Confidence-based Rewriting of Machine Translation Output

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Introduction

- Phrase-Based Statisical Machine Translation (PBSMT) systems use many features during decoding to assess the quality of translation hypotheses
- For other features, several difficulties of integration to overcome, e.g. :
  - **need of a complete hypothesis**
    e.g. sentence-level syntactic features
  - **computational cost**
    e.g. Neural Network language models
  - **need of a first decoding**
    e.g. *a posteriori* confidence models
- How to use such features *efficiently* in PBSMT ?

Reranking of translation hypotheses

A solution

- rerank the *n*-best list of the decoder using new, complex features
- can achieve good performance with some features
  (Och et al., 2004; Carter and Monz, 2011; Le et al., 2012; Luong et al., 2014)

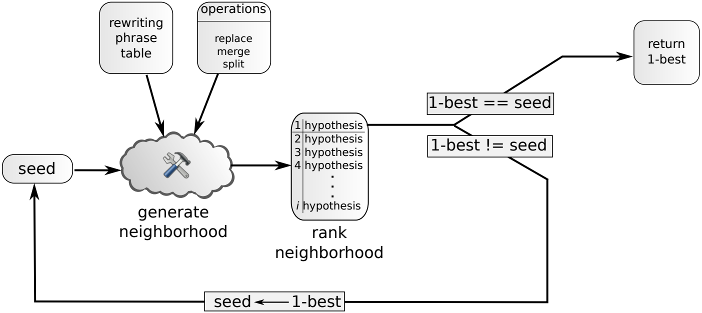
2 strong limitations

- lack of diversity (Gimpel et al., 2013)
- inherit a limited selection of hypotheses made by the decoder

A rewriting system

A `rewriter` to extend the exploration

- idea: search for new promising hypotheses **not** in the *n*-best list

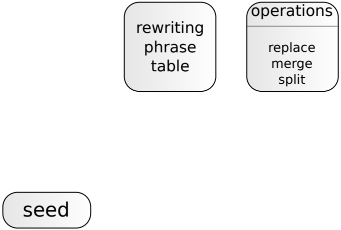


The seed: an hypothesis to rewrite

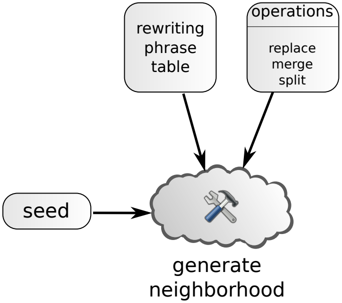
seed

A rewriting phrase table

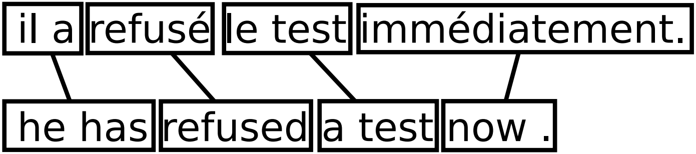
A set of rewriting operations



Neighborhood generation



Neighborhood generation : `replace`



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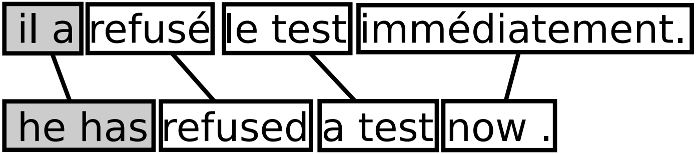


Neighborhood generation : `replace`

il a | refusé | le test | immédiatement.

he has | refused | a test | now .

he has refused a test now .

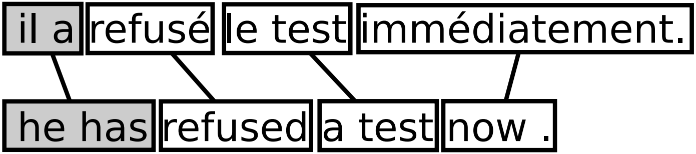
he refused a test now .

he had refused a test now .

it has refused a test now .

it refused a test now .

