How to train your multi bottom-up tree transducer

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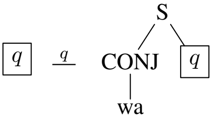
Synchronous Tree Substitution Grammar

$\boxed{q}$ $\boxed{q}$

Used rule

Next rule



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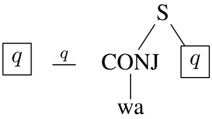

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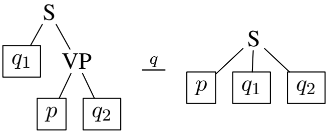

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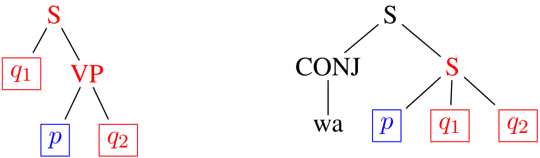

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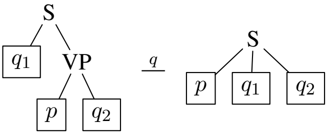

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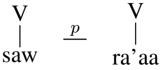

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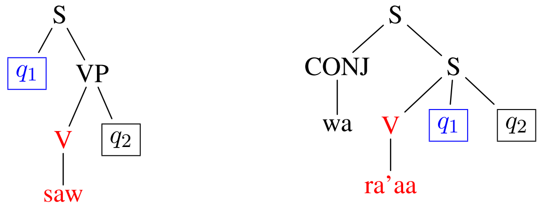

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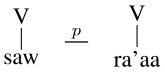

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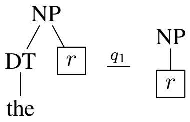

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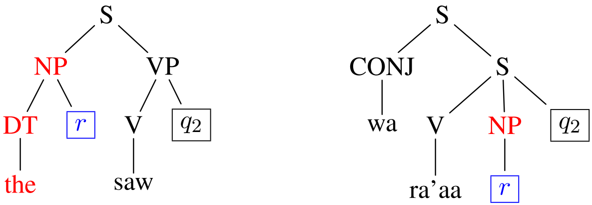

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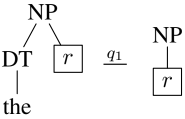

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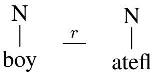

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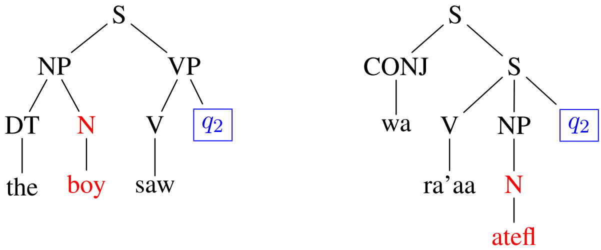

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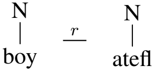

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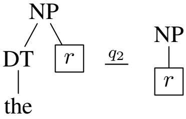

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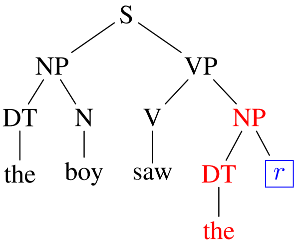

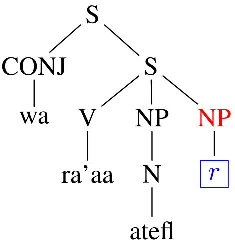

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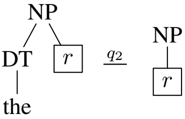

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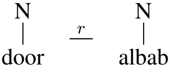

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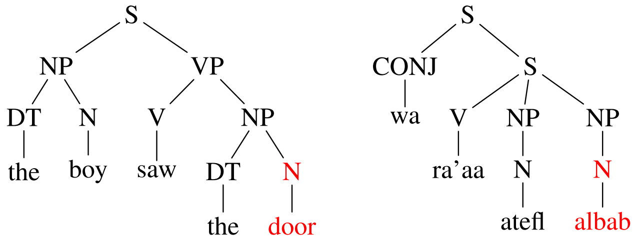

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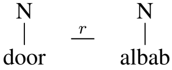

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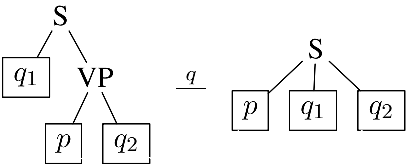
Synchronous Tree Substitution Grammar

Rule shape

- states can occur only once in lhs and rhs
- states in rhs $=$ states in lhs
- exactly one lhs and one rhs

