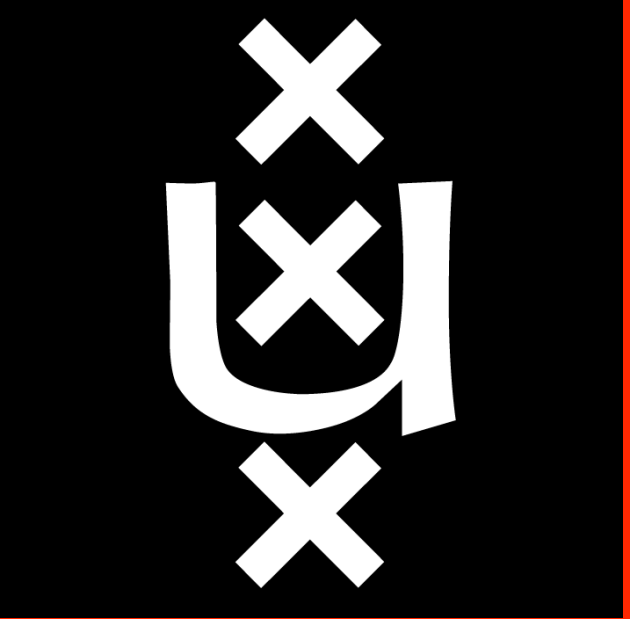


Christof Monz

Applied Language Technology
Reordering

Today's Class

- Distortion limit and distortion constraints
- Lexicalized reordering modeling
- Hierarchical Reordering modeling

Model Errors of Decoding

- Model errors occur if the highest model-scoring hypothesis is scored lower by some quality metric (e.g., BLEU) than another hypothesis with a lower model score
- The models used during decoding are inappropriate due to
  - noisy, unreliable estimates
  - lack of coverage
  - over-fitting to the training data
  - under-fitting of the models

Linear Reordering

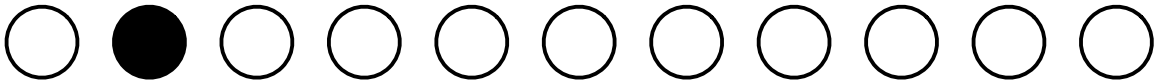
- So far we have only considered linear reordering where
  - phrases can be translated in any order
  - a distortion cost is computed based on the linear difference between the last translated word of the previously translated phrase (s_i) and the beginning of the next phrase (s_j): $h_{LD}(s_i, s_j) = -1 \cdot |\text{first\_pos}(s_j) - \text{last\_pos}(s_i) - 1|$
- In practice not all reorderings can be considered (for efficiency reasons) and distortion limits are introduced:
  - $\text{DL} = n$: Only consider reordering (s_i, s_j) if $h_{LD}(s_i, s_j) \leq n$
- How much do we lose by limiting reordering?
  - Consider long-distance reorderings (such as verb-final movements in German-English)

Linear Reordering Constraints

- A distortion limit by itself still allows for too many reorderings

Linear Reordering Constraints

- A distortion limit by itself still allows for too many reorderings



Linear Reordering Constraints

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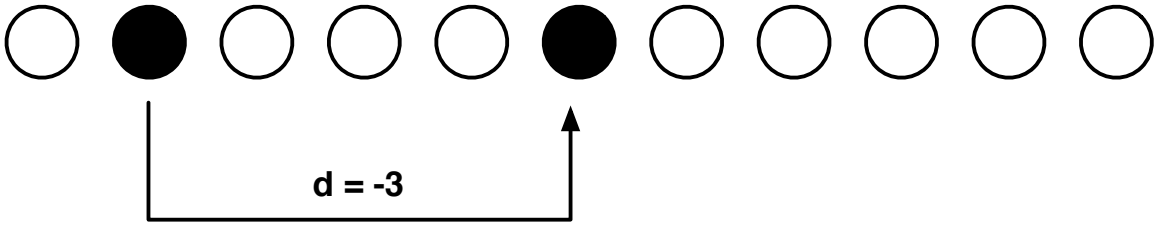

Linear Reordering Constraints

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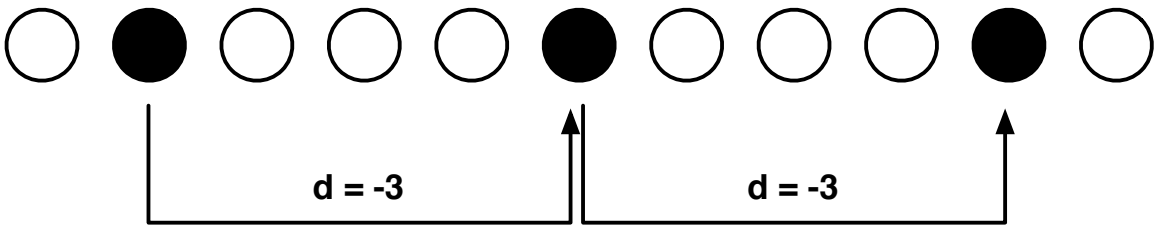

