

Extended Tree Transducers in Natural Language Processing

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Universität Stuttgart

Düsseldorf — June 22, 2015

Machine Translation

Original

Übersetzung (GOOGLE TRANSLATE)

- ▶ The addressees of this paper are students and students will be in the audience are.

Machine Translation

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- ▶ Die Adressaten dieses Vortrags sind Studierende und im Publikum werden sich Studierende befinden.

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- ▶ The addressees of this paper are students and students will be in the audience are.
- ▶ To scientific lecture, a public discussion follows on.

Machine Translation

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(The addressees of this talk are students, and students will be in the audience.)

- ▶ An den wissenschaftlichen Vortrag schließt sich eine öffentliche Diskussion an.

(The scientific lecture is followed by a public discussion.)

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Short History

Timeline

1. Dark age (60s–90s)

- ▶ rule-based systems (e.g., SYSTRAN)
- ▶ CHOMSKYAN approach
- ▶ perfect translation, poor coverage

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- ▶ cheap, automatically trained

3. Potential future

- ▶ semantics-based systems (e.g., FRAMENET-based)
- ▶ semi-supervised, statistical approach
- ▶ basic understanding of translated text

Some Fun

Applications

- ▶ Technical manuals

Example (An mp3 player)

The synchronous manifestation of lyrics is a procedure for can broadcasting the music, waiting the mp3 file at the same time showing the lyrics.

Some Fun

Applications

- ▶ Technical manuals

Example (An mp3 player)

With the this kind method that the equipments that synchronous function of support up broadcast to make use of document create setup, you can pass the LCD window way the check at the document contents that broadcast.

Some Fun

Applications

- ▶ Technical manuals

Example (An mp3 player)

That procedure returns offerings to have to modify, and delete, and stick top , keep etc. edit function.

Some Fun

Applications

- ▶ Technical manuals
- ▶  tripadvisor

Example (Hotel Uppsala, Sweden)

Wir hatten die Zimmer eingestuft wird als “Superior” weil sie renoviert wurde im letzten Jahr oder zwei. Unsere Zimmer hatten Parkettboden und waren sehr geräumig. Man musste allerdings nicht musste seitwärts bewegen.

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— *We stayed in rooms classified as “superior” because they had been renovated in the last year or two. Our rooms had wood floors and were roomy. You didn’t have to walk sideways to move around.*

Some Fun

Applications

- ▶ Technical manuals
- ▶  tripadvisor
- ▶ US military

Example (JONES, SHEN, HERZOG 2009)

Soldier: Okay, what is your name?

Local: Abdul.

Soldier: And your last name?

Local: Al Farran.

Some Fun

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I mean yes

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Soldier: What is your last name?

Local: every two weeks
my son's name is ismail

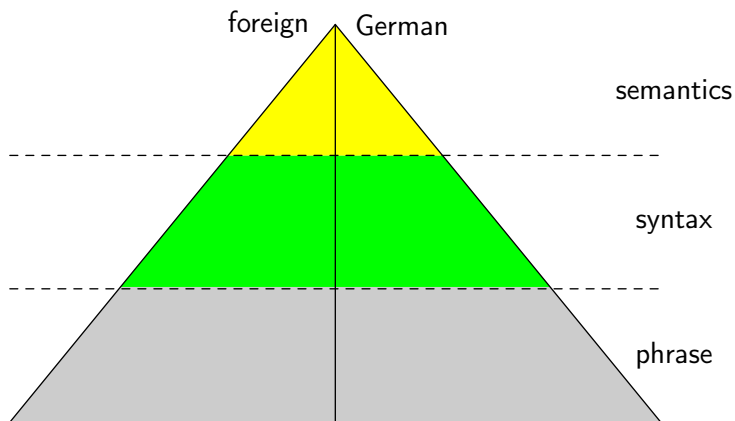
Some Fun

Applications

- ▶ Technical manuals
- ▶  tripadvisor
- ▶ US military
- ▶ MSDN, Knowledge Base
- ▶ ...

Machine Translation

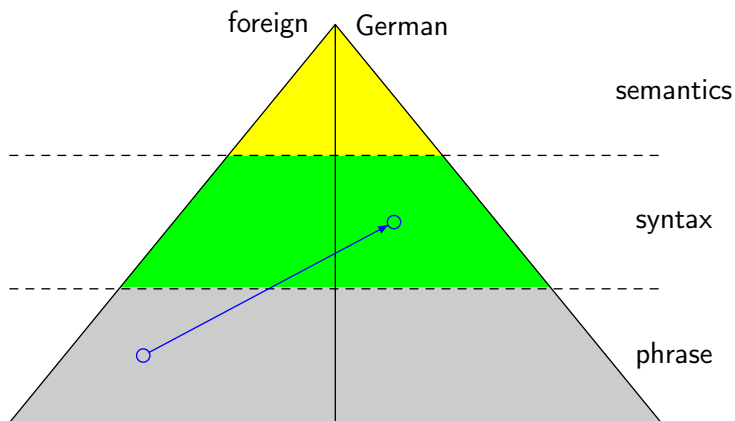
VAUQUOIS triangle:



Translation model:

Machine Translation

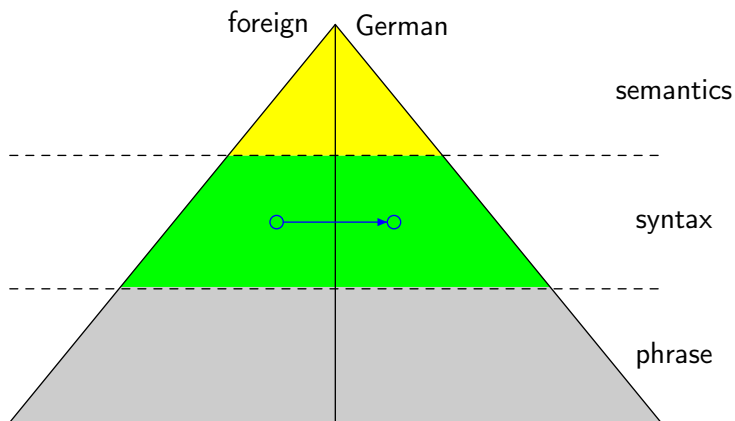
VAUQUOIS triangle:



