

# Rule-Based Reordering on Multiple Syntactic Levels in SMT

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## 1 Introduction

## 2 Multi-Level-Tree (MLT) Reordering

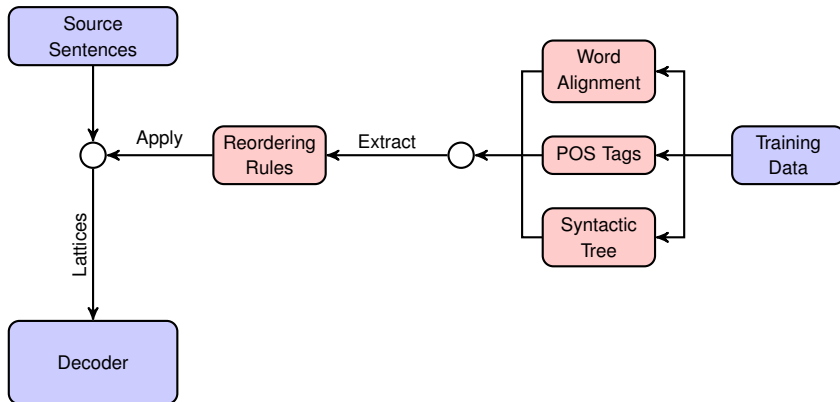
- Extension of tree rule based reordering to multiple syntactic levels

## 3 Evaluation

- English to Chinese: **0.43** Improvement of BLEU score
- Chinese to English: **0.30** Improvement of BLEU score

## 4 Conclusion

- Rule-based pre-ordering approaches [Rottmann and Vogel 2007; Niehues and Kolss 2009; Hermann et al. 2013]
- Hierarchical phrase-based model [Chiang 2007]
- More adaptive pre-ordering approach for Chinese based on syntactic structures



## ■ Short rules [Rottmann and Vogel 2007]

after the accident -> the accident after (0.5)

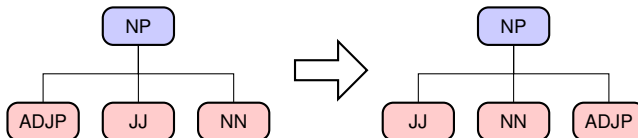
WRB MD DT -> DT WRB DT (0.3)

- Short rules [Rottmann and Vogel 2007]
- **Long rules** [Niehues and Kolss 2009]

NN \* MD -> \* MD NN (0.14)

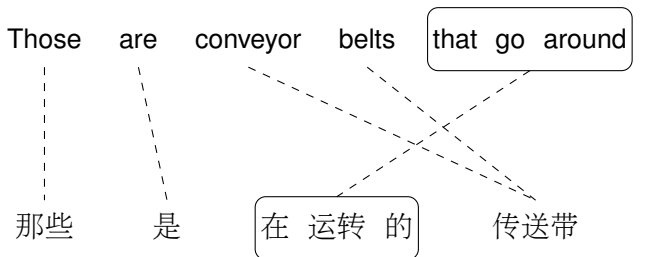
- Short rules [Rottmann and Vogel 2007]
- Long rules [Niehues and Kolss 2009]
- **Tree rules** [Hermann et al. 2013]

NP ( ADJP JJ NN )  $\rightarrow$  JJ NN ADJP (0.16)



## ■ Pre-modifier instead of post-modifier

- Adverbials
- Relative clauses
- Preposition phrases





- Pre-modifier instead of post-modifier
- **Questions**



- Pre-modifier instead of post-modifier
- Questions
- **Special sentence constructions**

*There aren't many people around that are really involved with architecture as clients.*

*Never would India have thought on this scale before.*

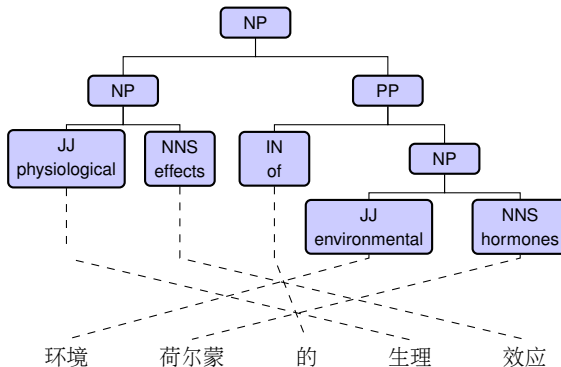
- Pre-modifier instead of post-modifier
- Questions
- Special sentence constructions
- **Long distance position change**