Linear Reordering Constraints

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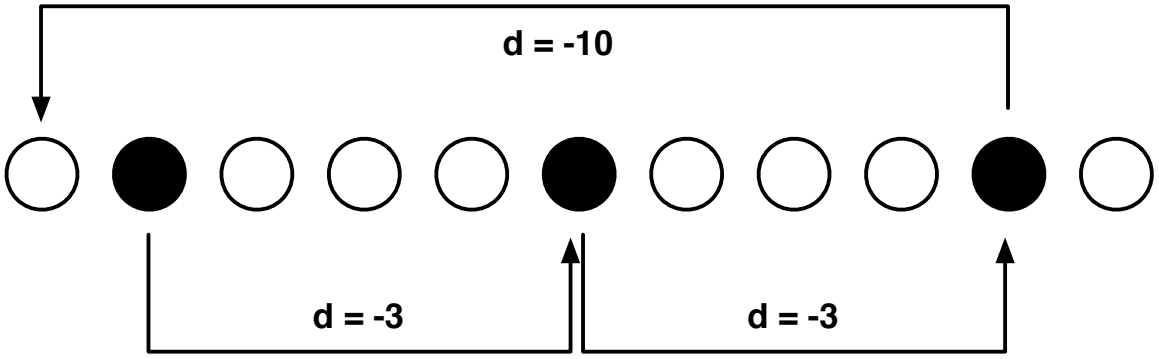
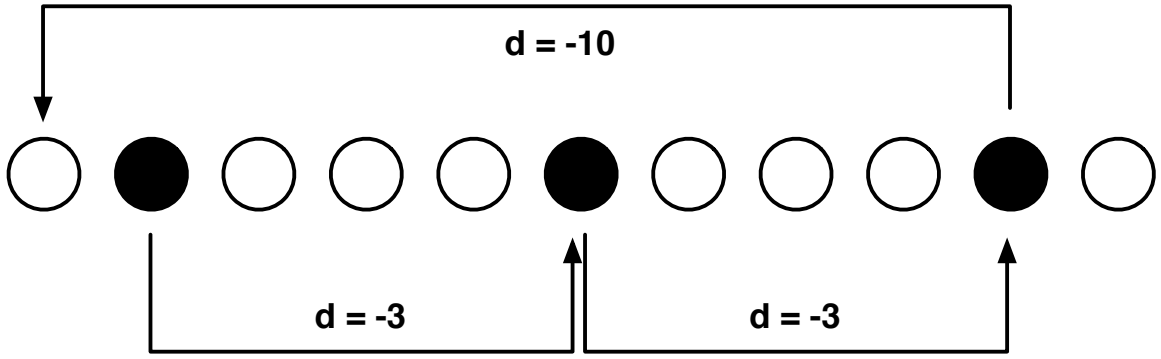


Linear Reordering Constraints

- A distortion limit by itself still allows for too many reorderings



- Additional constraints are required that take the 'global' amount of reordering into account

IBM Constraints

- The IBM constraints allow for reorderings such that at most k positions are uncovered before the last covered position

