Recursive Autoencoders for ITG-based Translation

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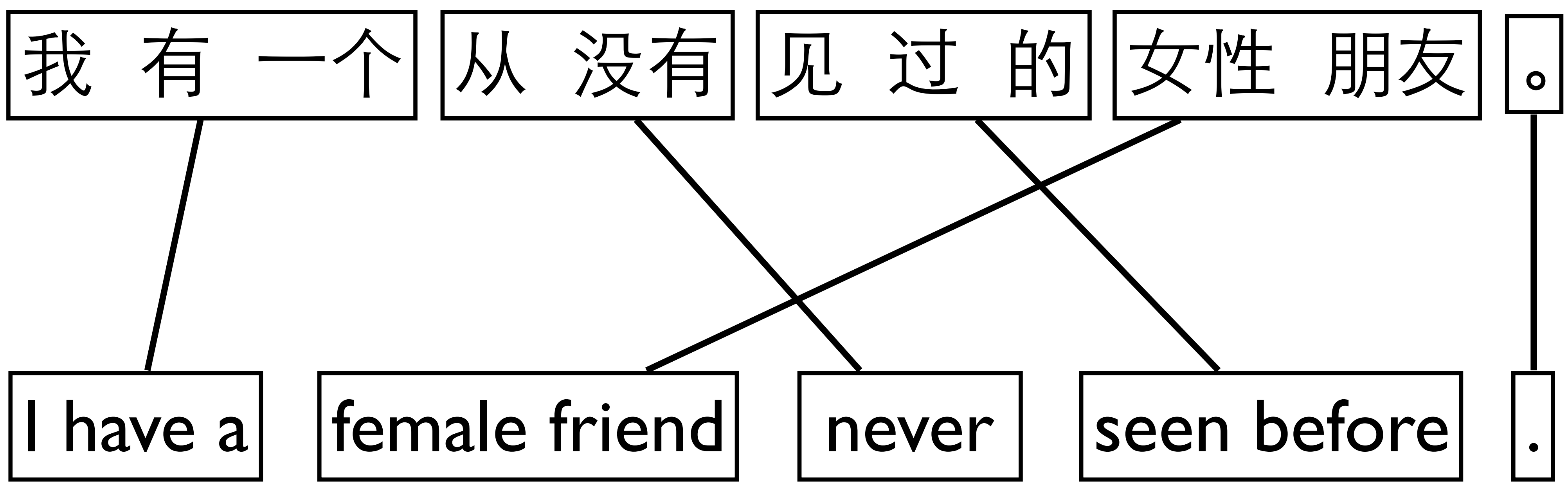
(Joint work with Yang Liu and Maosong Sun)

Overview

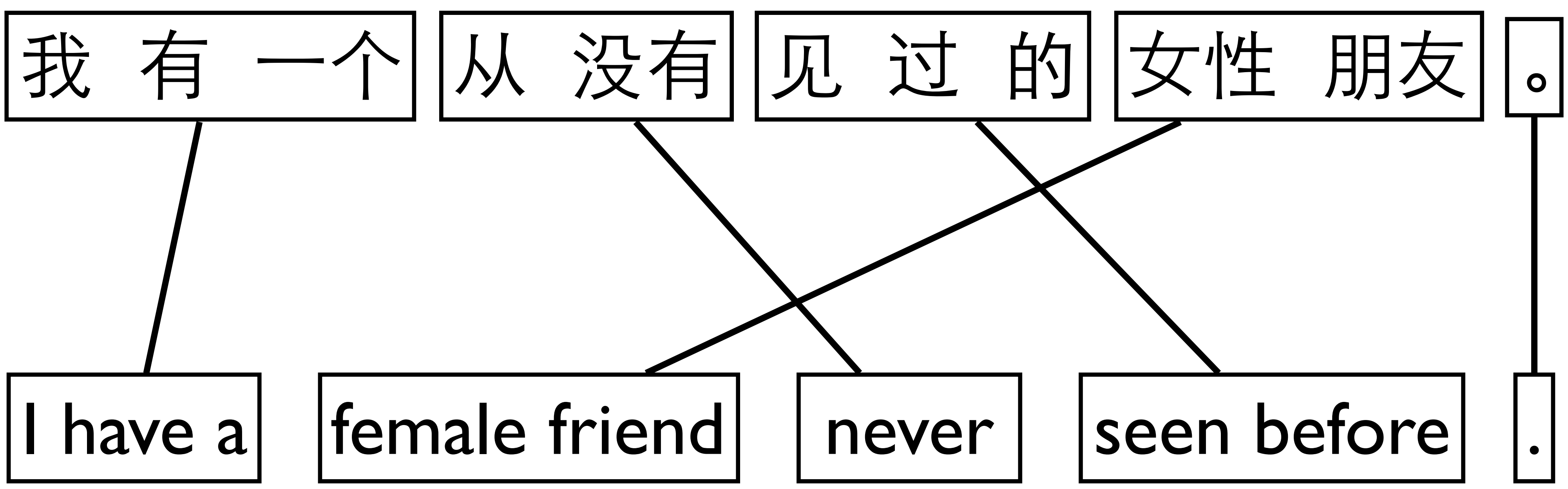
- Phrase reordering model is a critical problem in machine translation (MT), and is NP-complete



(Knight, 1999)

Distortion Models

- Distortion models: penalize relative displacement of source phrases



(Koehn et al., 2003; Och and Ney, 2004)

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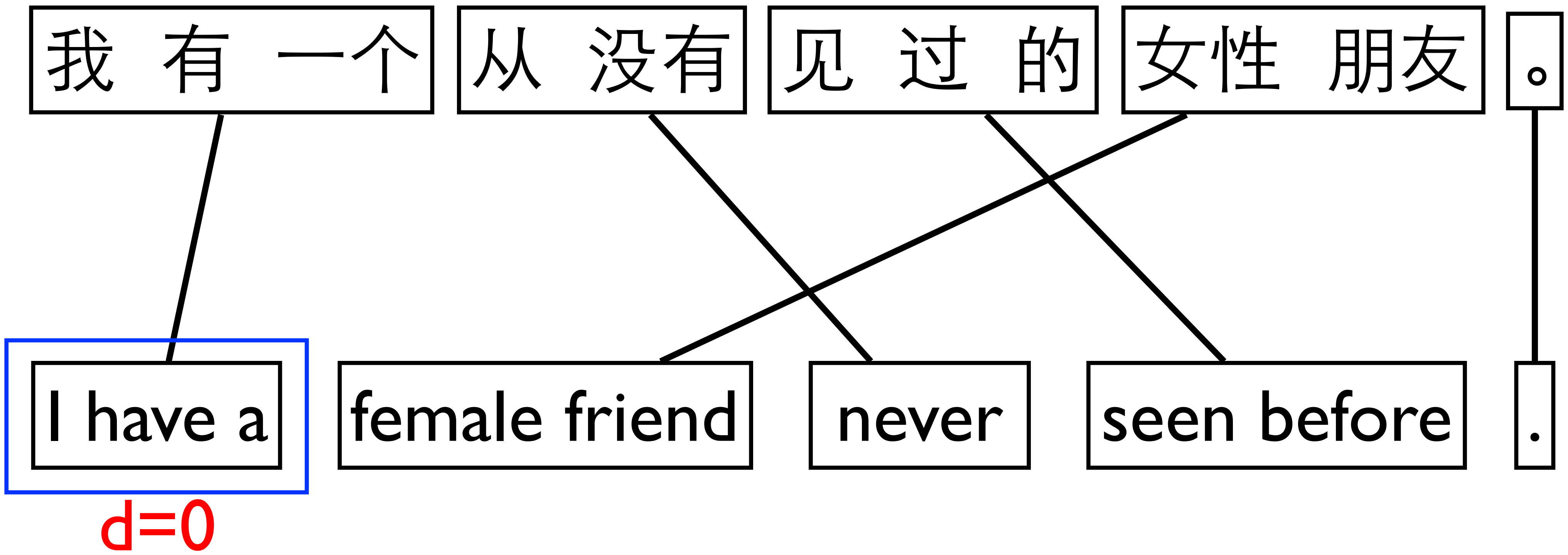

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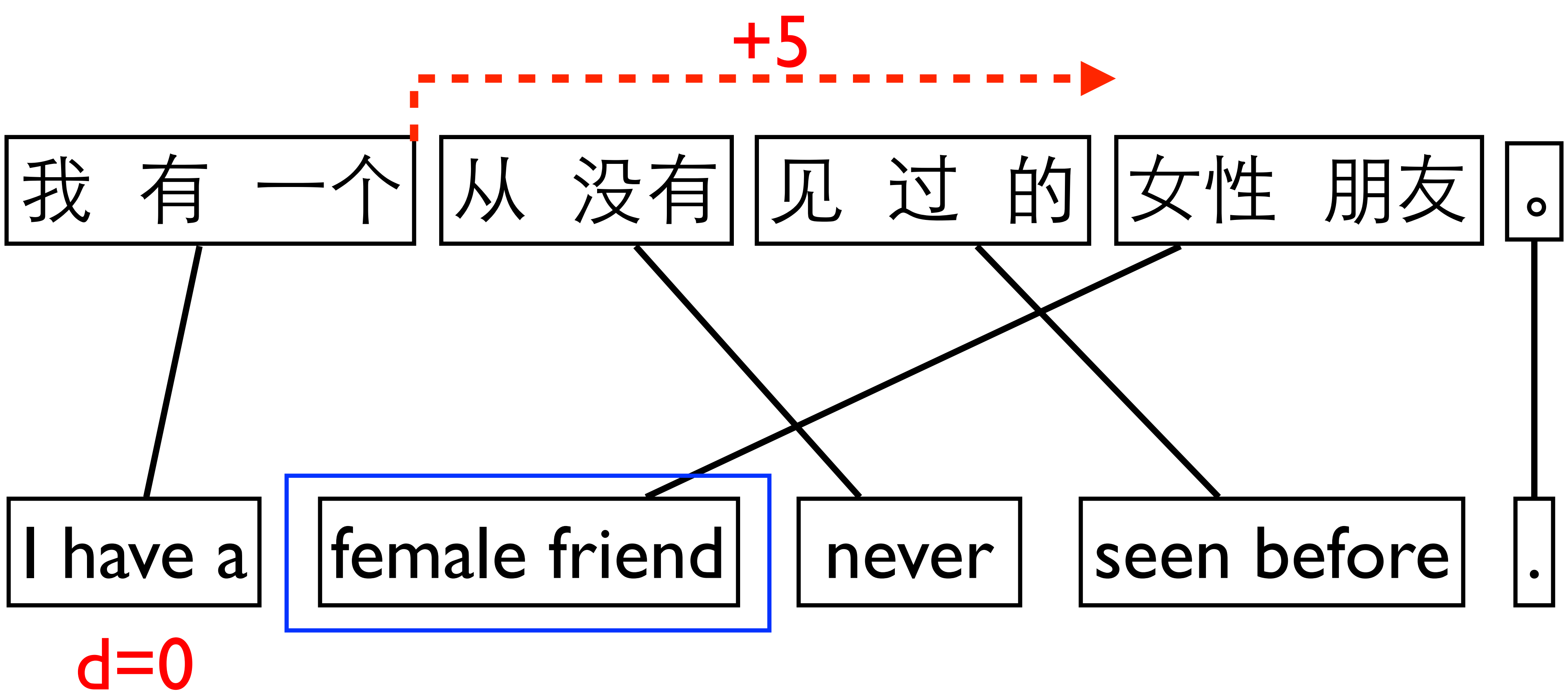

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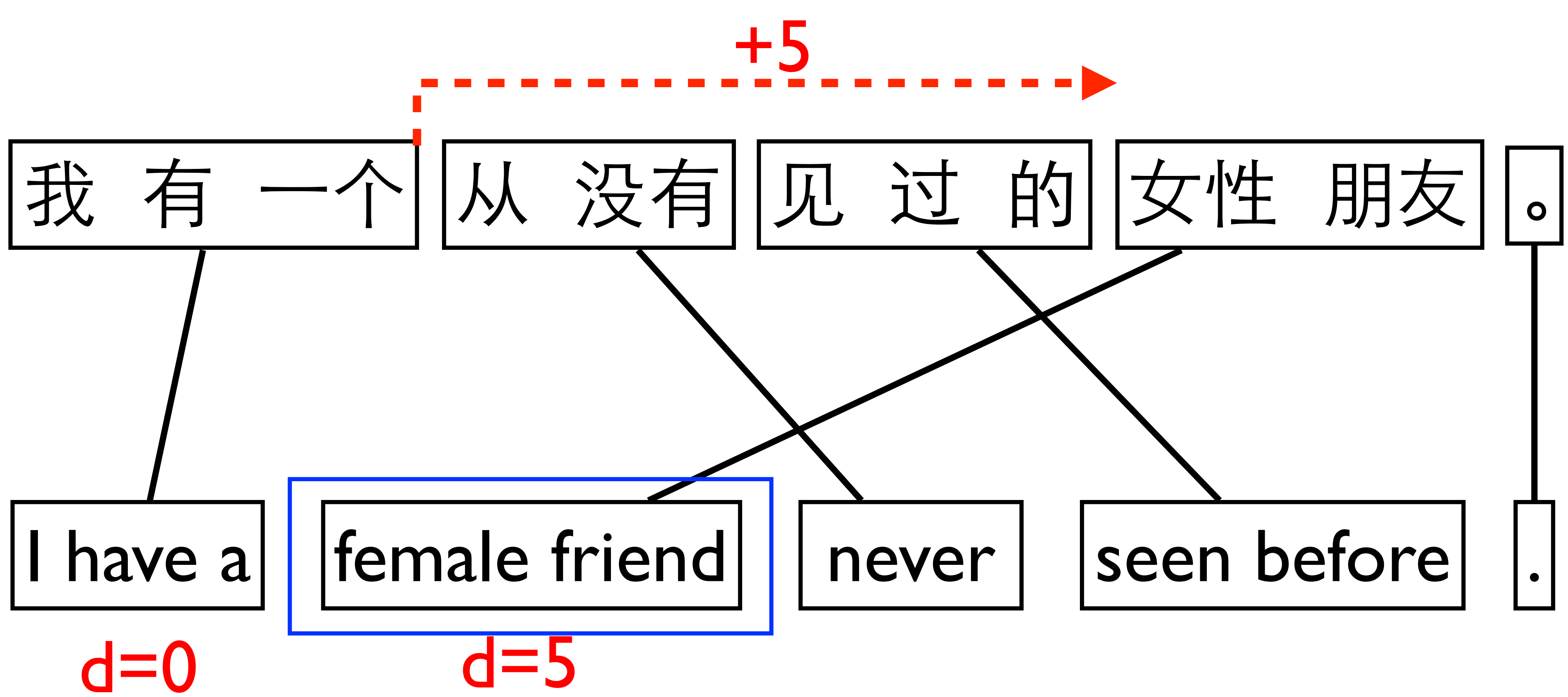

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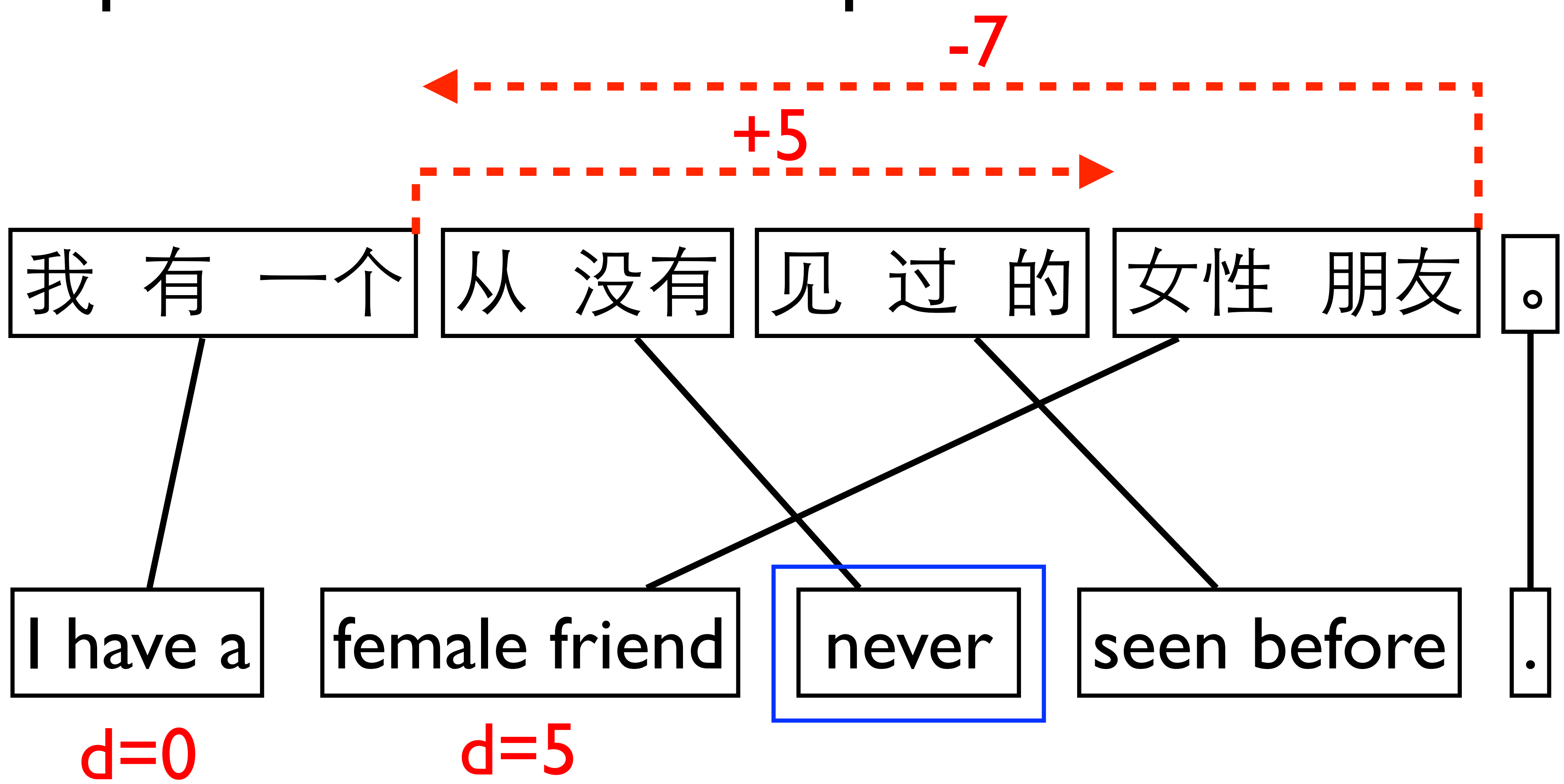

