Machine Translation
Phrase Models

Philipp Koehn, University of Edinburgh

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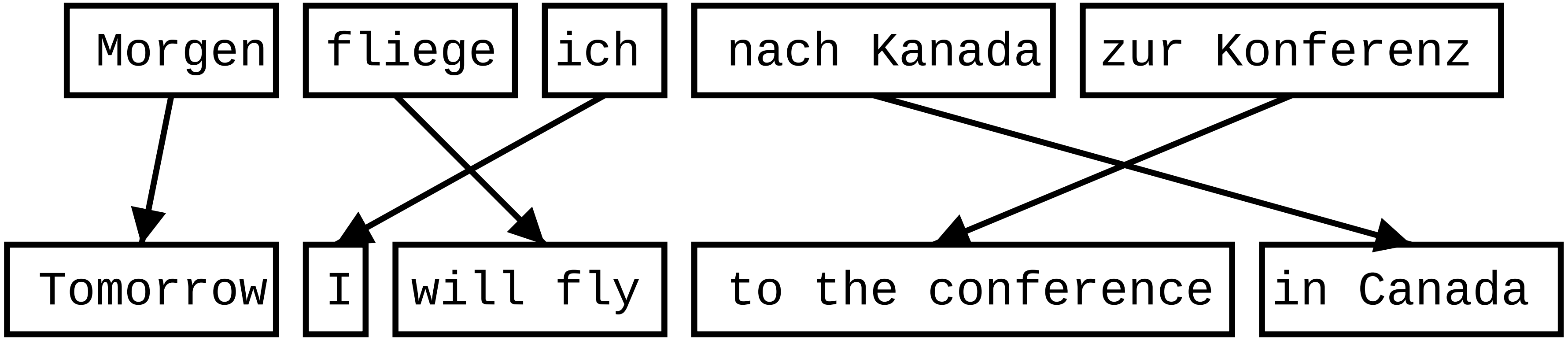
School of informatics

Phrase-based translation



- Foreign input is segmented in phrases
  - any sequence of words, not necessarily linguistically motivated
- Each phrase is translated into English
- Phrases are reordered

Phrase-based translation model

- Major components of phrase-based model
  - **phrase translation model** $\phi(\mathbf{f}|\mathbf{e})$
  - **reordering model** $\Omega(\mathbf{f}|\mathbf{e})$
  - **language model** $p_{\text{LM}}(\mathbf{e})$
- Bayes rule

$$\begin{aligned} \text{argmax}_{\mathbf{e}} p(\mathbf{e}|\mathbf{f}) &= \text{argmax}_{\mathbf{e}} p(\mathbf{f}|\mathbf{e}) p(\mathbf{e}) \\ &= \text{argmax}_{\mathbf{e}} \phi(\mathbf{f}|\mathbf{e})\ p_{\text{LM}}(\mathbf{e})\ \Omega(\mathbf{f}|\mathbf{e}) \end{aligned}$$

- Sentence $\mathbf{f}$ is decomposed into I phrases $\bar{f}_1^I = \bar{f}_1, ..., \bar{f}_I$
- Decomposition of $\phi(\mathbf{f}|\mathbf{e})$

$$\phi(\bar{f}_1^I|\bar{e}_1^I) = \prod_{i=1}^{I} \phi(\bar{f}_i|\bar{e}_i)\ \omega^{d(\text{start}_i - \text{end}_{i-1} - 1)})$$

Advantages of phrase-based translation

- *Many-to-many* translation can handle non-compositional phrases
- Use of *local context* in translation
- The more data, the *longer phrases* can be learned

