Machine Translation with Multi Bottom-up Tree Transducers

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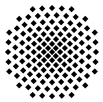

Machine translation

Translation

- Input:
  Official forecasts predicted just 3 percent, Bloomberg said.
- We (fast):
  Offiziellen Prognosen nur 3 Prozent prognostiziert,
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- Google (fast):
  Offizielle Prognosen vorhergesagt nur 3 Prozent,
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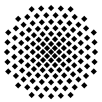

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- Input:
  The ECB wants to hold inflation to under two percent,
  or somewhere in that vicinity.
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  Die EZB die Inflation auf unter zwei Prozent
  oder irgendwo in die Nähe zu behalten will.
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- Input:
  The proposal to remove Article 365 from the Code of Criminal Procedure, upon which the former Prime Minister was sentenced, was supported by 147 members of parliament.
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  Der Vorschlag, Artikel 365 aus der Code der kriminellen Geschäftsordnung, auf die der ehemalige Ministerpräsident verurteilt wurde zu entfernen, wurde von 147 Abgeordneten des Parlaments unterstützt.
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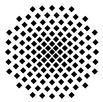

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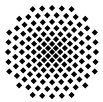

Machine translation

Translation

- Input:
  Their only excuse is that from their point of view, NATO raids were not controlled by an American general, but Allah, the greatness of whom they celebrated with each strike.
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  Ihre einzige Ausrede ist, dass aus ihrer Sicht, Schlachtzügen der NATO nicht von einem amerikanischen Allgemeinen, aber Allah, von denen die Größe sie mit jedem Streik feierte kontrolliert wurden.
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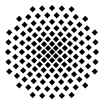
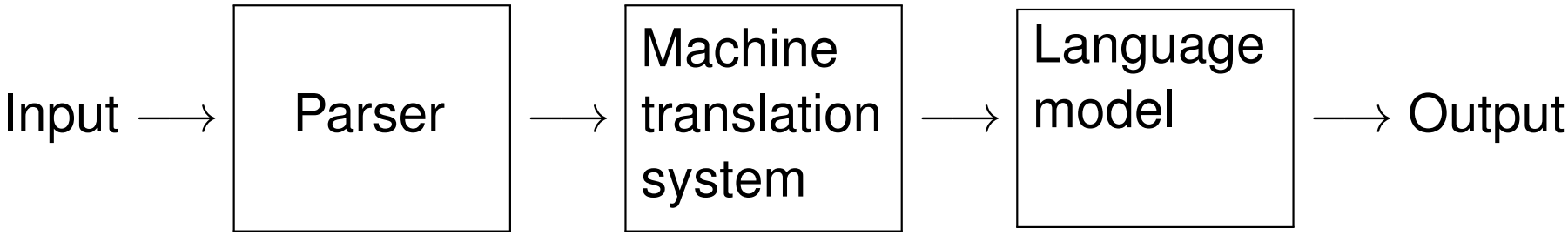


Syntax-based machine translation

Syntax-based systems



What do we have?

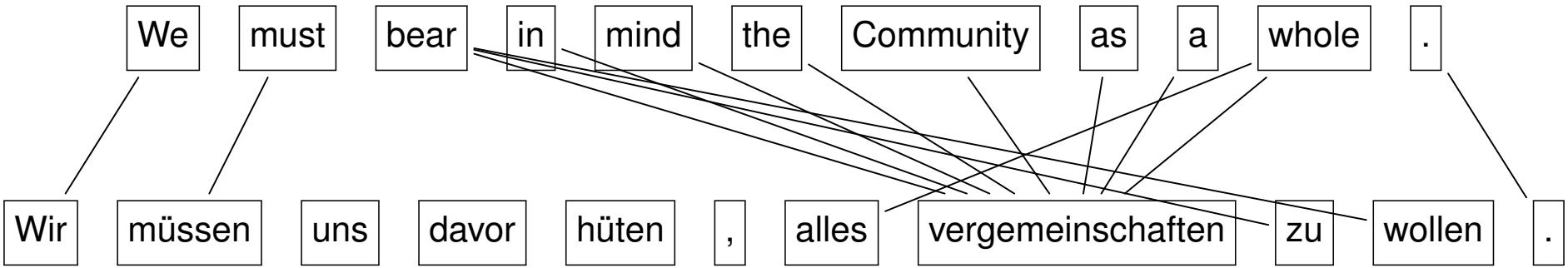
Input

- parallel text (English and German)
- here: EUROPARL

Example

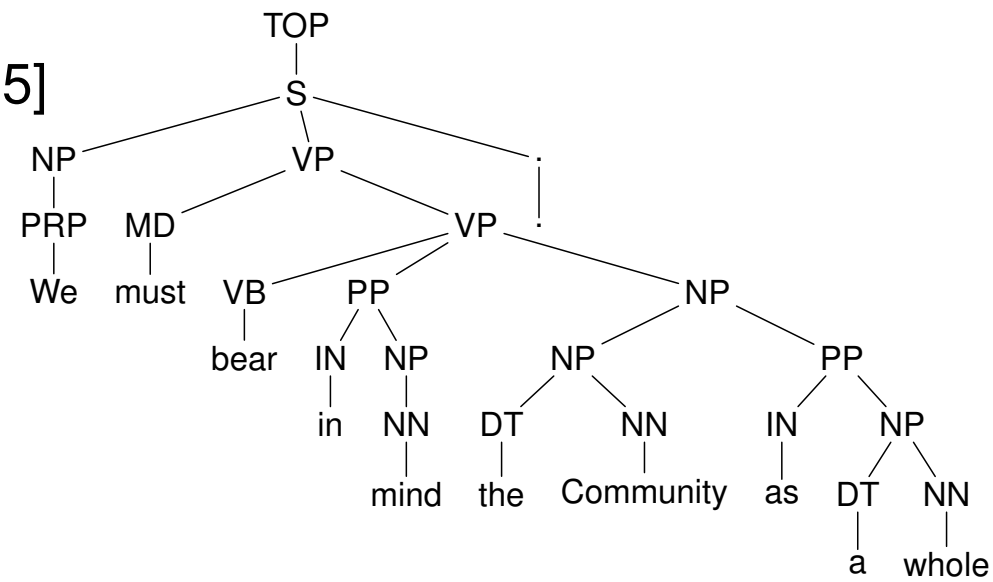
- “We must bear in mind the Community as a whole.”
- “Wir müssen uns davor hüten, alles vergemeinschaften zu wollen.”

Alignments by GIZA++ [OCH, NEY ’03]:

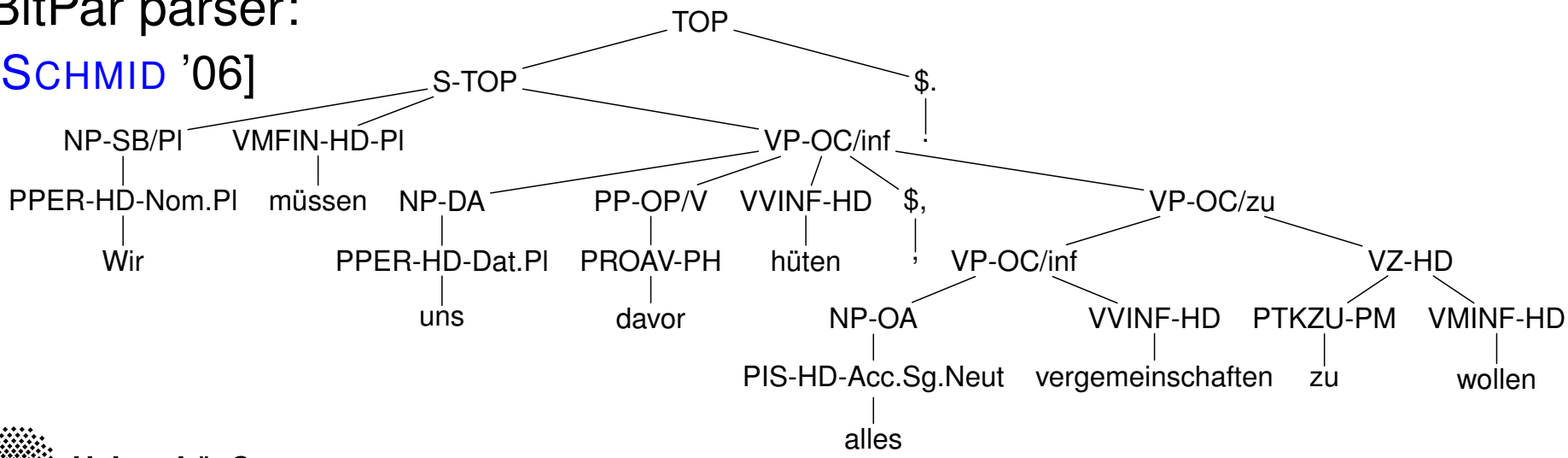


Parsing

CHARNIAK parser:
[CHARNIAK, JOHNSON '05]



BitPar parser:
[SCHMID '06]

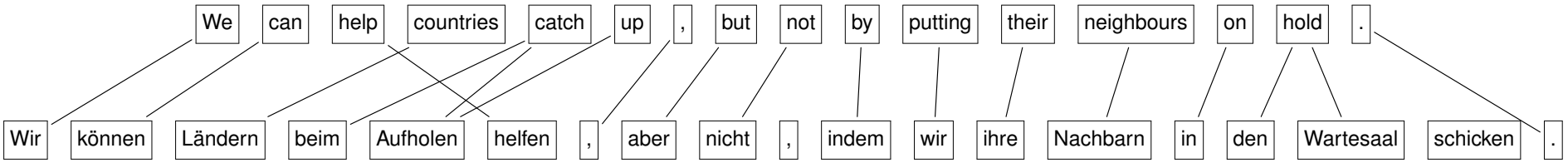


Better example

Example

- “We can help countries catch up,
  but not by putting their neighbours on hold.”
- “Wir können Ländern beim Aufholen helfen,
  aber nicht, indem wir ihre Nachbarn in den Wartesaal schicken.”

Alignments by GIZA++:



Better example

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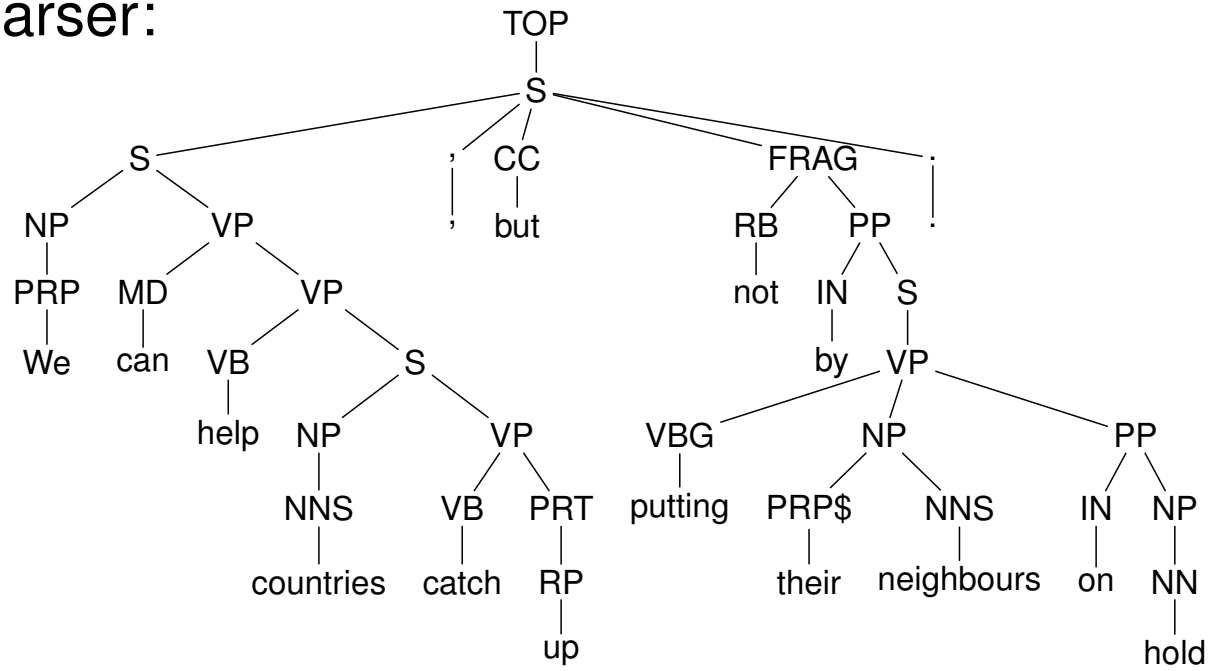
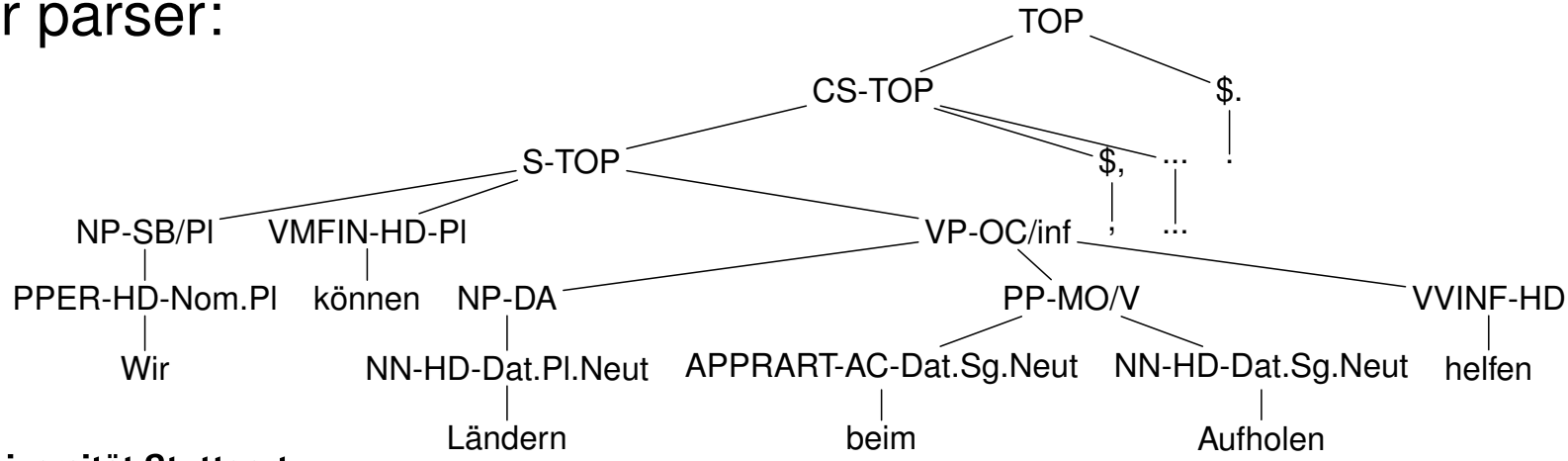


BitPar parser:



Small example

Input

Yugoslav President Voislav signed for Serbia.