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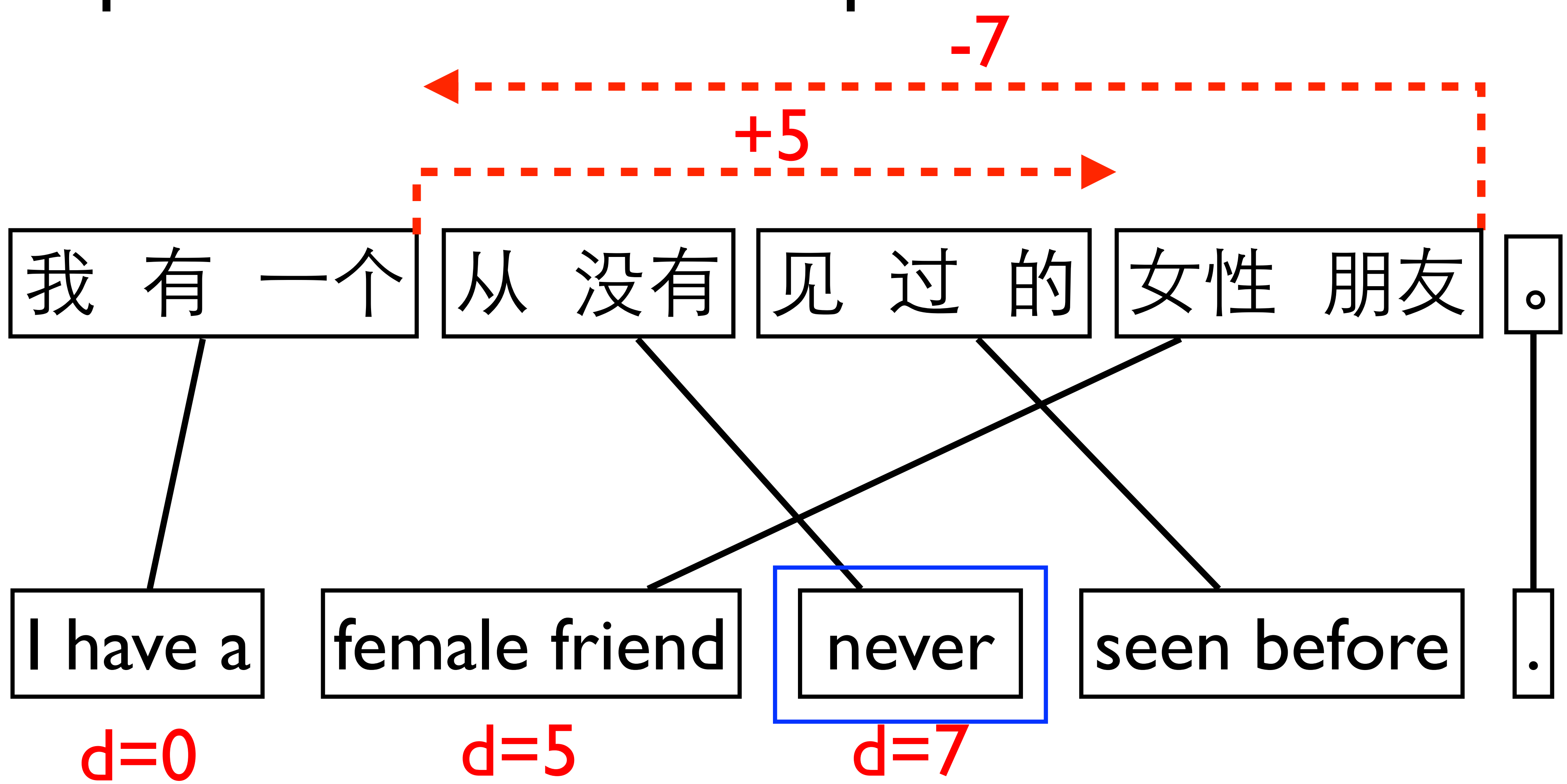

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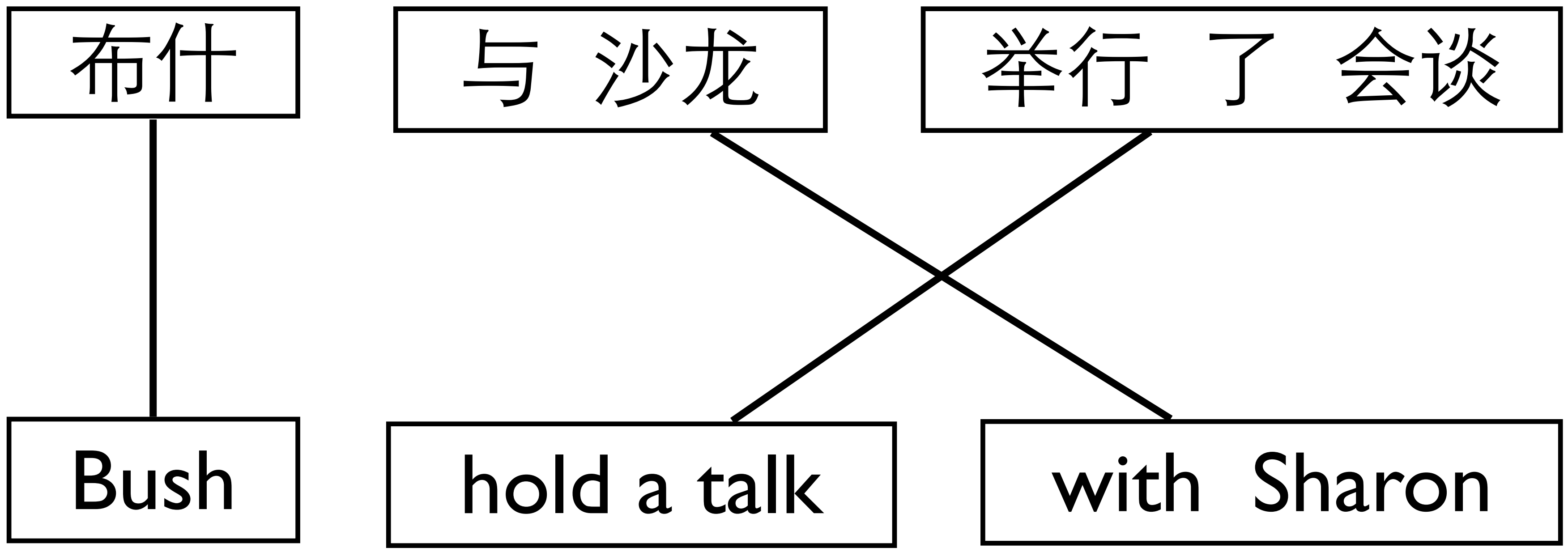
Lexicalized Reordering Models

- Lexicalized reordering models: penalize reordering conditioned on both the source and target phrases



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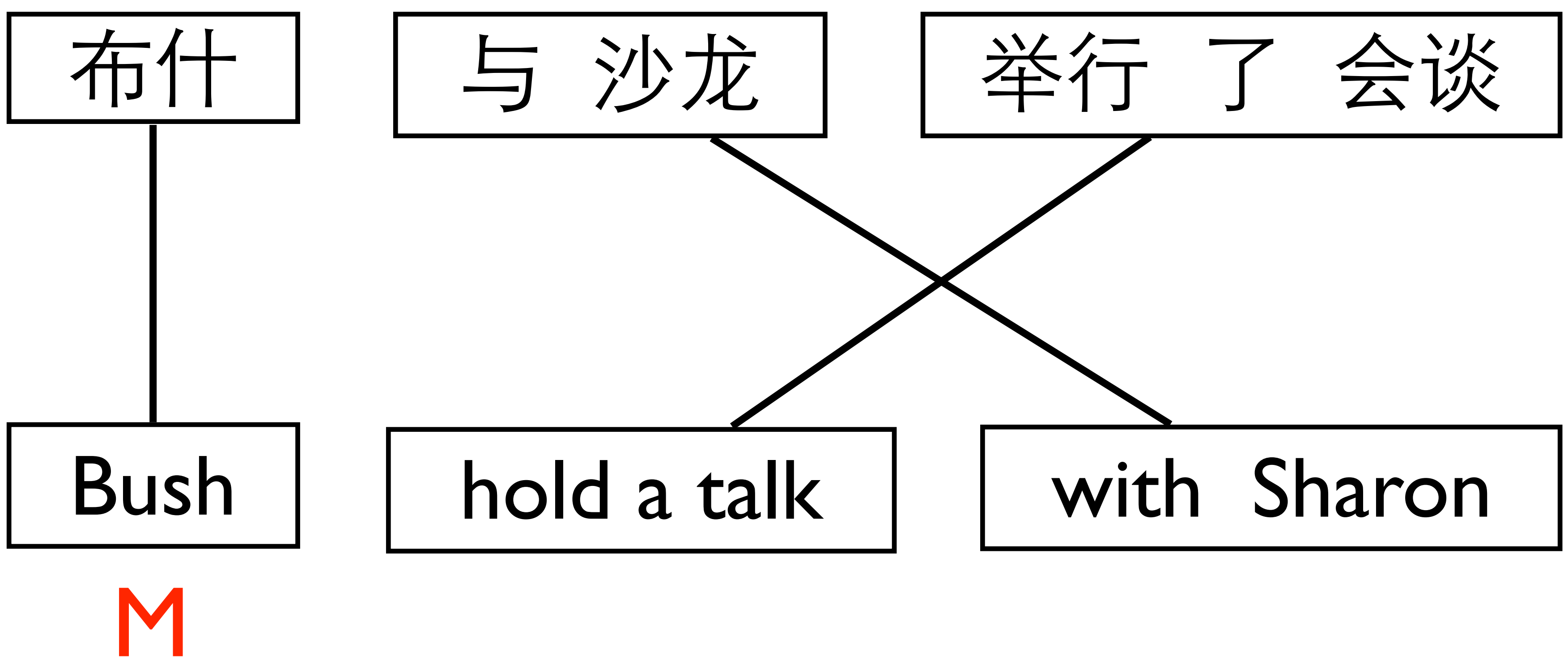

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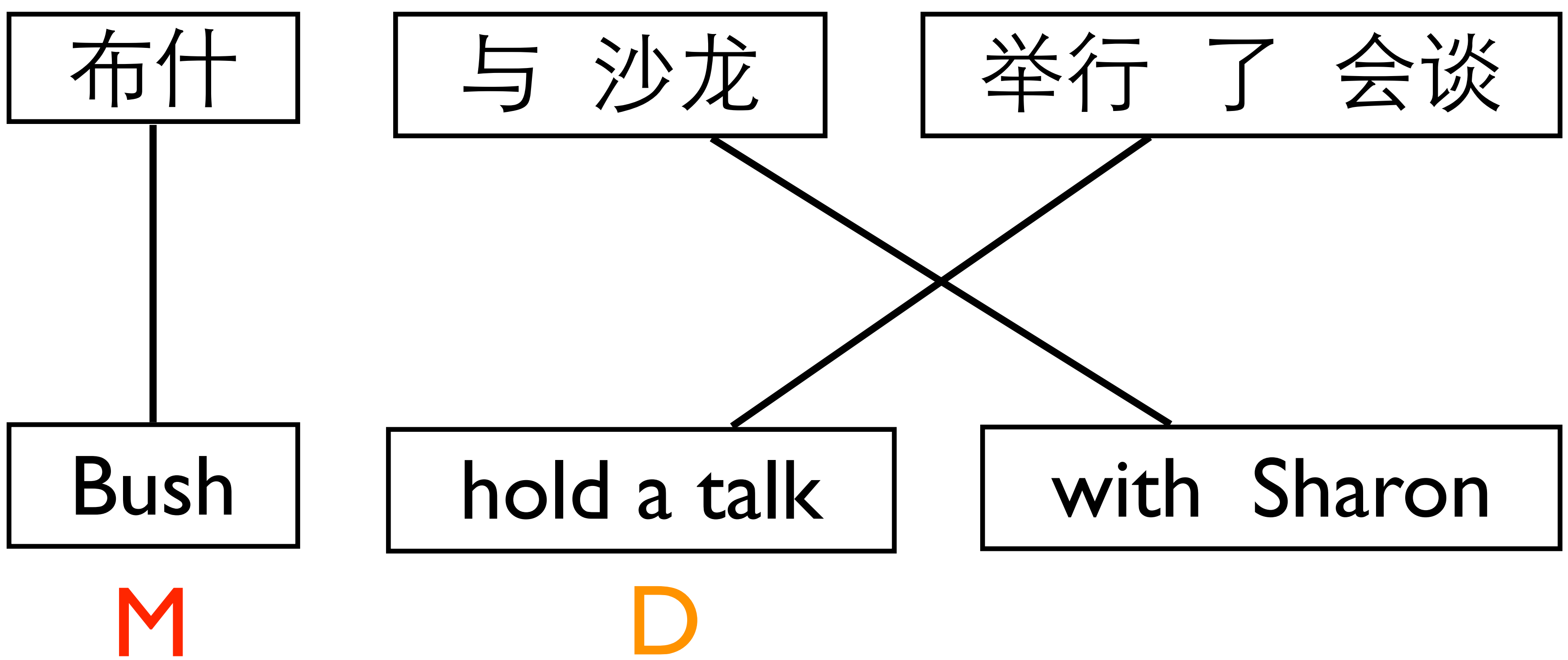

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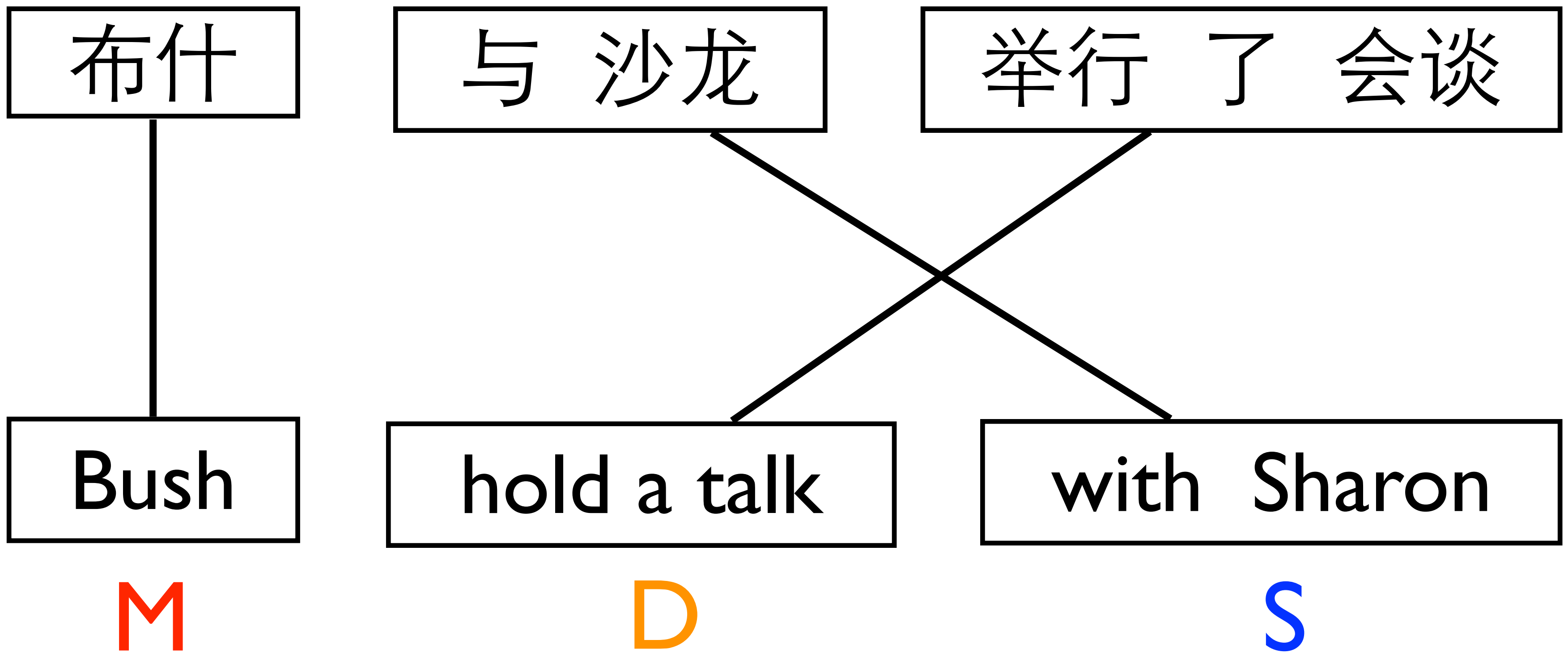