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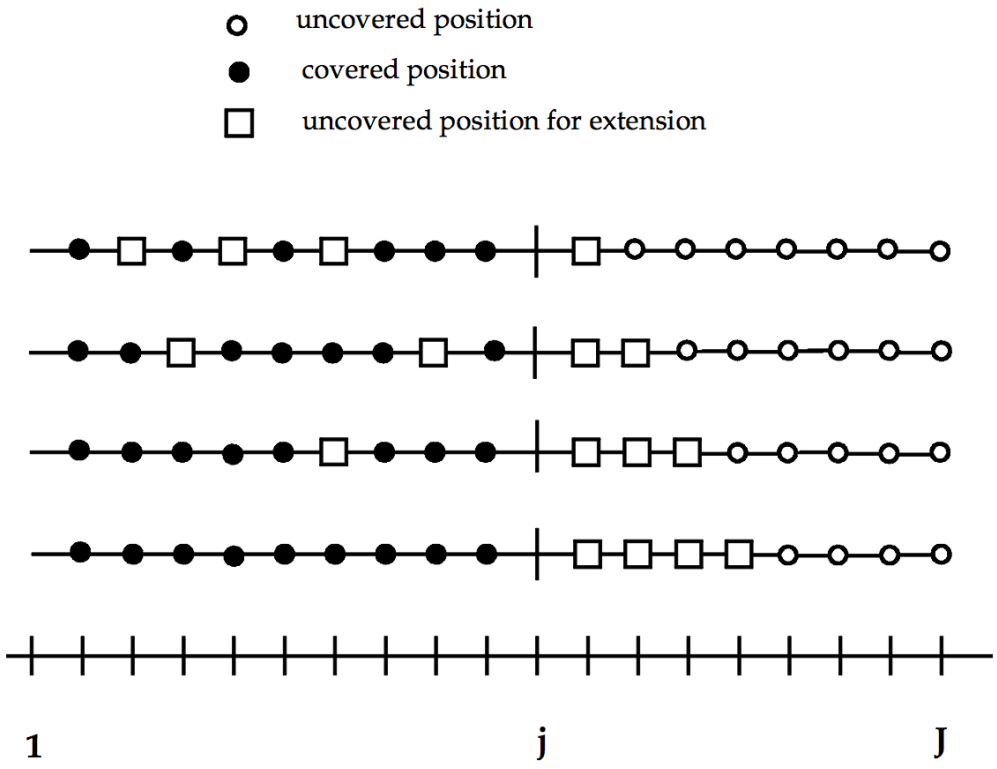
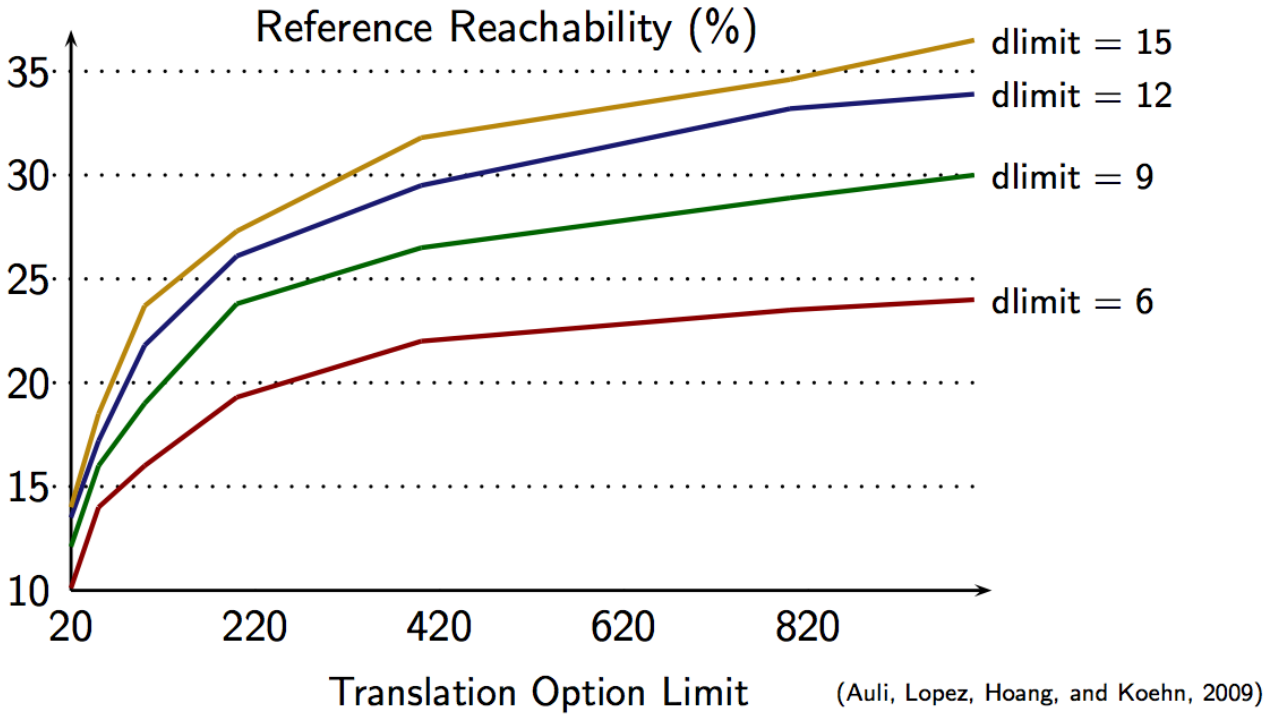


IBM Constraints

- The IBM constraints are often used in combination with a limit on the window size
- A window $w = n$ specifies the maximum distance (n) between the first uncovered position and the last translated word