و تولى التوقيع عن صربيا الرئيس اليوغوسلافي فويسلاف

Transliteration: *w twlY AltwqyE En SrbyA Alr}ys Alywgwslafy fwyslAf.*

And then the matter was decided, and everything was put in place.

ف كان ان تم الحسم و وضعت الأمور في نصاب ها

Transliteration: *f kAn An tm AlHsm w wDEt Al>mwr fy nSAb hA.*

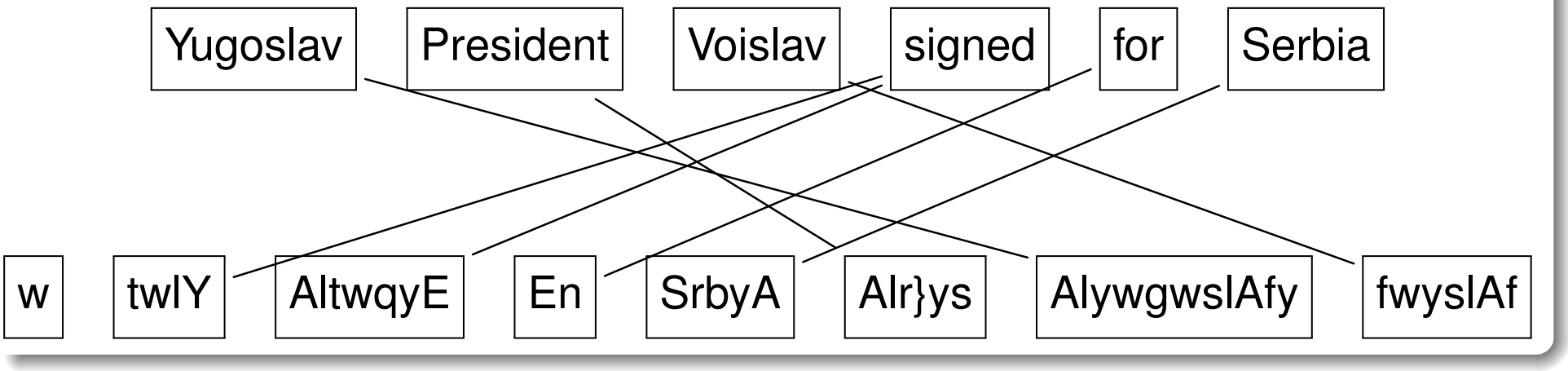
Below are the male and female winners in the different categories.

و هنا الأوائل و الأوليات في مختلف الفئات

Transliteration: *w hnA Al>wA}l w Al>wlyAt fy mxtlf Alf}At.*

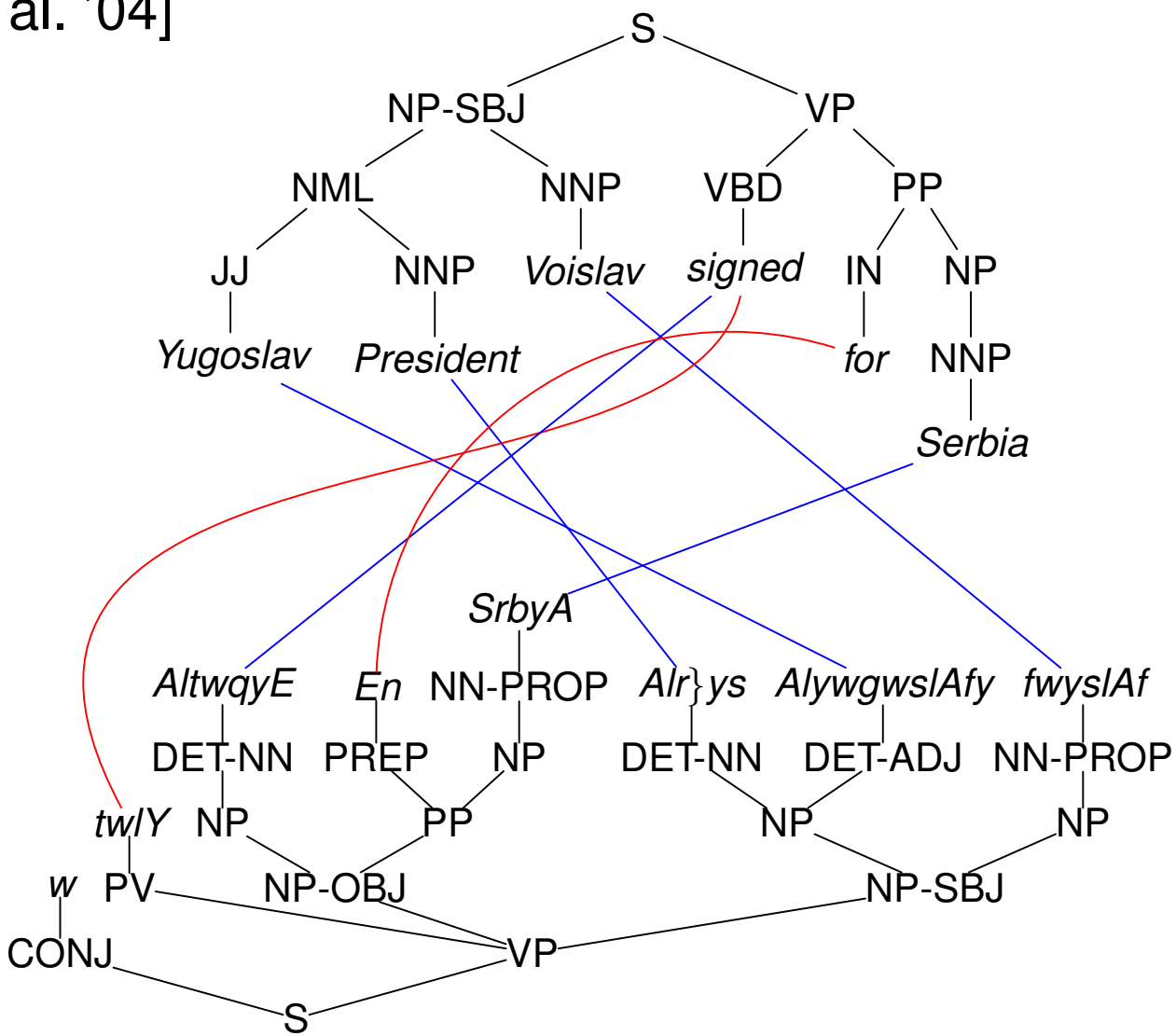
Small example

Alignment



GHKM rule extraction

[GALLEY et al. '04]



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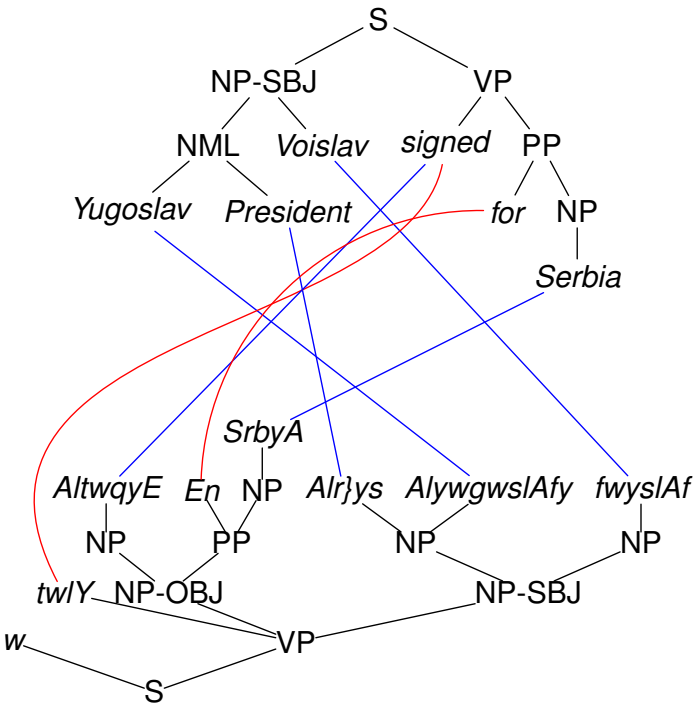
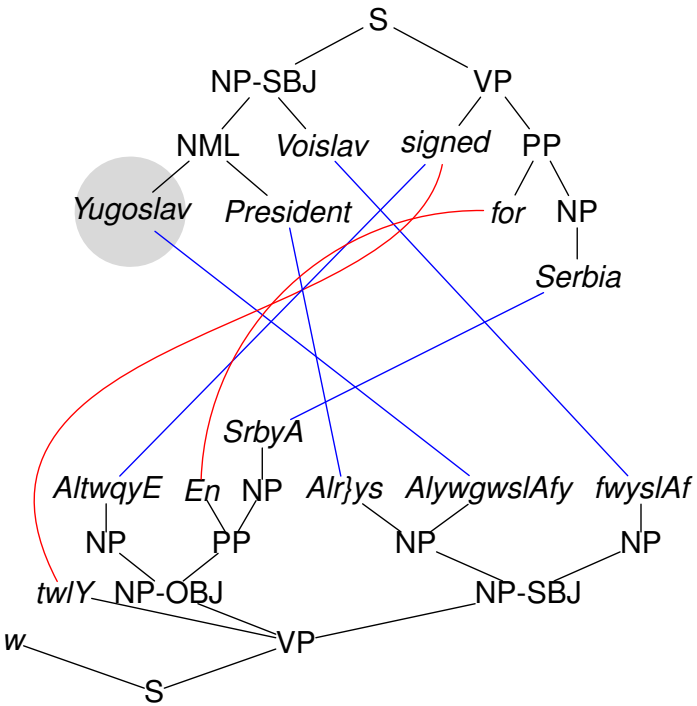


- Select next node bottom-up
- Identify maximal subtree of aligned nodes
- Identify subtree of nodes aligned to aligned nodes, etc.
- Extract rule and leave state
- Repeat

GHKM rule extraction



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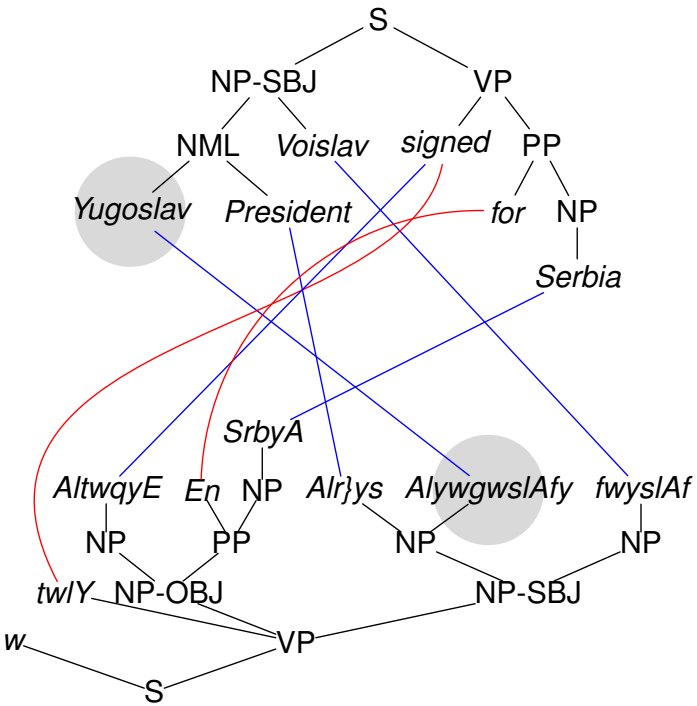

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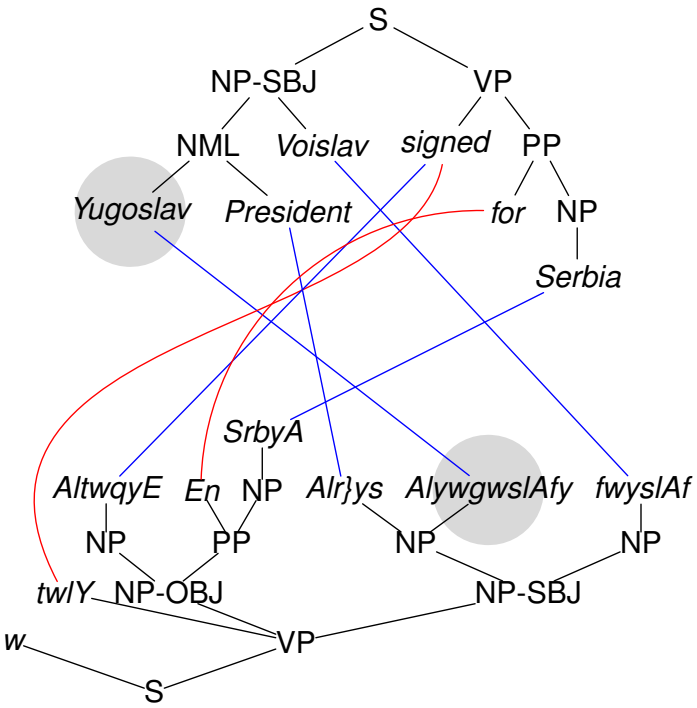