Translation model: [string-to-tree](#)

Machine Translation

VAUQUOIS triangle:



Translation model: [tree-to-tree](#)

Machine Translation

Training data

- ▶ parallel corpus
- ▶ word alignments
- ▶ parse trees for the target sentences

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Parallel Corpus

linguistic resource containing example translations

(sentence level)

Machine Translation

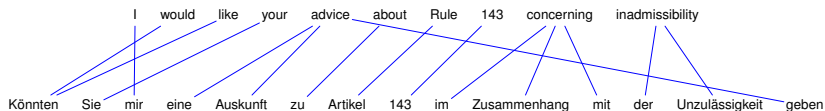
parallel corpus, word alignments, parse tree

I would like your advice about Rule 143 concerning inadmissibility

Könnten Sie mir eine Auskunft zu Artikel 143 im Zusammenhang mit der Unzulässigkeit geben

Machine Translation

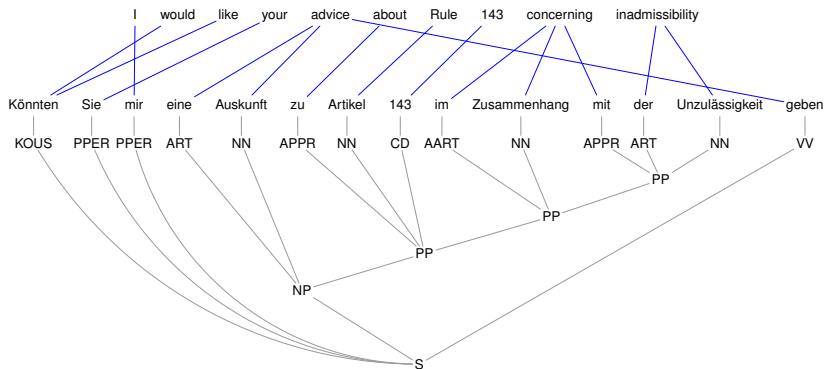
parallel corpus, **word alignments**, parse tree



via GIZA++ [OCH, NEY, 2003]

Machine Translation

parallel corpus, word alignments, **parse tree**



via BERKELEY parser [PETROV et al., 2006]

Extended Tree Transducer

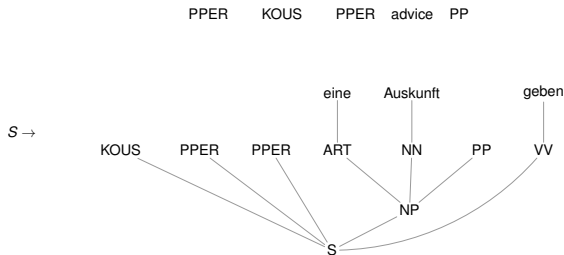
Extended top-down tree transducer (STSG)

- ▶ variant of [M., GRAEHL, HOPKINS, KNIGHT, 2009]
- ▶ rules of the form $NT \rightarrow (r, r_1)$
 - ▶ nonterminal NT
 - ▶ right-hand side r of context-free grammar rule
 - ▶ right-hand side r_1 of regular tree grammar rule

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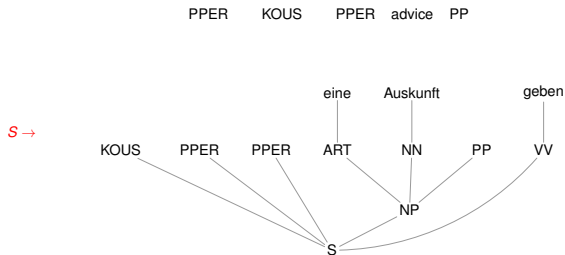
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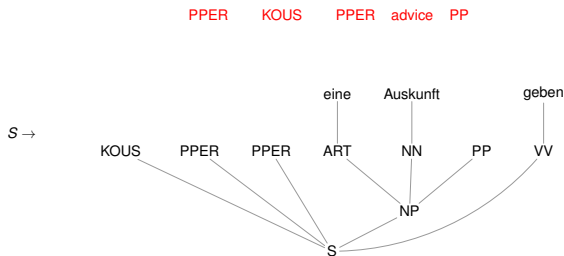
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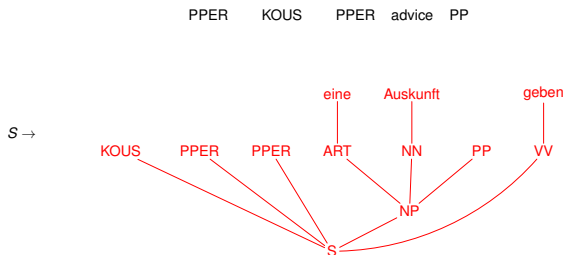
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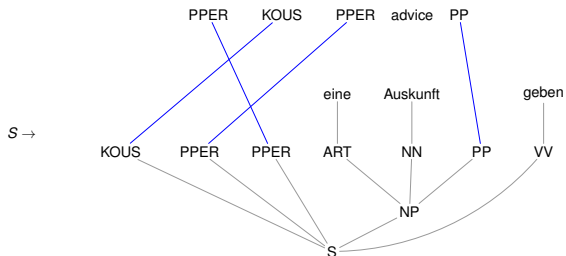
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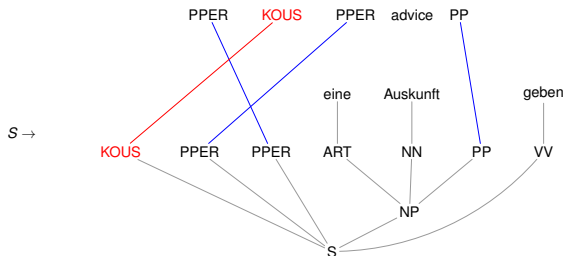
Extended Tree Transducer