*I find this very much disturbing **when we are talking about what is going on right and wrong with democracy these days.***

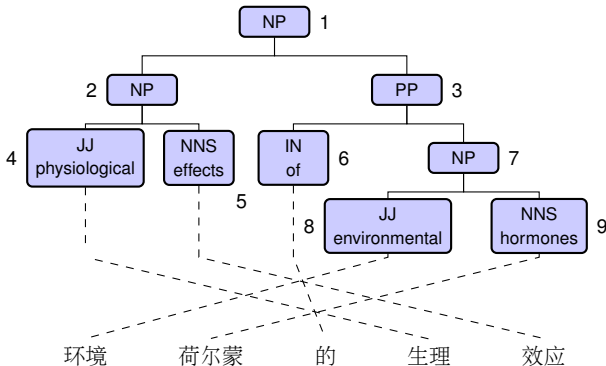
现在，每当我跟别人讨论我们的民主什么是对的，什么是错的我都为此觉得很无力。

# Reordering on multiple syntactic levels

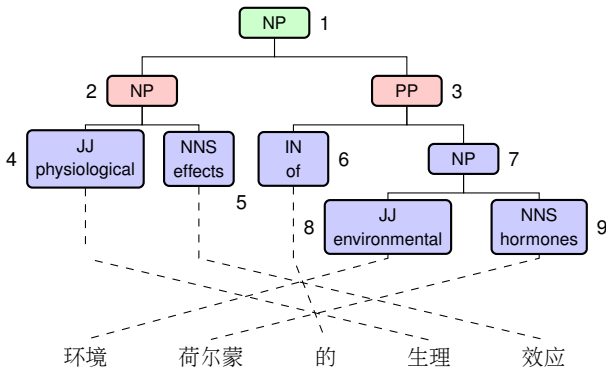
Extension of tree rule based reordering to multiple syntactic levels



# Reordering Patterns



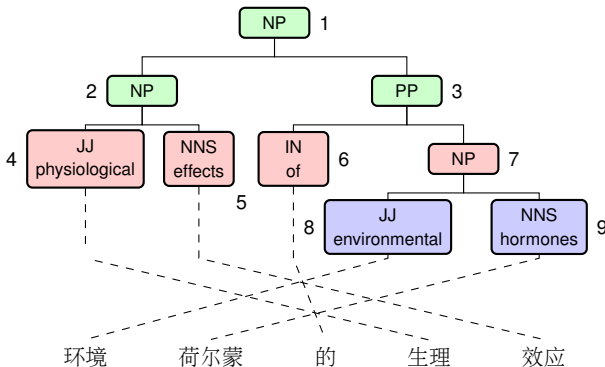
# Reordering Patterns



Root Depth Pattern

1 1 NP ( NP<sub>0</sub> PP<sub>1</sub> ) -> 1 0

# Reordering Patterns

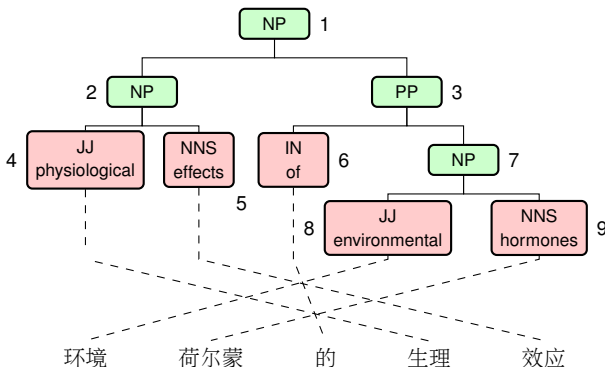


Root Depth Pattern

1 1 NP ( NP<sub>0</sub> PP<sub>1</sub> ) -> 1 0

1 2 NP ( NP ( JJ<sub>0</sub> NNS<sub>1</sub> ) PP ( IN<sub>2</sub> NP<sub>3</sub> ) ) -> 3 2 0 1