$\rightarrow$ bijective synchronization relation



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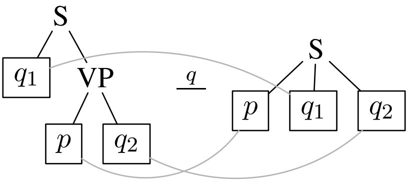

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Notes

- version with states (instead of locality tests)
- equivalent to linear nondeleting extended tree transducers
- implemented in TIBURON [May, Knight 2006]

Multi Bottom-up Tree Transducer

$\boxed{q}$ $\boxed{q}$

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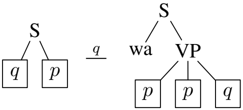

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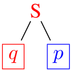

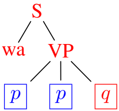

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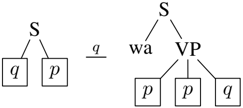

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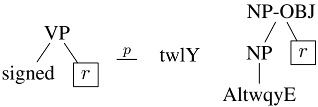

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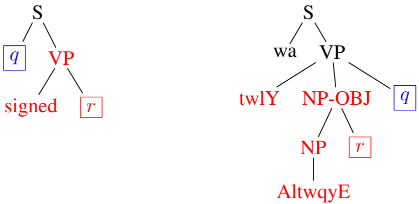

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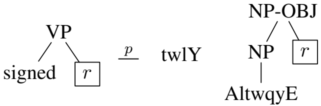

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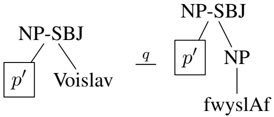

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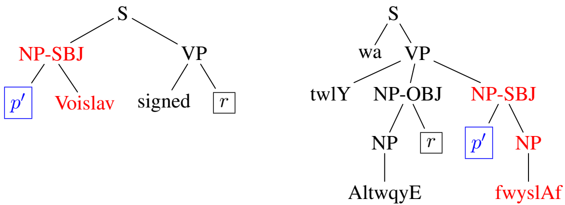

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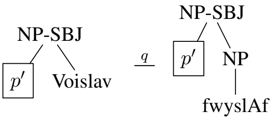

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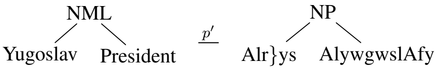

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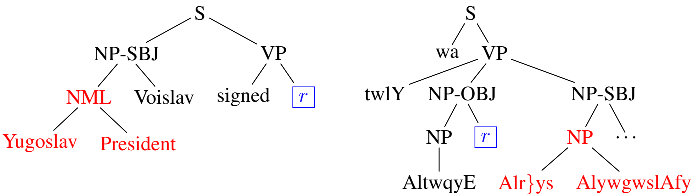

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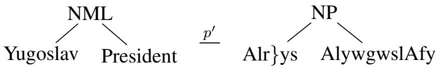

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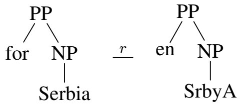

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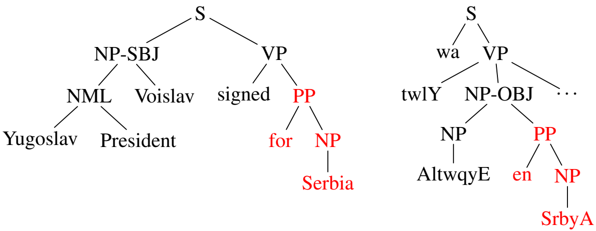

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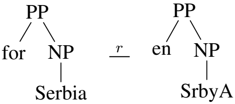

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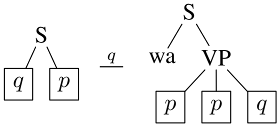
Multi Bottom-up Tree Transducer

Rule shape

- STSG: states can occur only once in lhs and rhs
  MBOT: states can occur only once in lhs
- STSG: states in rhs = states in lhs
  MBOT: states in rhs ⊆ states in lhs
- STSG: exactly one lhs and one rhs
  MBOT: exactly one lhs

→ STSG: bijective synchronization relation
MBOT: inverse synchronization relation is functional



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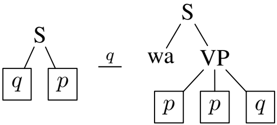

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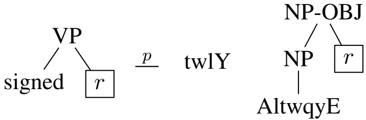