Neighborhood generation : `split`



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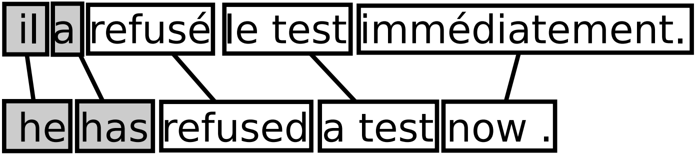

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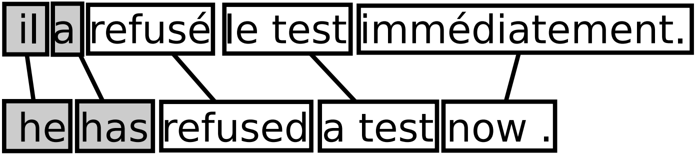
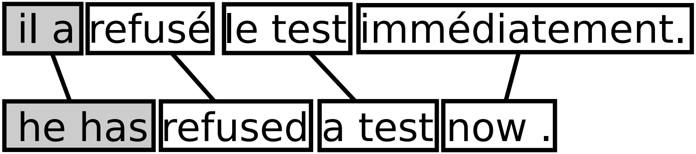


he has refused a test now .
he is refused a test now .
he had refused a test now .
it has refused a test now .
it have refused a test now .

Neighborhood generation : `merge`



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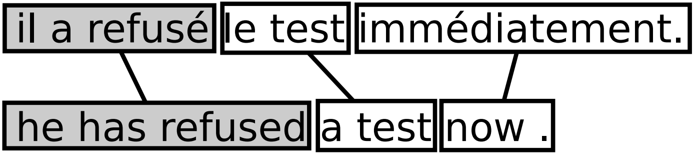


Neighborhood generation : `merge`

il a refusé | le test | immédiatement.

he has refused | a test | now .

he has refused a test now .

he refused a test now .

he rejected a test now .

he has just refused a test now .

he has a test now .

Rewriting phrase table

Building the rewriting table

- **Method 1**: take the *i* **best translations** according to $\mathbf{p(e|f)}$
- **Method 2**: take the **bi-phrases appearing in the decoder *k*-best list**

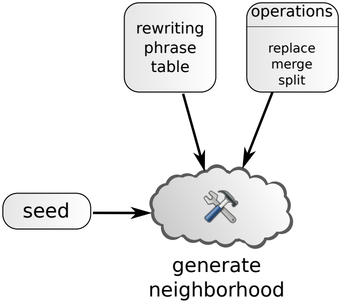
Method 1

- produces very large neighborhoods
- not suitable for costly features

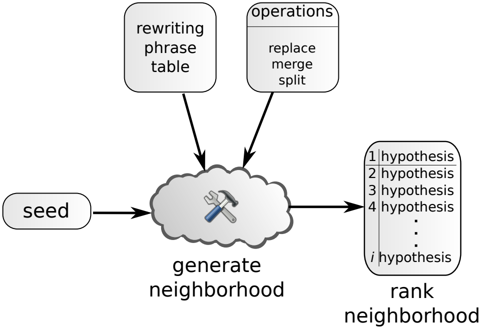
Method 2

- produces **very small** and **adapted** rewriting phrase table for **each sentence**
- keeps only bi-phrases for which the decoder was **the most confident**

Neighborhood generation



Ranking of the neighborhood



Ranking of the neighborhood

Objective

- rank (manageable) neighborhoods using complex features

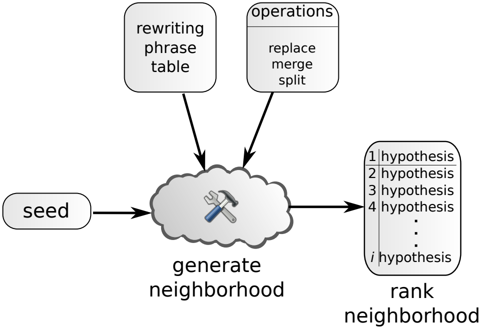
Training the reranker: 2 kinds of examples

- *n*-best produced by the decoder
- neighborhoods produced by one iteration of `rewriter`