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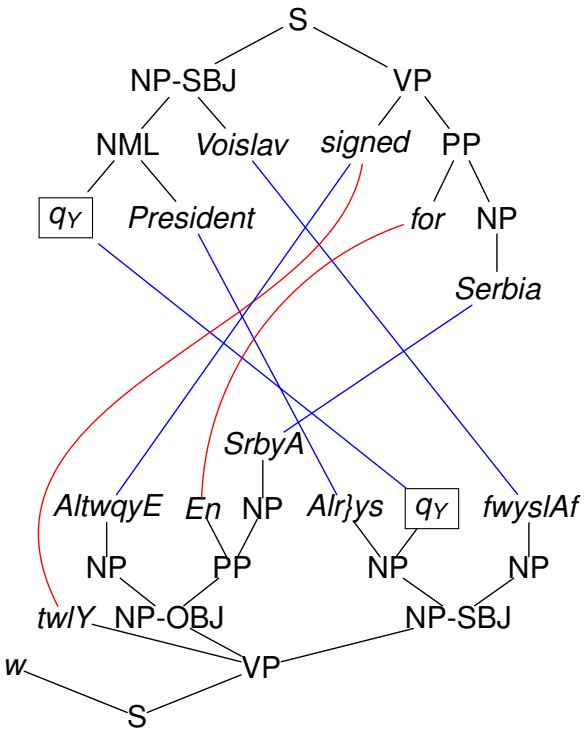

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  $Yugoslav \frac{q_Y}{} AlywgwslAfy$

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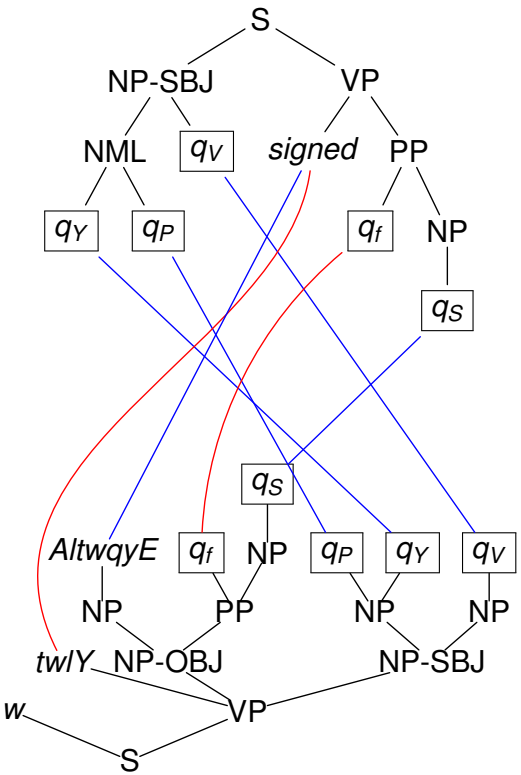

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$$\textit{Yugoslav} \xrightarrow{q_Y} \textit{AlywgwslAfy}$$

$$\textit{President} \xrightarrow{q_P} \textit{Alr\}ys}$$

$$\textit{Voislav} \xrightarrow{q_V} \textit{fwyslAf}$$

$$\textit{for} \xrightarrow{q_f} \textit{En}$$

$$\textit{Serbia} \xrightarrow{q_S} \textit{SrbyA}$$

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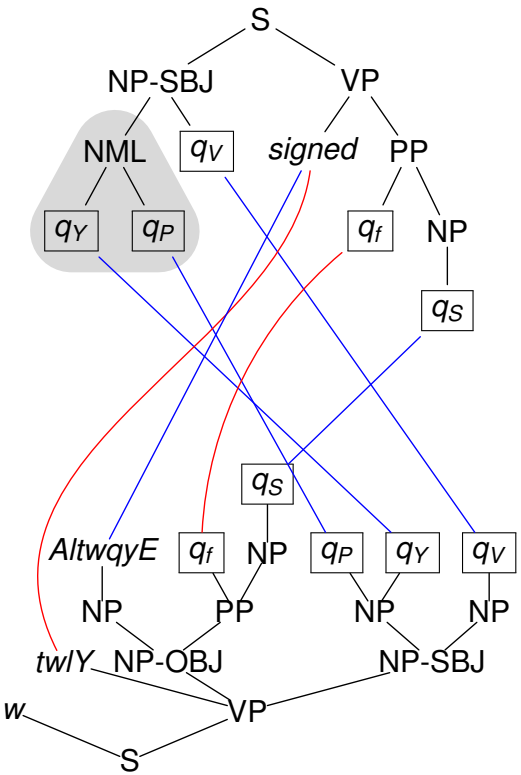

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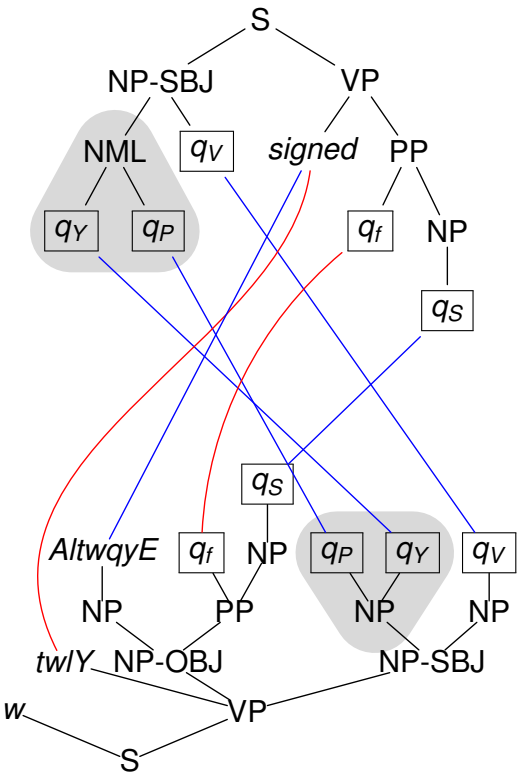

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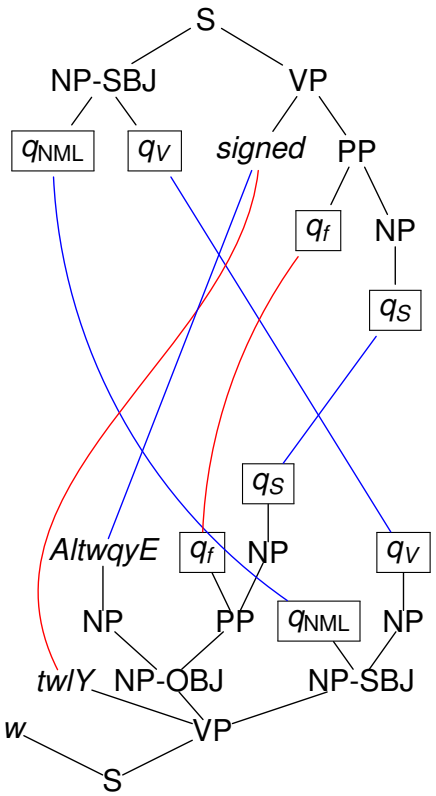

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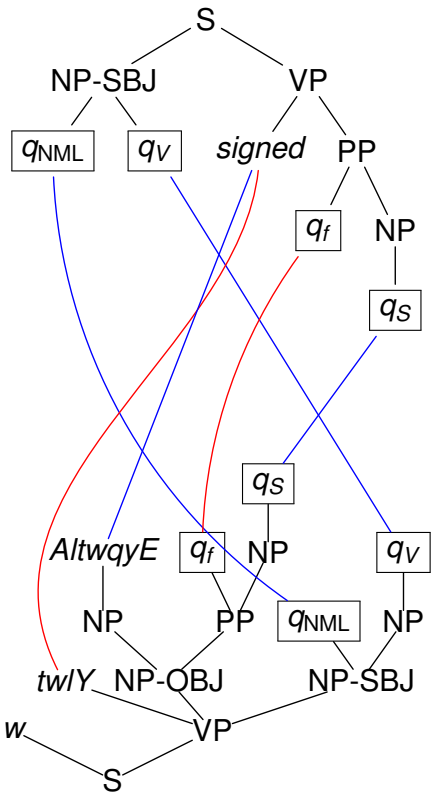

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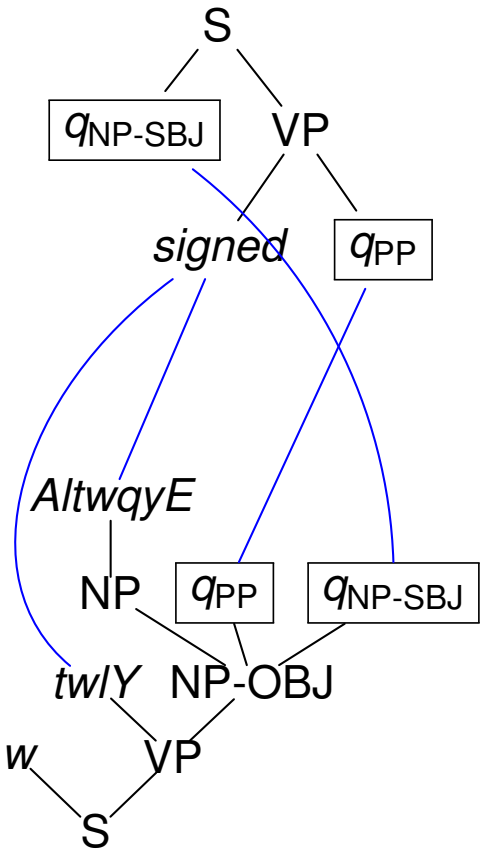

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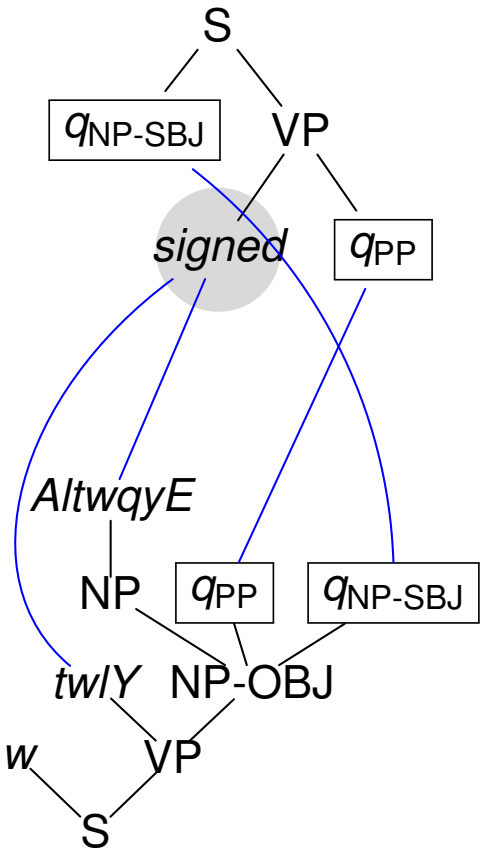

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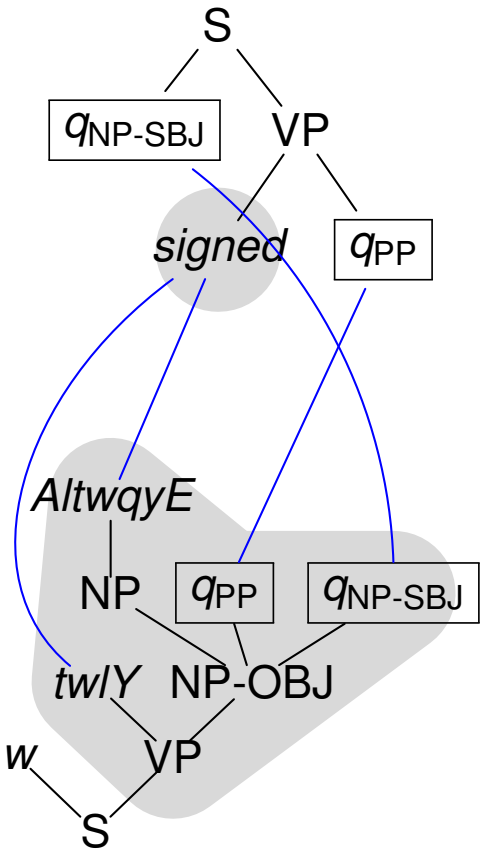

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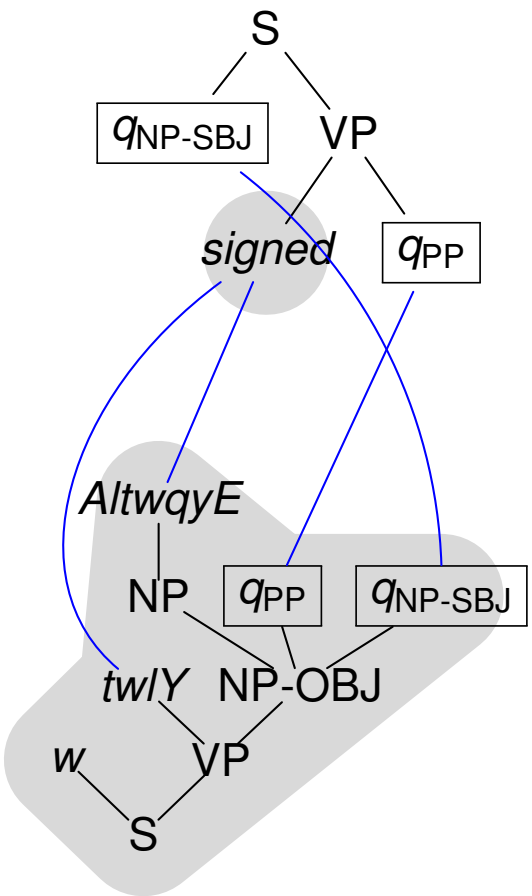