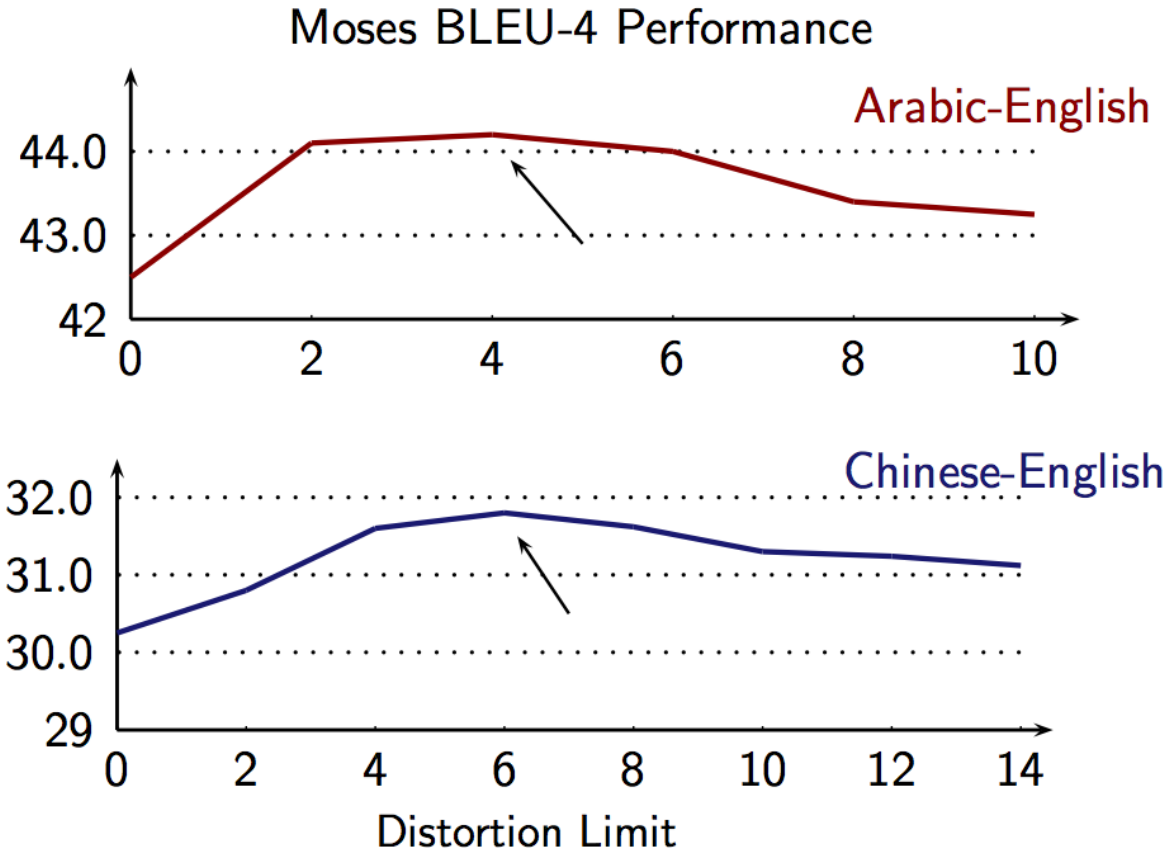
Search Constraints and Model Errors



(Auli, Lopez, Hoang, and Koehn, 2009)

- Increasing the distortion limit results in larger percentage of reachable references
- A reference (r) is reachable by the decoder if it can be produced by it, i.e., if $r \in \tilde{E}$

Distortion Limit and Quality



(Green et al., 2010)

- Increasing the distortion limit leads to increased noise and difficulties in discriminating good and poor hypotheses

Reordering and LMs

- Al-Onaizan & Papineni (2006): Reordering English wrt original Arabic word order

Arabic	Ezp_1 $AbrAhym_2$ $ystqbl_3$ $ms\&wlA_4$ $AqtSAdyA_5$ $sEwdyA_6$ fy_7 $bgdAd_8$
English	$Izzet_1$ $Ibrahim_2$ $Meets_3$ $Saudi_4$ $Trade_5$ $official_6$ in_7 $Baghdad_8$
Word Alignment	(Ezp_1,$Izzet_1$) ($AbrAhym_2$,$Ibrahim_2$) ($ystqbl_3$,$Meets_3$) ($ms\&wlA_4$,$official_6$) ($AqtSAdyA_5$,$Trade_5$) ($sEwdyA_6$,$Saudi_4$) (fy_7,in_7) ($bgdAd_8$,$Baghdad_8$)
Reordered English	$Izzet_1$ $Ibrahim_2$ $Meets_3$ $official_6$ $Trade_5$ $Saudi_4$ in_7 $Baghdad_8$

Reordering and LMs

- Al-Onaizan & Papineni (2006): Reordering English wrt original Arabic word order

Arabic	Ezp_1 AbrAhym_2 ystqbl_3 $\text{ms\&wlA}_4$ AqtSAdyA_5 sEwdyA_6 fy_7 bgdAd_8
English	Izzet_1 Ibrahim_2 Meets_3 Saudi_4 Trade_5 official_6 in_7 Baghdad_8
Word Alignment	(Ezp_1,Izzet_1) (AbrAhym_2,Ibrahim_2) (ystqbl_3,Meets_3) ($\text{ms\&wlA}_4$,official_6) (AqtSAdyA_5,Trade_5) (sEwdyA_6,Saudi_4) (fy_7,in_7) (bgdAd_8,Baghdad_8)
Reordered English	Izzet_1 Ibrahim_2 Meets_3 official_6 Trade_5 Saudi_4 in_7 Baghdad_8

- How well can the LM recover the correct order?

s	0	1	1	1	1	1	2	2	2	2
w	0	4	6	8	10	12	4	6	8	10
BLEUr1n4c	0.5617	0.6507	0.6443	0.6430	0.6461	0.6456	0.6831	0.6706	0.6609	0.6596