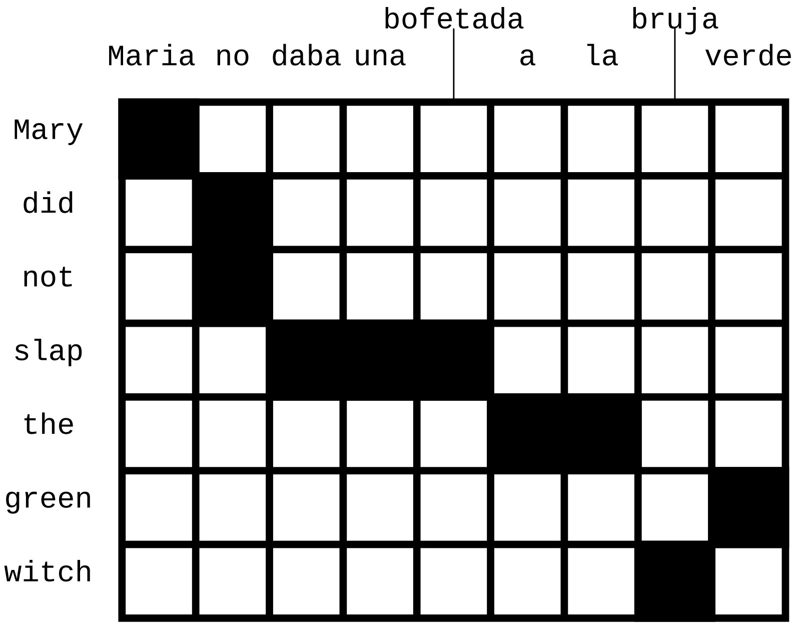
Phrase translation table

- Phrase translations for *den Vorschlag*

English	ϕ**(e|f)**	**English**	ϕ**(e|f)**
the proposal	0.6227	the suggestions	0.0114
's proposal	0.1068	the proposed	0.0114
a proposal	0.0341	the motion	0.0091
the idea	0.0250	the idea of	0.0091
this proposal	0.0227	the proposal ,	0.0068
proposal	0.0205	its proposal	0.0068
of the proposal	0.0159	it	0.0068
the proposals	0.0159	...	...

How to learn the phrase translation table?

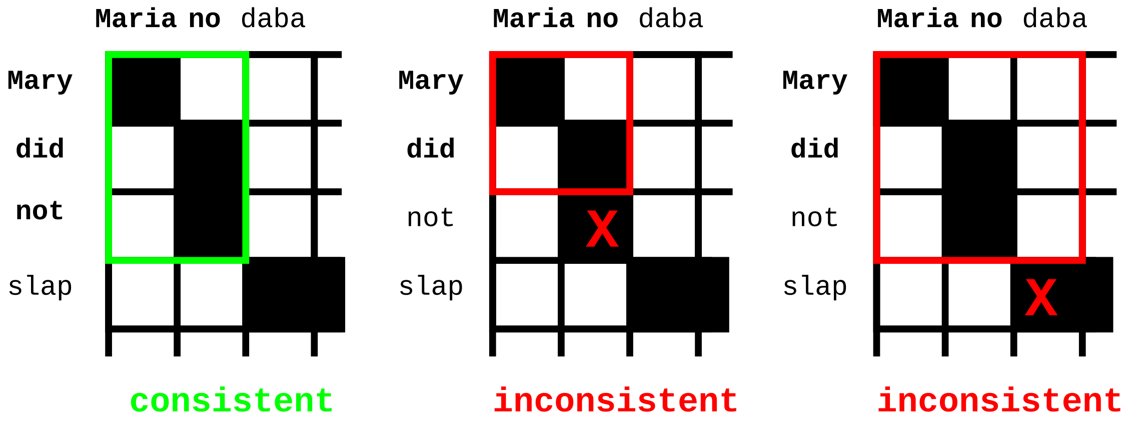
- Start with the *word alignment*:



	Maria	no	daba	una	bofetada	a	la	bruja	verde
Mary	■								
did		■							
not		■							
slap			■	■	■				
the						■	■		
green									■
witch								■	

- Collect all phrase pairs that are **consistent** with the word alignment

Consistent with word alignment

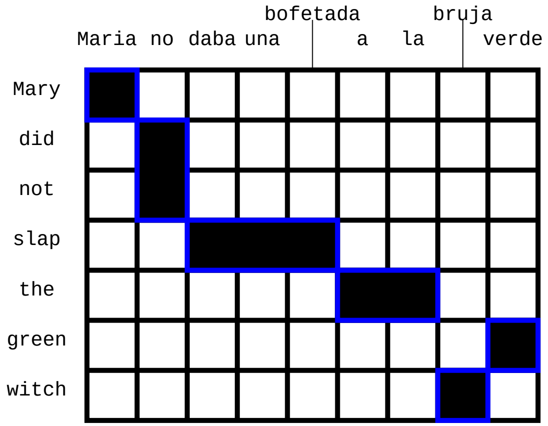


- **Consistent with the word alignment** :=

  phrase alignment has to *contain all alignment points* for all covered words

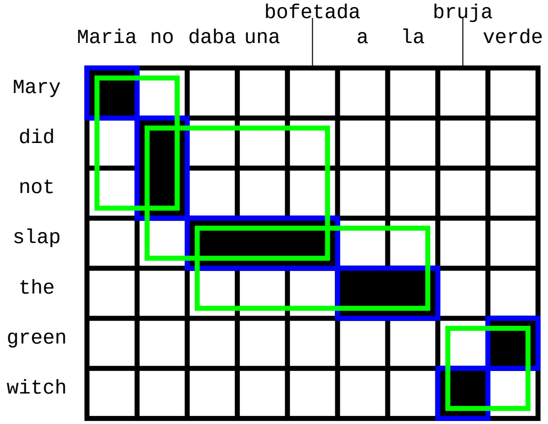
$$
\begin{aligned}
(\bar{e}, \bar{f}) \in BP \Leftrightarrow \quad & \forall e_i \in \bar{e} : (e_i, f_j) \in A \rightarrow f_j \in \bar{f} \\
\text{AND} \quad & \forall f_j \in \bar{f} : (e_i, f_j) \in A \rightarrow e_i \in \bar{e}
\end{aligned}
$$