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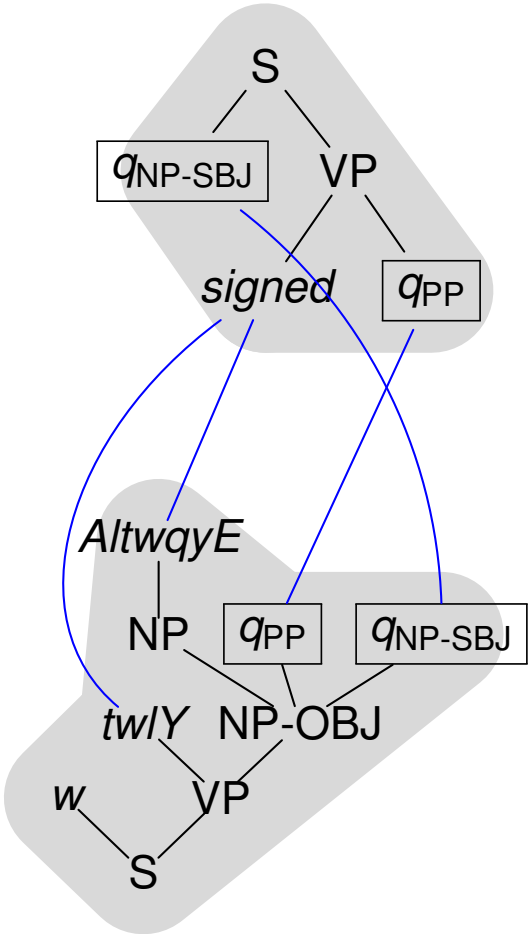

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Extended top-down tree transducer

Advantages

- ✓ simple and natural model
- ✓ easy to train (from linguistic resources) [GRAEHL et al. '08]
- ✓ symmetric

Implementation

- TIBURON [MAY, KNIGHT '06]

Extended top-down tree transducer

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Implementation

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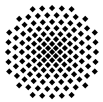
Extended top-down tree transducer

Disadvantages (also of STSG)

- ✗ no discontinuities
- ✗ not binarizable
  [AHO, ULLMAN '72; ZHANG et al. '06]
- ✗ inefficient input/output restriction
  [M., SATTA '10]
- ✗ not composable
  [ARNOLD, DAUCHET '82]



Our model — Syntax

Definition

Multi bottom-up tree transducer (MBOT)
system (Q, Σ, F, R)

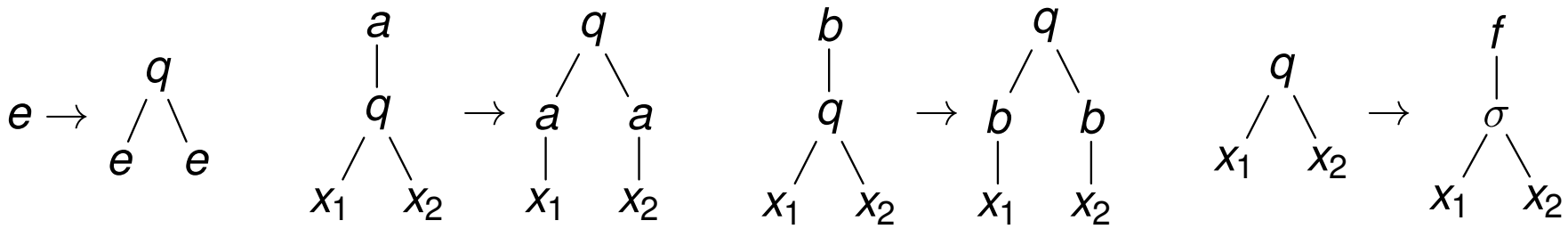
- Q *ranked* alphabet (states)
- Σ ranked alphabet (input/output symbols)
- $F \subseteq Q_1$ (final states)
- R finite set of rules $\ell \to r$ (rules)
  - linear $\ell \in T_\Sigma(Q(X))$ and $r \in Q(T_\Sigma(\mathrm{var}(\ell)))$
  - $\mathrm{var}(r) = \mathrm{var}(\ell)$

Our model — Syntax

Example

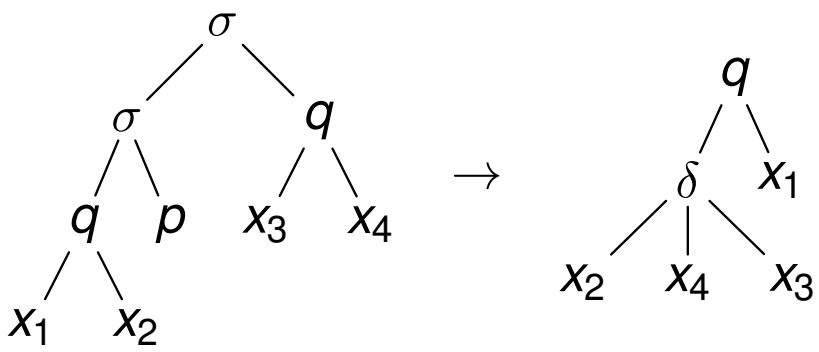
MBOT $(Q, \Sigma, \{f\}, R)$

- $Q = \{q^{(2)}, f^{(1)}\}$
- $\Sigma = \{\sigma^{(2)}, a^{(1)}, b^{(1)}, e^{(0)}\}$
- R contains:

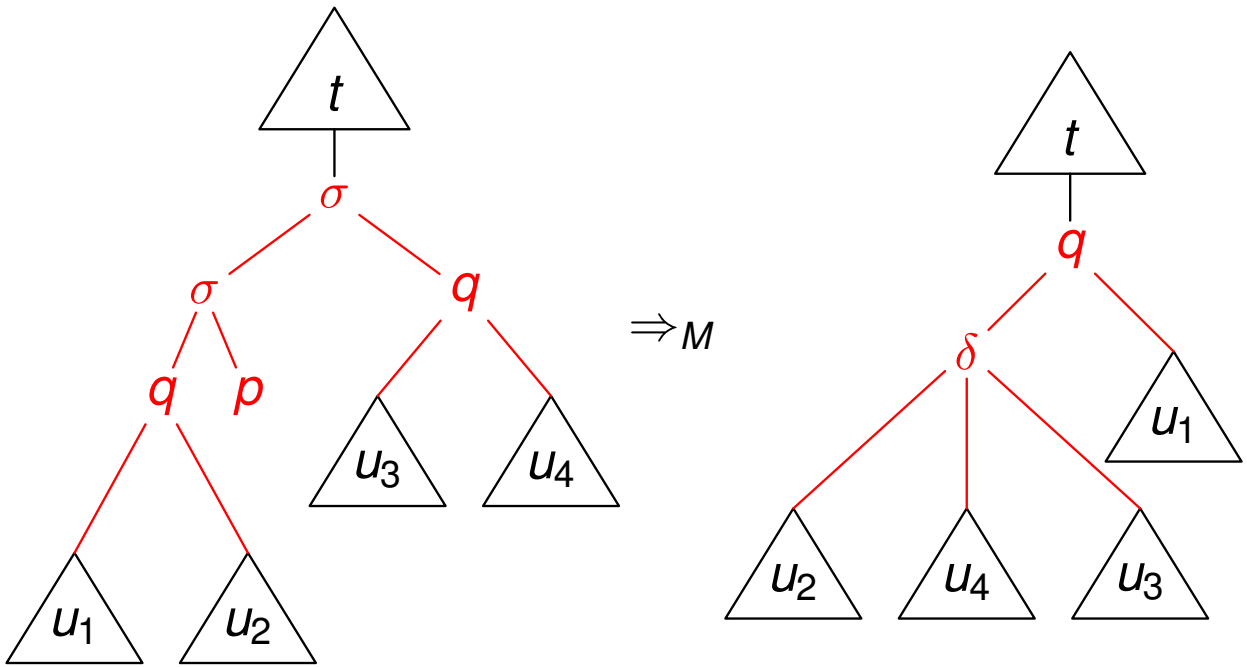


Our model — Semantics

Rule:



Derivation:



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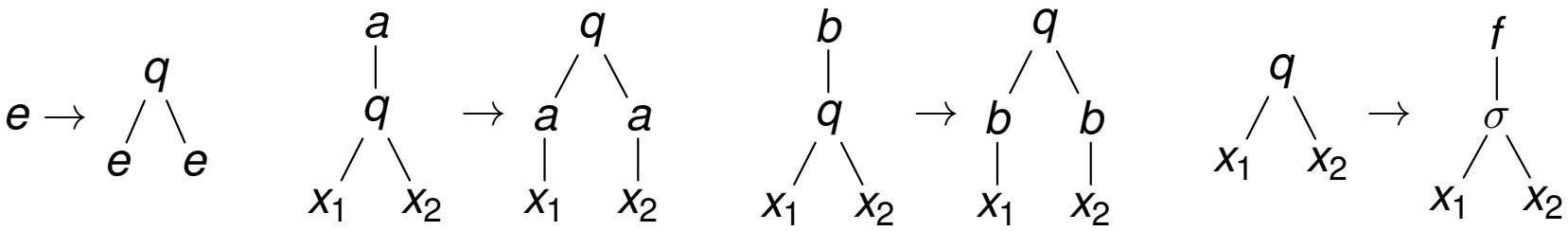

Example (Derivation)

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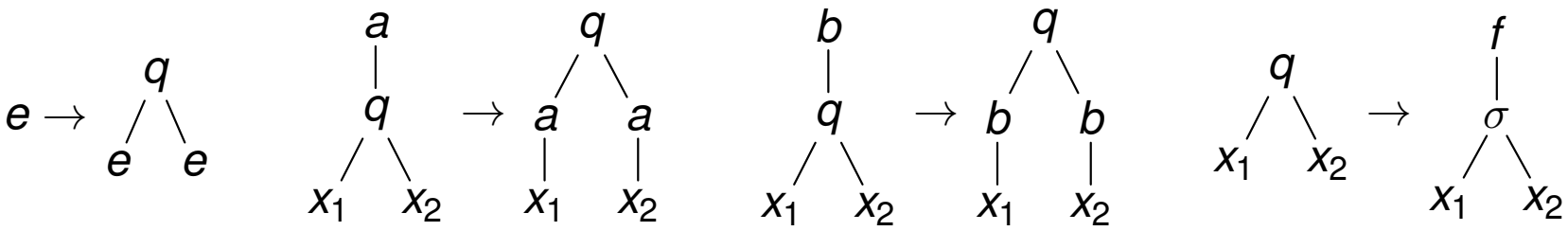

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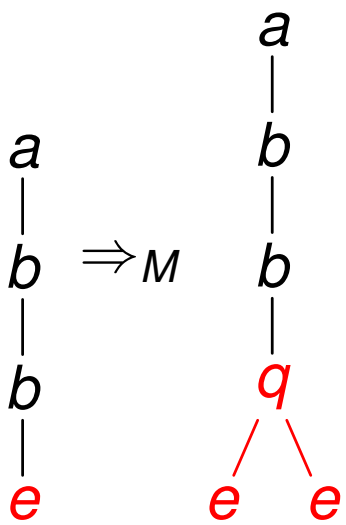

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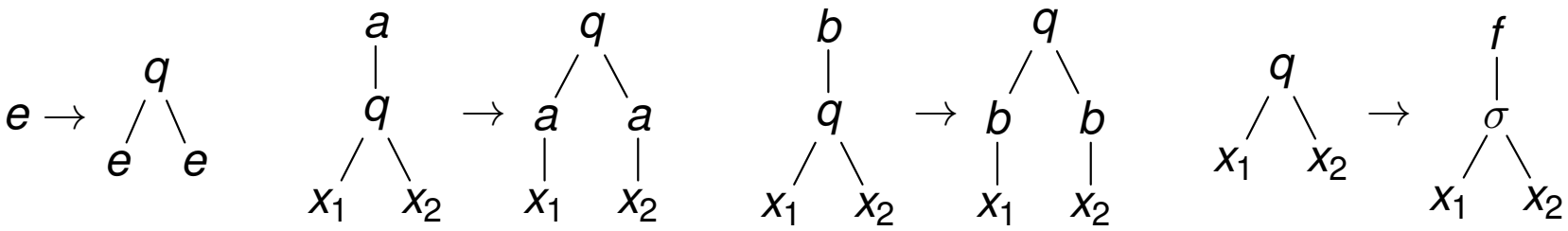

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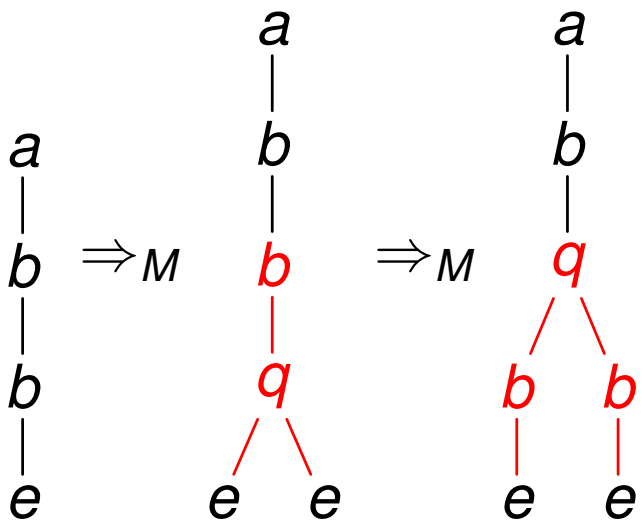