Rule application

1. Selection of synchronous nonterminals

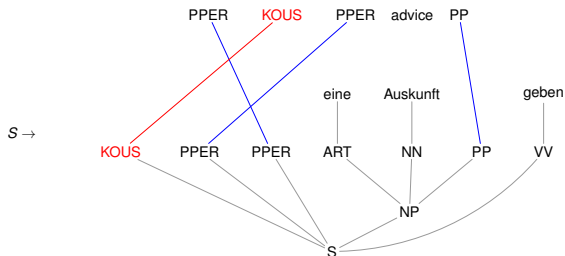
Extended Tree Transducer



Rule application

1. Selection of synchronous nonterminals

Extended Tree Transducer



Rule application

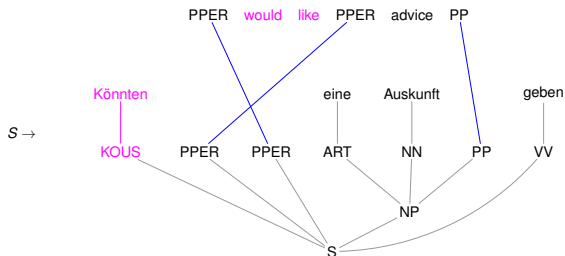
1. Selection of synchronous nonterminals
2. Selection of suitable rule

would like

KOUS →

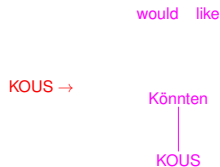
Könnten
|
KOUS

Extended Tree Transducer

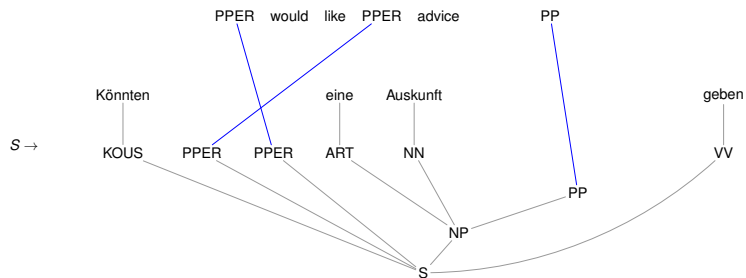


Rule application

1. Selection of synchronous nonterminals
2. Selection of suitable rule
3. Replacement on both sides



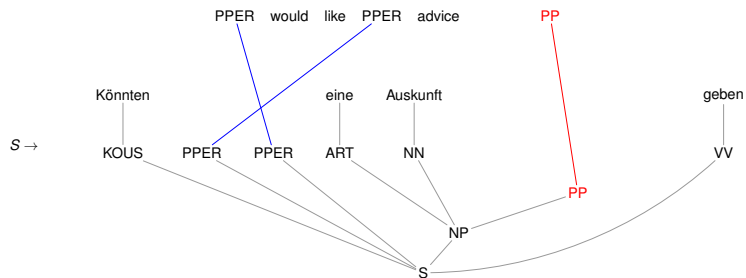
Extended Tree Transducer



Rule application

1. **synchronous nonterminals**

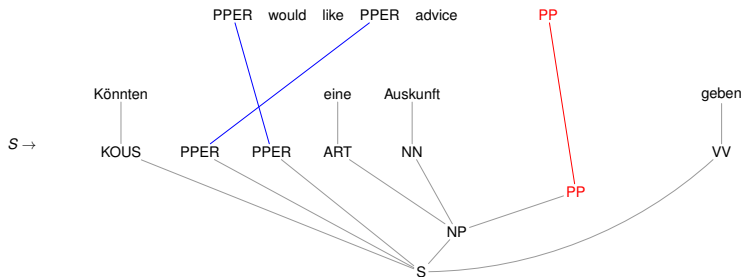
Extended Tree Transducer



Rule application

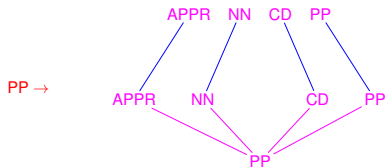
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Extended Tree Transducer

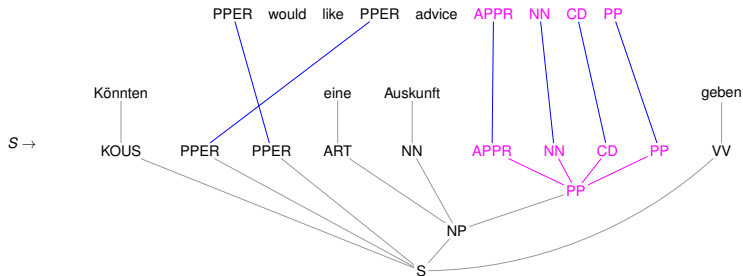


Rule application

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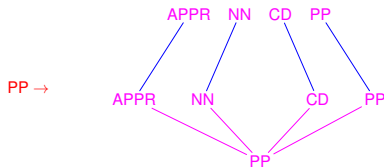


Extended Tree Transducer



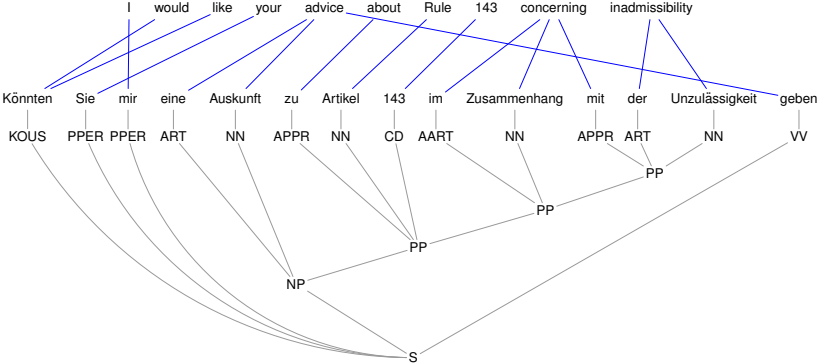
Rule application

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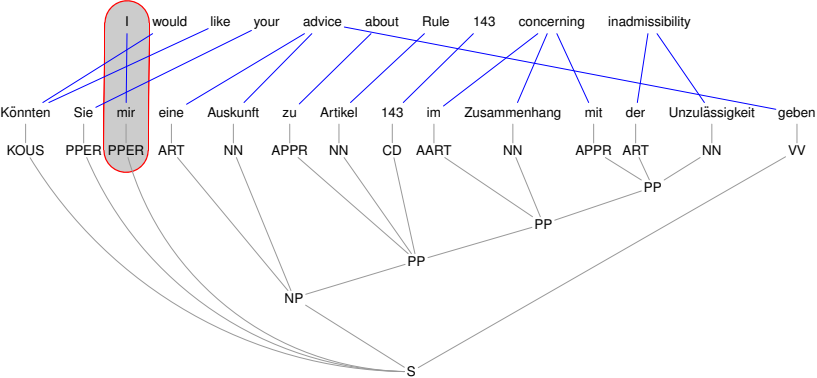
Rule extraction

following [GALLEY, HOPKINS, KNIGHT, MARCU, 2004]