# Reordering Patterns



Root Depth Pattern

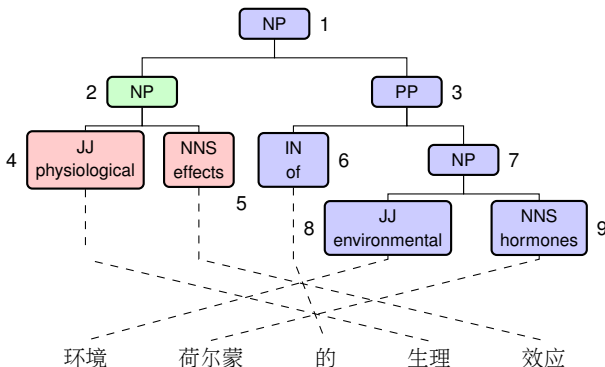
1 1 NP ( NP<sub>0</sub> PP<sub>1</sub> ) -> 1 0

1 2 NP ( NP ( JJ<sub>0</sub> NNS<sub>1</sub> ) PP ( IN<sub>2</sub> NP<sub>3</sub> ) ) -> 3 2 0 1

1 3 NP ( NP ( JJ<sub>0</sub> NNS<sub>1</sub> ) PP ( IN<sub>2</sub> NP ( JJ<sub>3</sub> NNS<sub>4</sub> ) ) ) -> 3 4 2 0 1



# Reordering Patterns



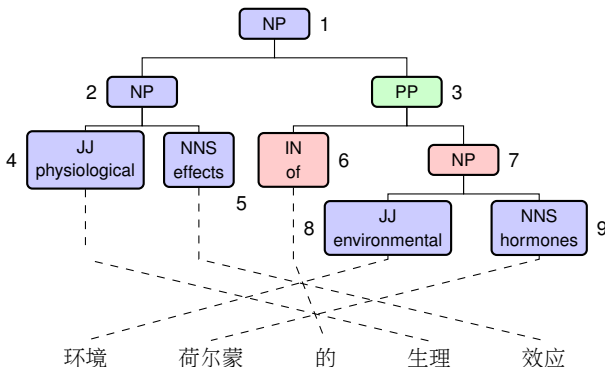
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1 3 NP ( NP ( JJ<sub>0</sub> NNS<sub>1</sub> ) PP ( IN<sub>2</sub> NP ( JJ<sub>3</sub> NNS<sub>4</sub> ) ) ) -> 3 4 2 0 1

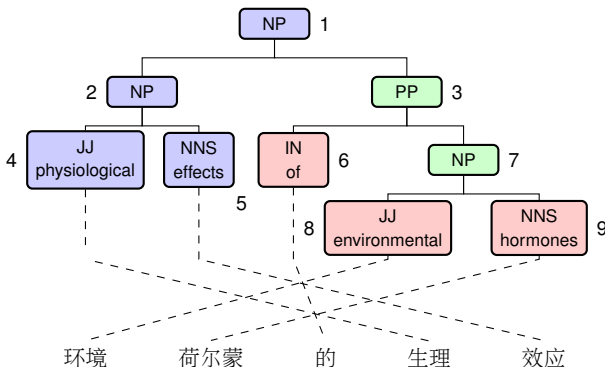
# Reordering Patterns



Root Depth Pattern

1	1	NP ( NP <sub>0</sub> PP <sub>1</sub> ) -> 1 0
1	2	NP ( NP ( JJ <sub>0</sub> NNS <sub>1</sub> ) PP ( IN <sub>2</sub> NP <sub>3</sub> ) ) -> 3 2 0 1
1	3	NP ( NP ( NP ( JJ <sub>0</sub> NNS <sub>1</sub> ) PP ( IN <sub>2</sub> NP ( JJ <sub>3</sub> NNS <sub>4</sub> ) ) ) ) -> 3 4 2 0 1
3	1	PP ( IN <sub>0</sub> NP <sub>1</sub> ) -> 1 0