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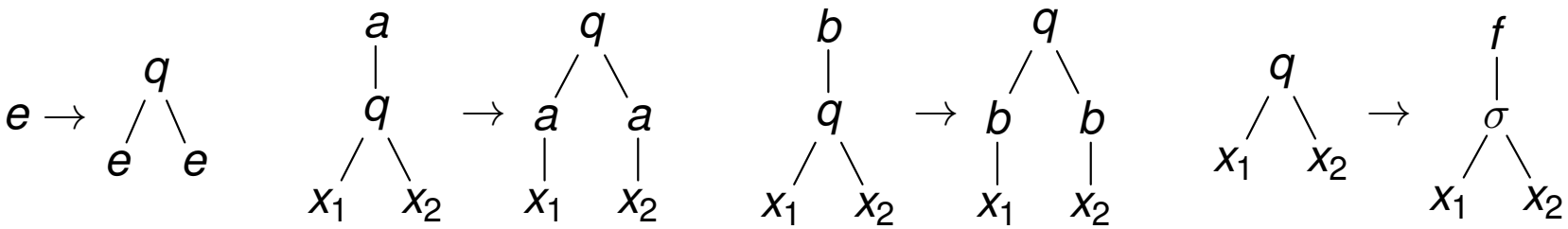

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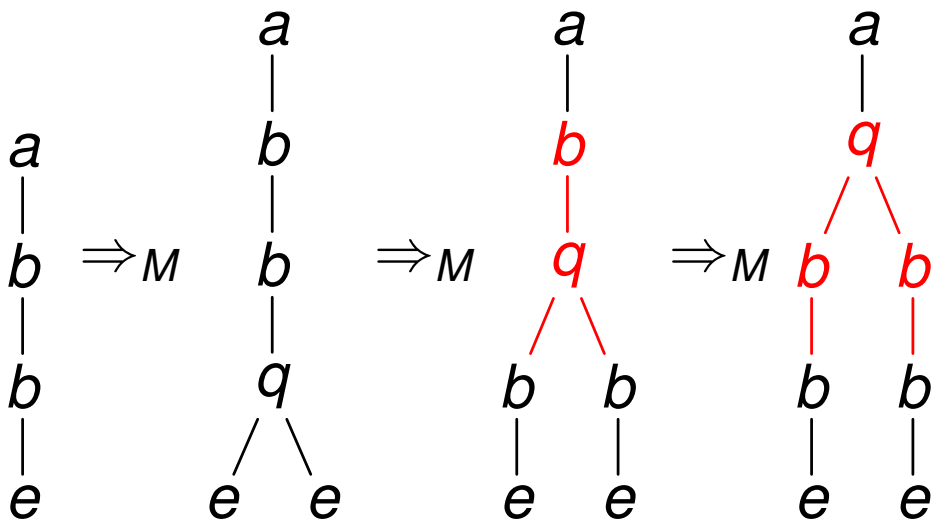

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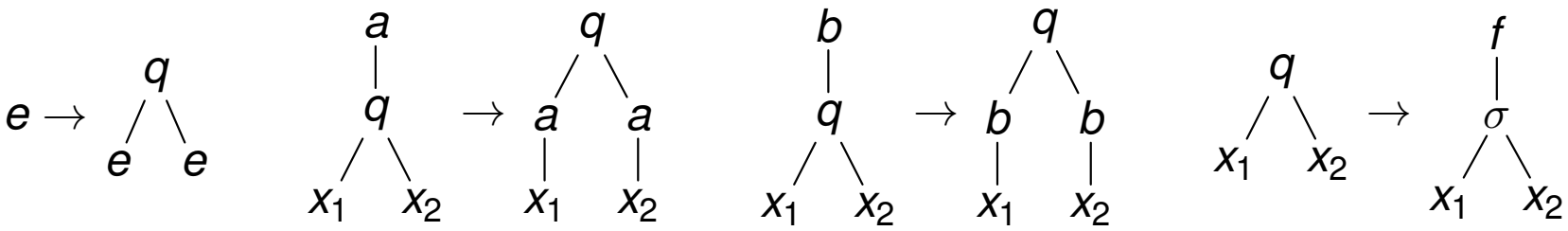

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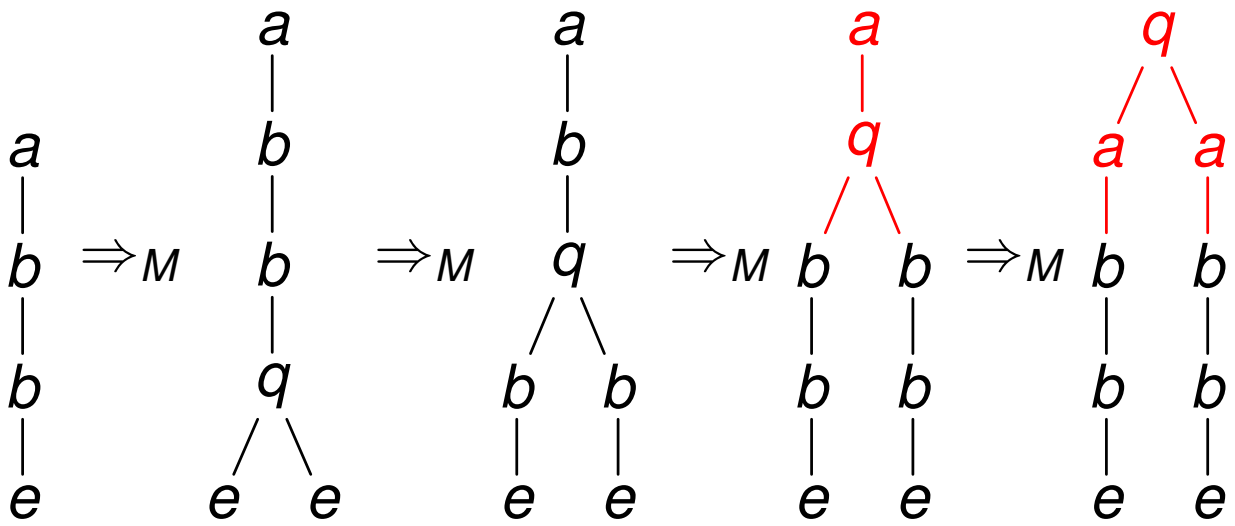

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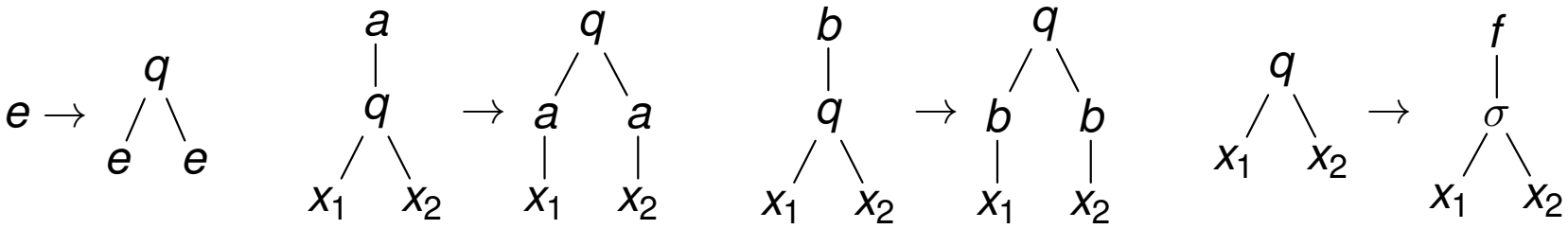

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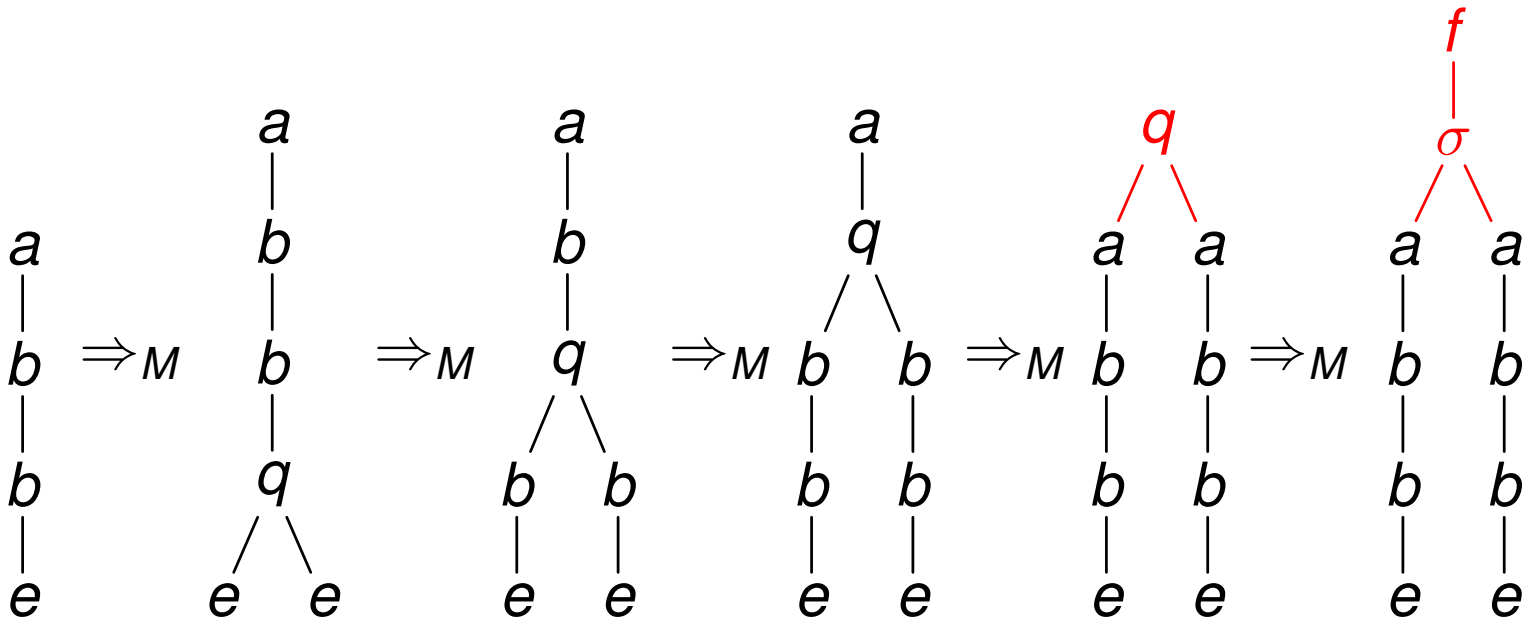


Our model — Semantics

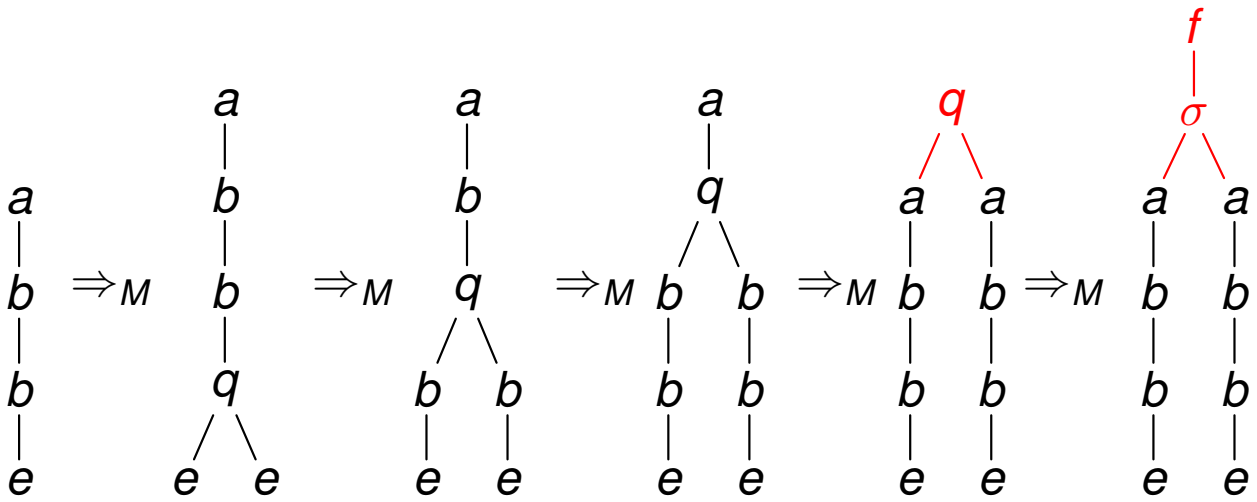
Definition

MBOT $M = (Q, \Sigma, F, R)$

$$\tau_M = \{(t, u) \in T_\Sigma \times T_\Sigma \mid \exists q \in F : t \Rightarrow_M^* q(u)\}$$

Discontinuities

Example (Derivation)

