Hierarchical Machine Translation

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Content

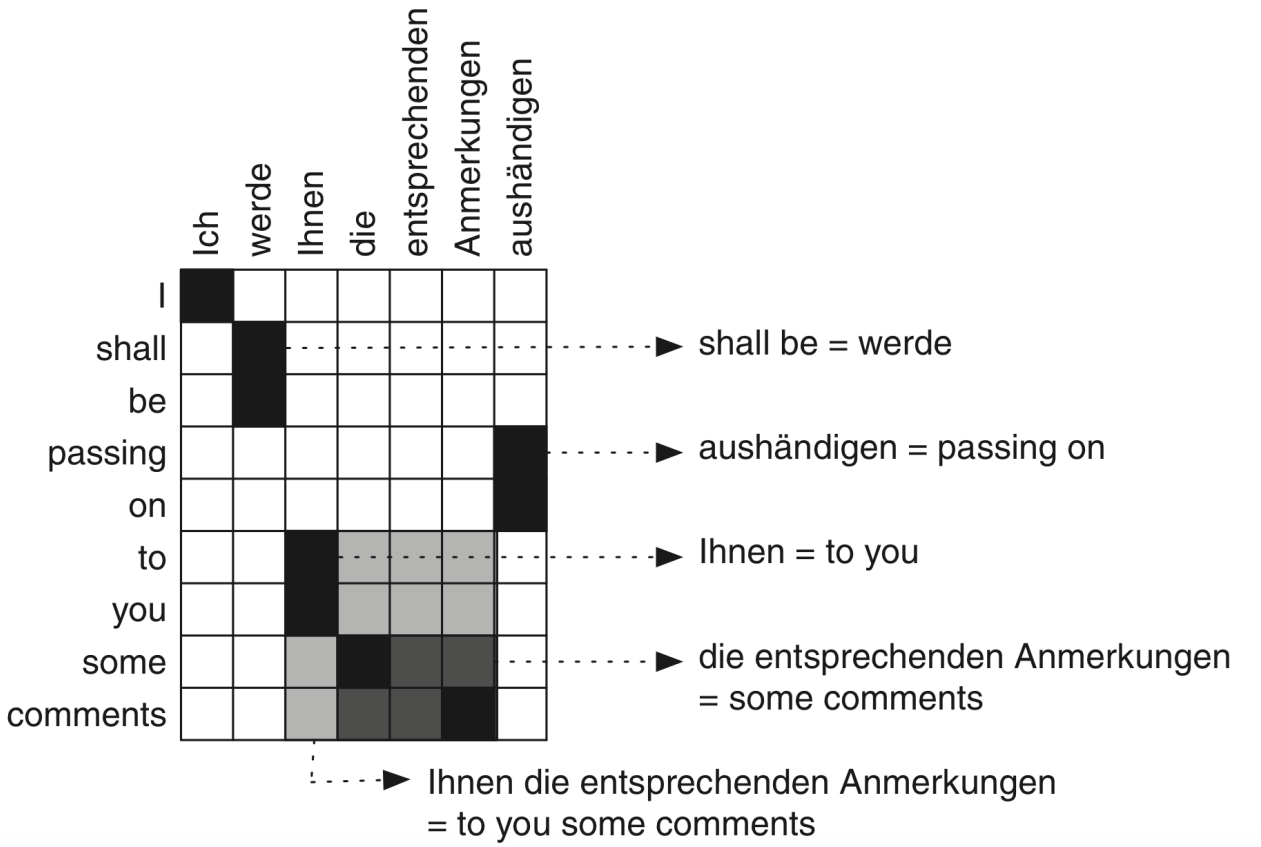

Figure: Koehn [2010]

werde X aushändigen | shall be passing on X

Why hierarchical structure?

Better generalisation

- compositionality
- reordering

Why is reordering important?

Monotone translation is unrealistic

- languages differ wrt word-order

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- languages differ wrt word-order
  e.g. different syntactic structure

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  e.g. rich morphology

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Reordering is arguably one of the hardest problems in MT

Why is reordering important?

Monotone translation is unrealistic

- languages differ wrt word-order
  e.g. different syntactic structure
  e.g. rich morphology

Reordering is arguably one of the hardest problems in MT

- part of the model of translational equivalences
  the part that determines the space of translations

Key aspects

Expressiveness

- how much can two languages differ wrt word order?