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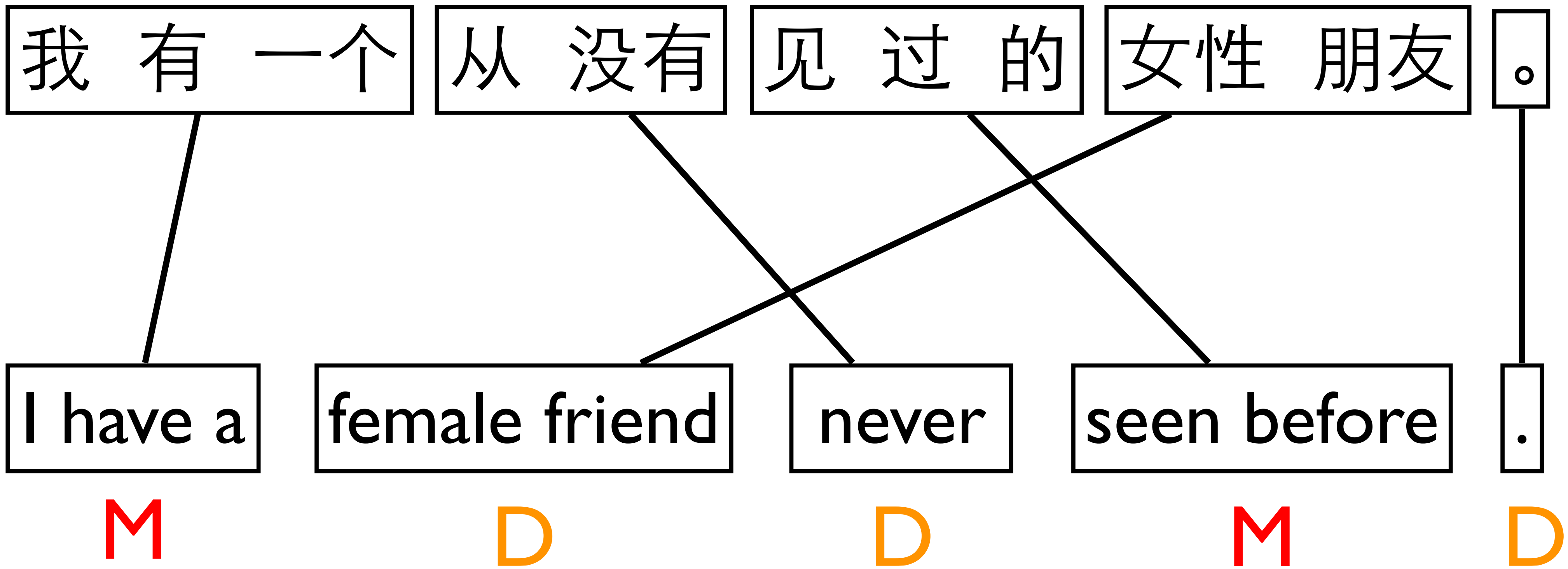
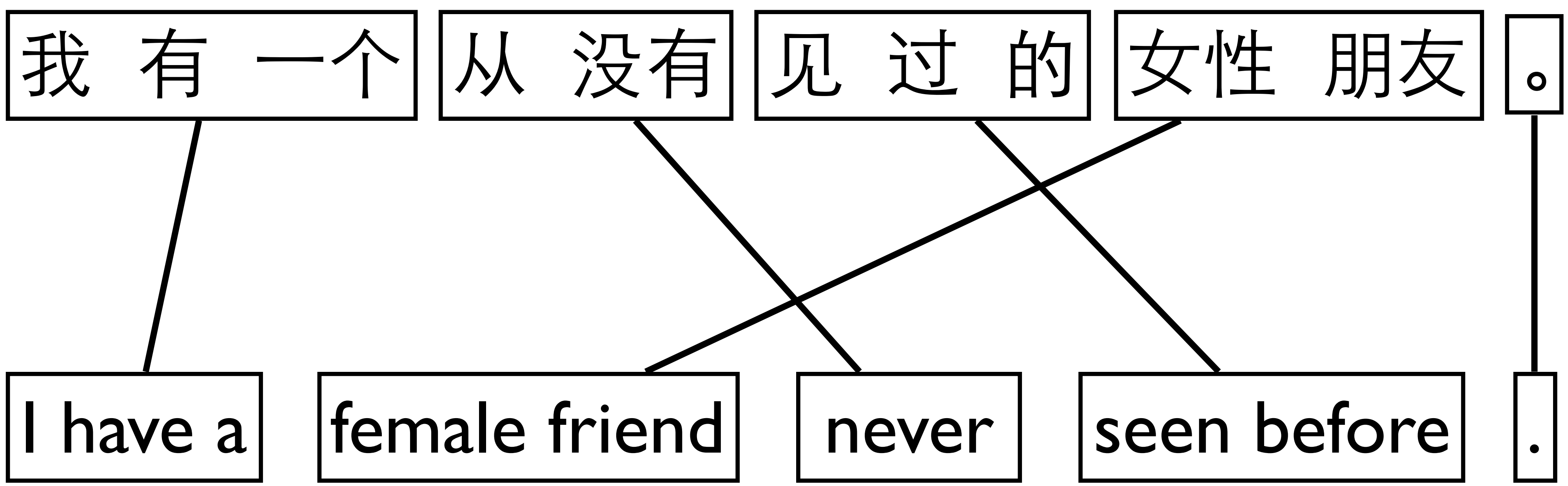


(Koehn et al., 2007)

Block Merging

- Reordering as block merging



(Wu, 1997; Xiong et al., 2006)

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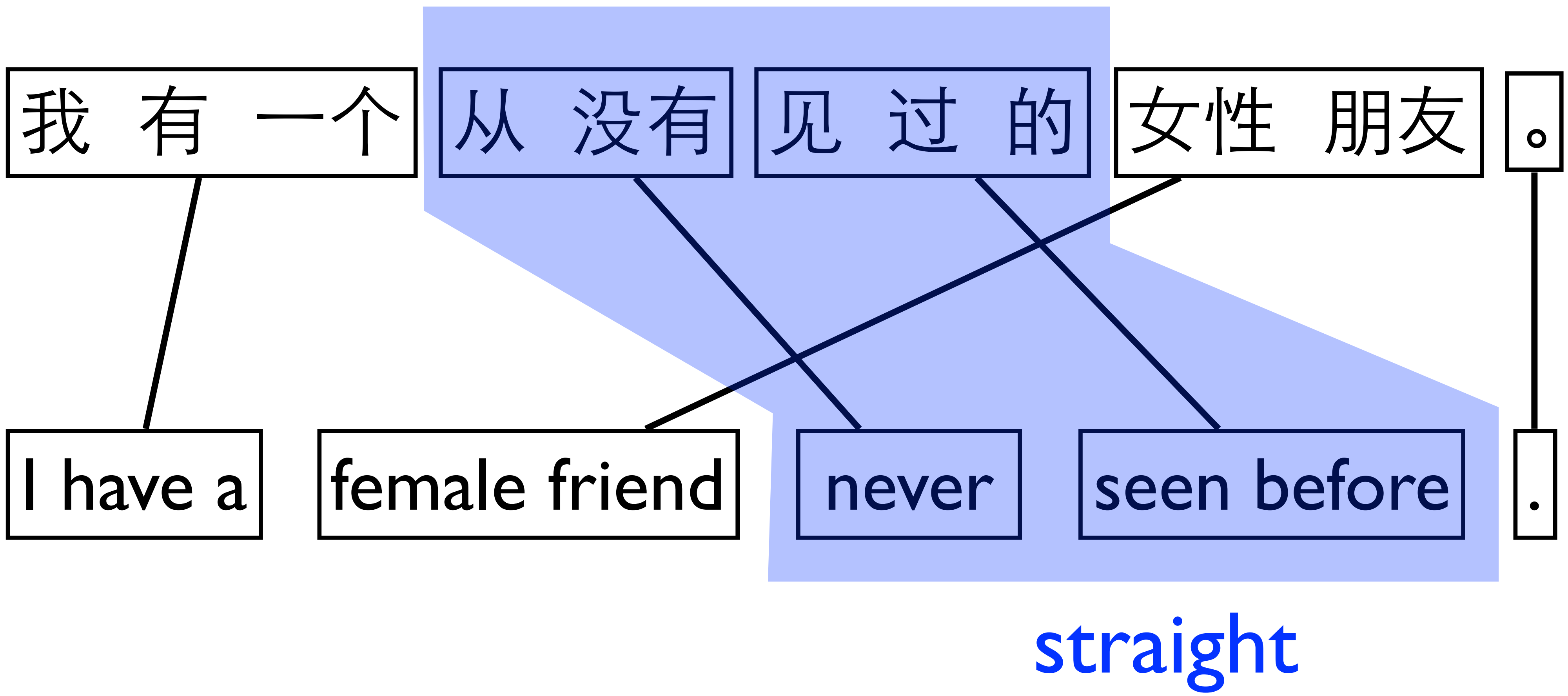

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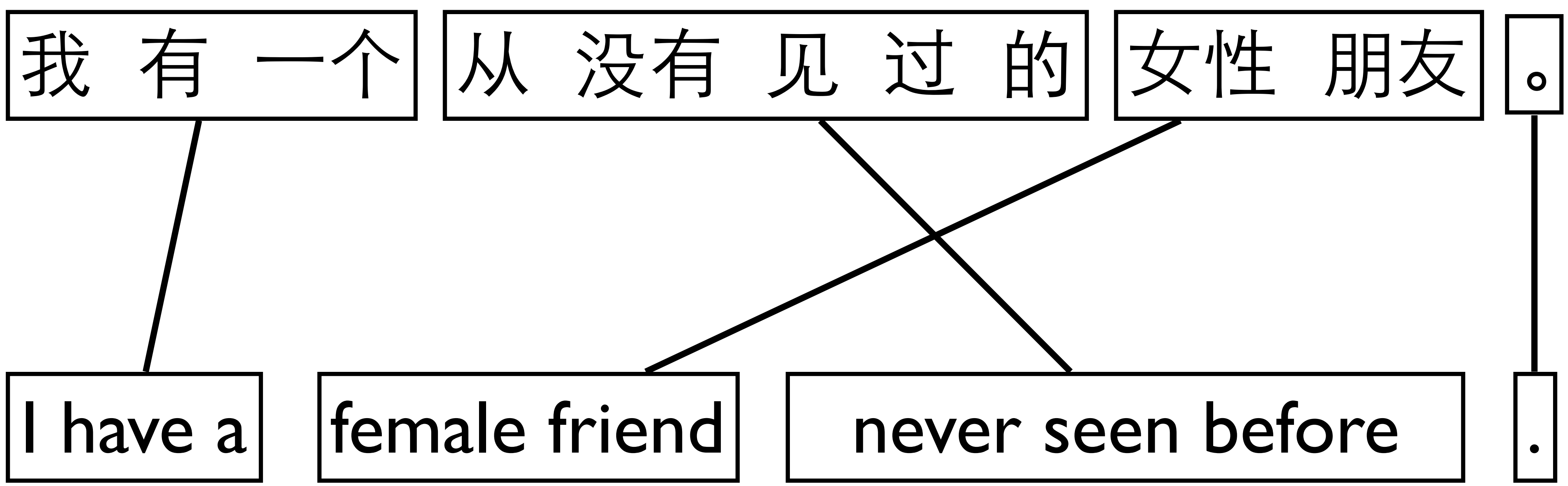

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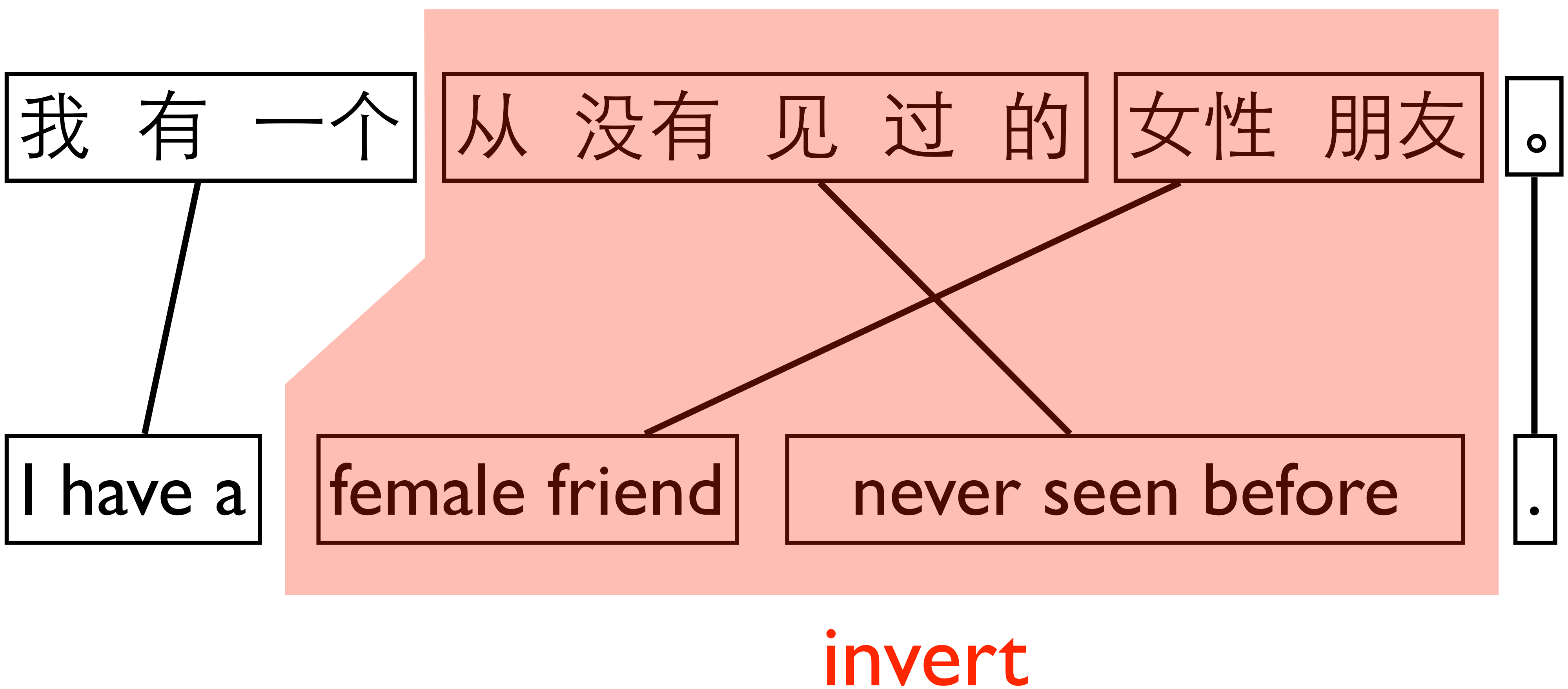

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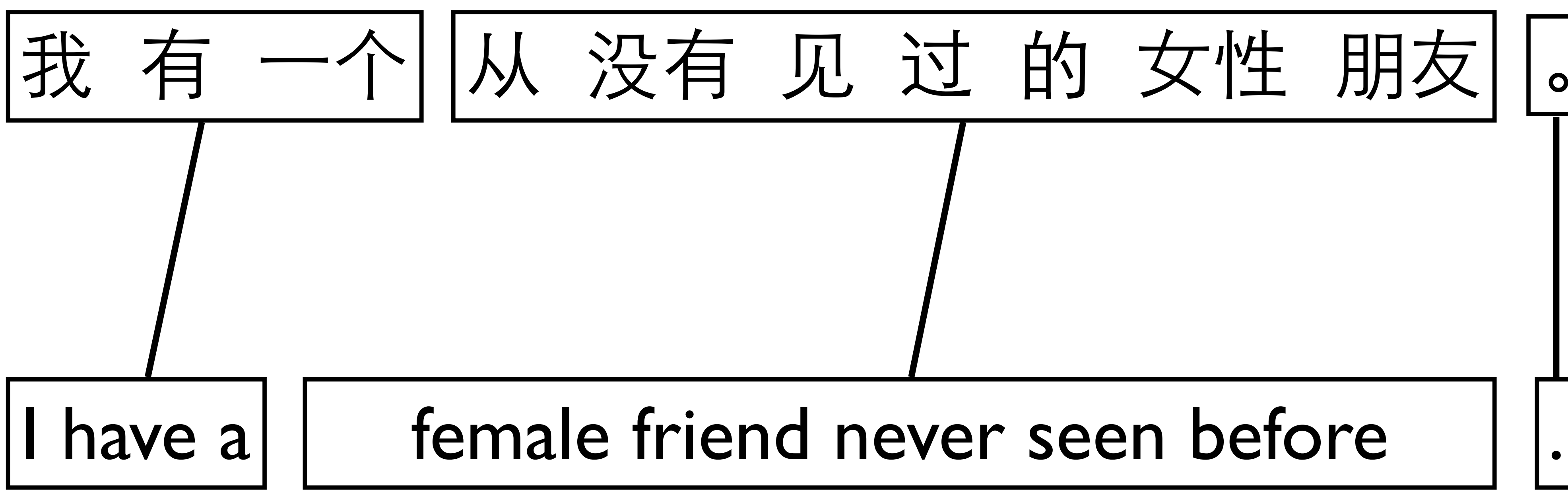

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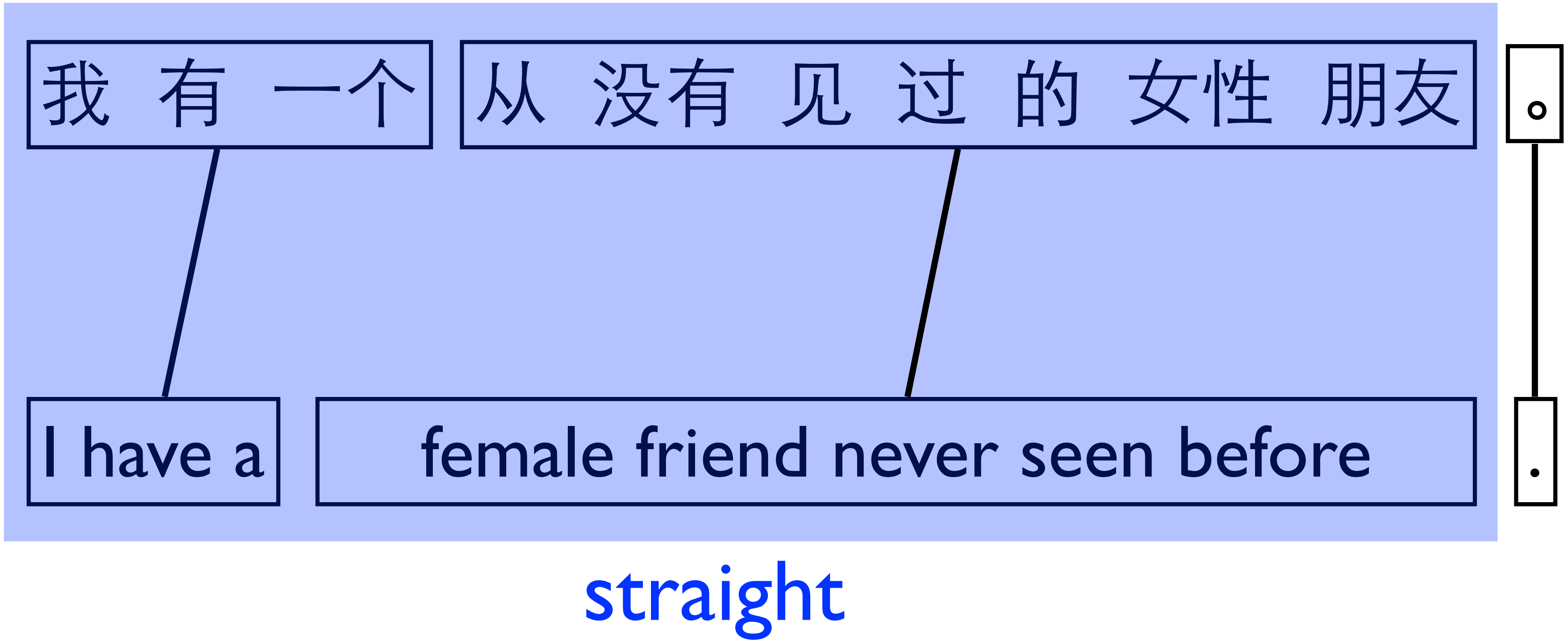