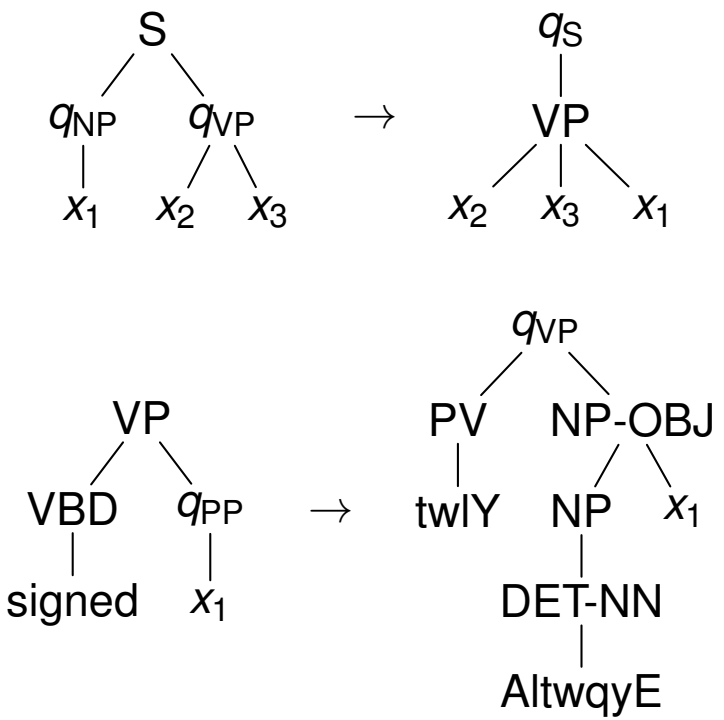


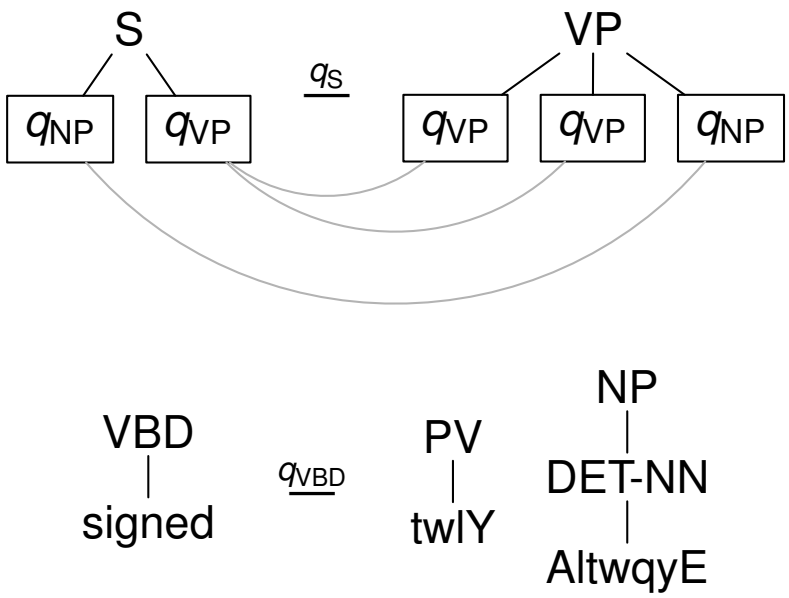
Discontinuities

✗ state covers 1 input subtree → no input discontinuities

✓ state covers several output subtrees → output discontinuities

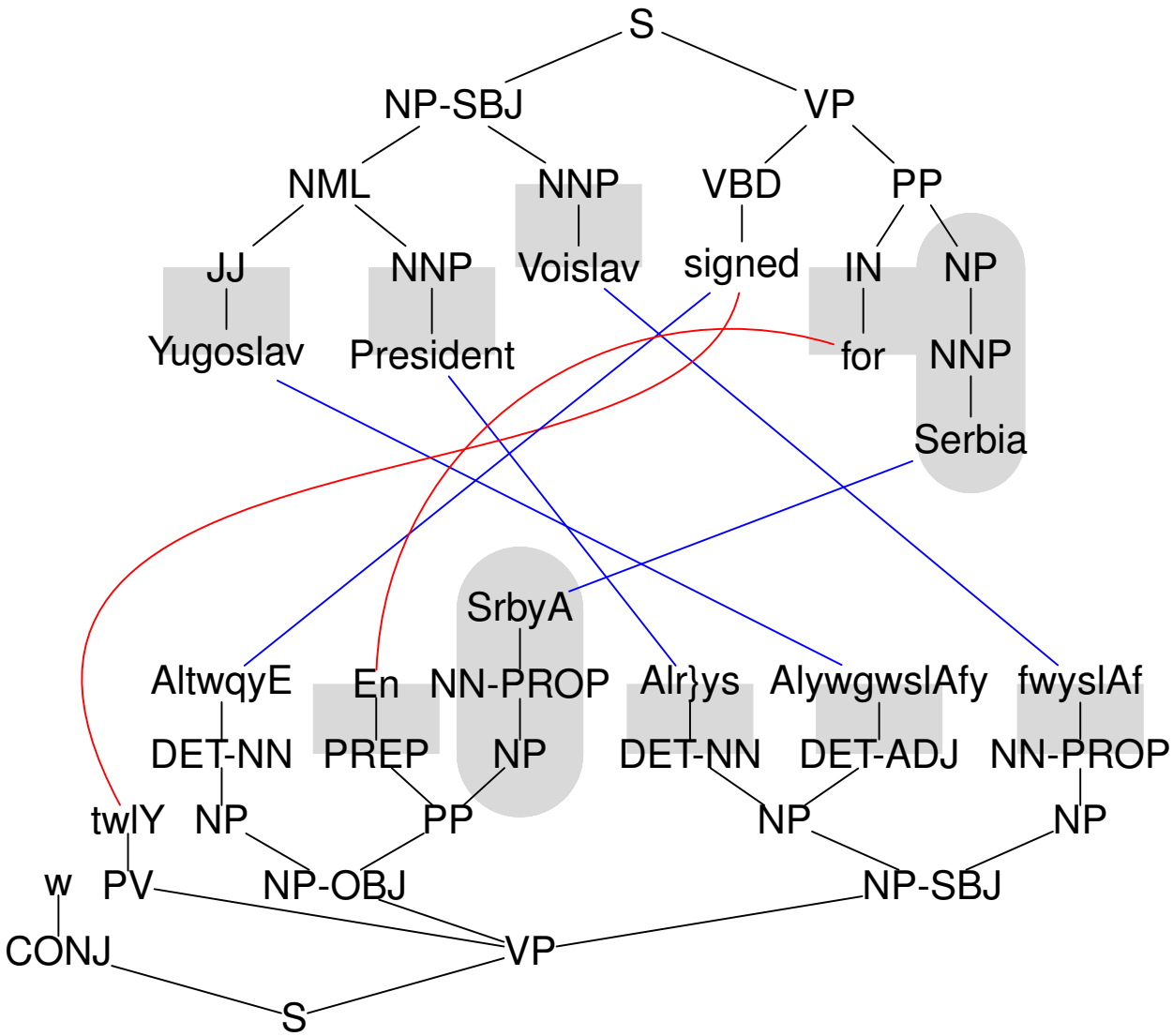
A top-down variant





[M. '11]

Rule extraction



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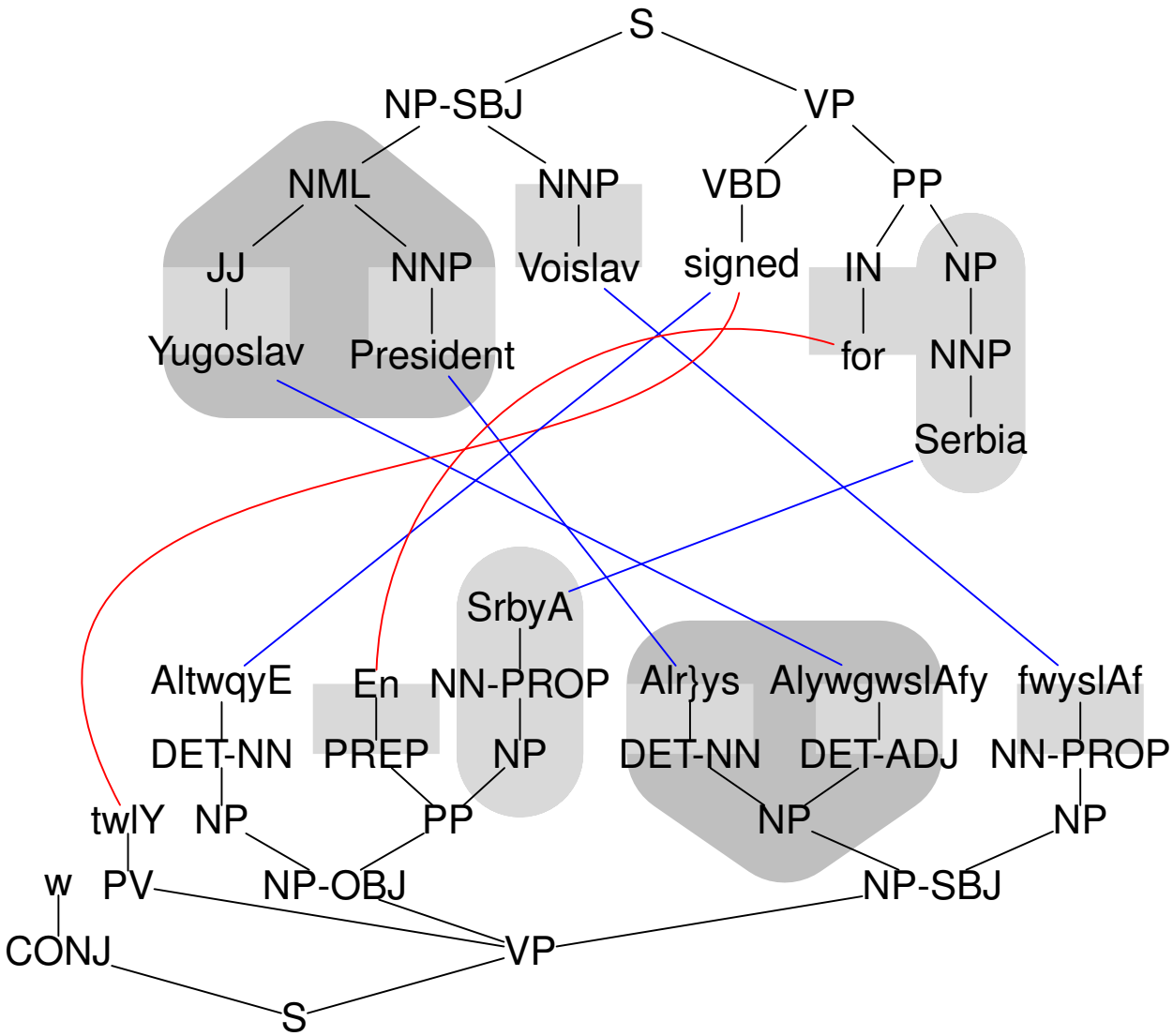

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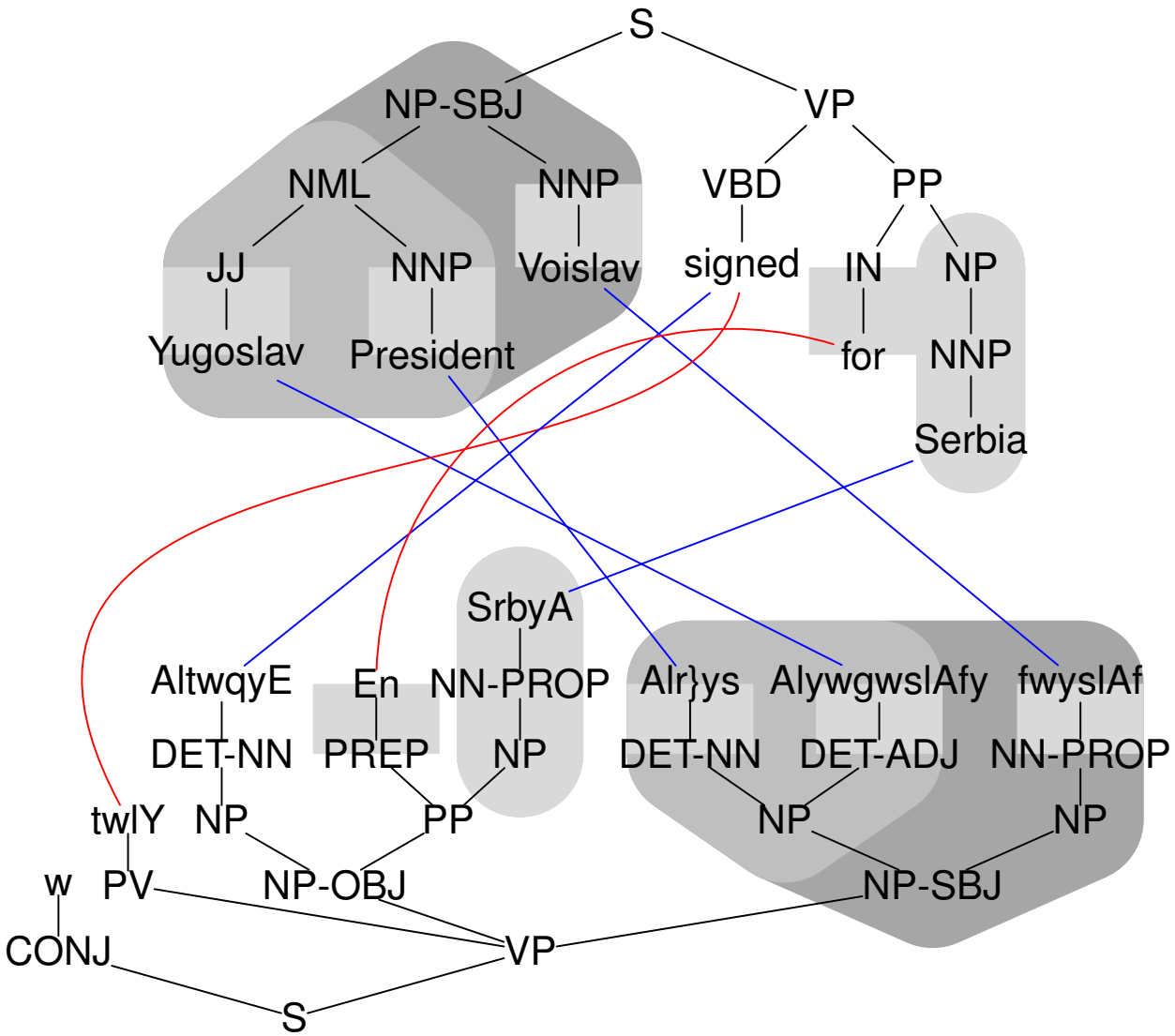