Word alignment induced phrases



(Maria, Mary), (no, did not), (slap, daba una bofetada), (a la, the), (bruja, witch), (verde, green)

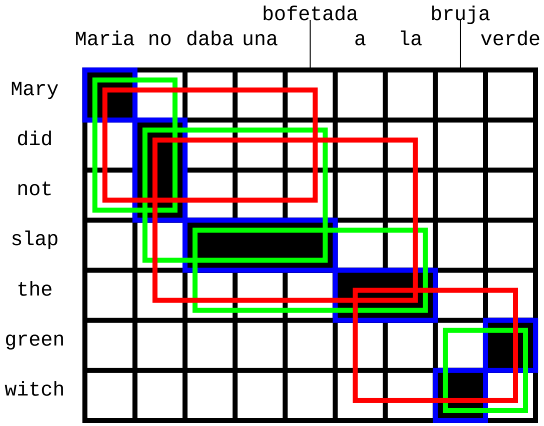
Word alignment induced phrases



(Maria, Mary), (no, did not), (slap, daba una bofetada), (a la, the), (bruja, witch), (verde, green),

(Maria no, Mary did not), (no daba una bofetada, did not slap), (daba una bofetada a la, slap the), (bruja verde, green witch)

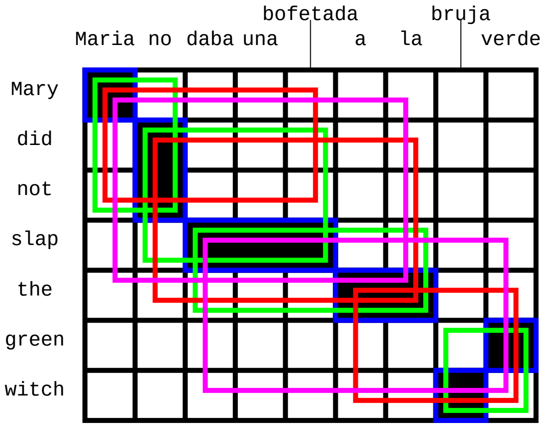
Word alignment induced phrases



(Maria, Mary), (no, did not), (slap, daba una bofetada), (a la, the), (bruja, witch), (verde, green),

(Maria no, Mary did not), (no daba una bofetada, did not slap), (daba una bofetada a la, slap the),
(bruja verde, green witch), (Maria no daba una bofetada, Mary did not slap),
(no daba una bofetada a la, did not slap the), (a la bruja verde, the green witch)

Word alignment induced phrases



(Maria, Mary), (no, did not), (slap, daba una bofetada), (a la, the), (bruja, witch), (verde, green),

(Maria no, Mary did not), (no daba una bofetada, did not slap), (daba una bofetada a la, slap the),

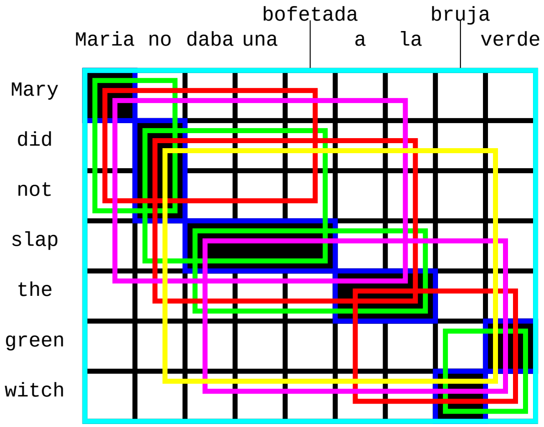
(bruja verde, green witch), (Maria no daba una bofetada, Mary did not slap),

(no daba una bofetada a la, did not slap the), (a la bruja verde, the green witch),

(Maria no daba una bofetada a la, Mary did not slap the),

(daba una bofetada a la bruja verde, slap the green witch)

Word alignment induced phrases (5)