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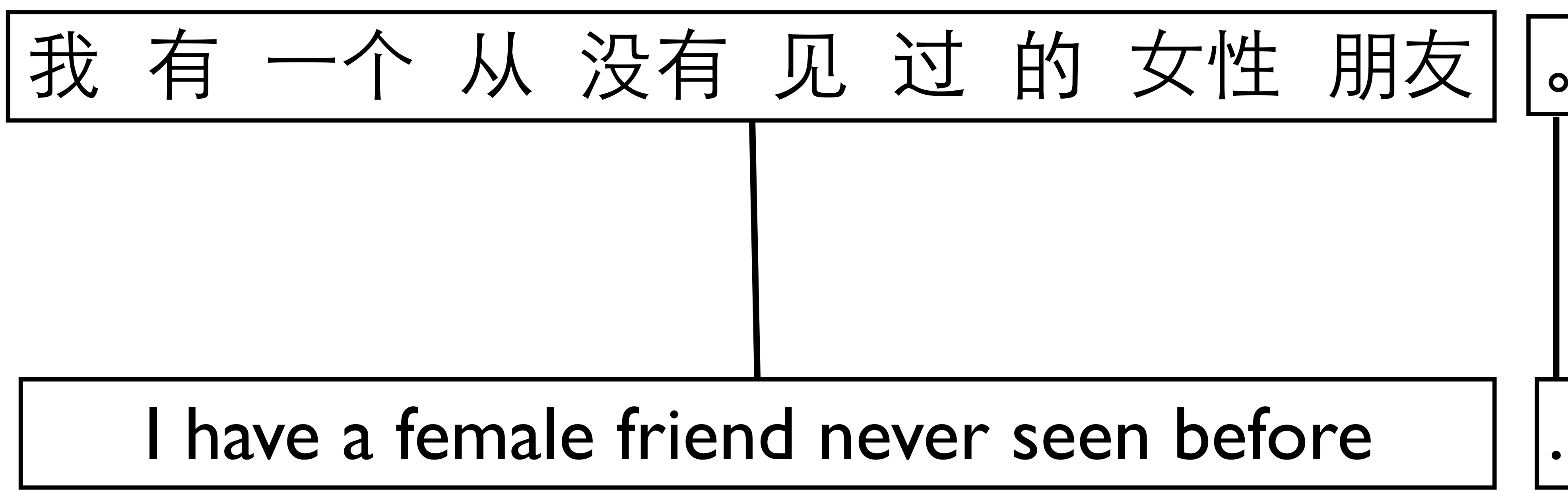

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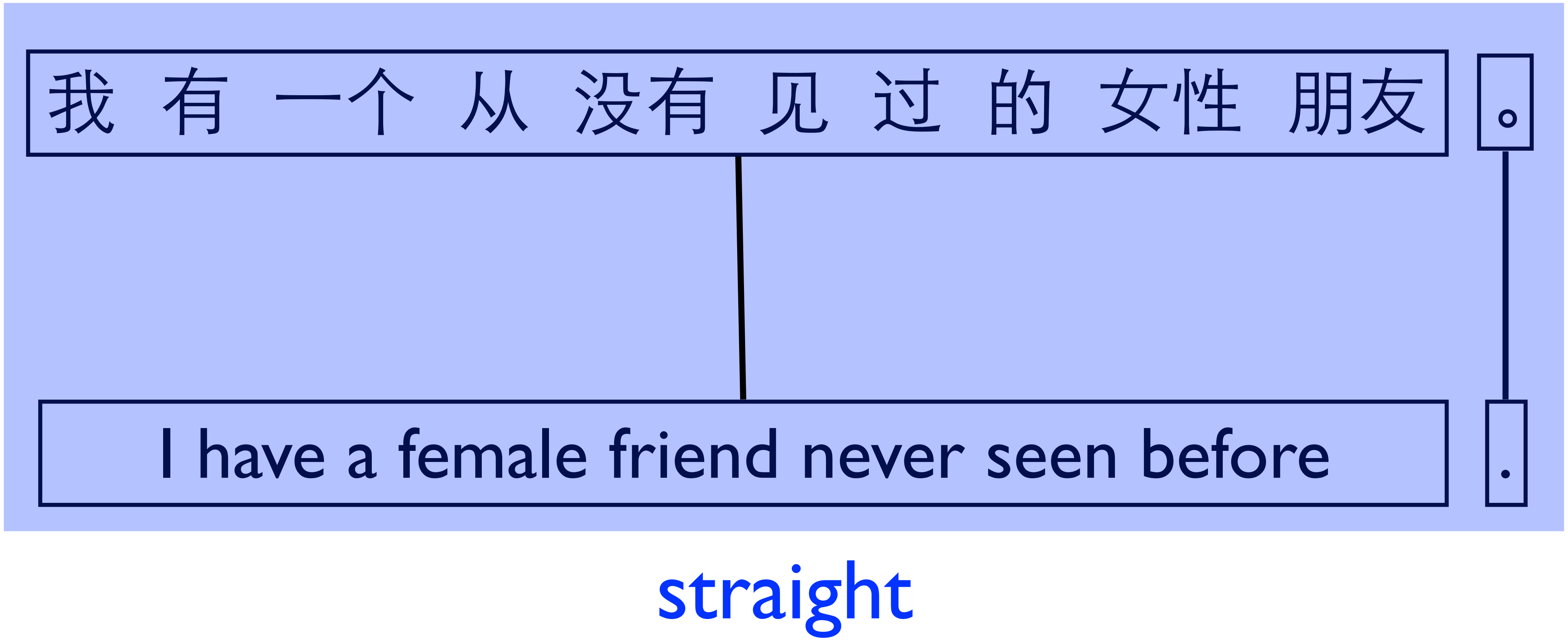


(Wu, 1997; Xiong et al., 2006)

Block Merging

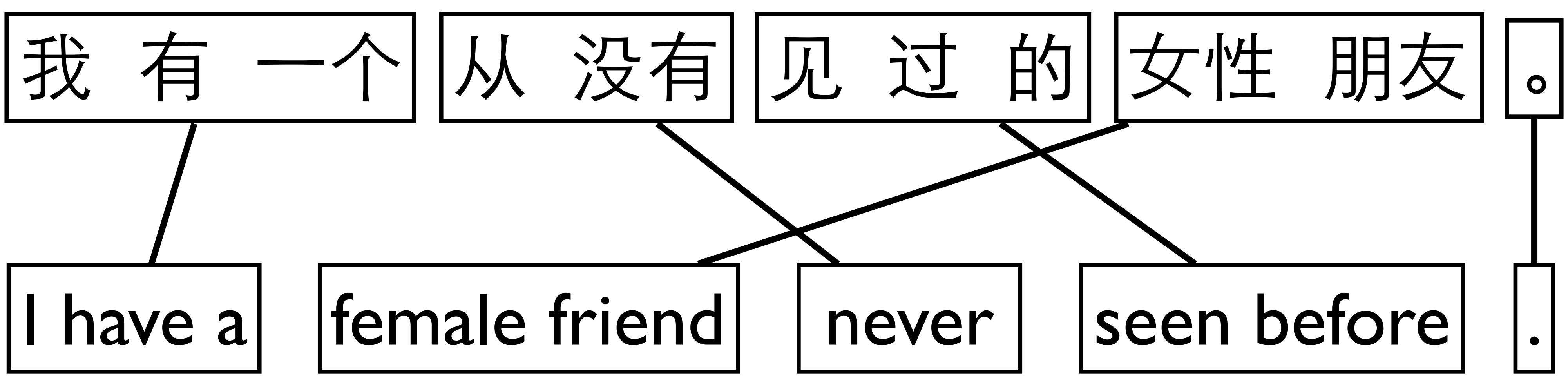
- Reordering as block merging

我 有 一个 从 没有 见 过 的 女性 朋友 。

I have a female friend never seen before .

(Wu, 1997; Xiong et al., 2006)

Block Merging



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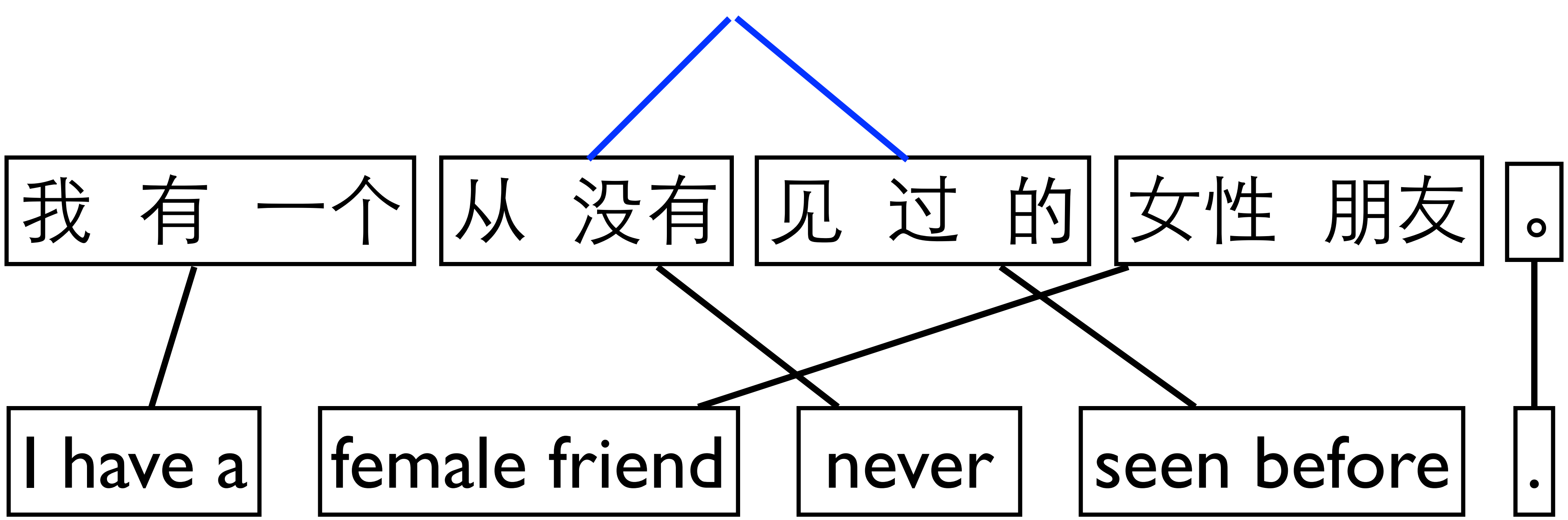

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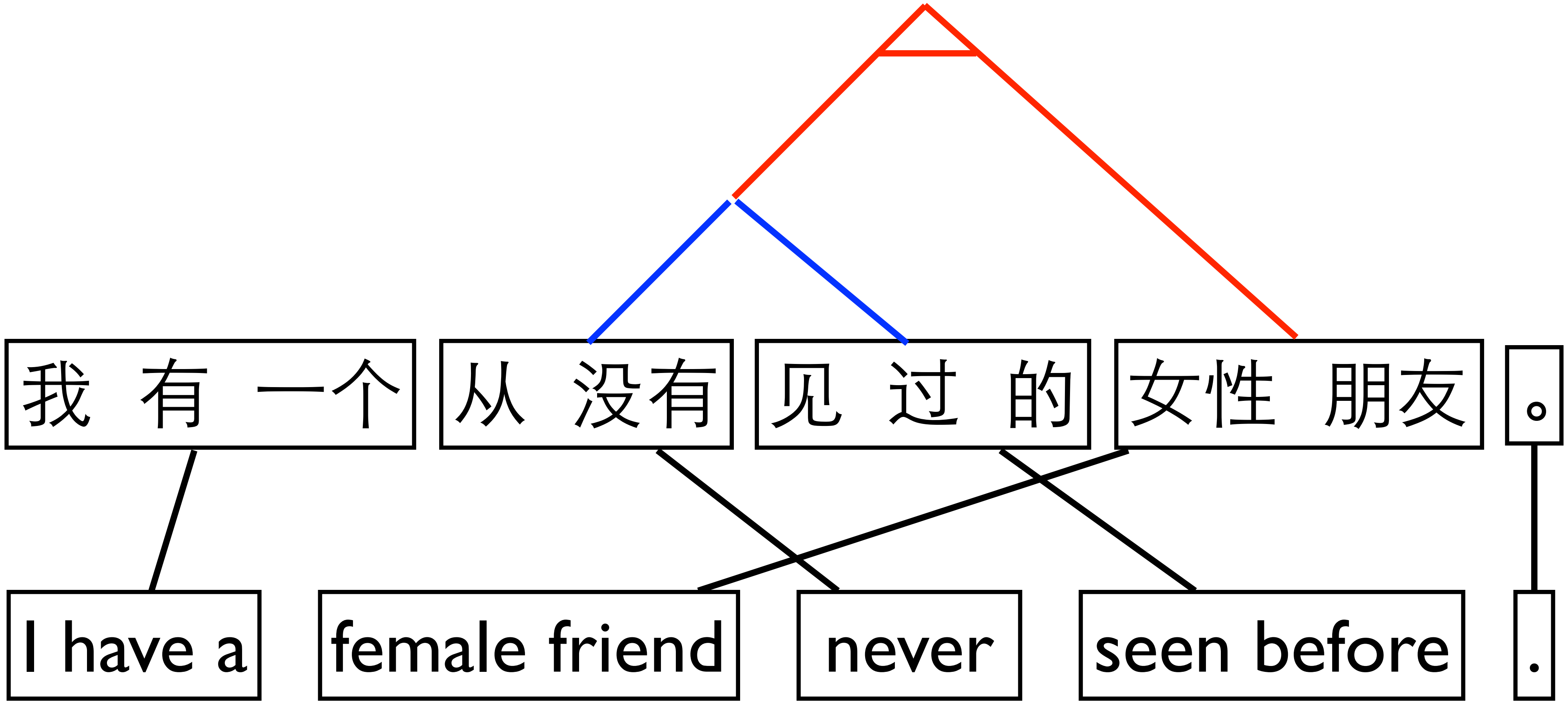

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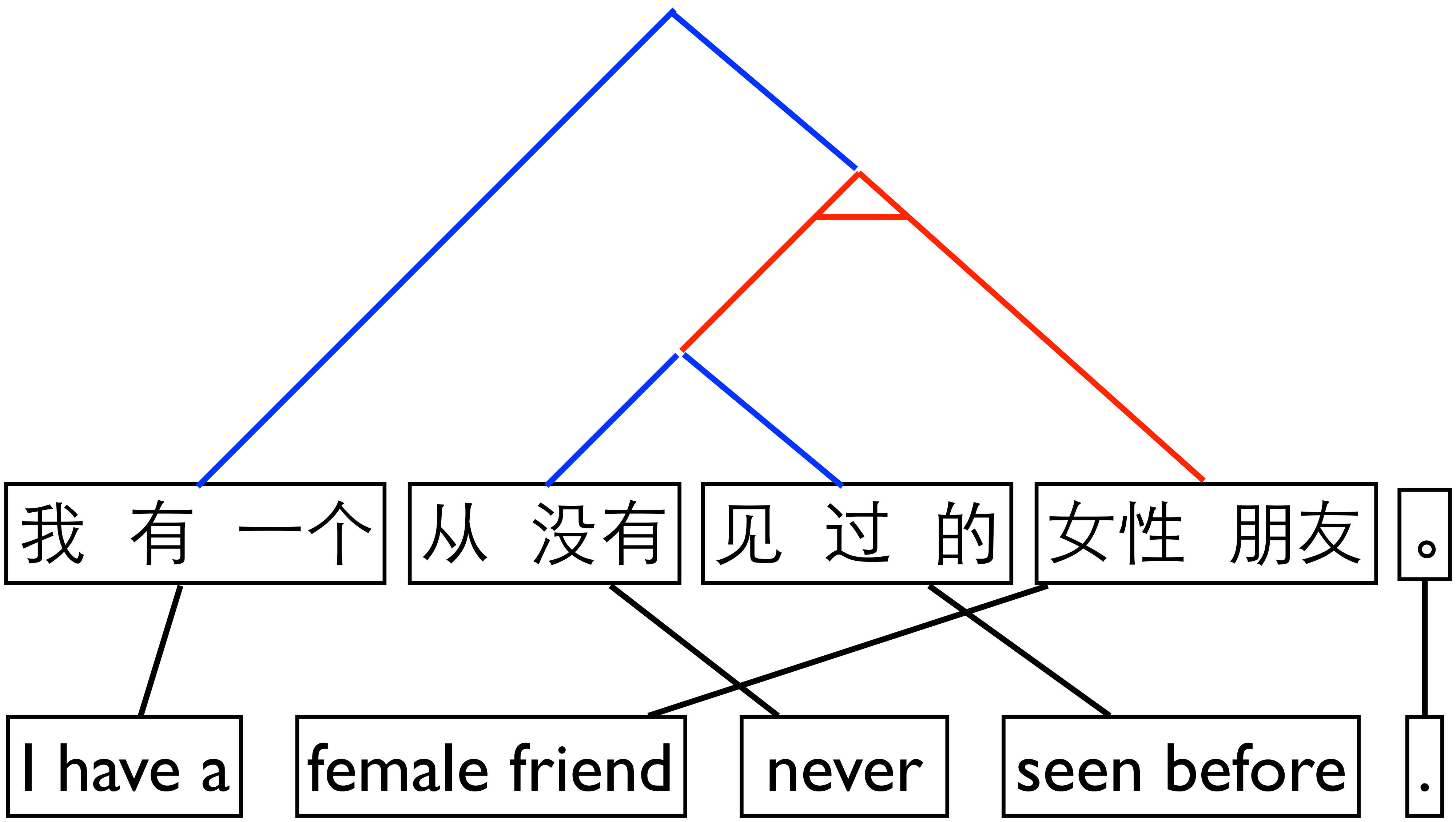