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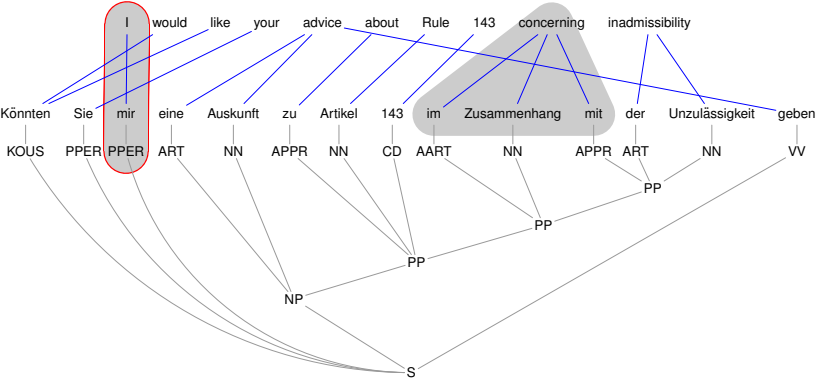
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extractable rules marked in red

Rule extraction

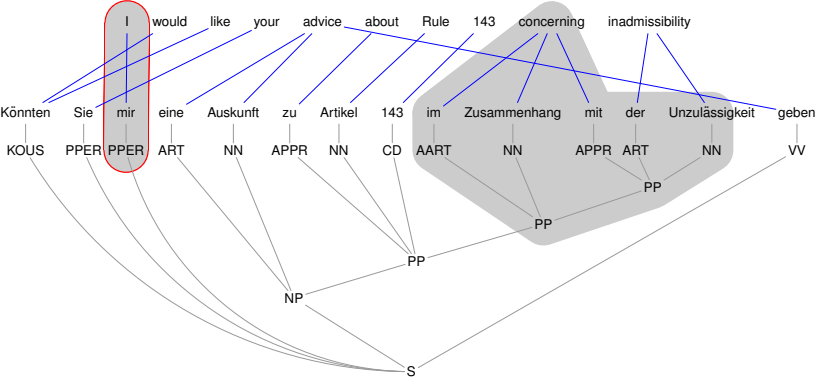
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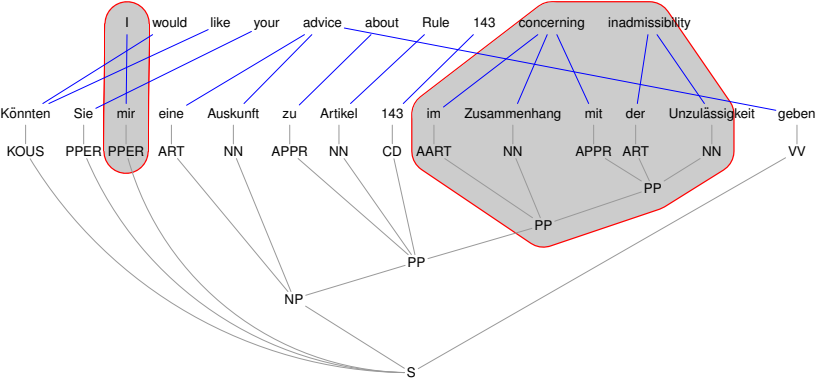
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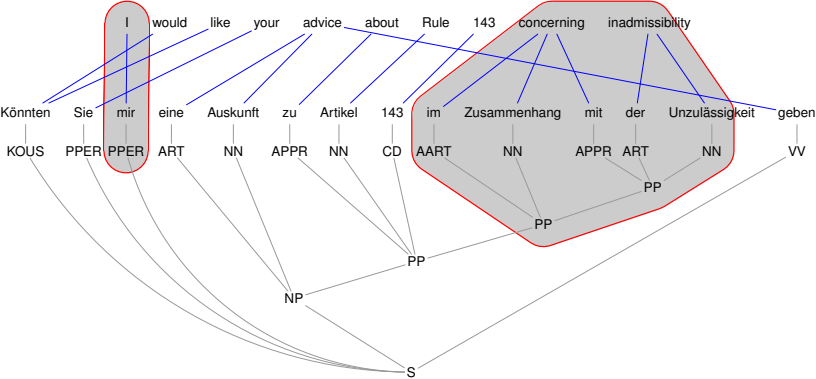
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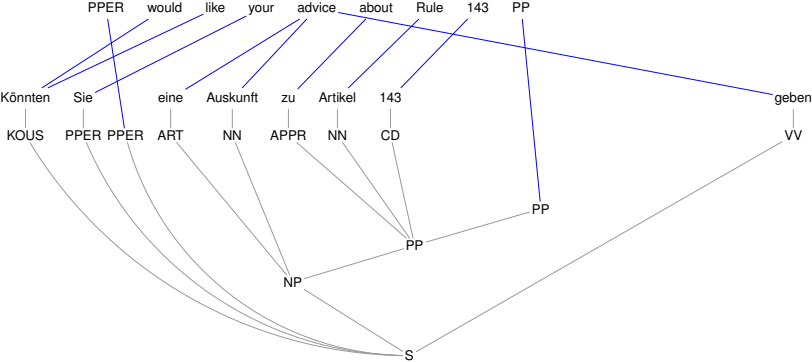
Rule extraction

Removal of extractable rule:



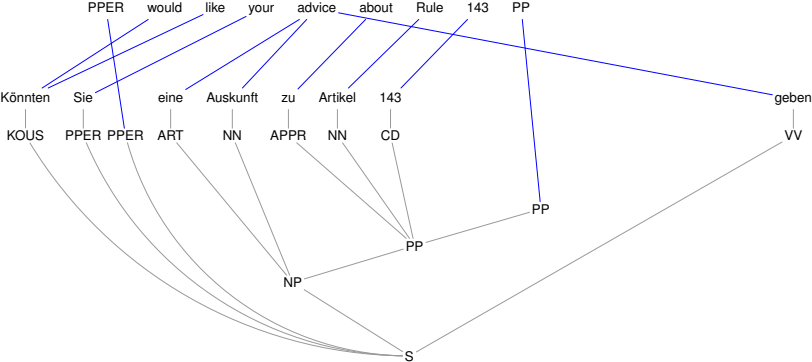
Rule extraction

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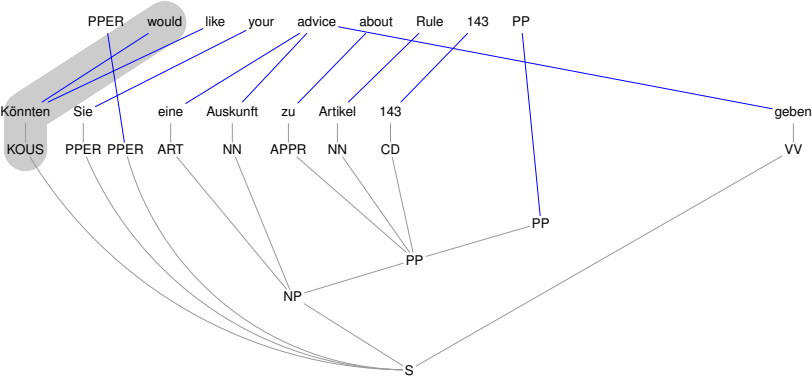
Rule extraction

Repeated rule extraction:



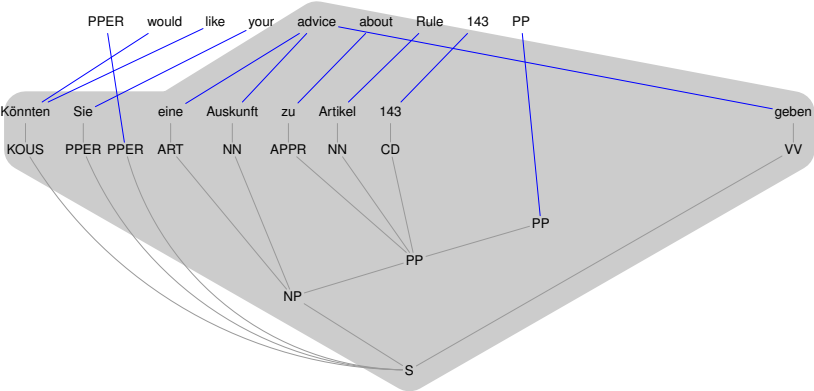
Rule extraction

Repeated rule extraction:



Rule extraction

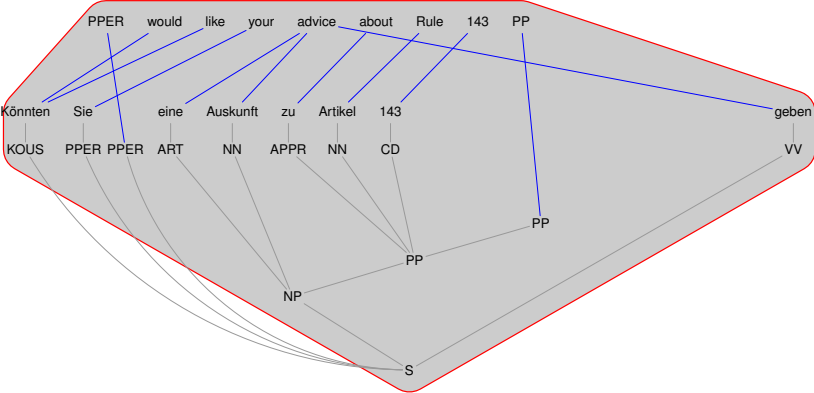
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Extended Tree Transducer

Advantages

- ▶ very simple
- ▶ implemented in MOSES [[KOEHN et al., 2007](#)]
- ▶ “context-free”

Extended Tree Transducer

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- ▶ very simple
- ▶ implemented in MOSES [KOEHN et al., 2007]
- ▶ “context-free”

Disadvantages

- ▶ problems with discontinuities
- ▶ composition and binarization not possible [M. et al., 2009] and [ZHANG et al., 2006]
- ▶ “context-free”

Extended Tree Transducer

Remarks

- ▶ synchronization breaks almost all existing constructions (e.g., the normalization construction)
- the basic grammar model **very important**

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- the basic grammar model **very important**
- ▶ **tree-to-tree** models use trees on both sides

Extended Tree Transducer

Major (tree-to-tree) models

1. linear top-down tree transducer (with look-ahead)
 - ▶ input-side: tree automaton
 - ▶ output-side: regular tree grammar
 - ▶ synchronization: mapping output NT to input NT

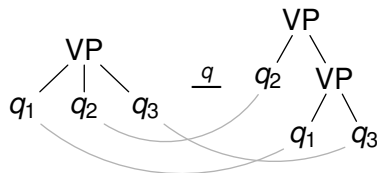
Extended Tree Transducer

Major (tree-to-tree) models

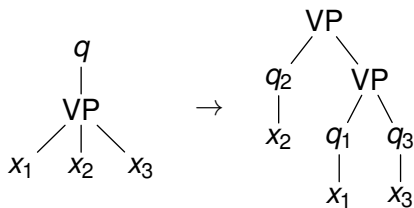
1. **linear top-down tree transducer (with look-ahead)**
 - ▶ input-side: tree automaton
 - ▶ output-side: regular tree grammar
 - ▶ synchronization: mapping output NT to input NT
2. **linear extended top-down tree transducer (w. look-ahead)**
 - ▶ input-side: regular tree grammar
 - ▶ output-side: regular tree grammar
 - ▶ synchronization: mapping output NT to input NT

Extended Tree Transducer

Synchronous grammar rule:



“Classical” top-down tree transducer rule:



Extended Tree Transducer

Syntactic restrictions

- ▶ **nondeleting** if synchronization bijective (in all rules)
- ▶ **strict** if r_1 not a nonterminal (for all rules $q \rightarrow (r, r_1)$)
- ▶ **$\underline{\epsilon}$ -free** if r not a nonterminal (for all rules $q \rightarrow (r, r_1)$)

Composition (COMP)