(Maria, Mary), (no, did not), (slap, daba una bofetada), (a la, the), (bruja, witch), (verde, green),

(Maria no, Mary did not), (no daba una bofetada, did not slap), (daba una bofetada a la, slap the), (bruja verde, green witch), (Maria no daba una bofetada, Mary did not slap), (no daba una bofetada a la, did not slap the), (a la bruja verde, the green witch),

(Maria no daba una bofetada a la, Mary did not slap the), (daba una bofetada a la bruja verde, slap the green witch), (no daba una bofetada a la bruja verde, did not slap the green witch),

(Maria no daba una bofetada a la bruja verde, Mary did not slap the green witch)

Probability distribution of phrase pairs

- We need a **probability distribution** $\phi(\bar{f}|\bar{e})$ over the collected phrase pairs

⇒ Possible *choices*

- *relative frequency* of collected phrases: $\phi(\bar{f}|\bar{e}) = \frac{\text{count}(\bar{f},\bar{e})}{\sum_{\bar{f}} \text{count}(\bar{f},\bar{e})}$
- or, conversely $\phi(\bar{e}|\bar{f})$
- use *lexical translation probabilities*

Reordering

- *Monotone* translation
  - do not allow any reordering

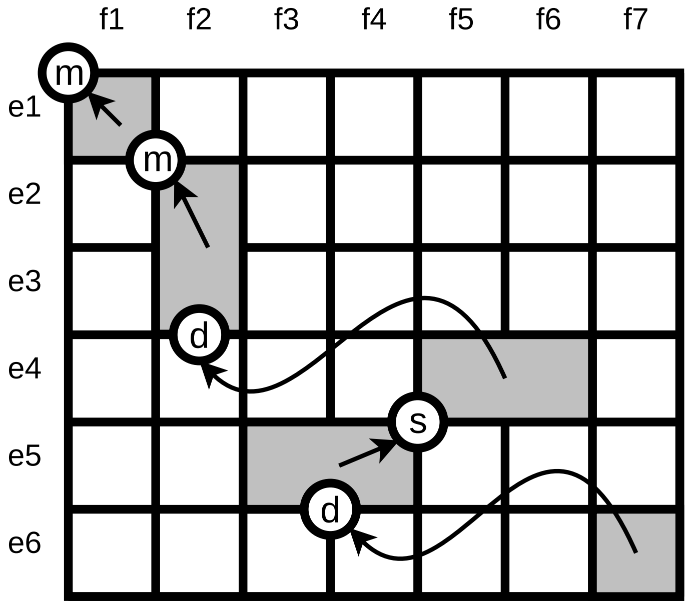
  → worse translations

- *Limiting* reordering (to movement over max. number of words) helps

- *Distance-based* reordering cost
  - moving a foreign phrase over n words: cost ω^n

- *Lexicalized* reordering model

Lexicalized reordering models

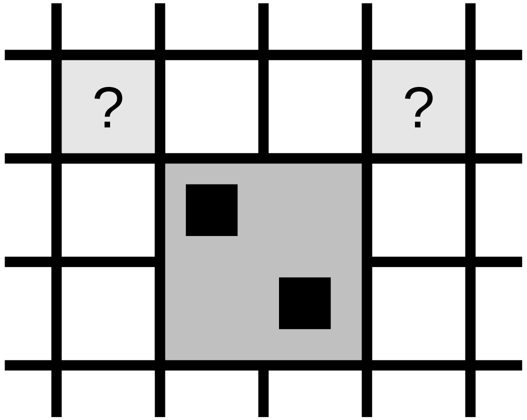


[from Koehn et al., 2005, IWSLT]

- Three **orientation** types: **monotone**, **swap**, **discontinuous**

- Probability $p(swap|e,f)$ depends on foreign (and English) *phrase* involved

Learning lexicalized reordering models



[from Koehn et al., 2005, IWSLT]

- Orientation type is *learned during phrase extractions*
- *Alignment point* to the *top left* (monotone) or *top right* (swap)?
- For more, see [Tillmann, 2003] or [Koehn et al., 2005]

Names and Numbers

- All word tokens are treated the same
- Names and numbers pose special problems
  - there are many different names and numbers
  - if input and output use different scripts, translation is not easy
- Name translation is hard
  - names may not have a properly defined spelling in non-native scripts
  - training data is not always easy to come by
  - treated as special **transliteration** problem

XML Markup

```
Er erzielte <NUMBER english='17.55'>17,55</NUMBER> Punkte .
```

- *Add additional translation options*
  - number translation
  - name translation

- Additional options
  - provide multiple translations
  - provide probability distribution along with translations
  - allow bypassing of provided translations