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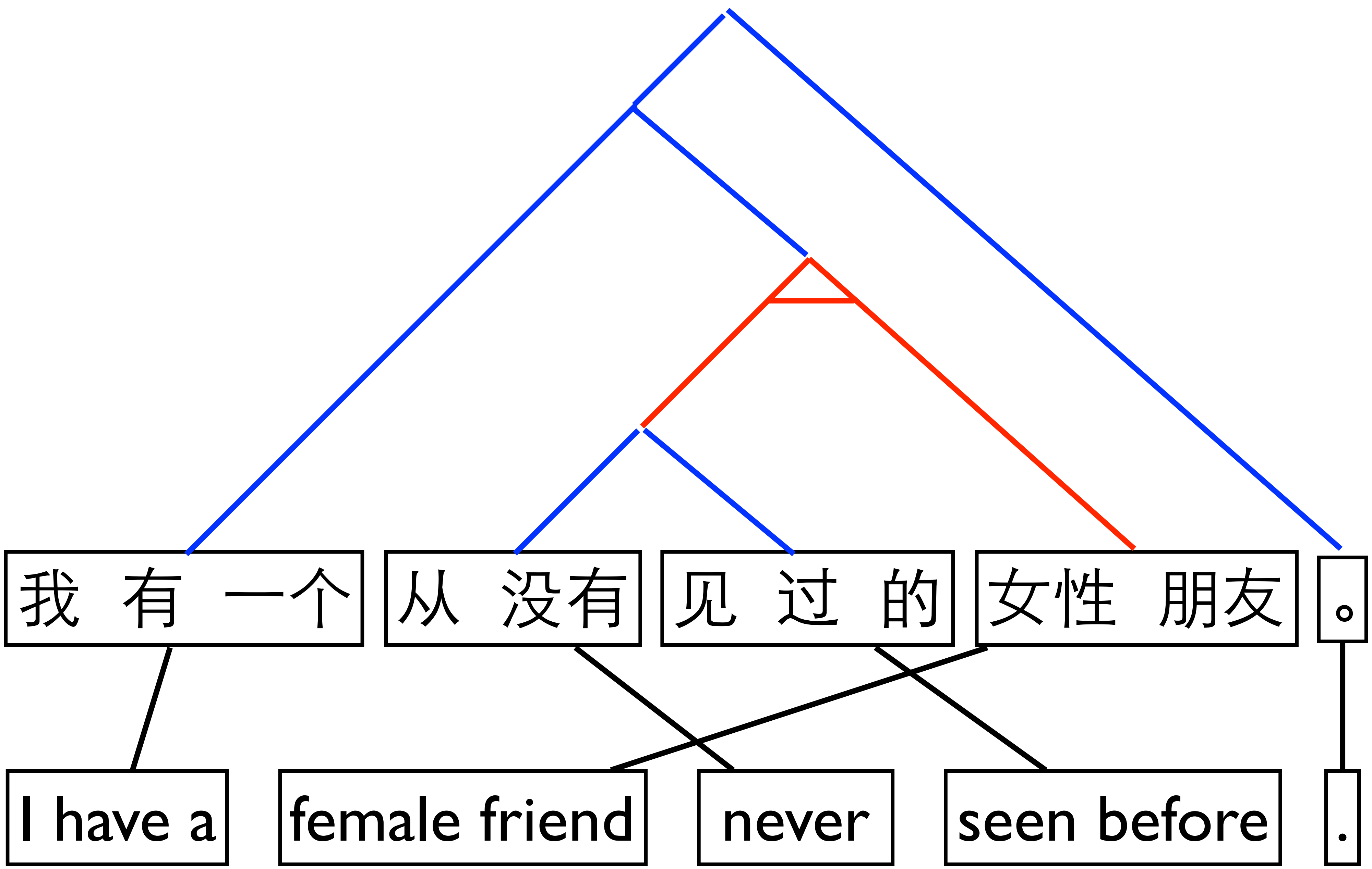


(Wu, 1997; Xiong et al., 2006)

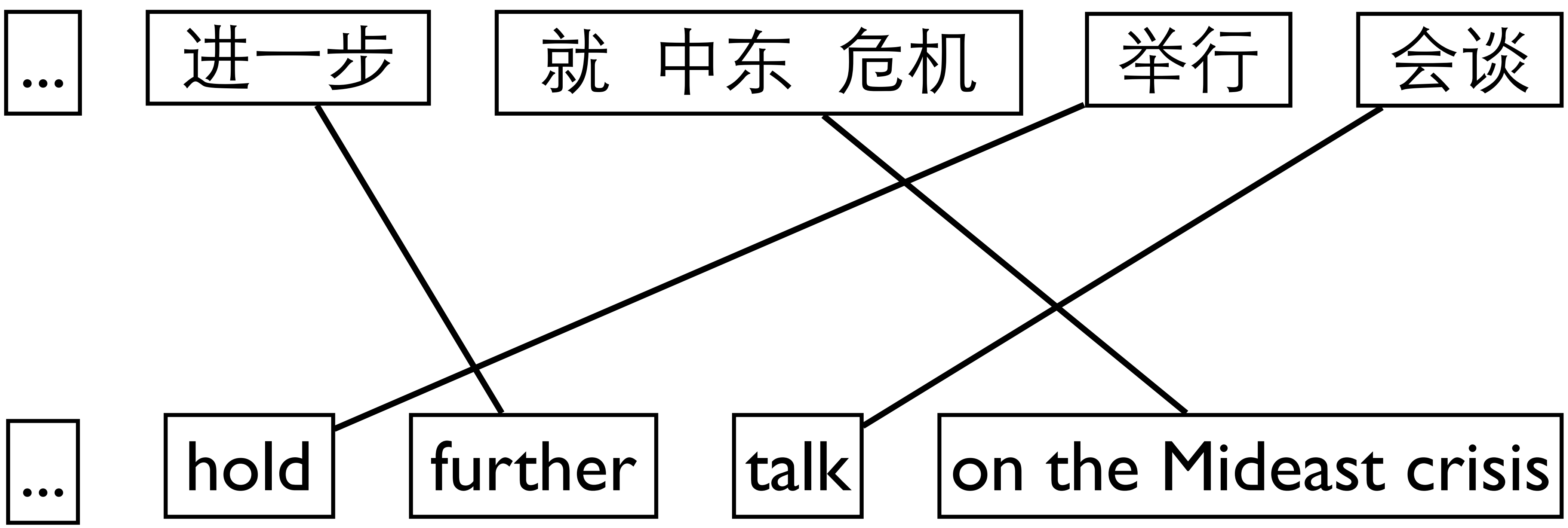
Block Merging

- Can you find a counter example?

(Huang et al., 2009)

Block Merging

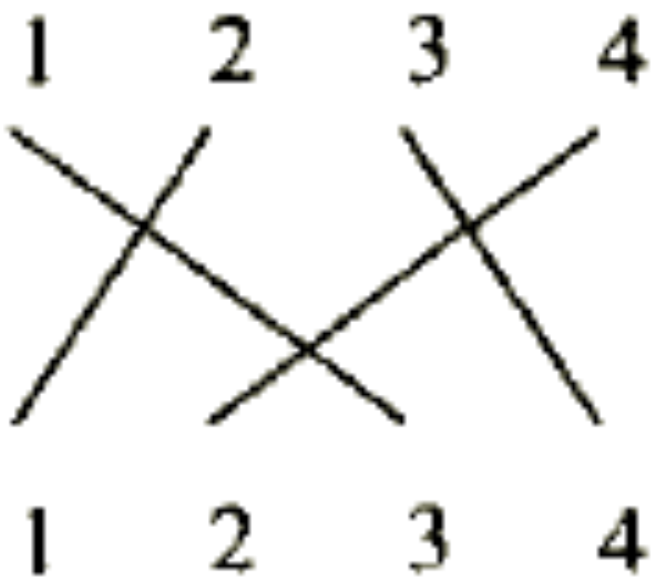
- Can you find a counter example?

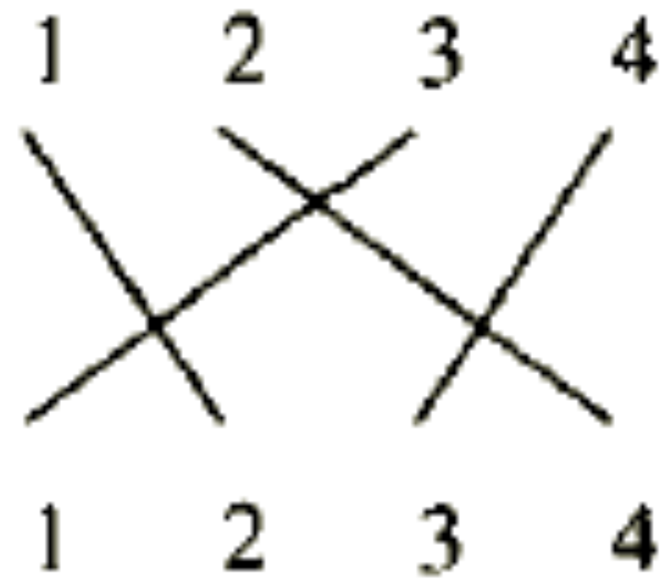


(Huang et al., 2009)

Block Merging

"inside-outside"





(Wu, 1997)

ITG

- Inversion transduction grammar (ITG)

$X \rightarrow [X^1, X^2]$: straight rule

$X \rightarrow \langle X^1, X^2 \rangle$: inverted rule

$X \rightarrow f/e$: lexical rules

(Wu, 1997)

ITG-based Reordering Model

- Type I: Incorporating ITG into left-to-right decoding to constrain the reordering space (e.g., Zens et al., 2004; Feng et al., 2010)
- Type II: Translation as ITG parsing, e.g.
  - Max-Ent ITG reordering model: using maximum entropy (MaxEnt) model to predict which rule to use (Xiong et al., 2006)

MaxEnt ITG Reordering Model

Potentially alleviates the data sparseness problem

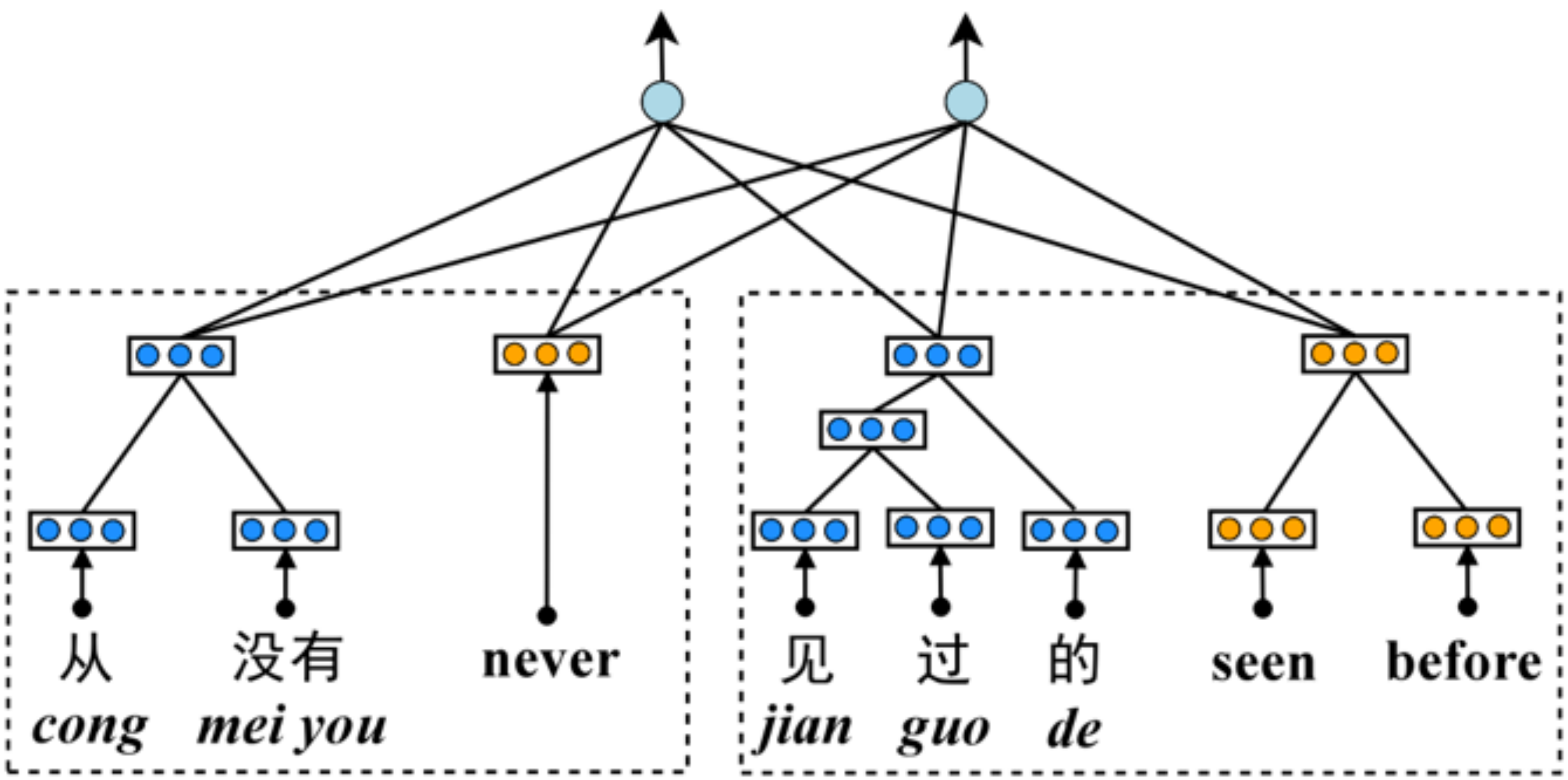
How to extract features from training examples?

- Which words are representative for predicting reordering?
- Xiong et al. (2006) only use boundary words

This Work

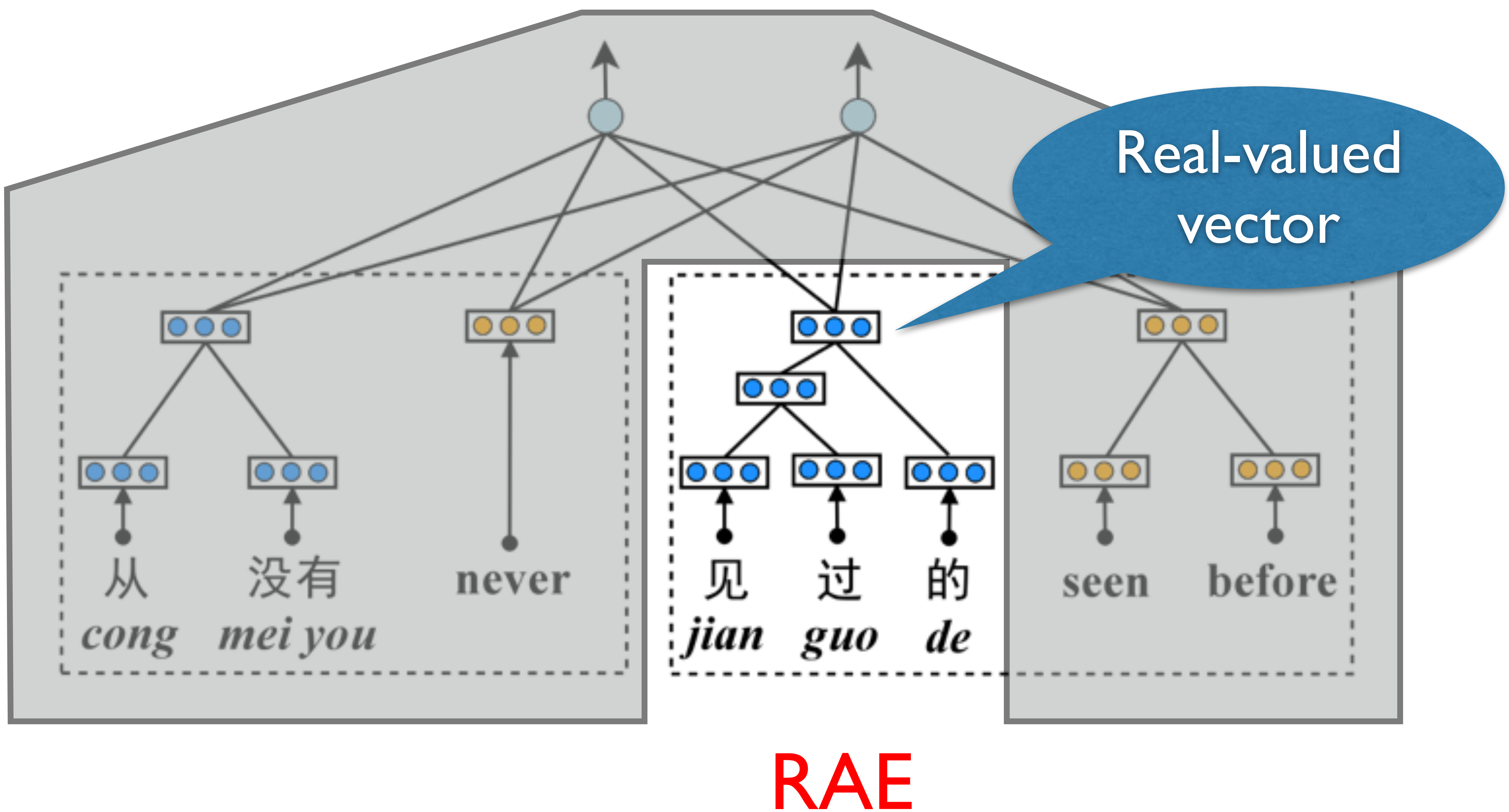
- We propose an ITG reordering classifier based on recursive autoencoders (RAE)
- Our model considers the whole phrases
  - RAEs can produce vector space representations for arbitrary strings
- Our system achieves 1.07 BLEU points improvement on NIST 2008 dataset

Neural ITG Reordering Model



"never seen before" v.s. "seen before never"