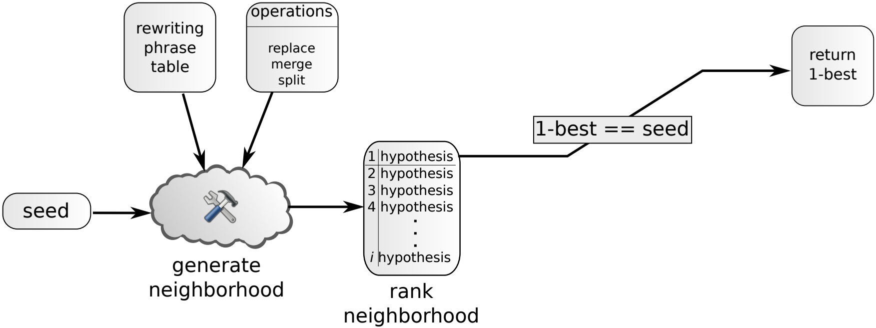
Training algorithm

- `kb-mira` (Cherry and Foster, 2012)

Ranking of the neighborhood



Greedy search



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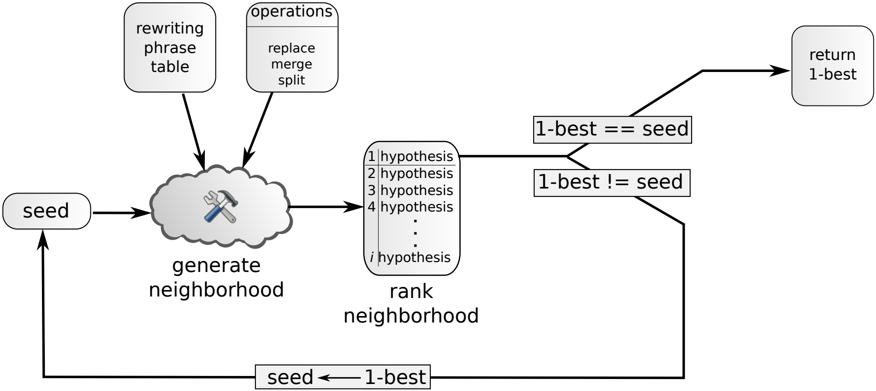

Greedy search

- greedy search algorithm for PBSMT (Langlais et al., 2007)
  - choose at each iteration the best rewriting/operation according to the (new) scoring function

Source	il a refusé le test immédiatement .
Reference	he refused the test straight away .
seed	$\boxed{\text{il a}_1}$ $\boxed{\text{refusé}_2}$ $\boxed{\text{le test}_3}$ $\boxed{\text{immédiatement .}_4}$
↓	$\boxed{\text{he has}_1}$ $\boxed{\text{refused}_2}$ $\boxed{\text{a test}_3}$ $\boxed{\text{now .}_4}$

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↓	$\boxed{\text{he has}_1}$ $\boxed{\text{refused}_2}$ $\boxed{\text{a test}_3}$ $\boxed{\text{now .}_4}$
`merge`	$\boxed{\text{il a refusé}_1}$ $\boxed{\text{le test}_2}$ $\boxed{\text{immédiatement .}_3}$
iteration 1	$\boxed{\text{he refused}_1}$ $\boxed{\text{a test}_2}$ $\boxed{\text{now .}_3}$

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Source	il a refusé le test immédiatement .
Reference	he refused the test straight away .
seed	[il a]$_1$ [refusé]$_2$ [le test]$_3$ [immédiatement .]$_4$
↓	[he has]$_1$ [refused]$_2$ [a test]$_3$ [now .]$_4$
`merge`	[il a refusé]$_1$ [le test]$_2$ [immédiatement .]$_3$
iteration 1	[he refused]$_1$ [a test]$_2$ [now .]$_3$
`split`	[il a refusé]$_1$ [le test]$_2$ [immédiatement]$_3$ [.]$_4$
iteration 2	[he refused]$_1$ [a test]$_2$ [straight away]$_3$ [.]$_4$