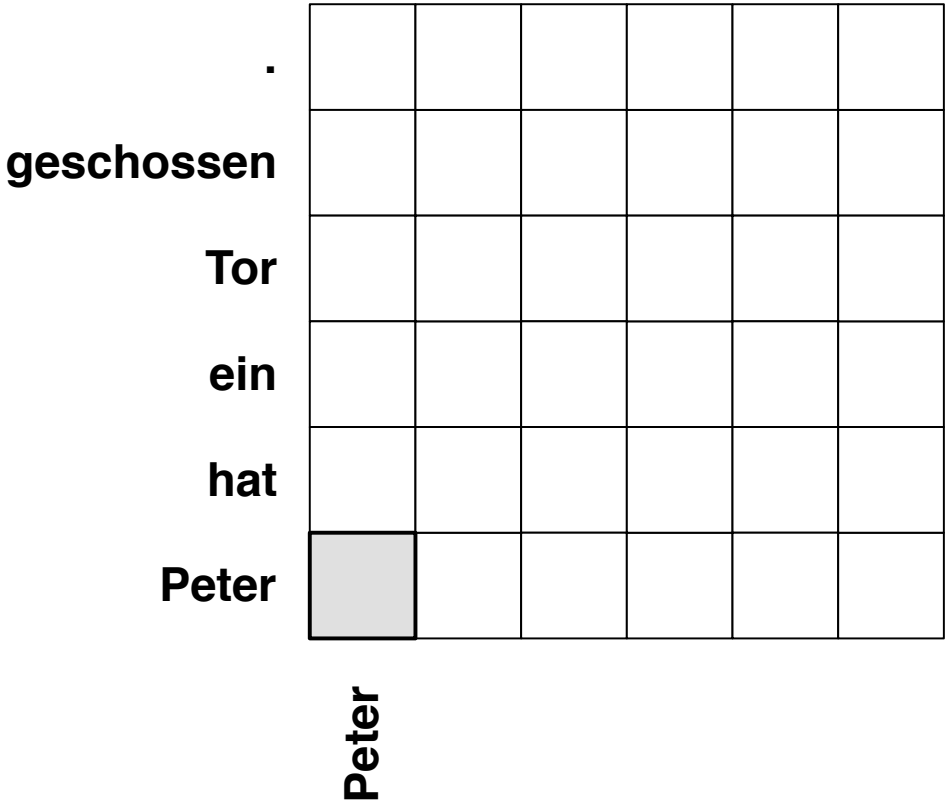
2	3	3	3	3	3	4	4	4	4	4
12	4	6	8	10	12	4	6	8	10	12
0.6626	**0.6919**	0.6751	0.6580	0.6505	0.6490	0.6851	0.6592	0.6317	0.6237	**0.6081**

Lexicalized Reordering

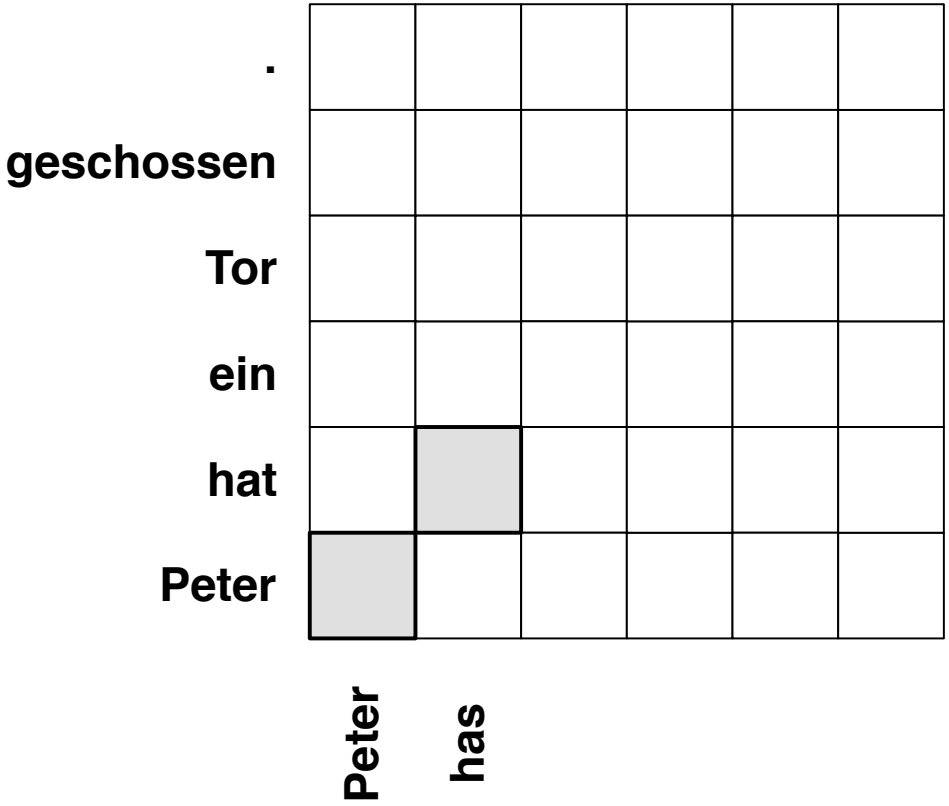
- Linear reordering is very lightly parameterized
  - only the length (+ some penalty for changing orientation)
- No information is encoded relating to
  - Syntactic structure
    - Source syntax
    - Target syntax
  - Lexicalization of the words/phrases involved in a reordering
- Lexicalized reordering (Tillmann 2004 and Koehn et al. 2005) introduces additional parameters
  - Which phrase (pair) are we jumping from
  - Which phrase (pair) are we jumping to