Neural ITG Reordering Model



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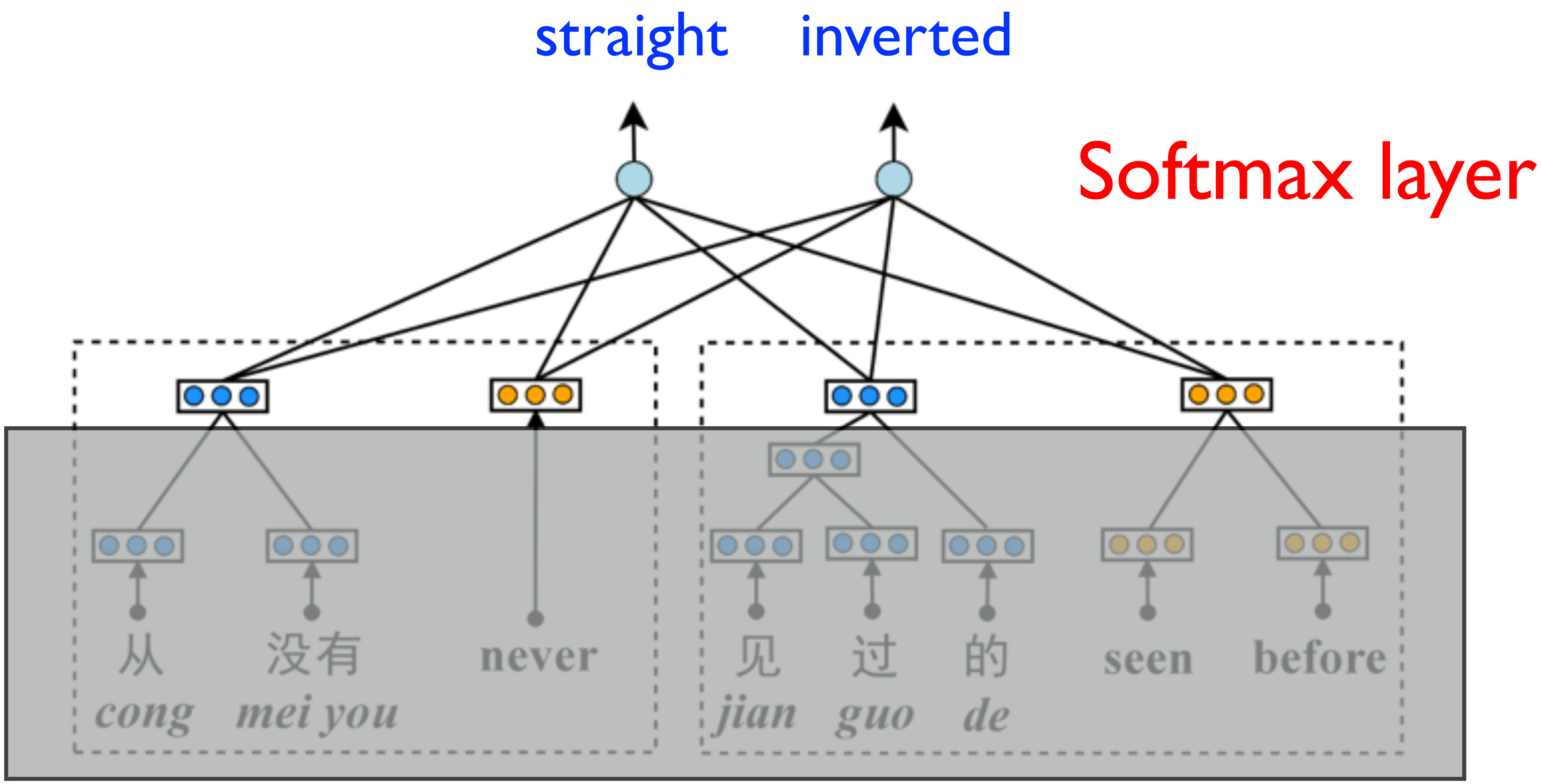
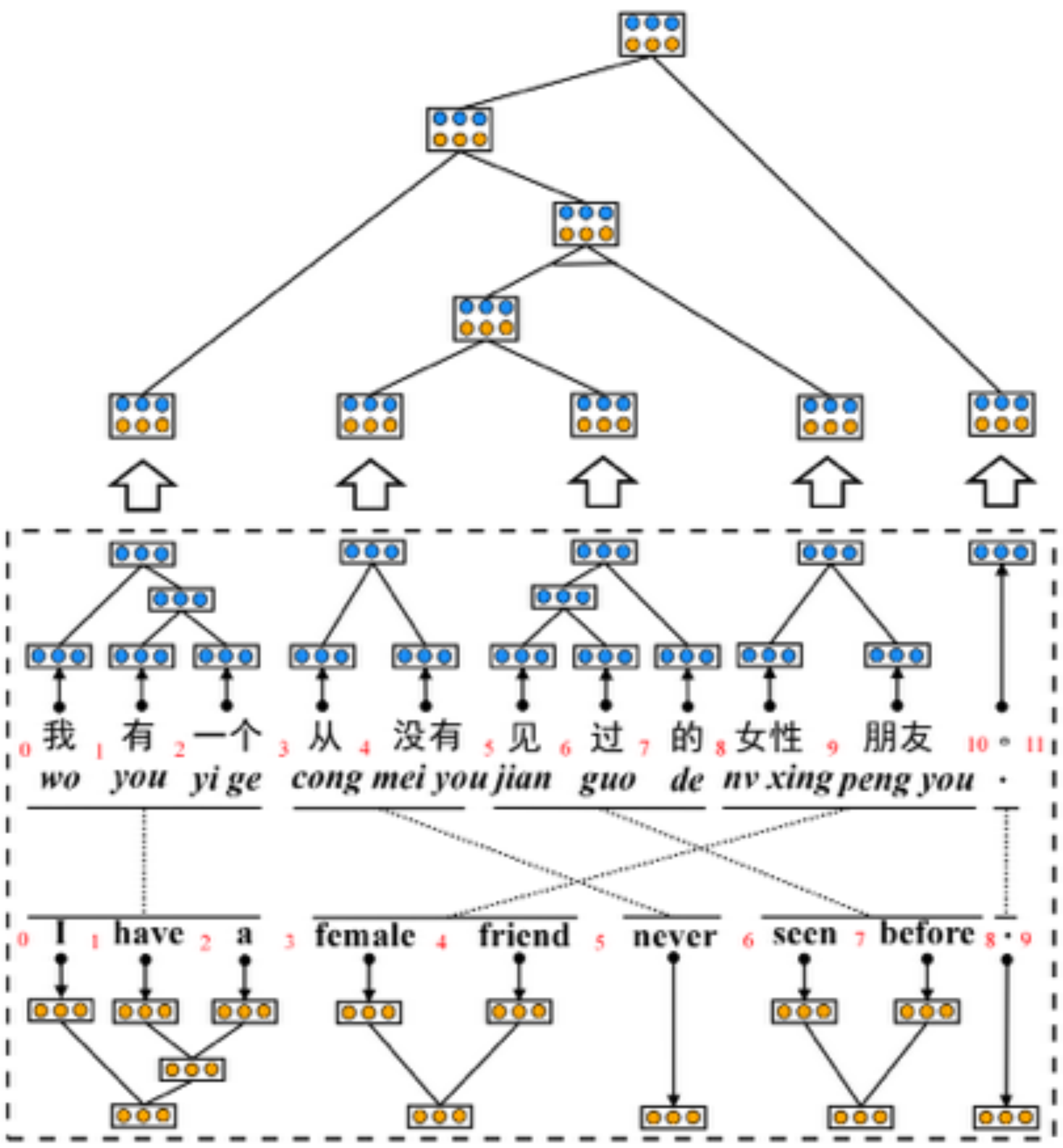


Translation



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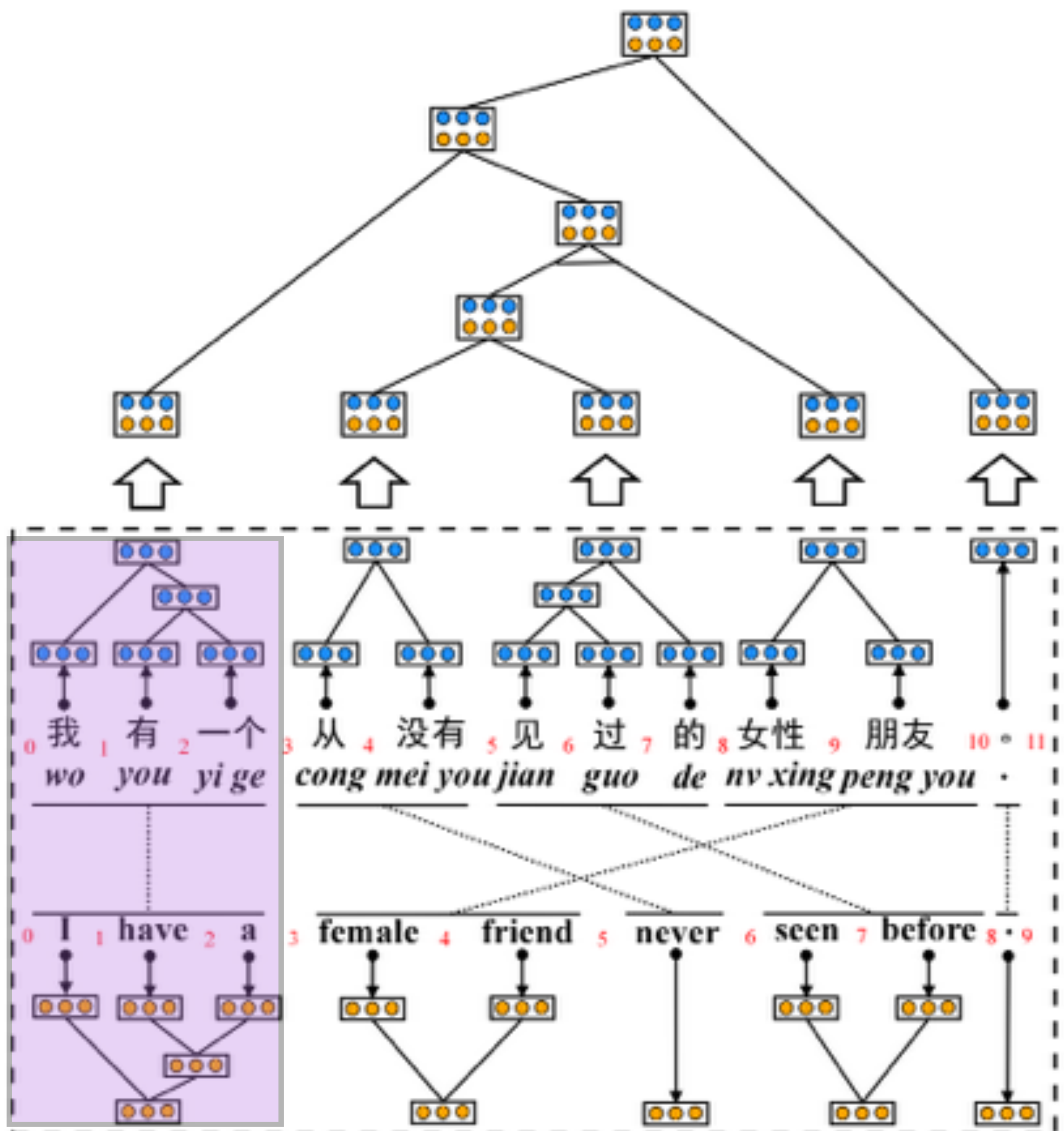

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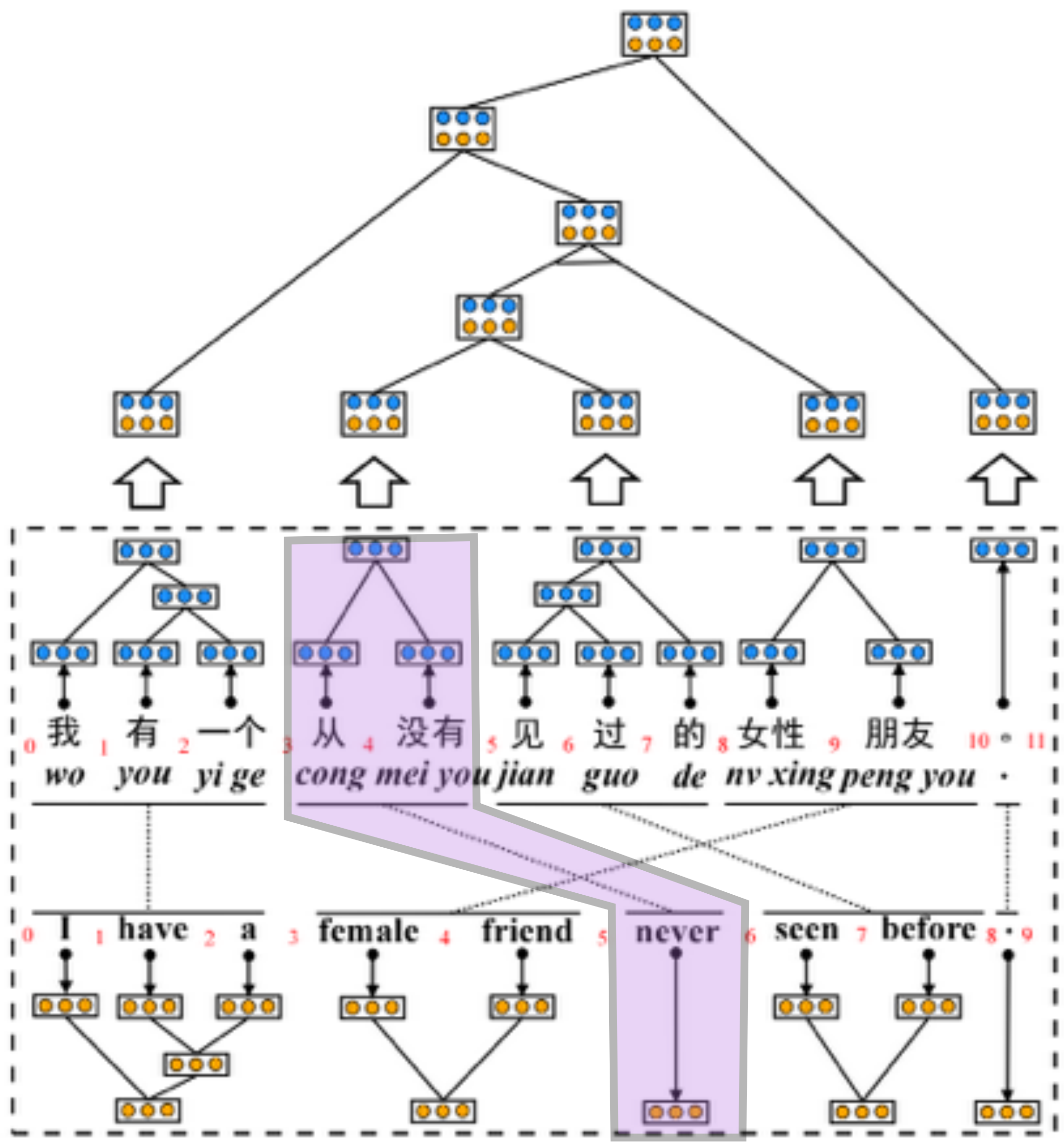

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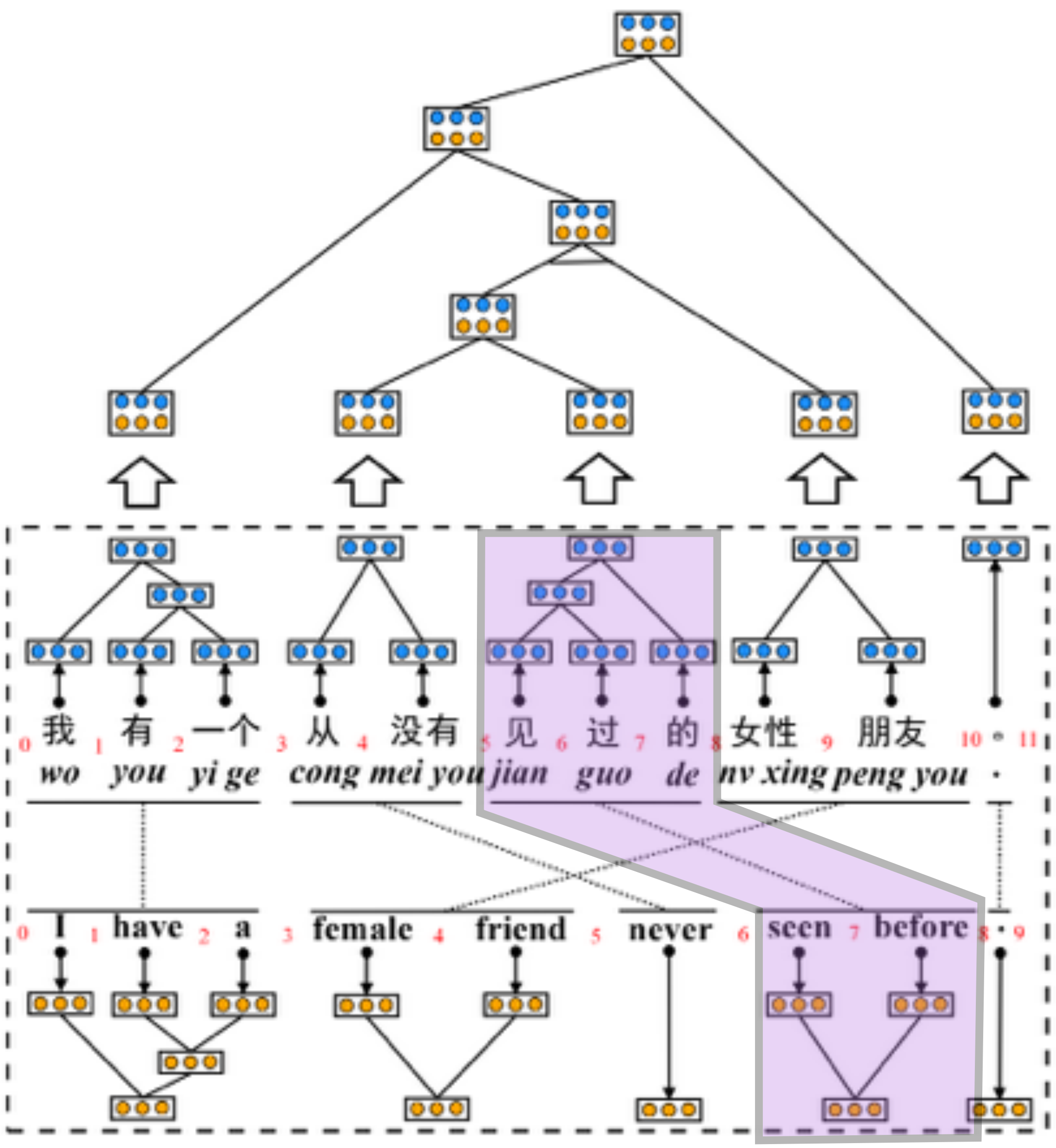