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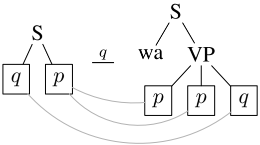

STSG vs. MBOT

property	STSG	MBOT
simple and natural	✓	?
symmetric	✓	✗
preserves regularity	✓	✗
inverse pres. regularity	✓	✓
binarizable	✗	✓
closed under composition	✗	✓
input parsing	$\mathcal{O}(\lvert M\rvert n^x)$	$\mathcal{O}(\lvert M\rvert n^3)$
output parsing	$\mathcal{O}(\lvert M\rvert n^x)$	$\mathcal{O}(\lvert M\rvert n^y)$

where $x = 2\,\mathrm{rk}(M) + 5$ and
$y = 2\,\mathrm{rk}(M) + 2$

Additional Expressive Power

Finite copying

$$\{\langle t, \sigma(t,t)\rangle \mid t \in T_\Sigma\}$$

- ✓ desirable [ATANLP participants, 2010]
  e.g., for cross-serial dependencies
- ✗ harms preservation of regularity

Non-contiguous rules

- ✓ $+0.64$ BLEU [Sun, Zhang, Tan, 2009] $25.92 \rightarrow 26.56$
- ✓ do not harm preservation of regularity

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Approach

Old approach

1. extract STSG rules
2. train STSG
3. convert to MBOT
4. work with MBOT

New approach

1. extract (restricted) MBOT rules
2. train MBOT
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Roadmap

1. Motivation
2. Relation to STSSG
3. Rule Extraction and Training
4. Preservation of Recognizability

Synchronous Tree-Sequence Substitution Grammar

Rule shape

- STSG: states can occur only once in lhs and rhs
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Expressive Power

Corollary

$$\text{STSG} \subseteq \text{MBOT} \subseteq \text{STSSG}$$

Theorem

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Claim

$$\text{MBOT}^{-1} ; \text{MBOT} = \text{STSSG}$$

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1. Motivation
2. Relation to STSSG
3. Rule Extraction and Training
4. Preservation of Recognizability