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Source	il a refusé le test immédiatement .
Reference	he refused the test straight away .
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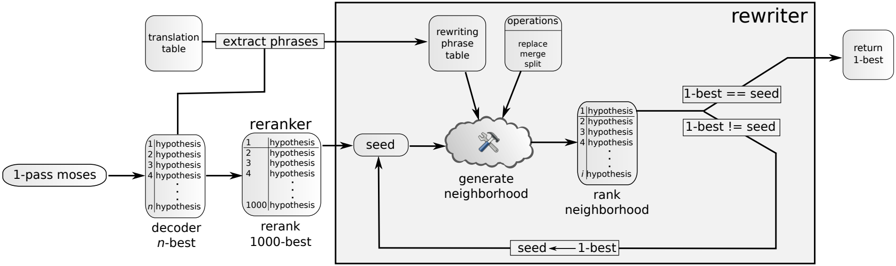
iteration 2	$\boxed{\text{he refused}_1}$ $\boxed{\text{a test}_2}$ $\boxed{\text{straight away}_3}$ $\boxed{\text{.}_4}$
`replace`	$\boxed{\text{il a refusé}_1}$ $\boxed{\text{le test}_2}$ $\boxed{\text{immédiatement}_3}$ $\boxed{\text{.}_4}$
iteration 3	$\boxed{\text{he refused}_1}$ $\boxed{\text{the test}_2}$ $\boxed{\text{straight away}_3}$ $\boxed{\text{.}_4}$

Experiments

The whole framework



Experimental settings

- **translation tasks**: English↔French
  - `Ted Talks`
  - `WMT'14 medical`
  - `WMT'12`
- **baseline systems**
  - `Moses` PBSMT (Koehn et al., 2007)
  - `kb-mira` reranker using all the features below
- **features**
  - decoder features : all the features used by the 1st-pass decoder
  - neural network models : 10-gram monolingual (Le et al., 2011) and bilingual (Le et al., 2012) `SOUL` models
  - Part-of-speech language model: 6-gram model
  - IBM1 scores
  - phrase posterior probabilities

Results

Task	system	en-fr BLEU	en-fr Δ	fr-en BLEU	fr-en Δ
WMT'12	1-pass Moses	31.8		29.4	
	reranker	32.9	+1.1	30.3	+0.9
TED Talks	1-pass Moses	32.3		32.5	
	reranker	32.8	+0.5	33.0	+0.5
WMT'14 medical	1-pass Moses	38.3			
	reranker	41.8	+3.5		

⇒ moderate (TED Talks) to strong (medical) improvements with reranker over the 1st-pass decoder

Results

Task	system	en-fr BLEU	en-fr Δ	fr-en BLEU	fr-en Δ
WMT'12	1-pass Moses	31.8		29.4	
	reranker	32.9	+1.1	30.3	+0.9
	rewriter	33.5	+1.7	30.8	+1.4
TED Talks	1-pass Moses	32.3		32.5	
	reranker	32.8	+0.5	33.0	+0.5
	rewriter	33.7	+1.4	33.4	+0.9
WMT'14 medical	1-pass Moses	38.3			
	reranker	41.8	+3.5		
	rewriter	43.4	+5.1		

$\Rightarrow$ `rewriter` increases by ∼50% the `reranker` improvement

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Task	system	en-fr BLEU	en-fr Δ	fr-en BLEU	fr-en Δ
WMT'12	1-pass Moses	31.8		29.4	
	reranker	32.9		30.3	
	rewriter	33.5	+0.6	30.8	+0.5
TED Talks	1-pass Moses	32.3		32.5	
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WMT'14 medical	1-pass Moses	38.3			
	reranker	41.8			
	rewriter	43.4	+1.6		

⇒ `rewriter` increases by ∼50% the `reranker` improvement

Analysis: outline

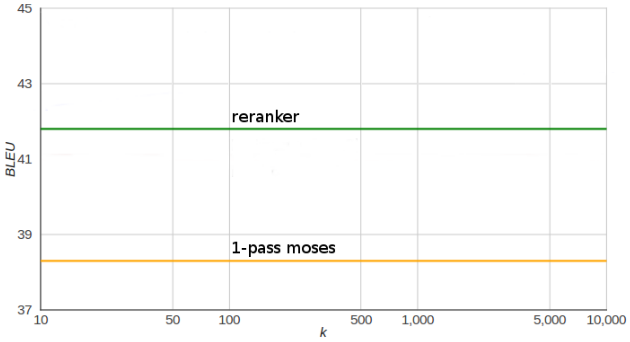
1. training procedure
2. rewriting phrase table
3. best attainable performance
4. performance depending on translation quality
5. sentence-level performance
6. other findings