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Expressiveness

- how much can two languages differ wrt word order?

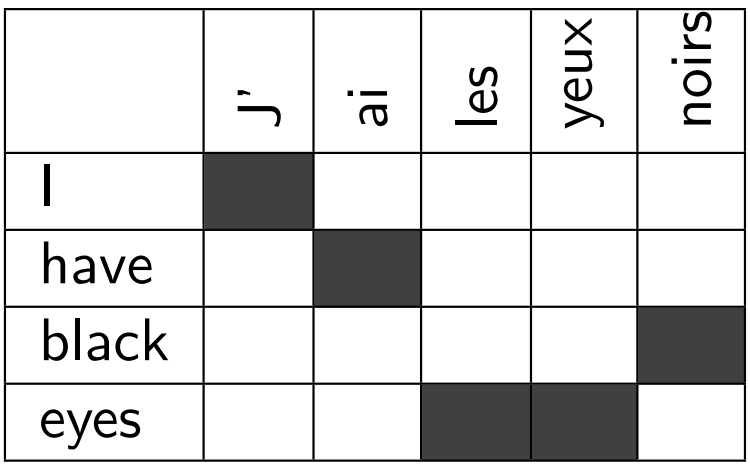
Modelling

- how many parameters do we have to estimate?

Content

Hierarchical phrase-based - Motivation

Local Reordering



Hierarchical phrase-based - Motivation

Local Reordering

	J'	ai	les	yeux	noirs
I	■				
have		■			
black					■
eyes			■	■	

- Monotone
  J'$_1$ ai$_2$ $\rightarrow$ I$_1$ have$_2$

Hierarchical phrase-based - Motivation

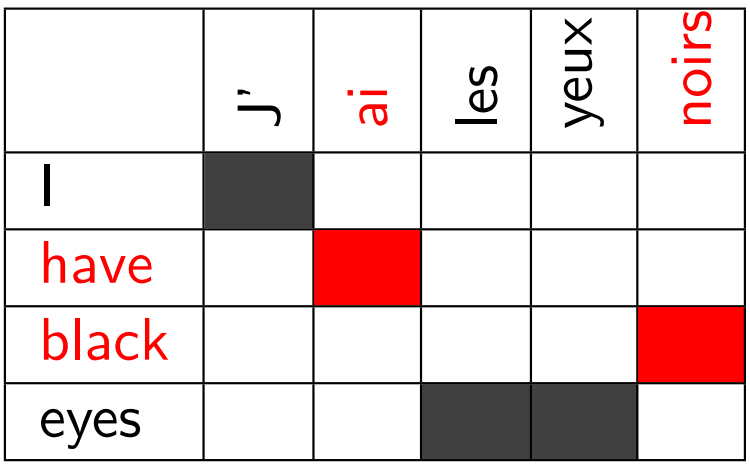
Local Reordering

	j'	ai	les	yeux	noirs
I	■				
have		■			
black					■
eyes			■	■	

- Swap
  les yeux$_4$ noirs$_5$ $\rightarrow$ black$_3$ eyes$_4$

Hierarchical phrase-based - Motivation

Local Reordering



- Discontinuous