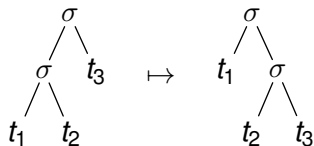
executing transformations $\tau \subseteq T_\Sigma \times T_\Delta$ and $\tau' \subseteq T_\Delta \times T_\Gamma$
one after the other:

$$\tau ; \tau' = \{(s, u) \mid \exists t \in T_\Delta : (s, t) \in \tau, (t, u) \in \tau'\}$$

Extended Tree Transducer

Rotations (ROT)

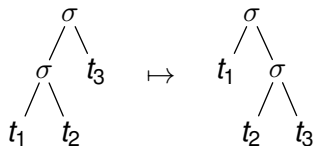
$$\{\langle \sigma(\sigma(t_1, t_2), t_3), \sigma(t_1, \sigma(t_2, t_3)) \rangle \mid t_1, t_2, t_3 \in T_\Sigma\}$$



Extended Tree Transducer

Rotations (ROT)

$$\{\langle \sigma(\sigma(t_1, t_2), t_3), \sigma(t_1, \sigma(t_2, t_3)) \rangle \mid t_1, t_2, t_3 \in T_\Sigma\}$$



Preservation of regularity (PRES)

Given $\tau \subseteq T_\Sigma \times T_\Delta$ and $L \subseteq T_\Sigma$ regular, is $\tau(L)$ regular?

$$\tau(L) = \{u \mid \exists t \in L: (t, u) \in \tau\}$$

Extended Tree Transducer

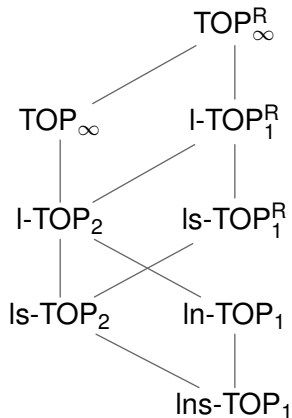
Notation

- ▶ $(X)TOP$ = class of tree transformations computable by (extended) top-down tree transducers
- ▶ $(X)TOP^R$ = class of . . . transducers with regular look-ahead
- ▶ $x-(X)TOP^{(R)}$ = class of . . . transducers with properties x

Example

$ln-TOP$ = class of tree transformations computable by linear and nondeleting top-down tree transducers

Top-down Tree Transducer



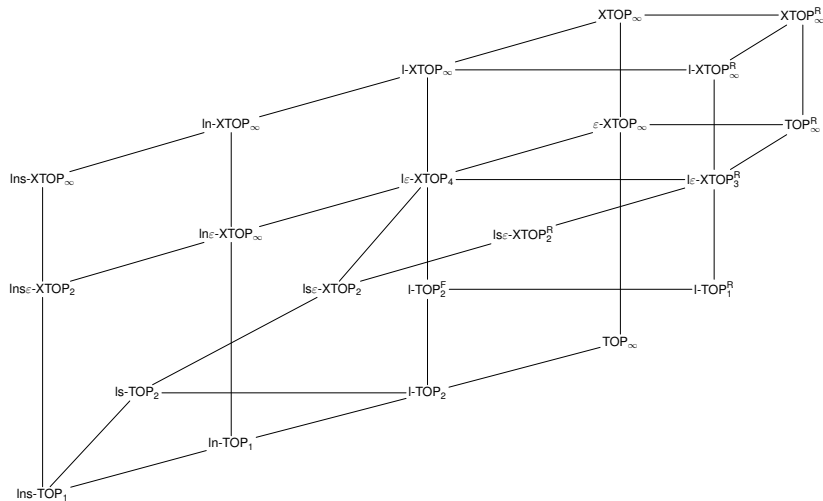
composition closure indicated in subscript

Top-down Tree Transducer

Model \ Criterion	ROT	SYM	PRES	PRES ⁻¹	COMP
Ins-TOP	X	X	✓	✓	✓
In-TOP	X	X	✓	✓	✓
Is-TOP	X	X	✓	✓	X ₂
I-TOP	X	X	✓	✓	X ₂
Is-TOP ^R	X	X	✓	✓	✓
I-TOP ^R	X	X	✓	✓	✓
TOP	✓	X	X	✓	X _∞
TOP ^R	✓	X	X	✓	X _∞

(SYM = symmetric)

Extended Top-down Tree Transducer

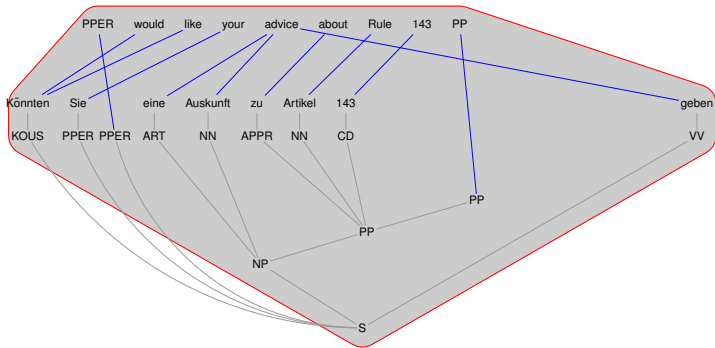


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Extended Top-down Tree Transducer

Model \ Criterion	ROT	SYM	PRES	PRES⁻¹	COMP
In-TOP	X	X	✓	✓	✓
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I-TOP ^R	X	X	✓	✓	✓
TOP ^R	✓	X	X	✓	X _∞
Ins _ε -XTOP	✓	✓	✓	✓	X ₂
Ins-XTOP	✓	X	✓	✓	X _∞
Is _ε -XTOP ^(R)	✓	X	✓	✓	X ₂
I _ε -XTOP	✓	X	✓	✓	X ₄
I _ε -XTOP ^R	✓	X	✓	✓	X ₃
(s)I-XTOP ^(R)	✓	X	✓	✓	X _∞
XTOP	✓	X	X	✓	X _∞
XTOP ^R	✓	X	X	✓	X _∞

Rule extraction



- ▶ very specific rule
- ▶ every rule for “advice” contains sentence structure
- ▶ (syntax “in the way”)