Input

- parallel bi-text
- parses for input and output
- word alignment

Output

- MBOT rules

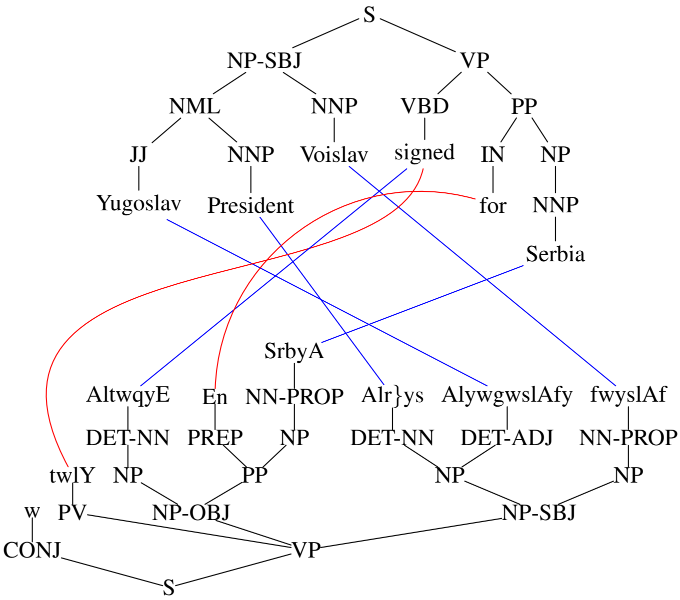
Rule Extraction

Input

- parallel bi-text
- parses for input and output
- word alignment

Output

- MBOT rules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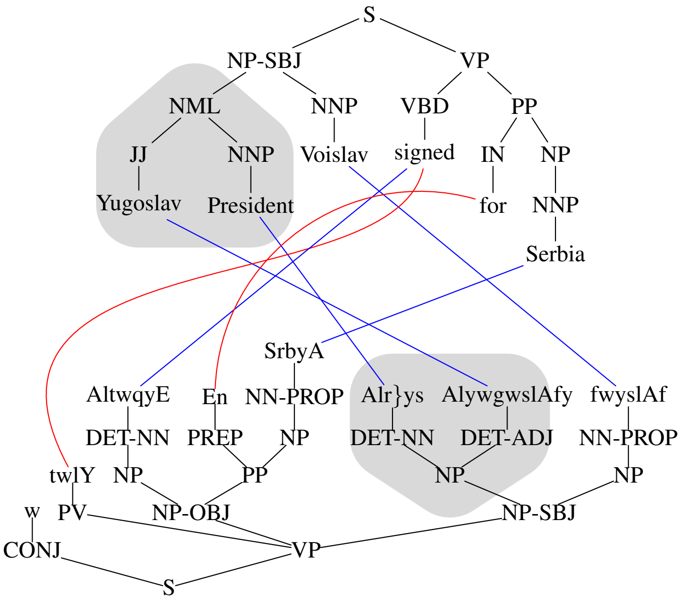
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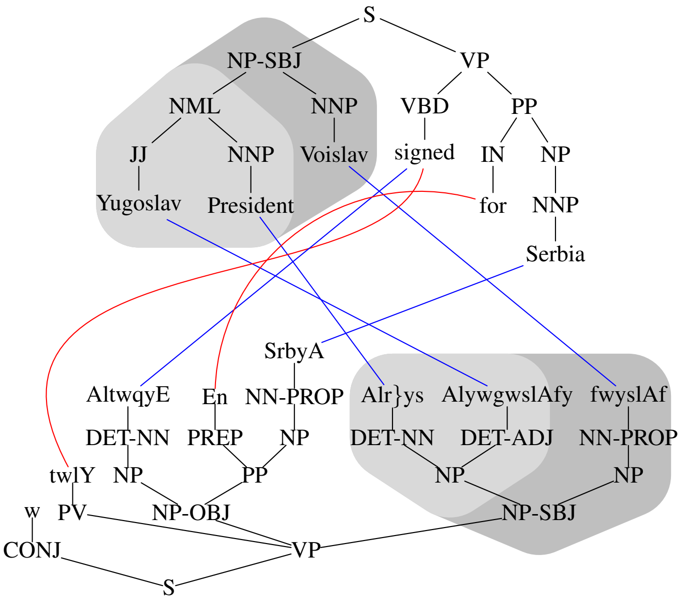
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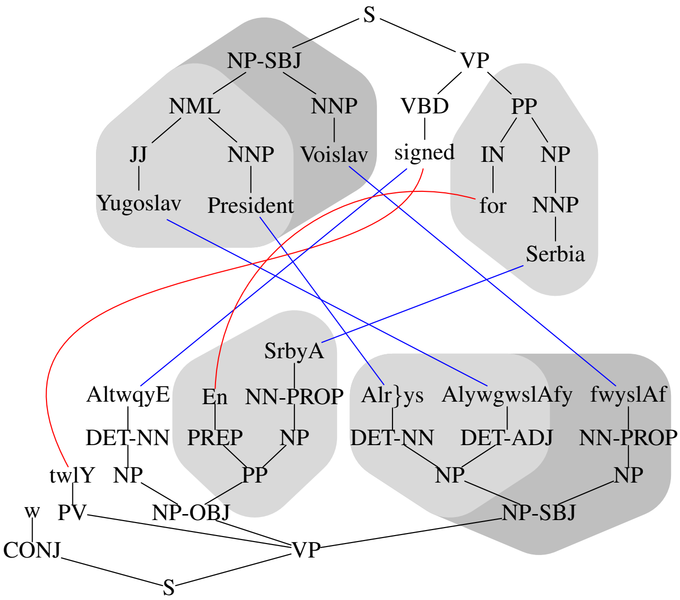
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DET-NN
PREP
NP
DET-NN
DET-ADJ
NN-PROP
twlY
NP
PP
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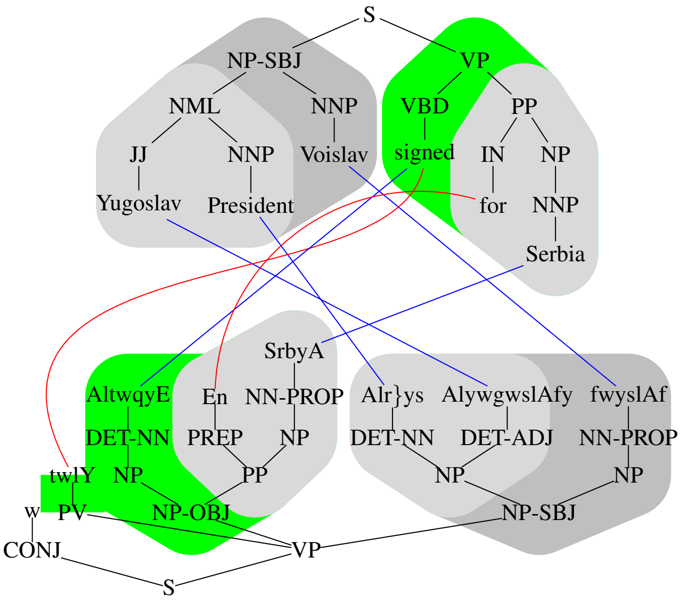
NP
w
PV
NP-OBJ
NP-SBJ
CONJ
VP
S