Training examples

	dev BLEU	test BLEU	Δ
`reranker`	44.1	41.8	
`rewriter` training			
`1-pass Moses` 1,000-best	44.1	39.2	-2.6
`rewriter` neighborhoods	44.5	**43.4**	**+1.6**

⇒ `rewriter` **must** be trained on `rewriter` neighborhoods

Rewriting phrase table performance



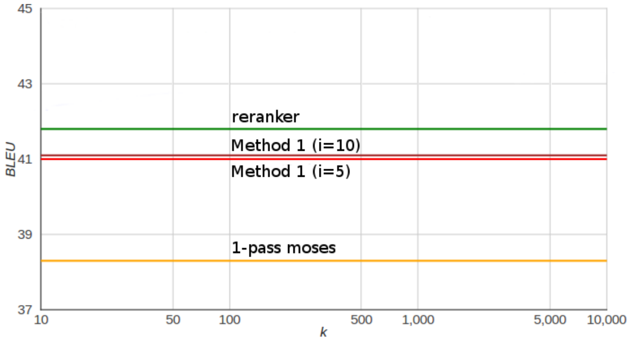
Method 1: extraction according to $p(e|f)$

- damages `reranker` output

Method 2: extraction from a k-best list

- improvements for all tested k, even for small values (best for k = 10,000)

Rewriting phrase table performance



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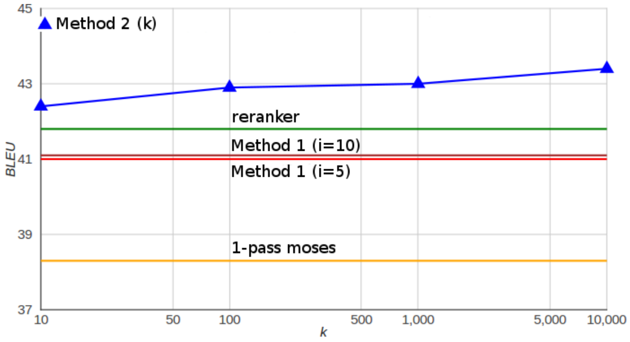

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- damages `reranker` output

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- improvements for all tested k, even for small values (best for k = 10,000)

Rewriting phrase table size

rewriting phrase table		unique bi-phrases	Δ-BLEU w.r.t. `reranker`
Method 1	i = 5	85,530	-0.8
	i = 10	149,887	-0.7
Method 2	k = 10	21,398	+0.6
	k = 100	28,730	+1.1
	k = 1,000	33,929	+1.2
	k = 10,000	38,455	+1.6

- compact phrase tables when extracted from k-best lists (Method 2)
- much larger when extracted according to $p(e|f)$ (Method 1)

Best attainable performance

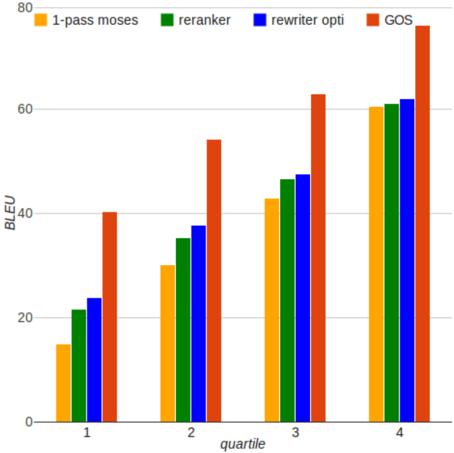
- Greedy Oracle Search (GOS) (Marie and Max, 2013)
  - make the best local decision at each iteration
  - use sentence-BLEU as scoring function

baseline		test BLEU	Δ
`reranker`		41.8	
rewriting phrase table			
method 1	i = 5	50.6	+8.8
	i = 10	54.5	+12.7
method 2	k = 10	45.9	+4.1
	k = 100	50.2	+8.4
	k = 1,000	53.3	+11.5
	k = 10,000	**58.7**	+16.9