Lexicalized Reordering

Lexicalized Reordering



Lexicalized Reordering



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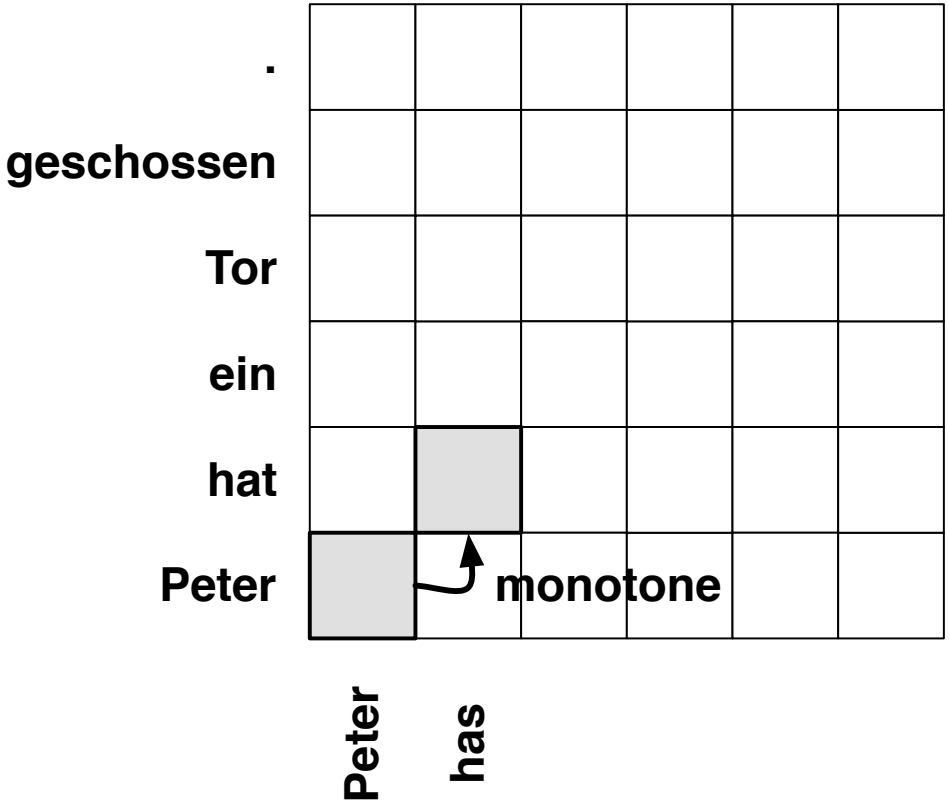

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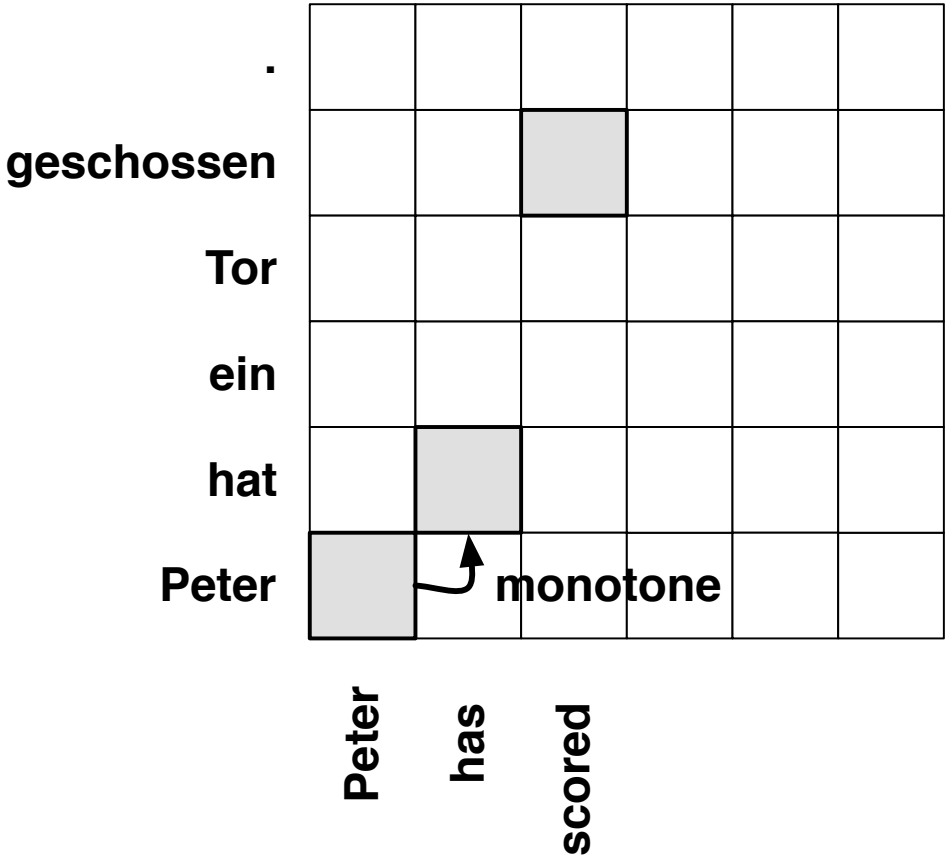