S
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CONJ
VP
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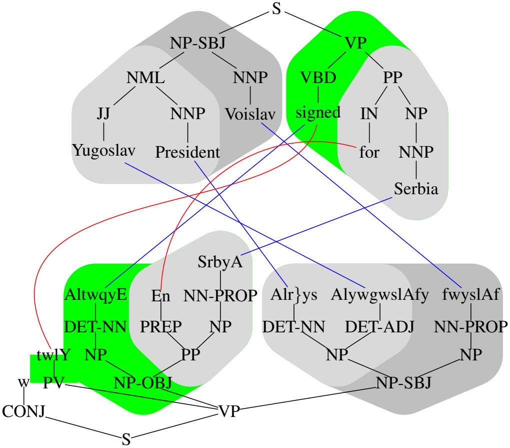
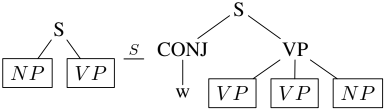
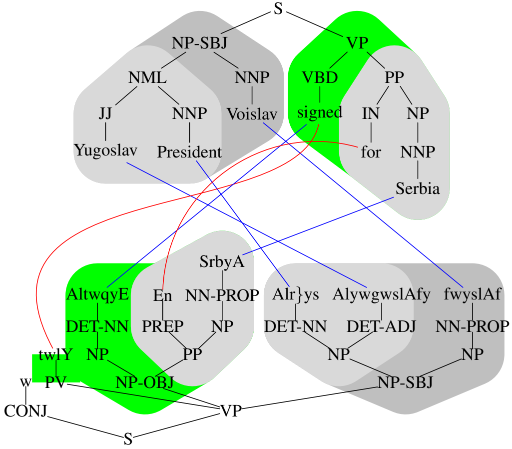
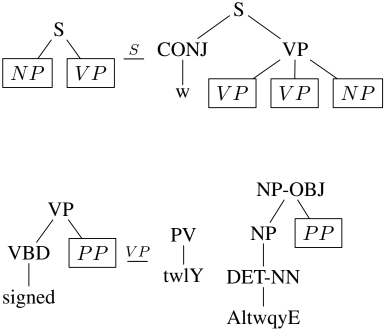
Rule Extraction





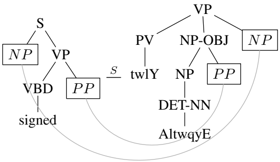
Rule Extraction





Extracted Rules

STSG rule

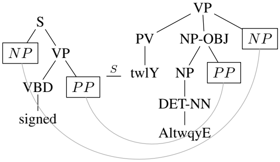


MBOT rules

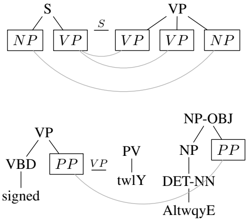
STSSG rule

Extracted Rules

STSG rule



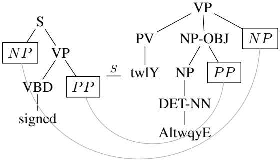
MBOT rules



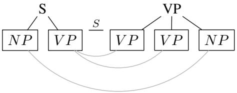
STSSG rule

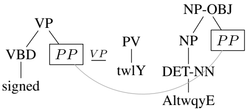
Extracted Rules

STSG rule

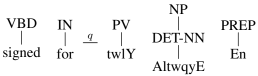


MBOT rules





STSSG rule



Definition

A tree language is regular if it can be represented by a TSG (with states).

Example

$$\{\sigma(t, t) \mid t \in T_\Sigma\}$$

is not regular.

Theorem

The set of derivations of an MBOT is regular.

Conclusion

Minimal adaptation of [Graehl, Knight, May 2008] can be used.

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Roadmap

Preservation of Regularity

Input

- MBOT M
- regular tree language L

Question

Is $\quad M(L) = \{t \mid \exists s \in L\colon \langle s, t\rangle \in M\} \quad$ regular?