  ai$_2$ X_{3-4} noirs$_5$ $\rightarrow$ have$_2$ black$_3$ X_4

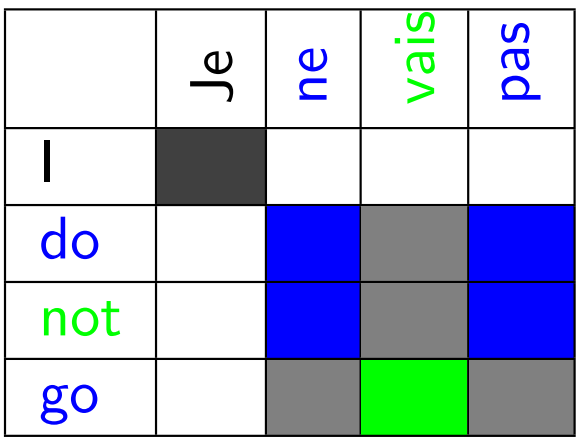
Hierarchical phrase-based - Motivation

Discontiguous Phrases

	Je	ne	vais	pas
I	■			
do		■		■
not		■		■
go			■	

Hierarchical phrase-based - Motivation

Discontiguous Phrases



- Gappy phrase
  ne vais pas → do not go
  ne X_{vais} pas → do not X_{go}

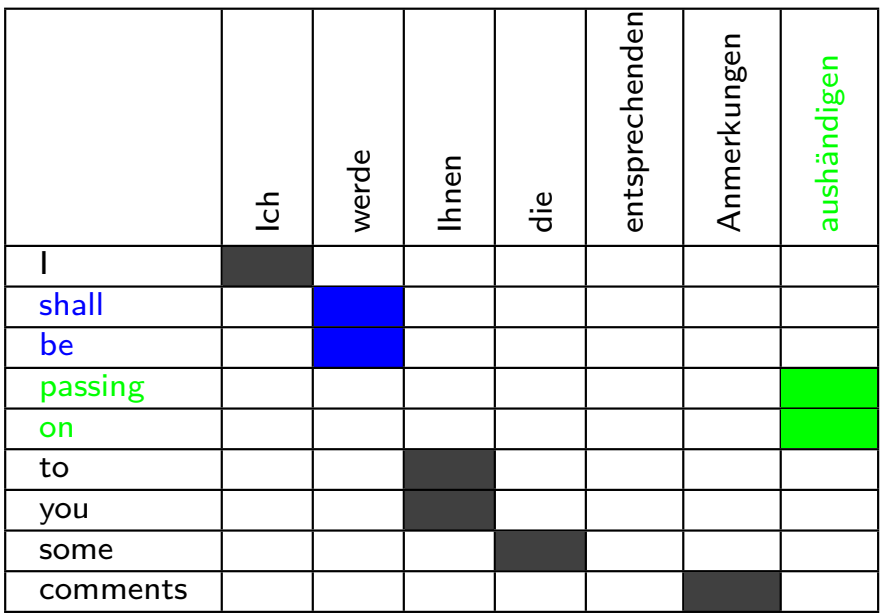
Hierarchical phrase-based - Motivation

Long Distance Reordering

	Ich	werde	Ihnen	die	entsprechenden	Anmerkungen	aushändigen
I	■						
shall		■					
be		■					
passing							■
on							■
to			■				
you			■				
some				■			
comments						■	

Hierarchical phrase-based - Motivation

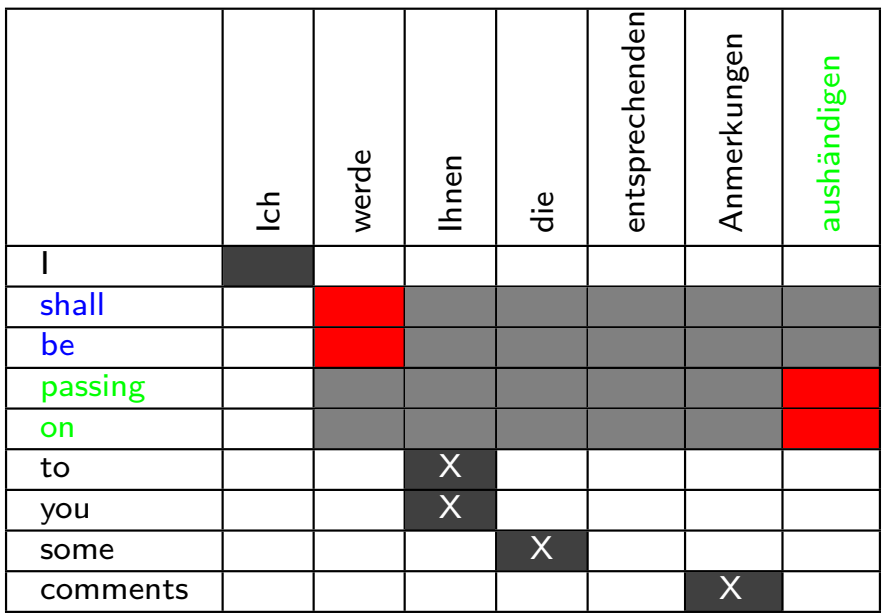
Long Distance Reordering



- How can we extract a biphrase for **shall be passing on**?