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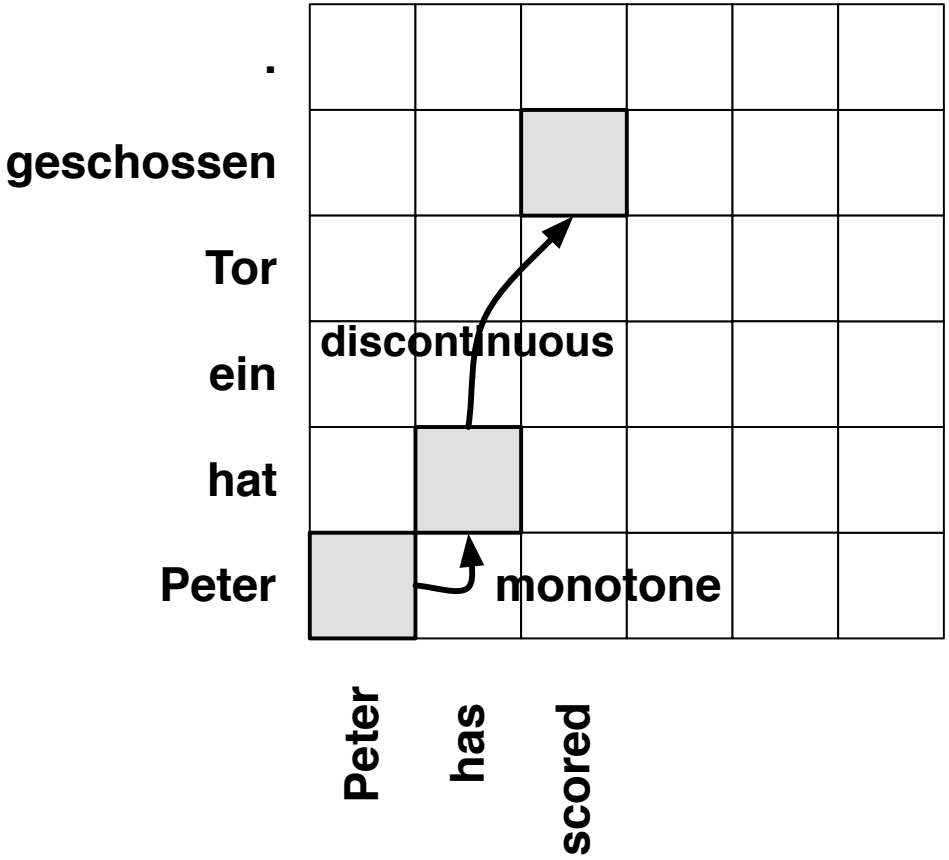

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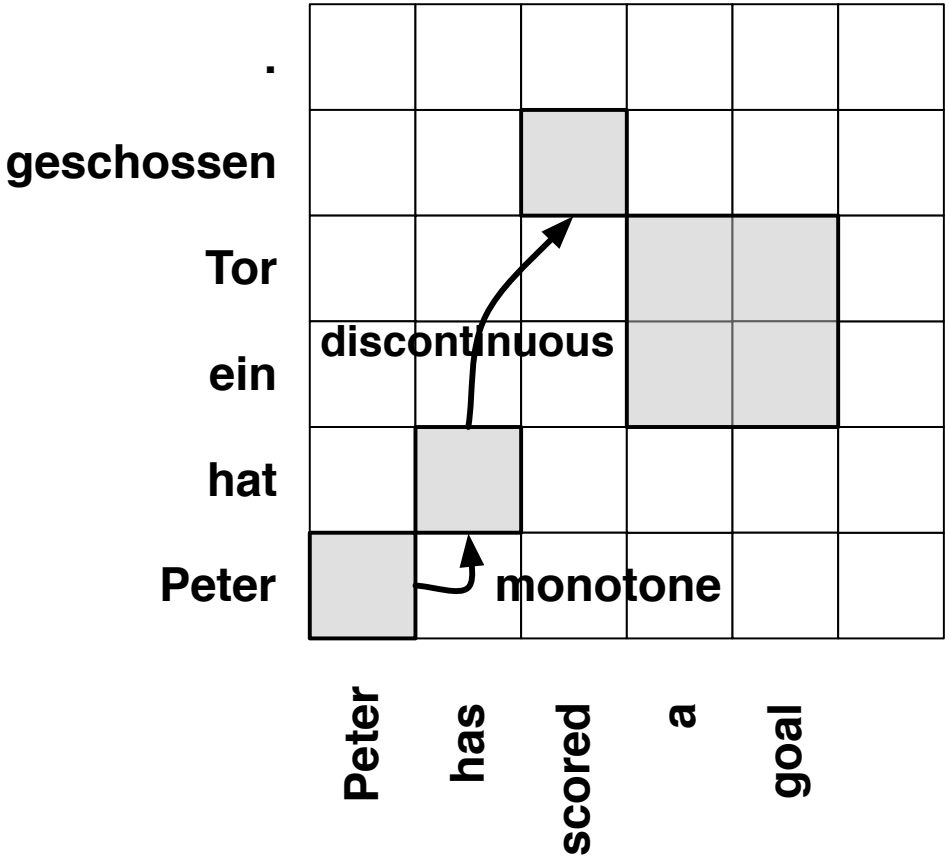