Example

- $M = \{\langle t, \sigma(t, t)\rangle \mid t \in T_\Sigma\}$
- infinite, but regular tree language $L \subseteq T_\Sigma$

Then $M(L) = \{\sigma(t, t) \mid t \in L\}$ is not regular.

Preservation of Regularity

Input

- MBOT M
- regular tree language L

Question

Is $M(L) = \{t \mid \exists s \in L \colon \langle s, t \rangle \in M\}$ regular?

Example

- $M = \{\langle t, \sigma(t, t) \rangle \mid t \in T_\Sigma\}$
- infinite, but regular tree language $L \subseteq T_\Sigma$

Then $M(L) = \{\sigma(t, t) \mid t \in L\}$ is not regular.

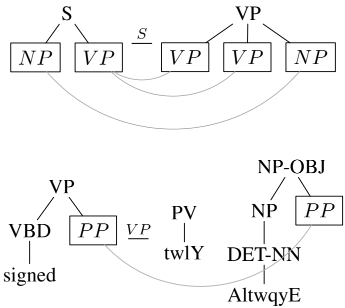
Preservation of Regularity

Why desired?

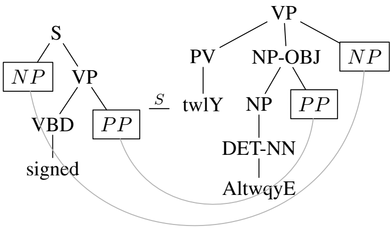
- easy and efficient representation of output languages
- allows intersection with (regular) language model
- allows bucket-brigade algorithms
  [May, Knight, Vogler, 2010]

Rule Composition

Input rules



Output rule



Rule Composition

Power MBOT

$$M^k = \{R_1 \circ \cdots \circ R_k \mid R_1, \ldots, R_k \in M\}$$

Explanation

- M^k contains k-fold composed rules
- composition fails if states do not match
- composition succeeds (with no effect) if no matchable states present

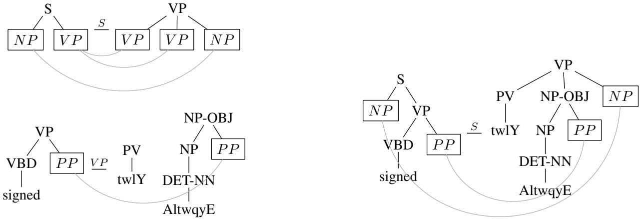
Finitely Collapsing

Definition

M is finitely collapsing if there exists $k \in \mathbb{N}$ such that

- every state occurs at most once in rhs of every rule of M^k.

Example



Finite Synchronization

Definition

M has finite synchronization if there exists $k \in \mathbb{N}$ such that

- all occurrences of a state occur in the same tree in the rhs of every rule of M^k.

Theorem (Raoult, 1997)

MBOT with finite synchronization and finitely collapsing MBOT preserve regularity.

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MBOT with finite synchronization and finitely collapsing MBOT preserve regularity.

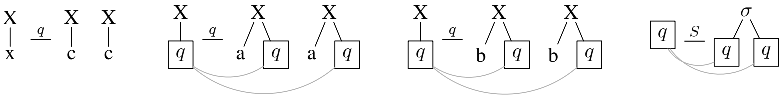
Copy-free

Definition

M is copy-free if there exists $k \in \mathbb{N}$ such that for every rule of M^k and all occurrences w of a state:

- w is the root of a tree in the rhs or
- w belongs to a fixed tree in the rhs.

Example (not copy-free)

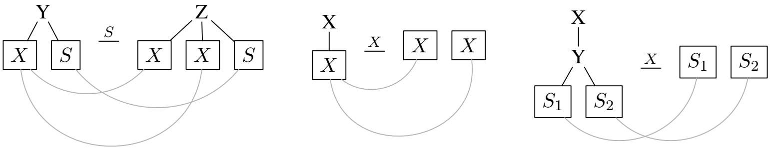


Definition

M is copy-free if there exists $k \in \mathbb{N}$ such that for every rule of M^k and all occurrences *w* of a state:

- *w* is the root of a tree in the rhs or
- *w* belongs to a fixed tree in the rhs.

Example (copy-free)



Main Result

Theorem

Copy-free MBOT preserve regularity.

Theorem

finitely collapsing $\subset$ *finite synchronization* $\subset$ *copy-free*

Note

All 3 restrictions can be guaranteed during rule extraction.

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Note
All 3 restrictions can be guaranteed during rule extraction.

Thank you for your attention!

References

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