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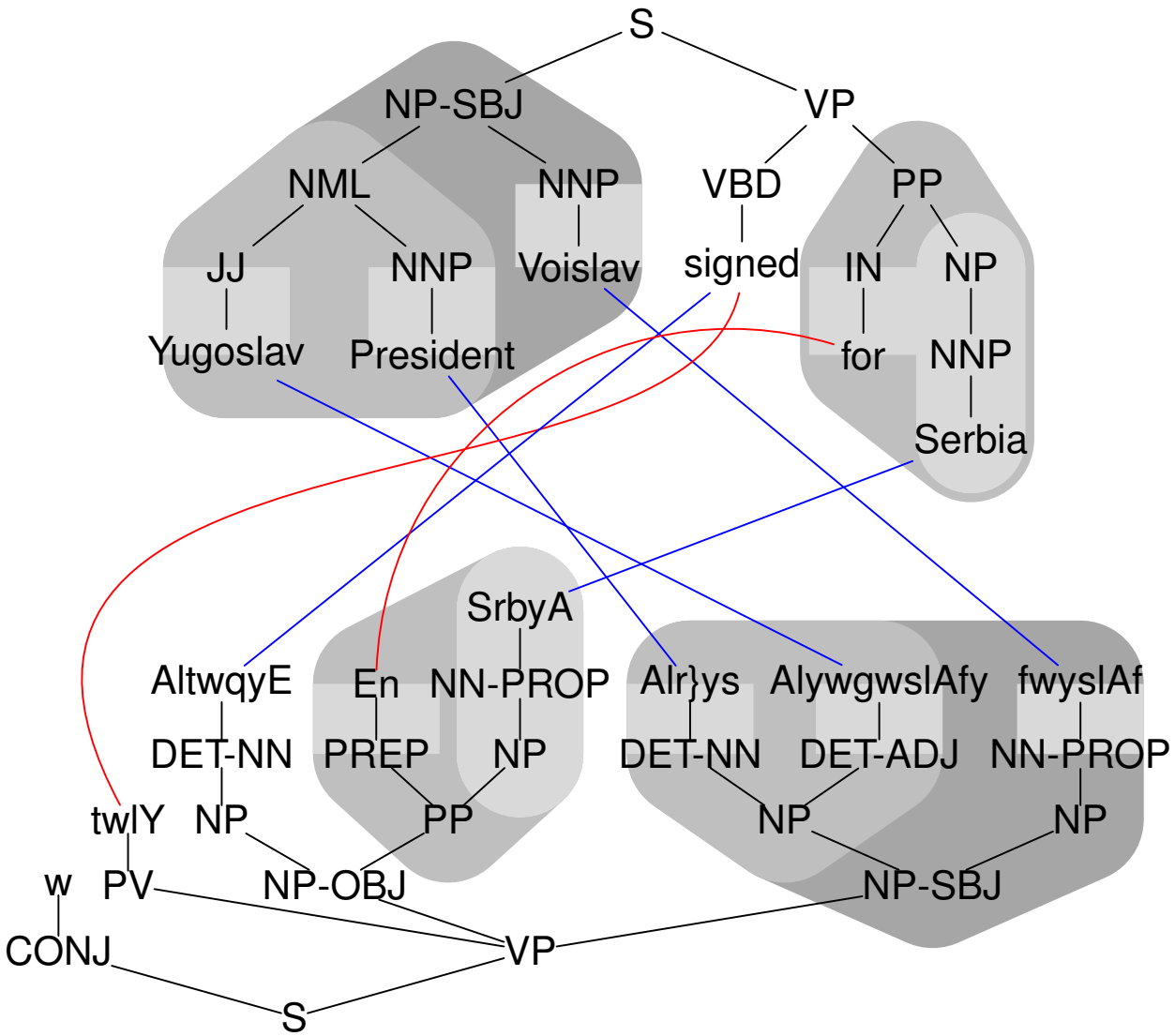

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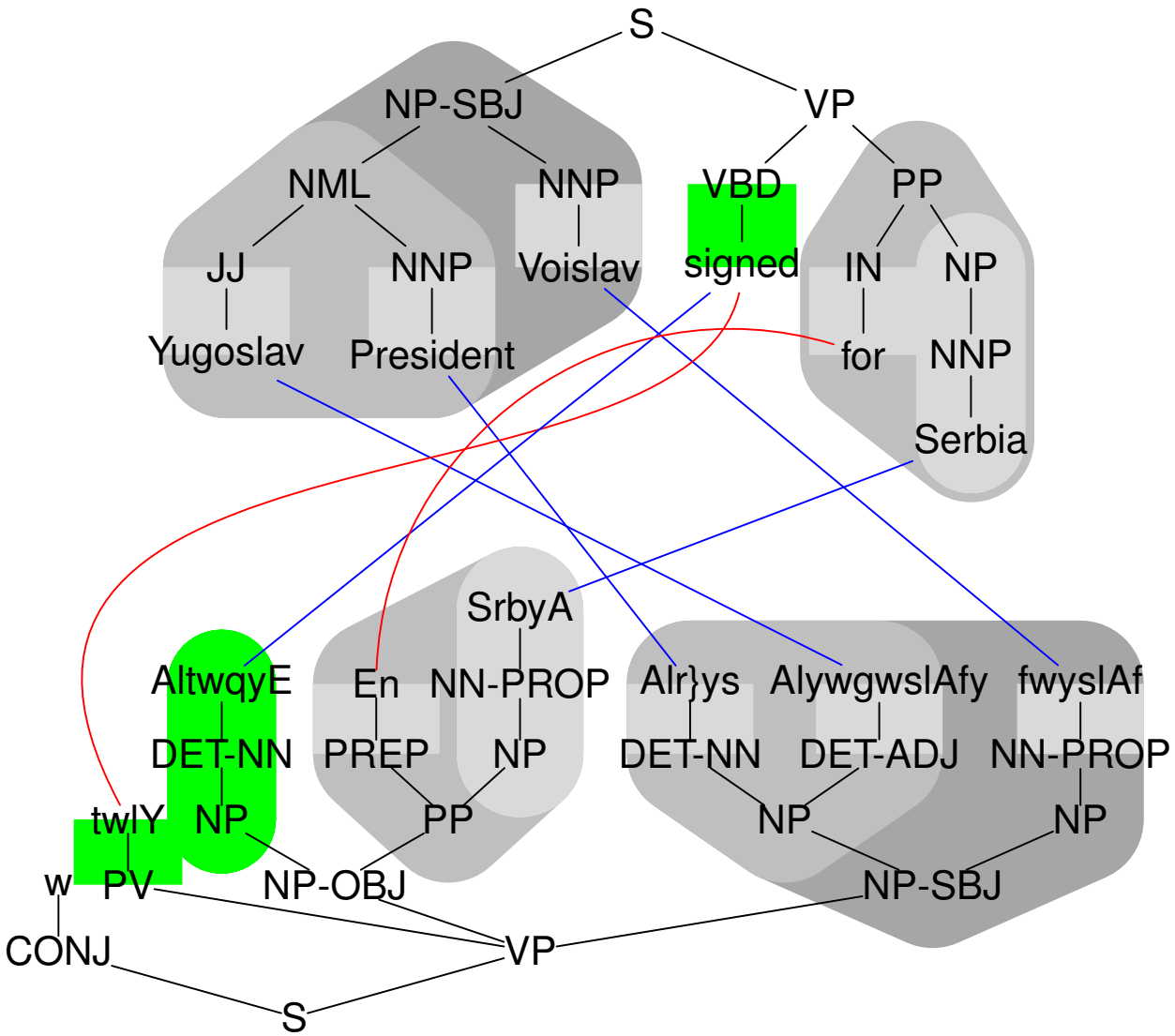

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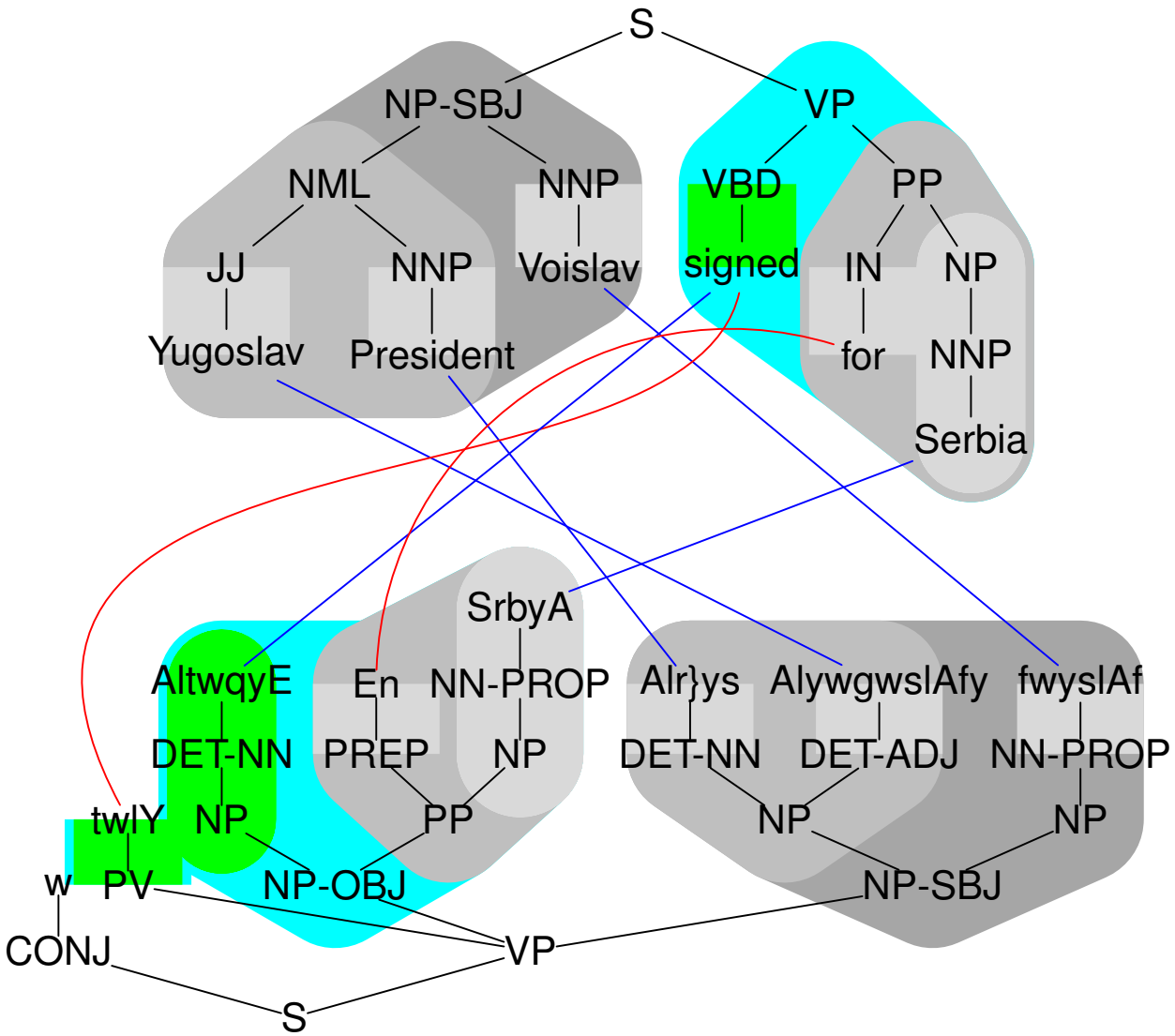

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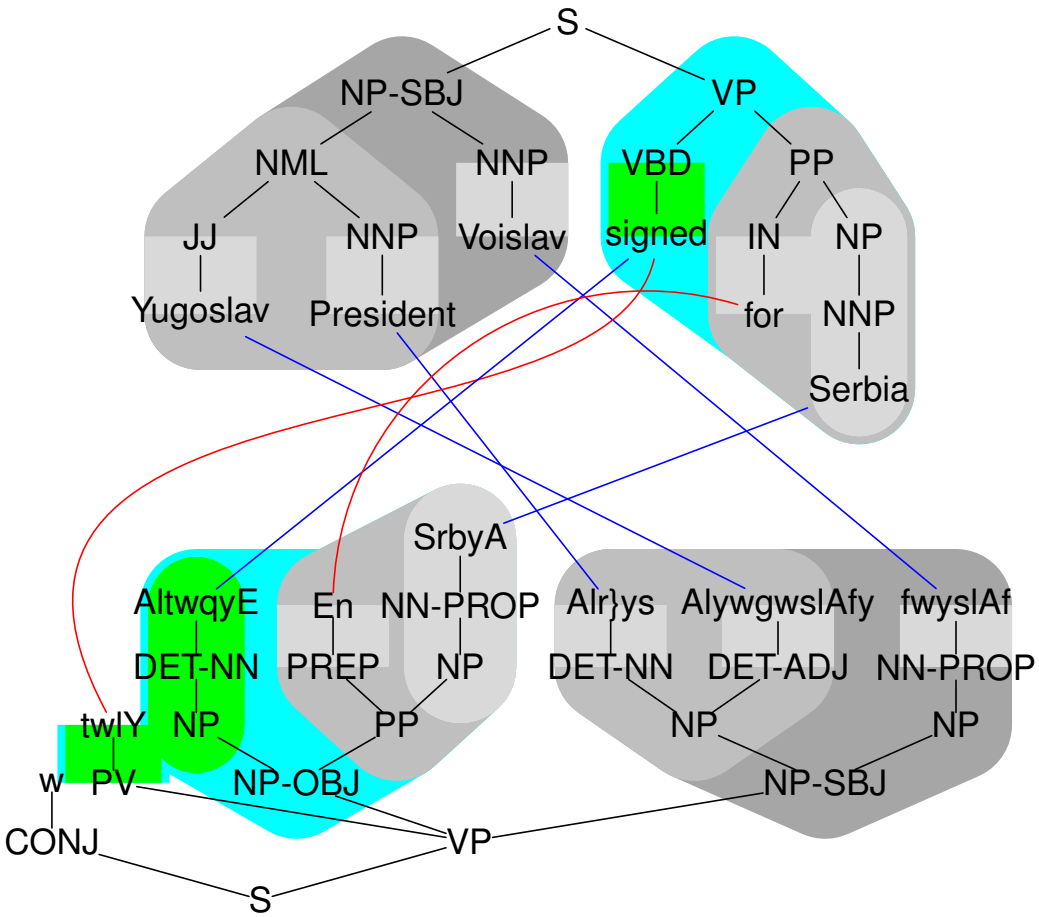