Hierarchical phrase-based - Motivation

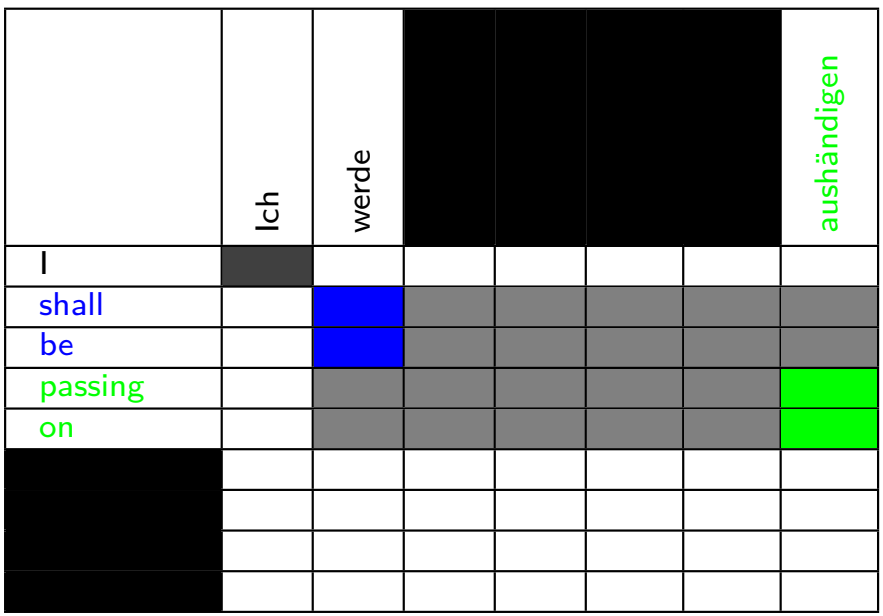
Long Distance Reordering



- How can we extract a biphrase for **shall be passing on**?
- We cannot, we need to extract **to you some comments** along

Hierarchical phrase-based - Motivation

Long Distance Reordering



- How can we extract a biphrase for **shall be passing on**?
- We cannot, we need to extract **to you some comments** along
- Unless we replace all those words by a variable

Hierarchical phrase-based - Motivation

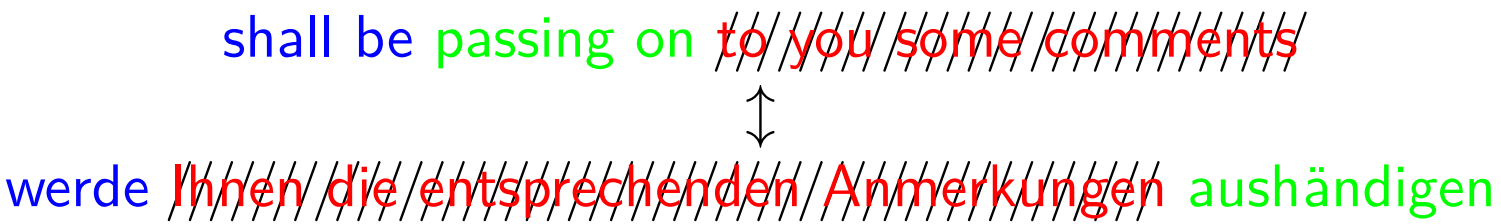
Long Distance Reordering

shall be passing on to you some comments

werde Ihnen die entsprechenden Anmerkungen aushändigen

Hierarchical phrase-based - Motivation

Long Distance Reordering



Hierarchical phrase-based - Motivation

Long Distance Reordering

shall be passing on X

$\updownarrow$

werde X aushändigen

Hiero

Extends phrase-based MT with hierarchical rules [Chiang, 2005]

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- conditions on word alignment

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Motivation

- long-distance reordering

Hiero

Extends phrase-based MT with hierarchical rules [Chiang, 2005]

- conditions on word alignment
- heuristic rule extraction
- heuristic scoring by relative frequency counting
- log-linear model
- SCFG decoding

Motivation

- long-distance reordering
- lexicalised reordering

Heuristic rule extraction

Initial phrase pairs created with same heuristic as PBSMT.

shall be passing on to you some comments

werde Ihnen die entsprechenden Anmerkungen aushändigen

Heuristic rule extraction

Initial phrase pairs created with same heuristic as PBSMT.