Extended Tree Transducer

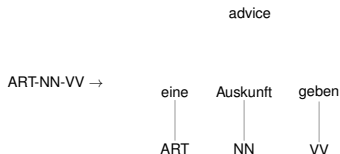
Extended Multi Bottom-up Tree Transducer (MBOT)

- ▶ variant of [M., 2010]
- ▶ rules of the form $NT \rightarrow (r, \langle r_1, \dots, r_n \rangle)$
 - ▶ nonterminal NT
 - ▶ right-hand side r of context-free grammar rule
 - ▶ right-hand sides r_1, \dots, r_n of regular tree grammar rule

Extended Tree Transducer

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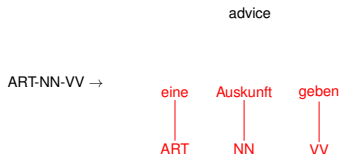
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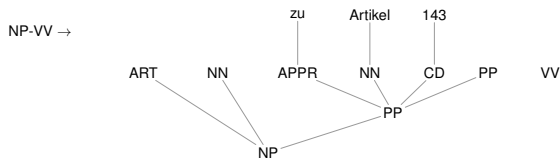


Extended Tree Transducer

Extended Multi Bottom-up Tree Transducer (MBOT)

- ▶ variant of [M., 2010]
- ▶ rules of the form $NT \rightarrow (r, \langle r_1, \dots, r_n \rangle)$
 - ▶ nonterminal NT
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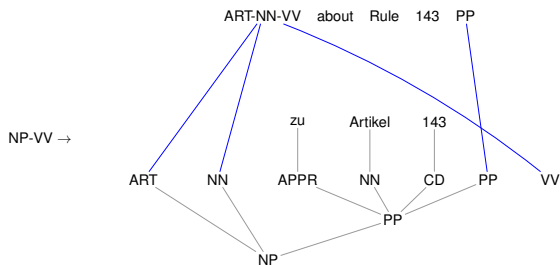
ART-NN-VV about Rule 143 PP



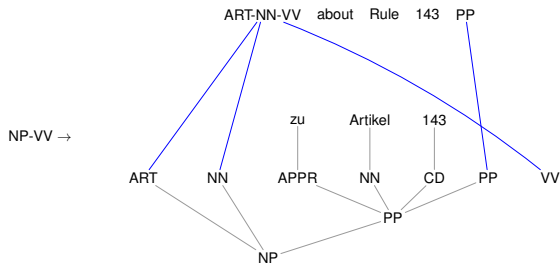
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- ▶ synchronization via map $NT \ r_1, \dots, r_n$ to $NT \ r$



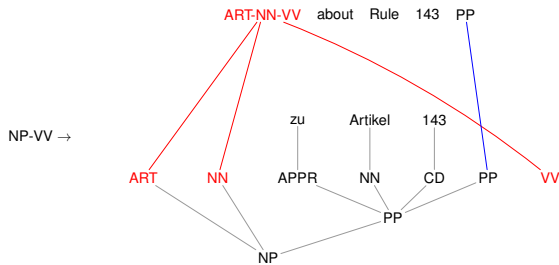
Extended Multi Bottom-up Tree Transducer



Rule application

1. synchronous nonterminals

Extended Multi Bottom-up Tree Transducer



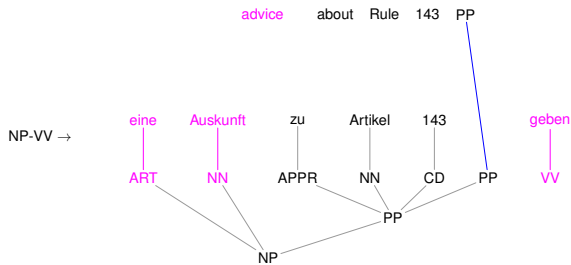
Rule application

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ART-NN-VV →

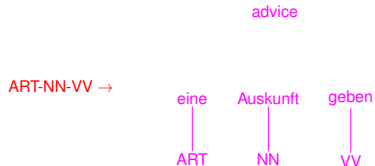


Extended Multi Bottom-up Tree Transducer



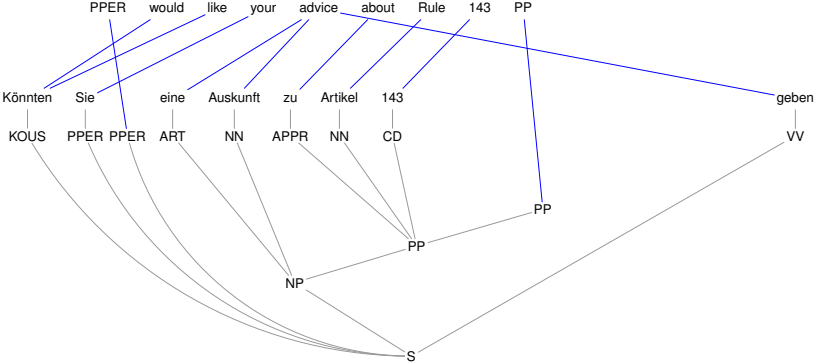
Rule application

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3. replacement



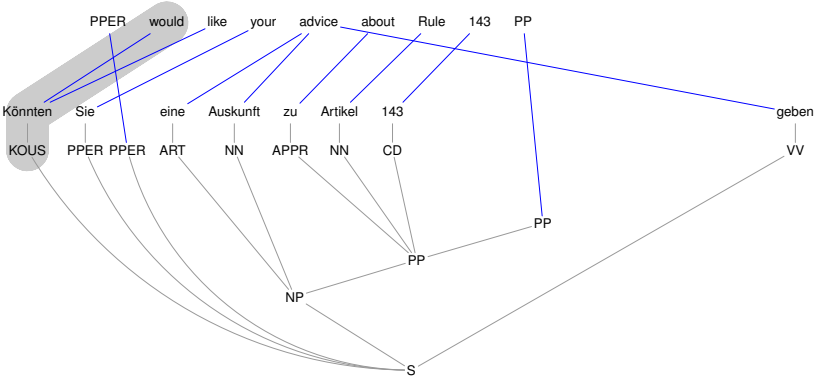
Rule extraction

following [M., 2011]