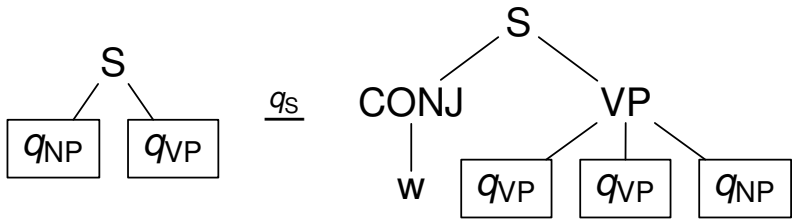

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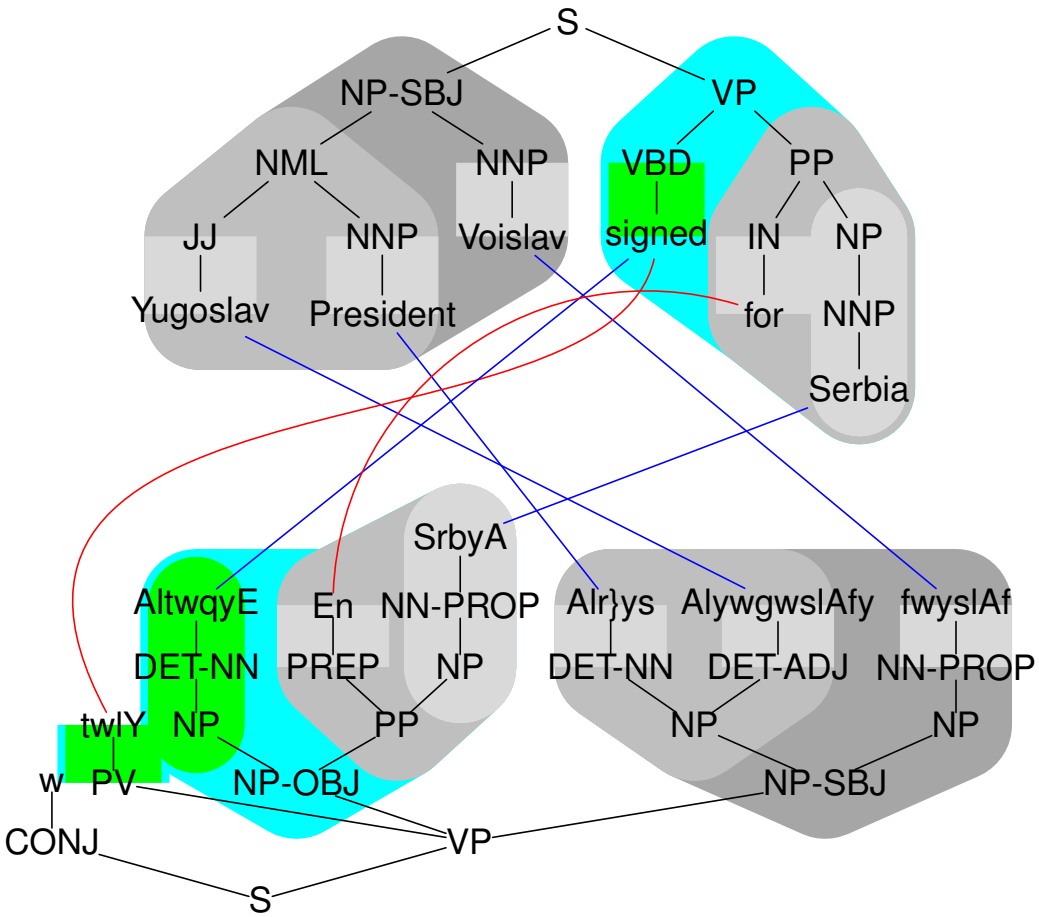
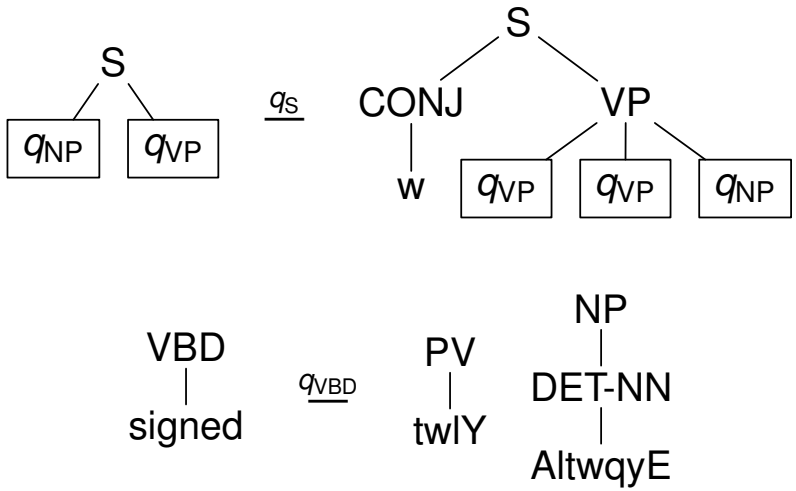
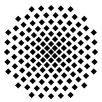




Theoretical summary

- ✓ generalize XTOP
- ✓ discontinuities
- ✓ binarizable
- ✓ efficient input/output restriction
- ✓ efficiently trainable
- ✓ closed under composition



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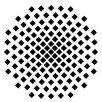

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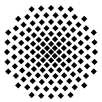

MBOT in machine translation

Moses [KOEHN et al. '07]

- framework for statistical MT
- implementations for many standard tasks
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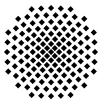
- supports syntax-based MT

We added

- MBOT rule support
- MBOT chart decoder
- adjusted language model calls



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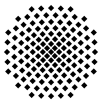

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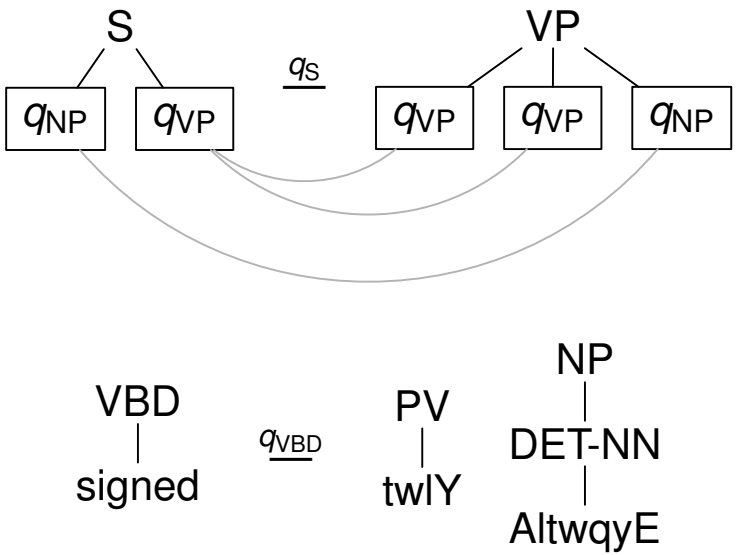

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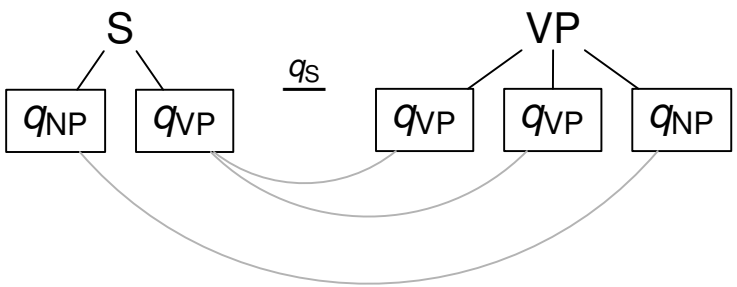

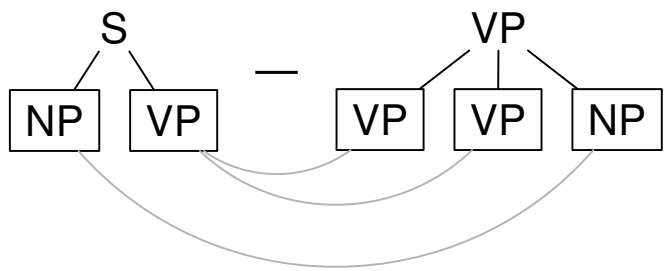

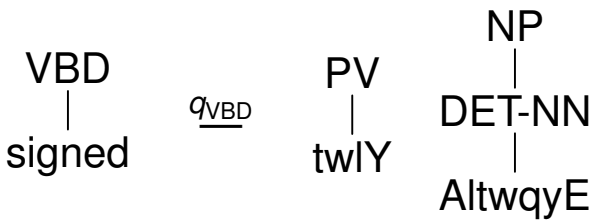

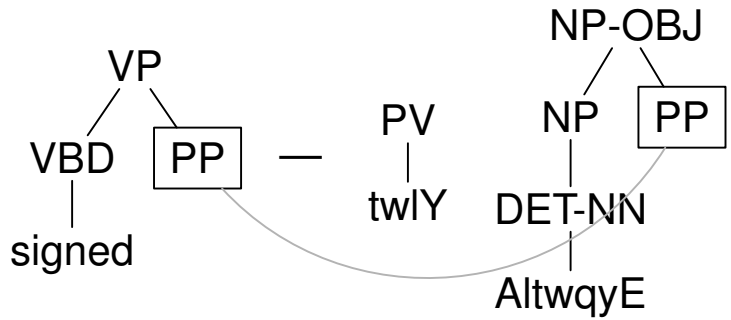

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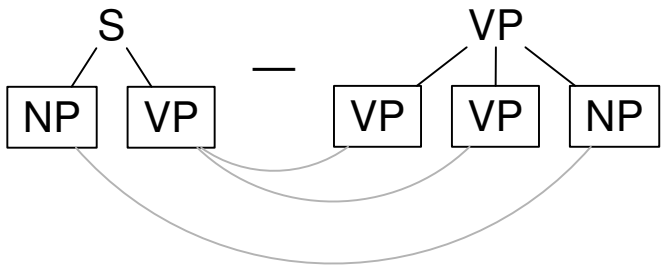
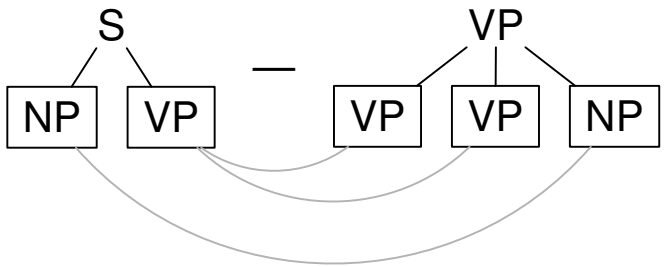



```
S(NP,VP) ||| VP(VP,VP,NP) ||| S ||| VP ||| 0-2 1-0 1-1 ||| ...
```

MBOT rule encoding

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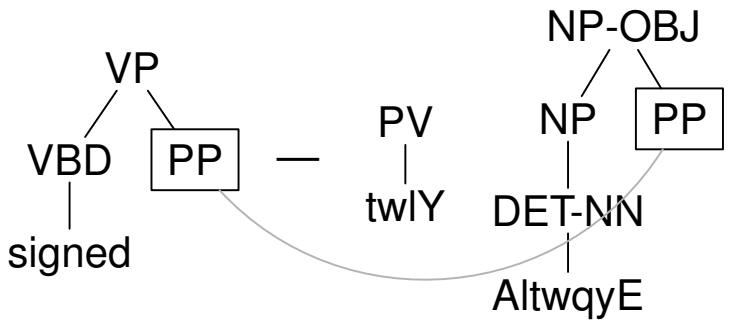



```
VP(VBD(signed),PP) ||| PV(twlY) || NP-OBJ(NP(DET-NN(AltwqyE)),PP) |||

VP ||| PV NP-OBJ ||| || 0-0 ||| ...
```

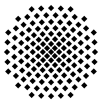
MBOT decoder

Fabienne Braune

- CYK-like chart parser
- only forward application
- supports all standard features
- integrated cube pruning with language model

Notes

- fast
- generated the examples in Motivation
- described in the ACL article you read



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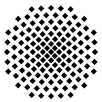

MBOT external tools

NINA SEEMANN

- rule extraction
- input/output restriction
- EM training
- conversion tools, pipeline scripts, . . .

Notes

- in PYTHON (not inside MOSES)
- computationally quite expensive
- variants for reduced POS-tags

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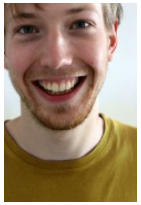
Exact MBOT decoder



DANIEL QUERNHEIM

- performs no cheats (no pruning, no flattening, etc.)
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- uses theoretical properties (1-symbol normal form)
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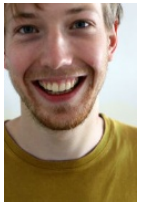

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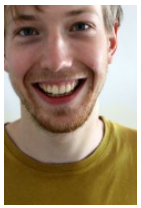
Posters and demos

Nina Seemann

- Poster: MBOT implementation in Moses

Fabienne Braune

- Demo: MBOT implementation in Moses



Daniel Quernheim

- Demo: Exact MBOT decoding