shall be passing on to you some comments

↕

werde Ihnen die entsprechenden Anmerkungen aushändigen

Heuristic rule extraction

Initial phrase pairs created with same heuristic as PBSMT.

shall be passing on X_1 some comments

↕

werde X_1 die entsprechenden Anmerkungen aushändigen

Heuristic rule extraction

Initial phrase pairs created with same heuristic as PBSMT.

shall be passing on X_1 some comments

↕

werde X_1 die entsprechenden Anmerkungen aushändigen

Heuristic rule extraction

Initial phrase pairs created with same heuristic as PBSMT.

shall be passing on X_1 X_2

$\updownarrow$

werde X_1 X_2 aushändigen

Heuristic rule extraction

Initial phrase pairs created with same heuristic as PBSMT.

$[X] \rightarrow$ shall be passing on X_1 X_2 | werde X_1 X_2 aushändigen

$[X] \rightarrow$ shall be passing on X_3 | werde X_3 aushändigen

$[X] \rightarrow$ to you | Ihnen

$[X] \rightarrow$ some comments | die entsprechenden Anmerkungen

$[X] \rightarrow$ to you some comments | Ihnen die entsprechenden Anmerkungen

Hiero - Scoring

Relative frequency: assume all fragments have been "observed"
Give a count of one to phrase pair occurrence, then distribute its weight equally among the obtained rules.

- Joint rule probatility: $p(LHS, RHS_{source}, RHS_{target})$

$$p(X, \text{la maison } X_1, \text{the } X_1 \text{ house})$$

- Rule application probability: $p(RHS_{source}, RHS_{target}|LHS)$

$$p(\text{la maison } X_1, \text{the } X_1 \text{ house}|X)$$

- Direct translation probability: $p(RHS_{target}|RHS_{source}, LHS)$

$$p(\text{the } X_1 \text{ house}|\text{la maison } X_1, X)$$

- Noisy-channel translation probability: $p(RHS_{source}|RHS_{target}, LHS)$

$$p(\text{la maison } X_1|\text{the } X_1 \text{ house}, X)$$

- Lexical translation probability

$\prod_{t_i \in RHS_{target}} p(t_i|RHS_{source}, a)$ $\prod_{s_i \in RHS_{source}} p(s_i|RHS_{target}, a)$

Hiero - Model

Log-linear combination of features

Hiero - Model

Log-linear combination of features Linear model

$$S_\theta(e, d, f) = \theta^T \sum_{r_{s,t} \epsilon d} h_i(r_{s,t}|e, f)$$

where s is a span over F,
t is a span over E
and r is a rule.
Weighted synchronous CFG.
LM.

Hiero - Model

(0) J' (1) ai (2) les (3) yeux (4) noir (5)
(0) I (1) have (2) black (3) eyes (4)

$$X[0-2/0-2] \rightarrow \text{J' ai}|\text{I have}$$

$$X[2-4/3-4] \rightarrow \text{les yeux}|\text{eyes}$$

$$X[2-5/2-4] \rightarrow X[2-4]\text{noir}|\text{black}X[3-4]$$

$$S[0-5/0-4] \rightarrow X[0-2]X[2-5]|X[0-2]X[2-4]$$

Content

Decoding by Parsing

J' ai les yeux noirs

1. PRP0/PRP $\rightarrow$ J' | I
2. JJ $\rightarrow$ noirs | black
3. NP0/NP $\rightarrow \overset{DT}{les}\ \overset{NN}{yeux}$ JJ | JJ
4. VP0/VP $\rightarrow \overset{VB}{ai}$ NP0 | $\overset{VB}{have}$ NP
5. S $\rightarrow$ PRP0 VP0 | PRP VP

Decoding by Parsing

J'$_1$ ai les yeux noirs

PRP0$_1$

J'$_1$

PRP$_1$

I$_1$

1. PRP0/PRP $\rightarrow$ J' | I
2. JJ $\rightarrow$ noirs | black
3. NP0/NP $\rightarrow \overset{DT}{les}\ \overset{NN}{yeux}$ JJ | JJ
4. VP0/VP $\rightarrow \overset{VB}{ai}$ NP0 | $\overset{VB}{have}$ NP
5. S $\rightarrow$ PRP0 VP0 | PRP VP

