Papineni et al., 2002) Scores



	Lin-EBMT	C.1	C.2	C.3	C.1+2	C.1+3	C.2+3	C.1+2+3	C.1+2+3 1:2
🟪 Romanian-German	0,2867	0,2842	0,2857	0,2891	0,2836	0,2891	0,2875	0,2875	0,2894
🟩 German-Romanian	0,2643	0,2658	0,2682	0,2627	0,2654	0,2627	0,2633	0,2633	0,2646
🟥 Romanian-English	0,3597	0,3695	0,3711	0,3633	0,3712	0,3632	0,3656	0,3656	0,3668
🟦 English-Romanian	0,2997	0,3067	0,3042	0,3083	0,3062	0,3083	0,3073	0,3073	0,3085

Evaluation

Best Score Differences:

- English-Romanian: 0.0088
- Romanian-English: 0.0115
- German-Romanian: 0.0039
- Romanian-German: 0.0027

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Conclusions & Further Work

- Impact of word-order constraints

Further work:

- Additional constraints;
- Priorities for the constraints are used (weighting);
- Different corpus and languages;
- Manual analysis of the data;
- N-grams of several lengths etc.

Discussions

Thank you for your attention!

Suggestions ... Questions ...