# Reordering Patterns



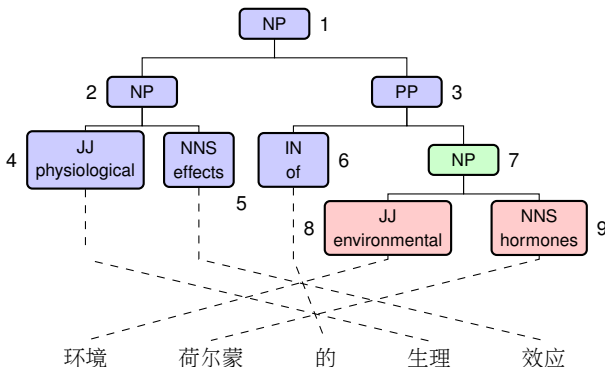
Root Depth Pattern

```

1 1 NP ( NP0 PP1 ) -> 1 0
1 2 NP ( NP ( JJ0 NNS1 ) PP ( IN2 NP3 ) ) -> 3 2 0 1
1 3 NP ( NP ( JJ0 NNS1 ) PP ( IN2 NP ( JJ3 NNS4 ) ) ) -> 3 4 2 0 1
3 1 PP ( IN0 NP1 ) -> 1 0
3 2 PP ( IN0 NP ( JJ1 NNS2 ) ) -> 1 2 0

```

# Reordering Patterns



Root Depth Pattern

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3 1 PP ( IN0 NP1 ) -> 1 0
3 2 PP ( IN0 NP ( JJ1 NNS2 ) ) -> 1 2 0
    