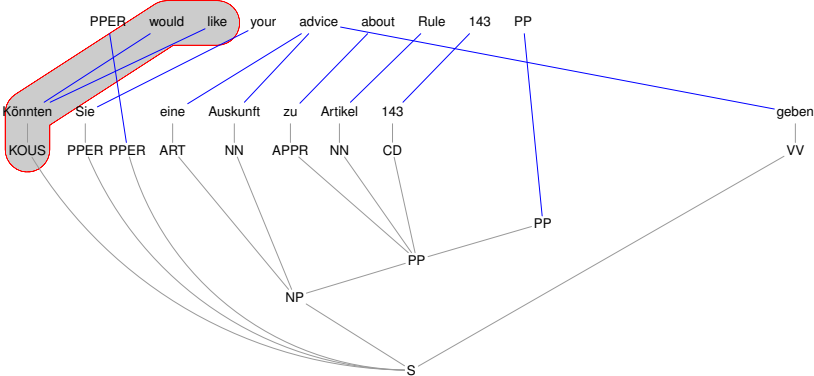
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Rule extraction

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extractable rules marked in red

Extended Multi Bottom-up Tree Transducer

- ▶ complicated discontinuities
- ▶ also available in MOSES [[BRAUNE et al., 2013](#)]
- ▶ binarizable, composable

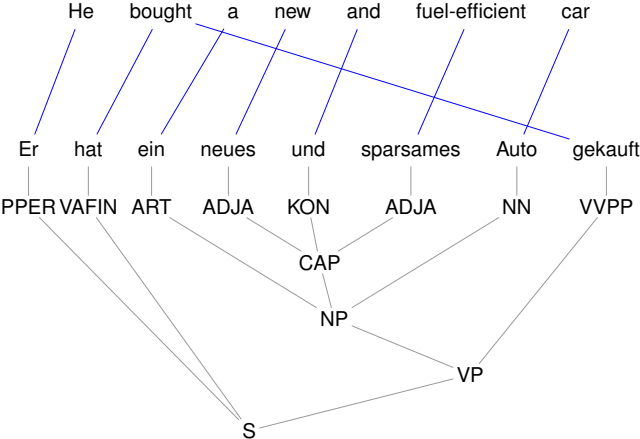
Extended Multi Bottom-up Tree Transducer

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- ▶ also available in MOSES [[BRAUNE et al., 2013](#)]
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Disadvantages

- ▶ output not regular (as tree language)
- ▶ not symmetric (input context-free; output not)

Discontinuity



Extended Multi Bottom-up Tree Transducer

Theorem [ENGELFRIET et al., 2009]

$$\text{I-XTOP}^R = \text{I-XBOT}$$

Proof.

Standard construction trading input-deletion for output-deletion
see $\text{I-TOP} \subseteq \text{I-BOT}$ by [ENGELFRIET '75] □

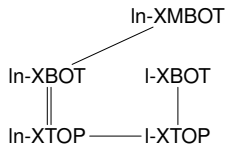
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Extended Multi Bottom-up Tree Transducer

Theorem [ENGELFRIET et al., 2009]

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- ▶ guess subtrees that will be deleted
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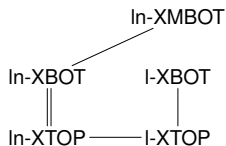
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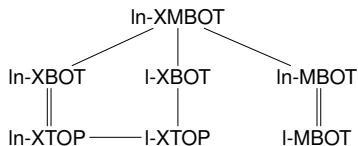
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Extended Multi Bottom-up Tree Transducer

Theorem [ENGELFRIET et al., 2009]

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Proof.

- ▶ decompose large left-hand sides using “multi”-states
- ▶ attach finite effect of ε -rules



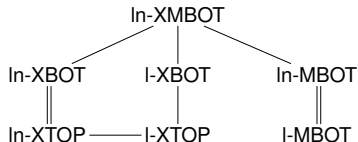
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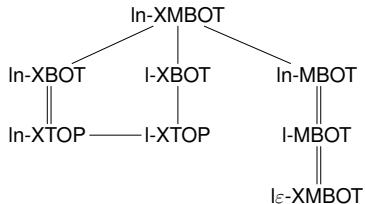
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Extended Multi Bottom-up Tree Transducer

Theorem [M., 2014]

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Extended Multi Bottom-up Tree Transducer

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$$\text{In-MBOT} \not\subseteq (\text{In-XTOP}^R)^*$$

Theorem [GILDEA, 2012]

$$y_{\text{out}}(\text{In-MBOT}) = \text{LCFRS}$$

Summary

Model \ Criterion	ROT	SYM	PRES	$PRES^{-1}$	COMP
In-TOP	X	X	✓	✓	✓
I-TOP	X	X	✓	✓	X ₂
I-TOP ^R	X	X	✓	✓	✓
TOP ^R	✓	X	X	✓	X _∞
Ins _ε -XTOP	✓	✓	✓	✓	X ₂
Ins-XTOP	✓	X	✓	✓	X _∞
Is _ε -XTOP ^(R)	✓	X	✓	✓	X ₂
I _ε -XTOP	✓	X	✓	✓	X ₄
I _ε -XTOP ^R	✓	X	✓	✓	X ₃
(s)I-XTOP ^(R)	✓	X	✓	✓	X _∞
XTOP ^(R)	✓	X	X	✓	X _∞
I(n)-XMBOT	✓	X	X	✓	✓
XMBOT	✓	X	X	✓	X _∞
reg.-preserving I-XMBOT	✓	X	✓	✓	✓
invertable I-XMBOT	✓	✓	✓	✓	✓

Evaluation

Task	System	BLEU
English → German	STSG	15.22
	MBOT	15.90
	phrase-based	16.73
	hierarchical	16.95
	GHKM	17.10
English → Arabic	STSG	48.32
	MBOT	49.10
	phrase-based	50.27
	hierarchical	51.71
	GHKM	46.66
English → Chinese	STSG	17.69
	MBOT	18.35
	phrase-based	18.09
	hierarchical	18.49
	GHKM	18.12

from [SEEMANN, BRAUNE, M., 2015]

Some More Fun

Translation

- ▶ **Input:**

Official forecasts predicted just 3 percent, Bloomberg said.

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- ▶ **Input:**
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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.

- ▶ **Google:**

Die EZB will die Inflation auf unter zwei Prozent zu halten, oder irgendwo in der Nähe.

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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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- ▶ **Google:**

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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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Literature

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