$\{$I$_1\}$

Decoding by Parsing

J'$_1$ ai les yeux noirs$_2$

PRP0$_1$ JJ$_2$

| |

J'$_1$ noirs$_2$

PRP$_1$ JJ$_2$

| |

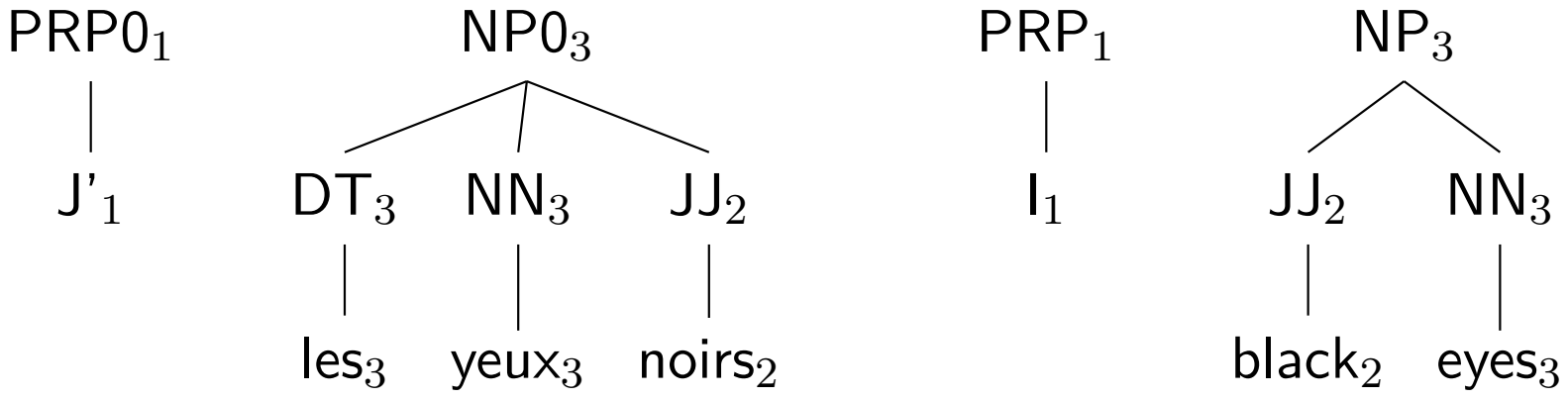
I$_1$ black$_2$

1. PRP0/PRP $\rightarrow$ J' | I
2. JJ $\rightarrow$ noirs | black
3. NP0/NP $\rightarrow \overset{DT}{les}\ \overset{NN}{yeux}$ JJ | JJ
4. VP0/VP $\rightarrow \overset{VB}{ai}$ NP0 | $\overset{VB}{have}$ NP
5. S $\rightarrow$ PRP0 VP0 | PRP VP