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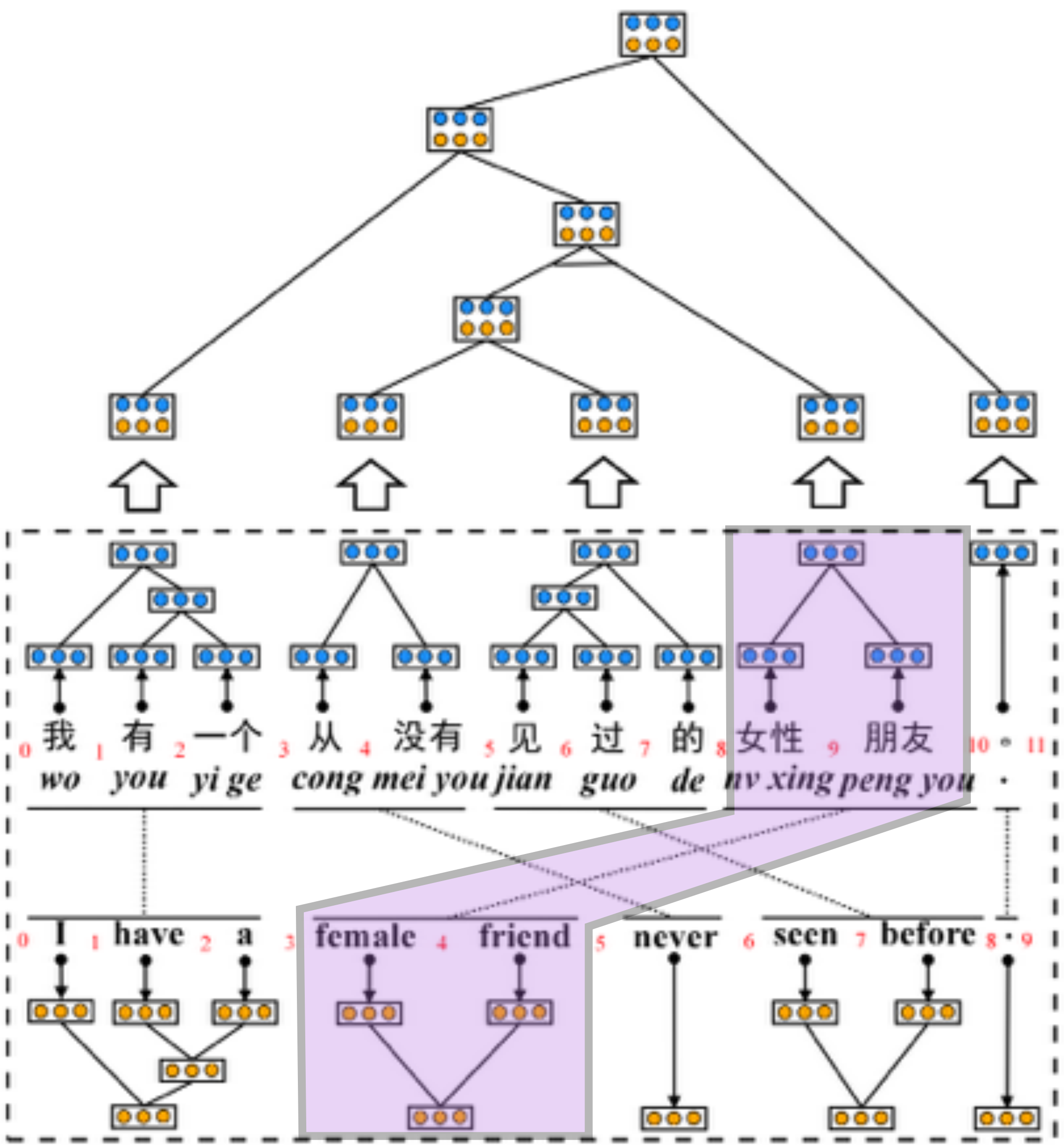

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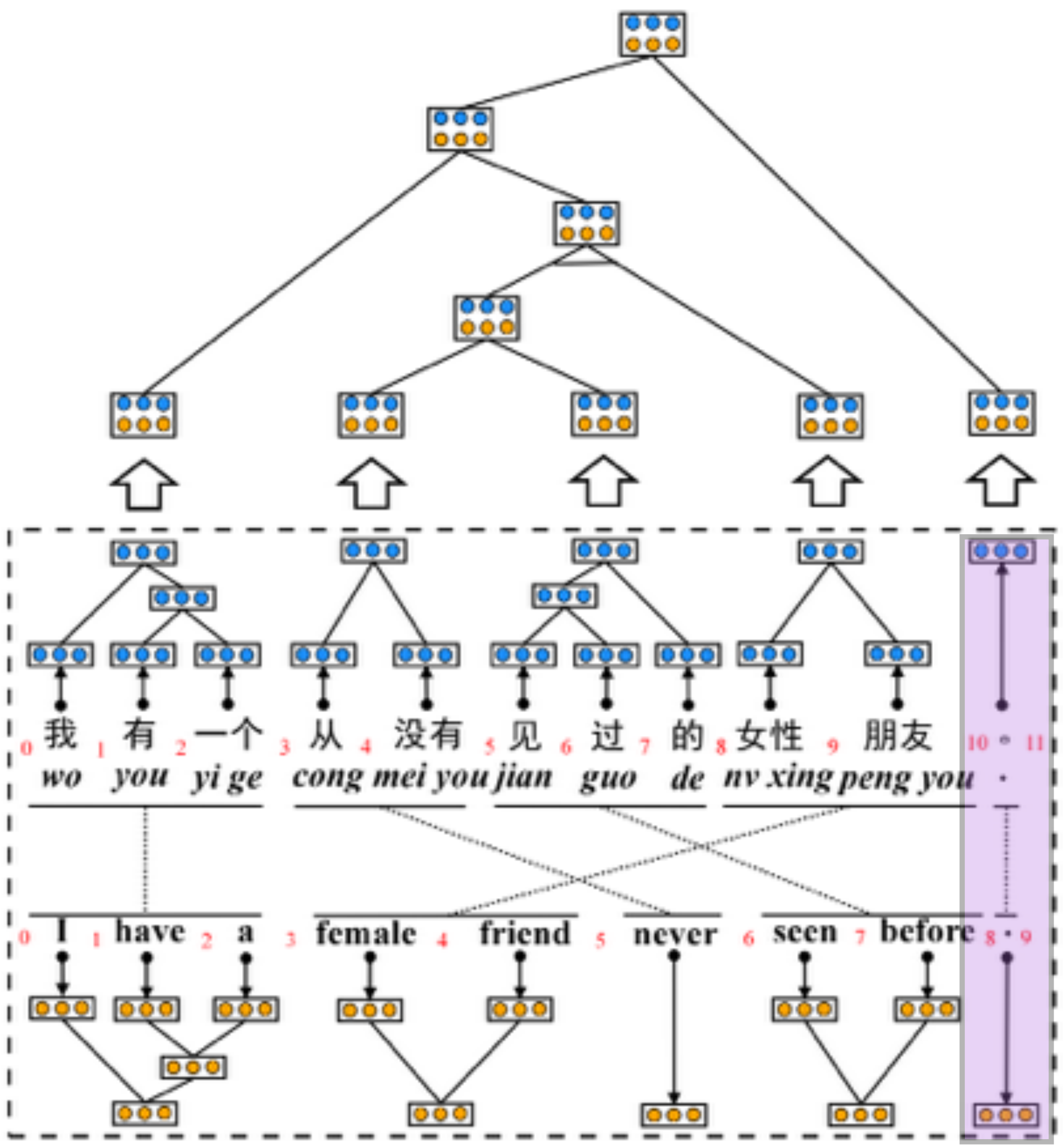

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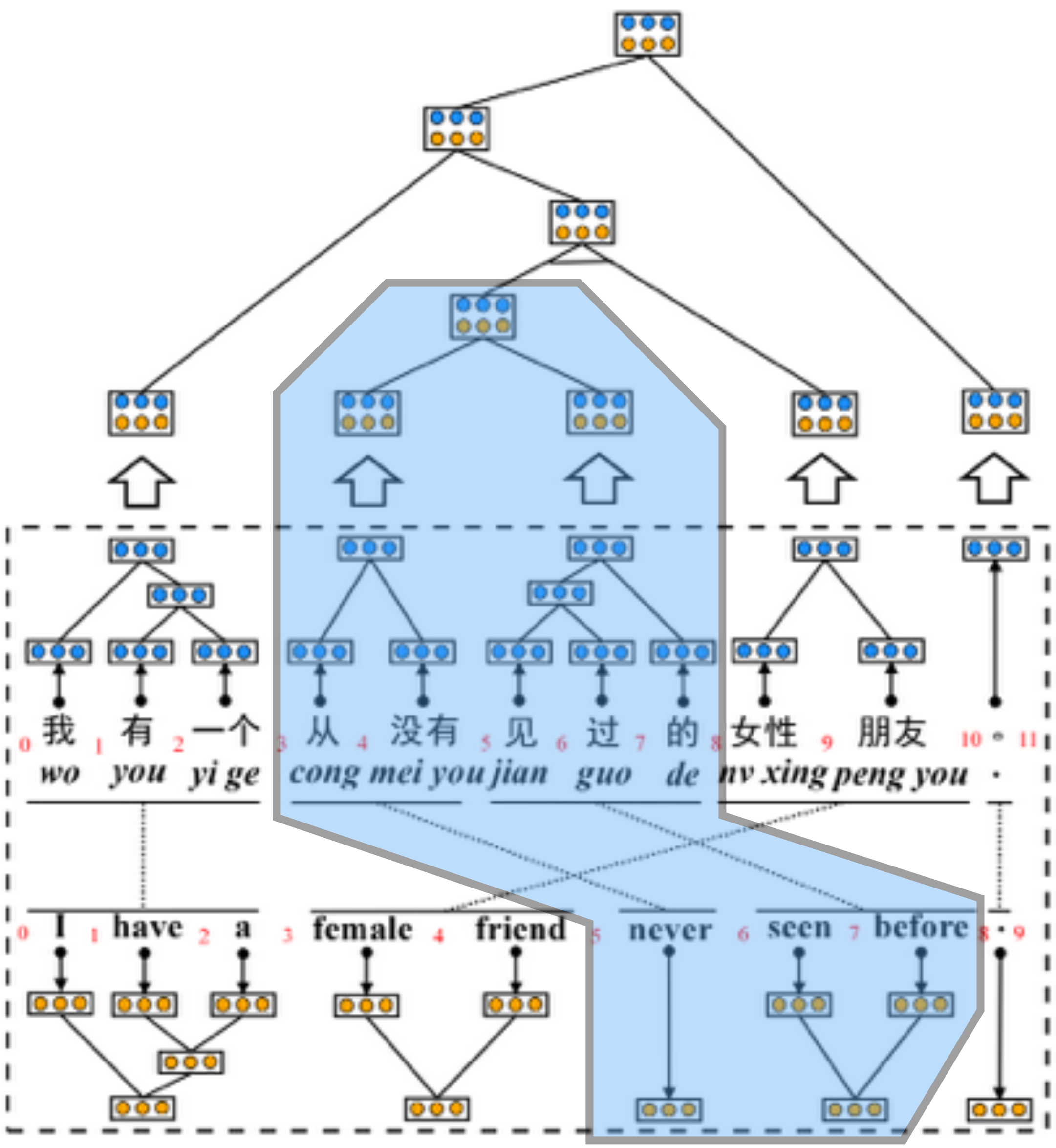

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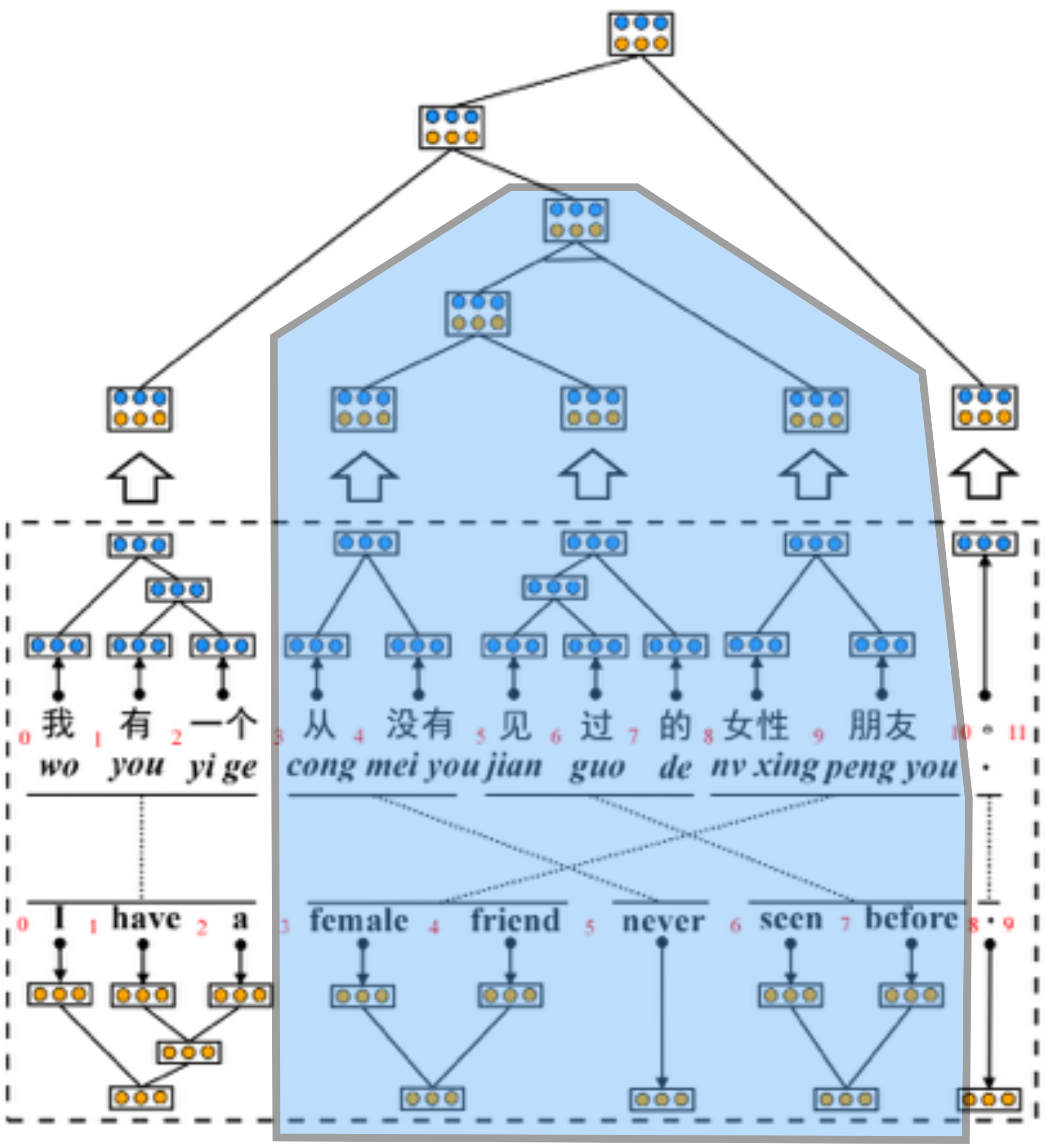

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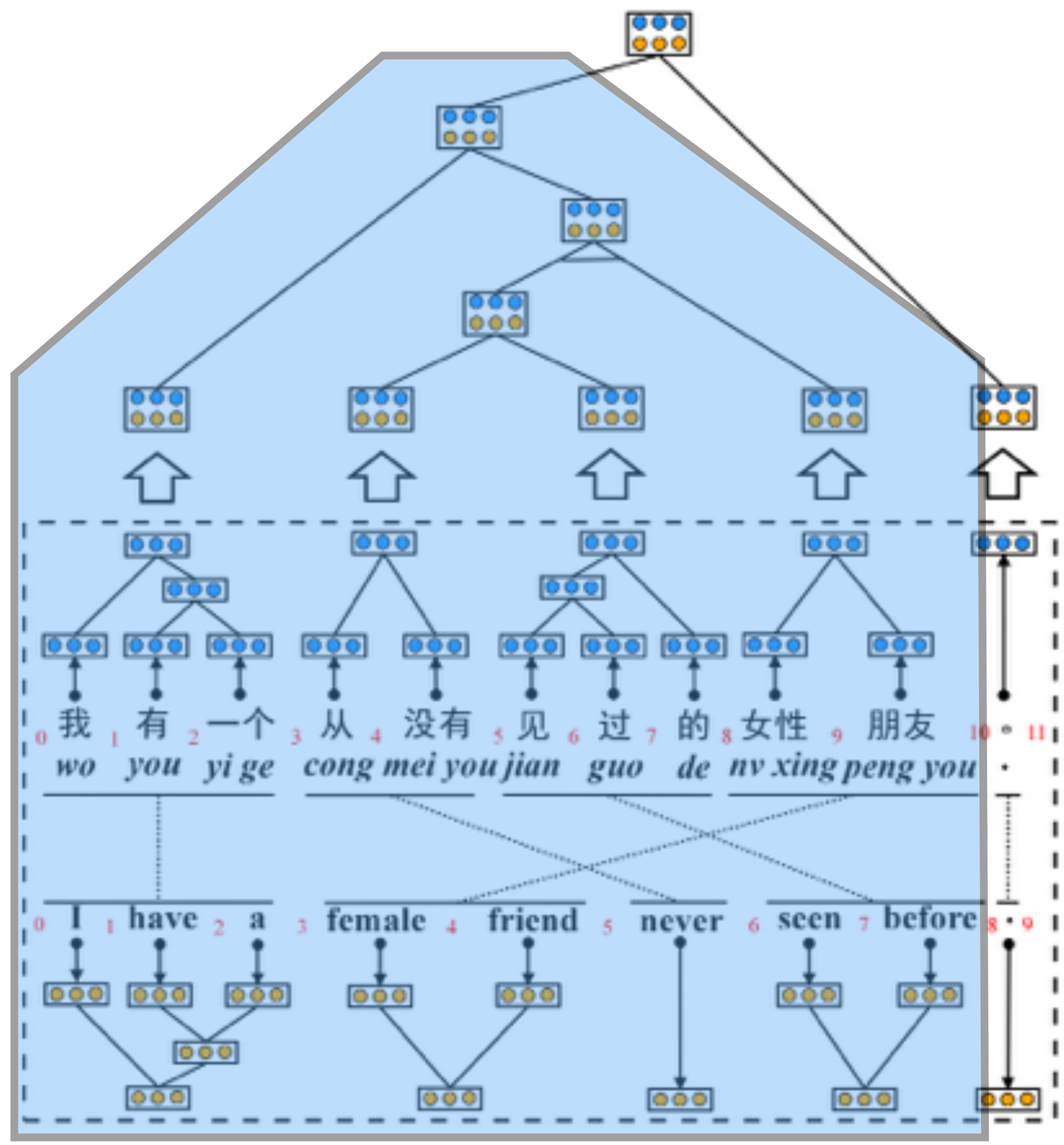