```

- **Search from all internal nodes with all possible depths**
- Rule probability

ADJP ( JJ , JJ ) -> 0 2 1	[0.02989130 = 11 / 368]
ADJP ( JJ , JJ ) -> 1 0 2	[0.07880435 = 29 / 368]
ADJP ( JJ , JJ ) -> 1 2 0	[0.02173913 = 8 / 368]
ADJP ( JJ , JJ ) -> 2 0 1	[0.02717391 = 10 / 368]

- Rule pruning
- Rule number doubles in comparison with tree rules

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- **Search from all internal nodes with all possible depths**
- Search depth decreases to avoid duplicate applications

1. PP ( IN<sub>0</sub> NP<sub>1</sub> ) -> 1 0 [0.39]  
2. PP ( IN<sub>0</sub> NP ( JJ<sub>1</sub> NNS<sub>2</sub> ) ) -> 1 0 2 [0.04]  
3. PP ( IN<sub>0</sub> NP ( JJ<sub>1</sub> NNS<sub>2</sub> ) ) -> 1 2 0 [0.33]

- Reorderings as paths in word lattices (size doubles approx.)
- Threshold for adding a path

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# Results: English → Chinese

Data: LDC & TED, 1 reference

Train: 75MB / 454K sentences

Dev: 164KB / 919 sentences

Test: 263KB / 1663 sentences

	BLEU Score	Improvement	TER
Baseline	12.07		72.15
+Short Rules	12.50	0.43	71.41
+Long Rules	12.99	0.92	70.71
+Tree Rules	13.38	1.31	68.27
<b>+MLT Rules</b>	<b>13.81</b>	<b>1.74</b>	<b>68.20</b>
<b>Oracle Reordering</b>	<b>18.58</b>	<b>6.51</b>	<b>62.13</b>
Long Rules	12.31	0.24	71.81
Tree Rules	13.30	1.23	70.42
<b>MLT Rules</b>	<b>13.68</b>	<b>1.61</b>	<b>70.25</b>

# Results: Chinese → English

Data: LDC, 3 references

Train: 47MB / 303K sentences

Dev: 142KB / 919 sentences

Test: 220KB / 1663 sentences

	BLEU Score	Improvement	TER
Baseline	21.80		62.09
+Short Rules	22.90	1.10	61.64
+Long Rules	23.13	1.33	61.43
+Tree Rules	23.84	2.04	60.95
<b>+MLT Rules</b>	<b>24.14</b>	<b>2.34</b>	<b>60.79</b>
<b>Oracle Reordering</b>	<b>26.80</b>	<b>5.00</b>	<b>56.97</b>
Long Rules	22.10	0.30	62.21
Tree Rules	23.35	1.55	61.52
<b>MLT Rules</b>	<b>23.96</b>	<b>2.16</b>	<b>60.83</b>

## ■ Better translation quality

- English to Chinese: **0.43** Improvement of BLEU score
- Chinese to English: **0.30** Improvement of BLEU score

## ■ Better syntactic structure

- More possible reorderings
- Improvement for more complicated reorderings

## ■ Space for further improvement

- Better translation quality
  - English to Chinese: **0.43** Improvement of BLEU score
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- **Better syntactic structure**
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- Better translation quality
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- **Space for further improvement**

- **Better reordering approaches**
- Vector presentation instead of POS tags as features
- Reordering with less information

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# Thank you for your attention

## English -> Chinese

Data Set		#Sentence	#Word		Size (Byte)	
			English	Chinese	English	Chinese
Training Data	LDC	303K	10.96M	8.56M	60.88M	47.27M
	TED	151K	2.58M	2.86M	14.24M	15.63K
Development Data		919	30K	25K	164K	142K
Test Data		1663	47K	38K	263K	220K

## Chinese -> English

Data Set		#Sentence	#Word		Size (Byte)	
			Chinese	English	Chinese	English
Training Data		303K	8.56M	10.96M	47.27M	60.88M
Development Data		919	25K	30K	142K	164K
Test Data		1663	38K	47K	220K	263K

System: English → Chinese

Data set: test data

	Number of Rules	Size of Lattices
Short Rules	362873	13M
Long Rules	106081	6.8M
Tree Rules	5067	7.3M
MLT Rules	10312	12M

# Results: English → German

Data: NC-v9, EPPS-v7 & newstest  
Dev: 376KB / 3003 sentences

Train: 301MB / 2121K sentences  
Test: 328KB / 3000 sentences

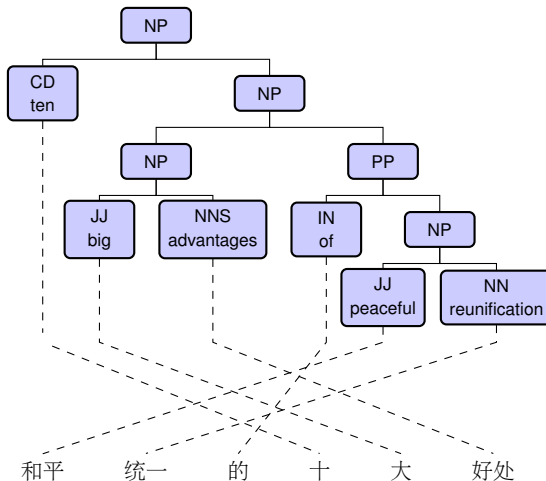
	BLEU Score	Improvement	TER
Baseline	18.45		64.77
+Short Rules	19.09	0.64	63.80
+Long Rules	19.16	0.71	63.74
+Tree Rules	19.34	0.89	62.43
<b>Oracle Reordering</b>	<b>22.51</b>	<b>4.06</b>	<b>58.97</b>
Long Rules	18.65	0.20	64.45
Tree Rules	19.13	0.68	62.48
<b>MLT Rules</b>	<b>19.16</b>	<b>0.71</b>	<b>63.78</b>



# Some Most Frequent MLT Rules

PP ( IN NP ) -> 1 0 [0.3865 = 118538 / 306657]  
NP ( DT NN ) -> 1 0 [0.2280 = 44557 / 195428]  
NP ( NP PP ) -> 1 0 [0.6547 = 38840 / 59329]  
PP ( IN NP ( NN ) ) -> 1 0 [0.3879 = 24449 / 63033]  
NP ( DT NNS ) -> 1 0 [0.2052 = 10873 / 52990]  
NP ( DT JJ NN ) -> 1 2 0 [0.1441 = 8197 / 56867]  
PP ( IN S ) -> 1 0 [0.4290 = 6455 / 15045]  
PP ( IN NP ( NNS ) ) -> 1 0 [0.3541 = 6317 / 17839]  
PP ( IN S ( VP ) ) -> 1 0 [0.4332 = 6153 / 14205]  
VP ( VBN PP ) -> 1 0 [0.6157 = 6078 / 9872]  
PP ( IN NP ( JJ NN ) ) -> 1 2 0 [0.4362 = 5217 / 11959]  
...  
NP ( NP ( DT NN ) PP ( IN NP ) ) -> 0 3 2 1 [0.2113 = 1270  
/ 6009]  
...

# Reordering on multiple syntactic levels





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