$\{$I$_1$,black$_2$$\}$

Decoding by Parsing

J'$_1$ ai les yeux$_3$ noirs$_2$

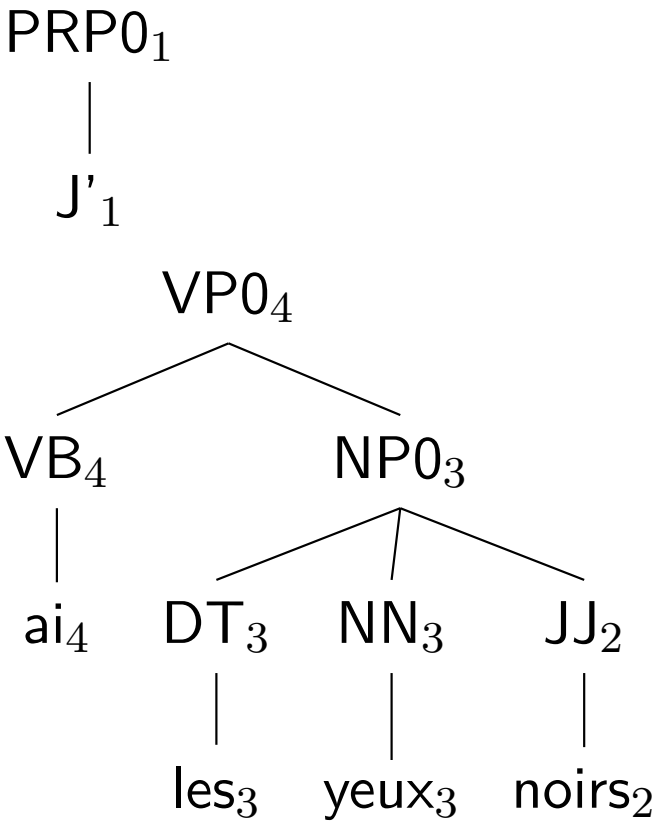


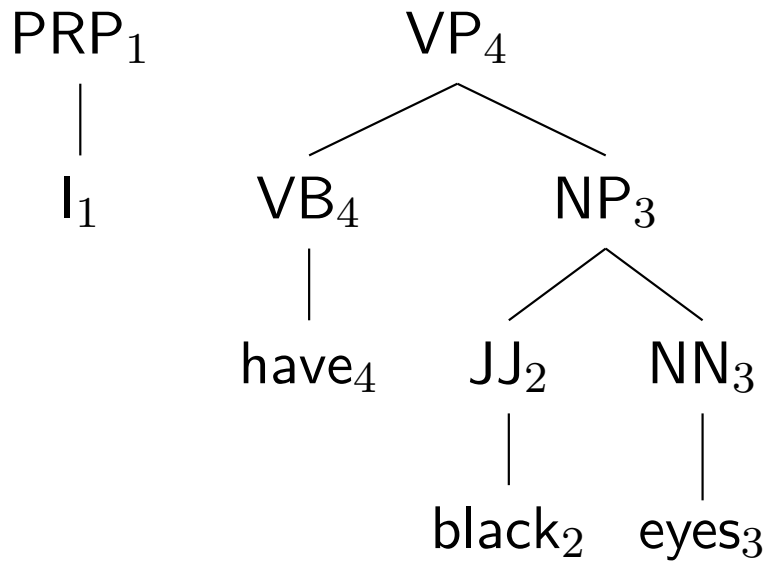
1. PRP0/PRP $\rightarrow$ J' | I
2. JJ $\rightarrow$ noirs | black
3. NP0/NP $\rightarrow \overset{DT}{les}\ \overset{NN}{yeux}$ JJ | JJ
4. VP0/VP $\rightarrow \overset{VB}{ai}$ NP0 | $\overset{VB}{have}$ NP
5. S $\rightarrow$ PRP0 VP0 | PRP VP