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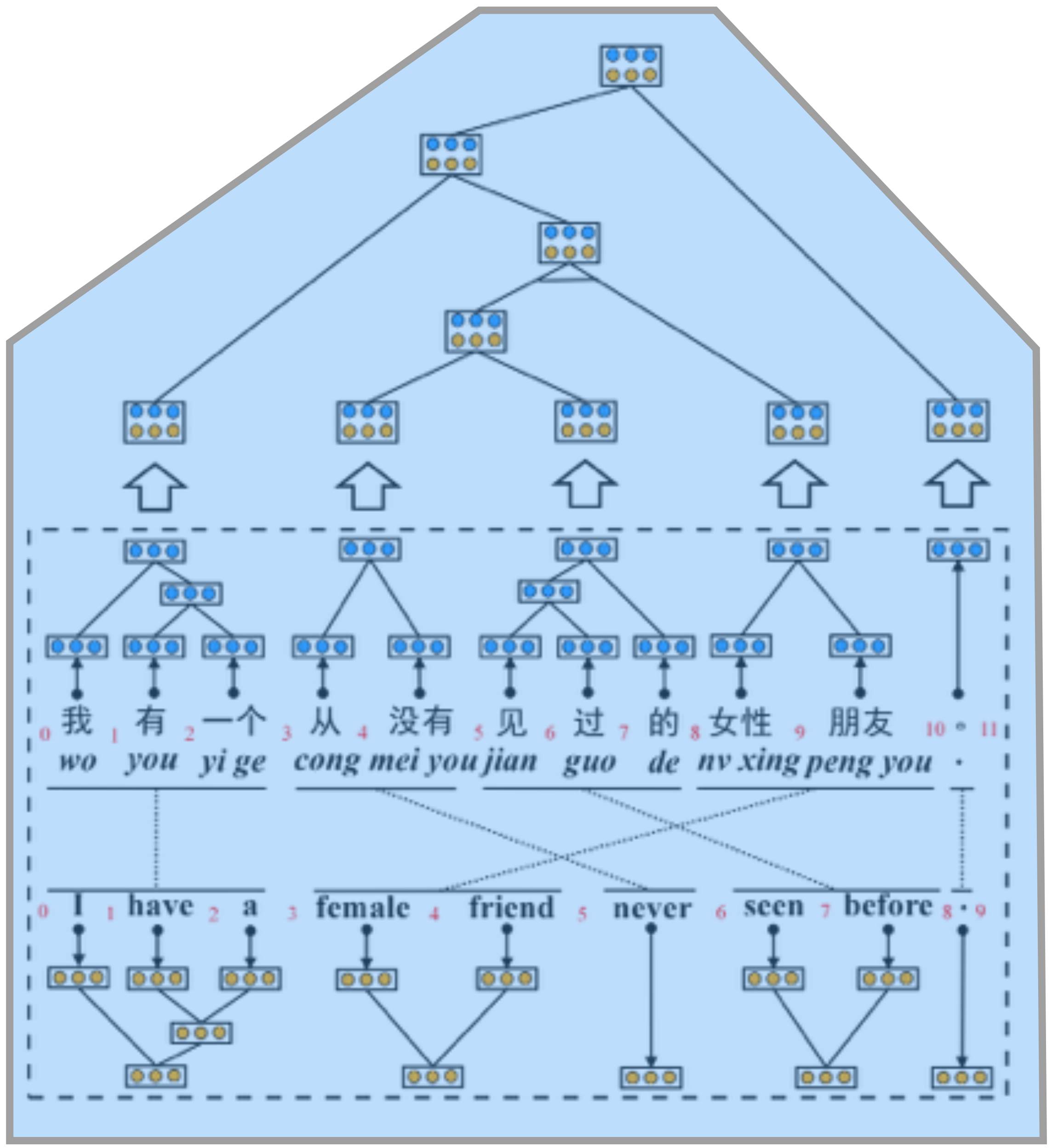
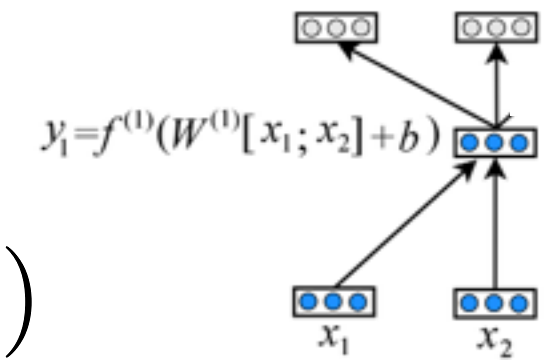


Autoencoders

- Each word is represented as a vector, e.g.
  - “female” ➤ $[0.1\ 0.8\ 0.4]^T$
  - “friend” ➤ $[0.7\ 0.1\ 0.5]^T$
- What is the vector representation of “female friend”?

Autoencoders

- Encoding



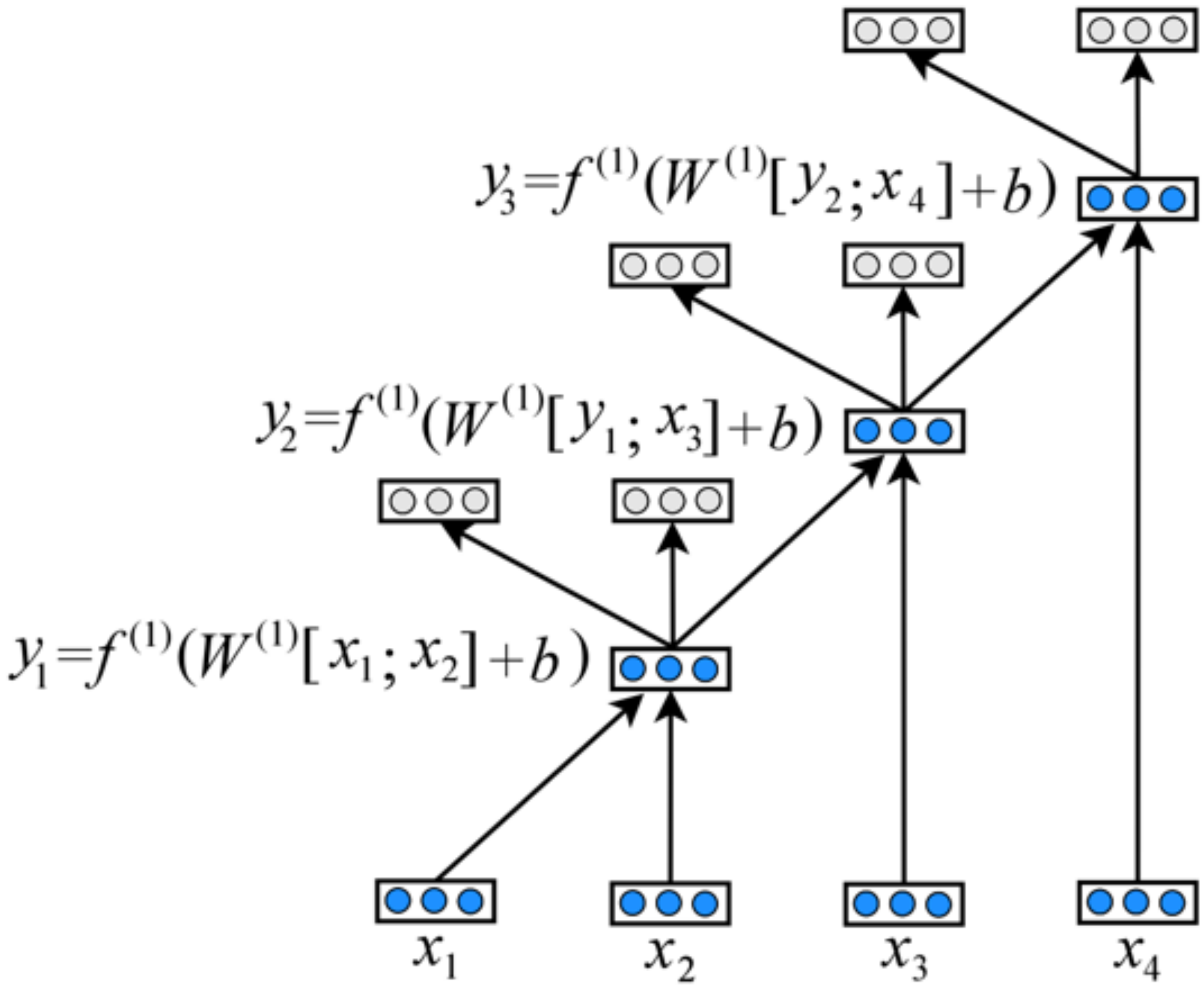
$$p = f^{(1)}(W^{(1)}[c_1; c_2] + b^{(1)})$$

- Decoding

$$[c'_1; c'_2] = f^{(2)}(W^{(2)}p + b^{(2)})$$

- What about multi-word strings?

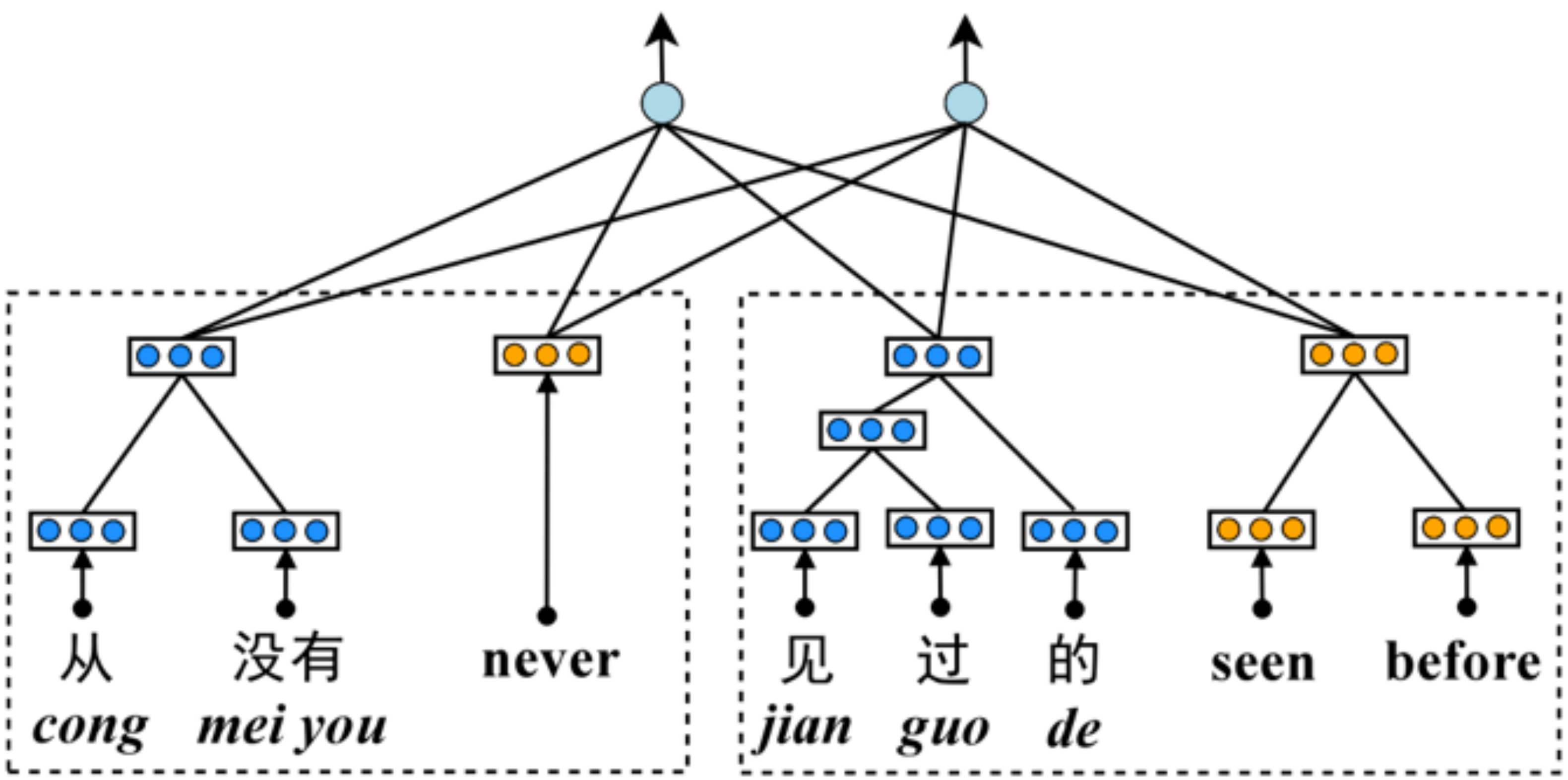
Recursive Autoencoders



(Socher et. al, 2011)

Training

Reordering error: how well the classifier predicts the merging order?



Reconstruction error: how well the learned vector space representations represent the corresponding strings?

Reconstruction Error

- Reconstruction error

$$E_{rec}([c_1; c_2]; \theta) = \frac{1}{2} || [c_1; c_2] - [c'_1; c'_2] ||^2$$

- Source side average reconstruction error

$$E_{rec,s}(S; \theta) = \frac{1}{N_s} \sum_i \sum_{p \in T_R^\theta(t_i, s)} E_{rec}([p.c_1, p.c_2]; \theta)$$

- Total reconstruction error

$$E_{rec}(S; \theta) = E_{rec,s}(S; \theta) + E_{rec,t}(S; \theta)$$

Reordering Error

- Average cross-entropy error

$$E_{reo}(S;\theta) = \frac{1}{|S|}\sum_i \left(-\sum_o d_{t_i}(o) \cdot log(P_\theta(o|t_i)) \right)$$

- Joint training objective

$$J = \alpha E_{rec}(S;\theta) + (1-\alpha)E_{reo}(S;\theta) + R(\theta)$$

$$R(\theta) = \frac{\lambda_L}{2}||\theta_L - \theta_{L_0}||^2 + \frac{\lambda_{rec}}{2}||\theta_{rec}||^2 + \frac{\lambda_{reo}}{2}||\theta_{reo}||^2$$

Optimization

- Hyper-parameters optimization
  - $\alpha, \lambda_L, \lambda_{rec}, \lambda_{reo}$
  - Optimized by random search (Bergstra and Bengio, 2012)
- Training objective optimization: L-BFGS
  - Using backpropagation through structures to compute gradients (Goller and Kuchler, 1996)

Experiments

- Training corpus: 1.23M sentence pairs
- Language model: 4-gram language model trained on the Xinhua portion of the GIGAWORD corpus
- Dev. set: NIST 2006 MT dataset
- Test set: NIST 2008 MT dataset
- Metric: case-insensitive BLEU-4 score

BLEU-4

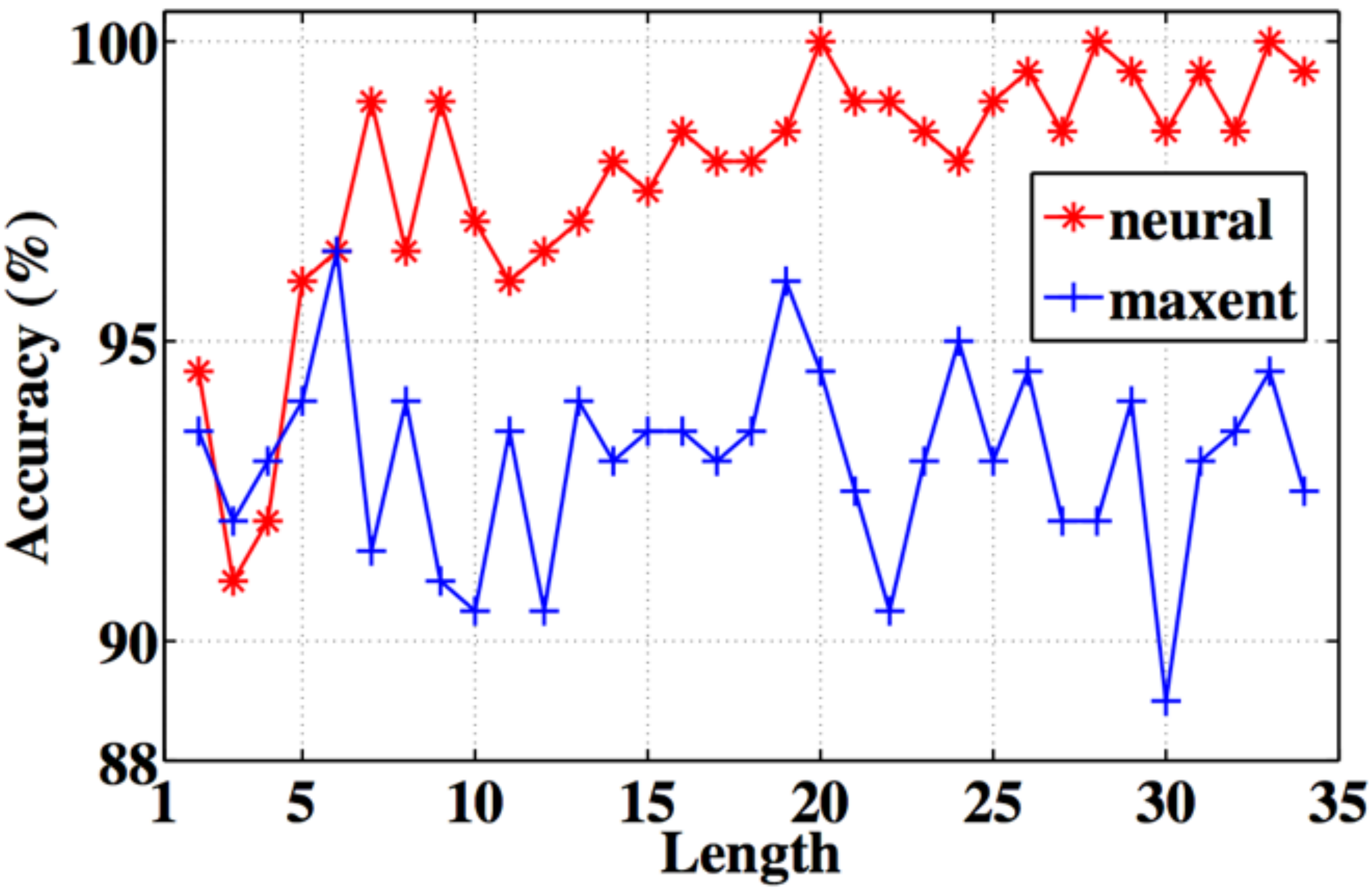
System	NIST06 (dev)	NIST08 (tst)
maxent	30.40	23.75
neural	**31.61***	**24.82***

*: significantly better ($p < 0.01$)

BLEU-4

Sentence Length	>	=	<
[1, 10]	43	121	57
[11, 20]	181	67	164
[21, 30]	170	11	152
[31, 40]	105	3	90
[41, 50]	69	1	53
[51, 119]	40	0	30

Classification Accuracy



Conclusion

- We have presented an ITG reordering classifier based on RAEs
- Feature work
  - Combine linguistically-motivated labels with recursive neural networks
  - Investigate more efficient decoding algorithms
  - Apply our method to other phrase-based and even syntax-based systems

Reference

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Thanks!

Backup Slides

Training Data Size

# of examples	NIST06 (dev)	NIST08 (tst)
100,000	30.88	23.78
200,000	30.75	23.89
300,000	30.80	24.35
400,000	31.01	24.45
6,004,441	31.61	24.82

Cluster Examples

Cluster 1	Cluster 2	Cluster 3
works for	these people who	of the three
verify on	the reasons why	on the fundamental
tunnels from	the story of how	over the entire
transparency in	the system which	through its own
opinion at	the trend towards	with the best