⇒ strong oracle improvements, even for compact rewriting tables

⇒ extracting from k-best lists much more promising

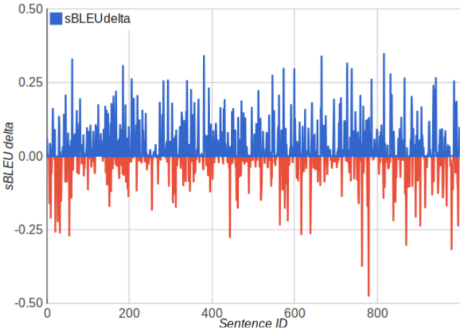
Performance depending on translation quality



- `rewriter` improvement :
  - quartile 4 : +1.4 BLEU
  - quartile 1 : +9.0 BLEU

⇒ larger improvements on bad/difficult translations

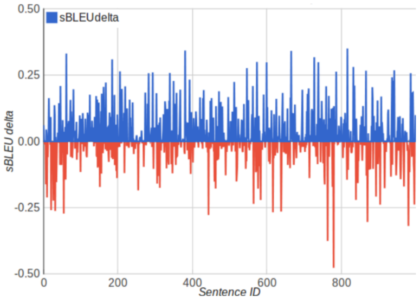
Sentence-level performance



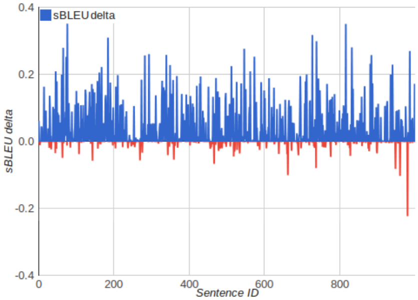
- according to sentence-BLEU, after rewriting :
  - 40.8% better
  - 29.2% worse
  - 30% unchanged

⇒ large room for further improvement

Sentence-level performance: semi-oracle experiment



(a) automatic rewriting



(b) semi-oracle rewriting

- protecting the phrases appearing in the reference translation: +1.5 BLEU

⇒ strong value of better confidence estimates

Other findings

1. 70% of **new** hypotheses **not** in `1-pass Moses` 1,000-best
2. on average (only) 116 hypotheses per sentence in the neighborhood
3. searching using a **beam** of size 10: 1.6 $\rightarrow$ 1.9 BLEU
4. manual evaluation revealed both **fluency** and **accuracy** improvements

Conclusion

- an **efficient** and **simple** procedure to make a **better use of features** difficult to integrate during decoding
- **produces useful hypotheses not in the decoder *n*-best list**
- relies on the **decoder confidence** to extract the rewriting rules
- improvements on **3 different tasks** and **2 language directions** over a reranked baseline **using the same features**

Future work

- exploit more features : lexical-coherence (Hardmeier et al., 2012), syntactic features (Post, 2011), word posterior probabiliy (Ueffing and Ney, 2007), etc.
- identify correct phrases to protect them from rewriting
- adapt `rewriter`'s objective function to the sentence
- use a `paraphrase` operation rewriting the source sentence to produce new target phrases (Marie and Max, 2013)
- use automatic alternative reference translations (Madnani and Dorr, 2013)
- use `rewriter` in interaction with human translators

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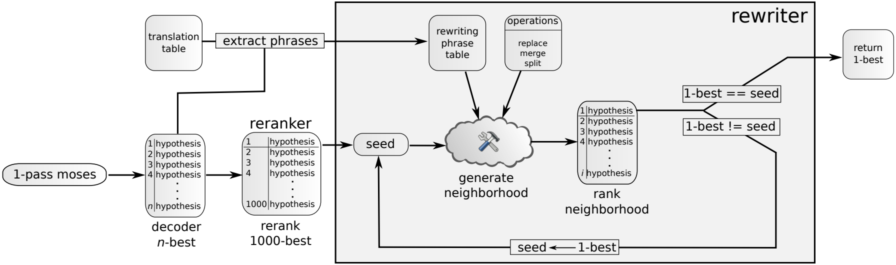
Thanks for listening !
Questions ?



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Benjamin Marie & Aurélien Max

emnlp$_{2014}$

Carter, S. and Monz, C. (2011). Syntactic discriminative language model rerankers for statistical machine translation. Machine Translation.

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