$\{$I$_1$, black$_2$ eyes$_3\}$

Decoding by Parsing

J'$_1$ ai$_4$ les yeux$_3$ noirs$_2$



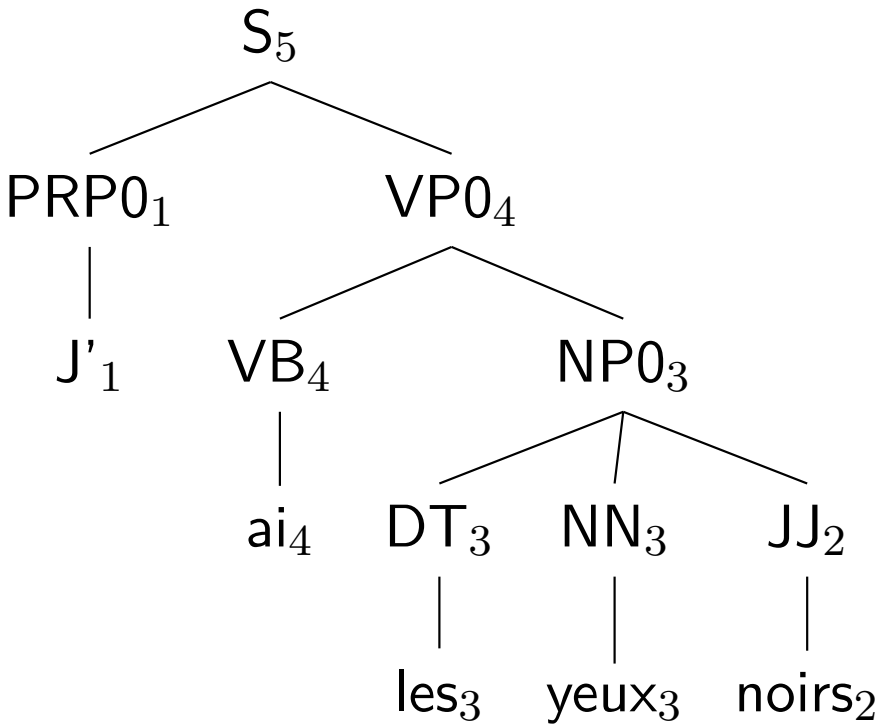


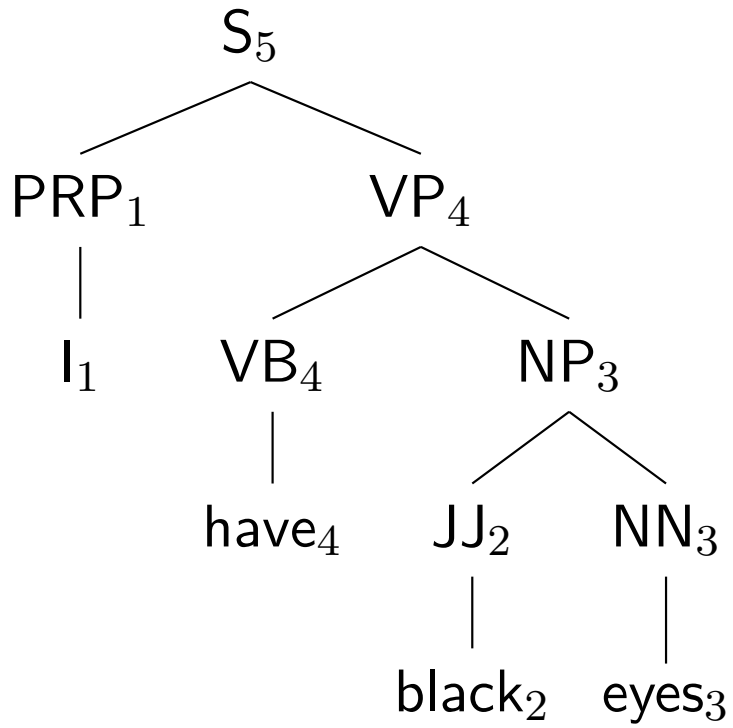
1. PRP0/PRP → J' | I
2. JJ → noirs | black
3. NP0/NP → $\overset{DT}{les}\ \overset{NN}{yeux}$ JJ | JJ
4. VP0/VP → $\overset{VB}{ai}$ NP0 | $\overset{VB}{have}$ NP

{I$_1$, have$_4$ black$_2$ eyes$_3$}

Decoding by Parsing

J'$_1$ ai$_4$ les yeux$_3$ noirs$_2$





1. PRP0/PRP → J' | I
2. JJ → noirs | black
3. NP0/NP → $\overset{DT}{les}\ \overset{NN}{yeux}$ JJ | JJ
4. VP0/VP → $\overset{VB}{ai}$ NP0 | $\overset{VB}{have}$ NP
5. S → PRP0 VP0 | PRP VP

{I$_1$ have$_4$ black$_2$ eyes$_3$}

Decoding

Phrase-based

Tree-based

Decoding

Phrase-based

- Left-to-Right

Tree-based

- Bottom-Up

Decoding

Phrase-based

- Left-to-Right
- Beam Search

Tree-based

- Bottom-Up
- Chart Parsing (In the next Lab.)

Decoding

Phrase-based

- Left-to-Right
- Beam Search
- Formally intersection:

Tree-based

- Bottom-Up
- Chart Parsing (In the next Lab.)
- Formally intersection:

Decoding

Phrase-based

- Left-to-Right
- Beam Search
- Formally intersection:
- FST (TM) $\times$ FSA (LM)

Tree-based

- Bottom-Up
- Chart Parsing (In the next Lab.)
- Formally intersection:
- SCFG (TM) $\times$ FSA (LM)

Questions?

References I

David Chiang. A hierarchical phrase-based model for statistical machine translation. In *Proceedings of the 43rd Annual Meeting of the Association for Computational Linguistics (ACL'05)*, pages 263–270, Ann Arbor, Michigan, June 2005. Association for Computational Linguistics. doi: 10.3115/1219840.1219873. URL `http://www.aclweb.org/anthology/P05-1033`.

Philipp Koehn. *Statistical Machine Translation*. Cambridge University Press, New York, NY, USA, 1st edition, 2010. ISBN 0521874157, 9780521874151.