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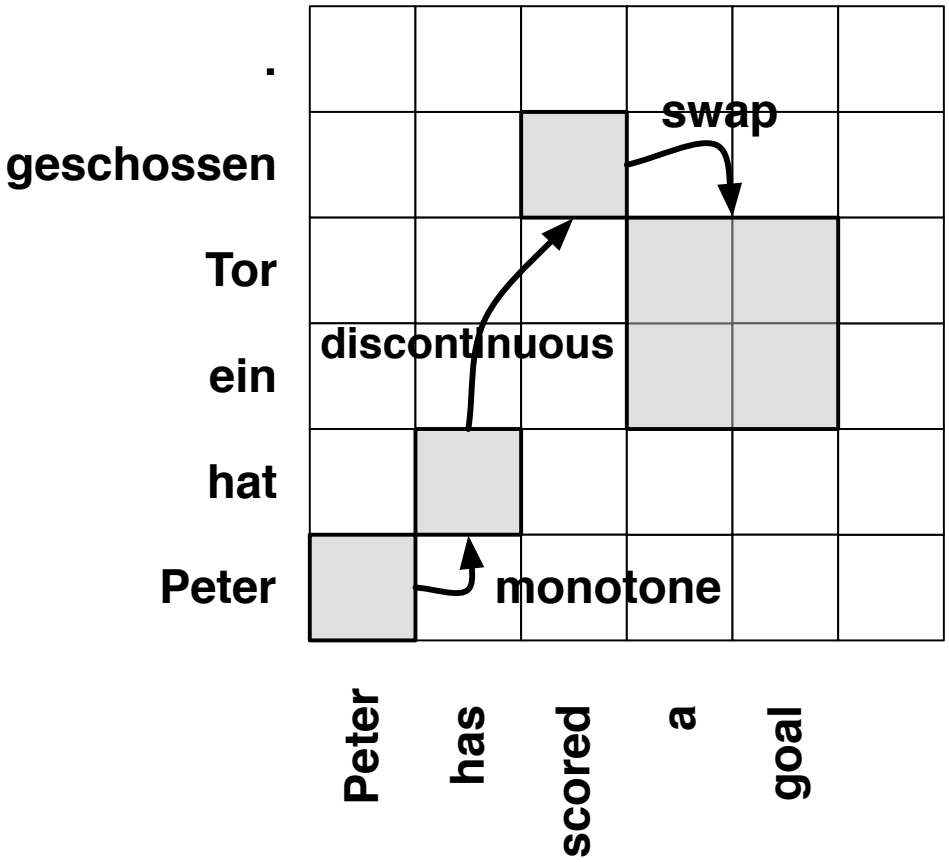

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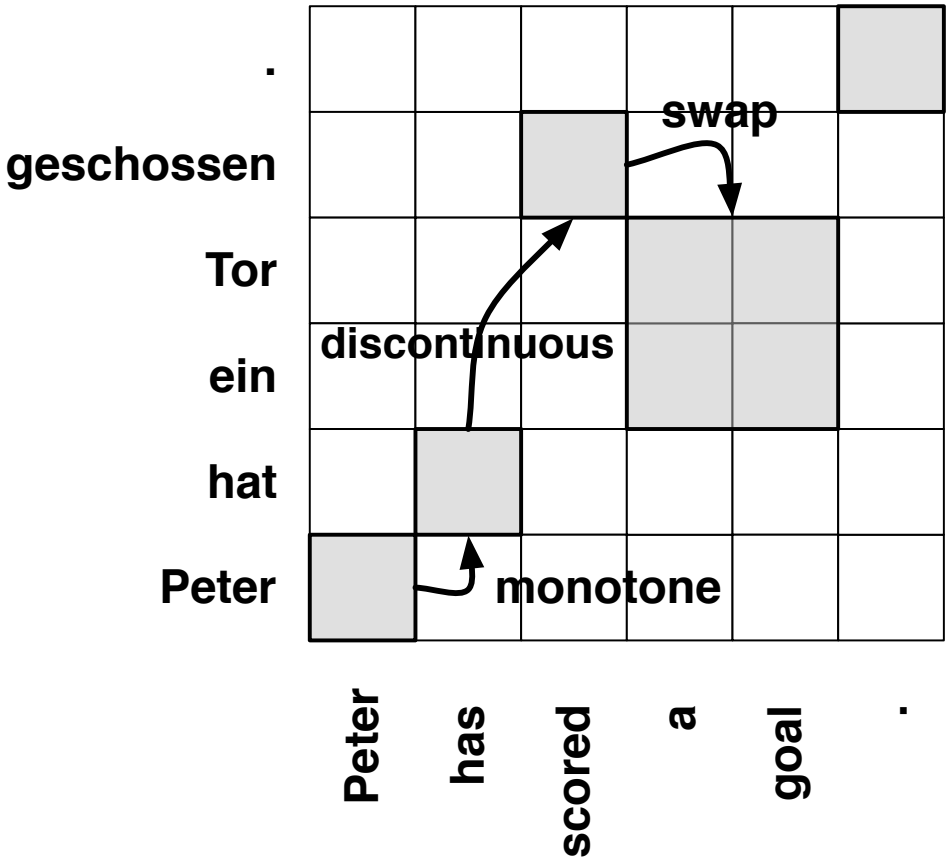

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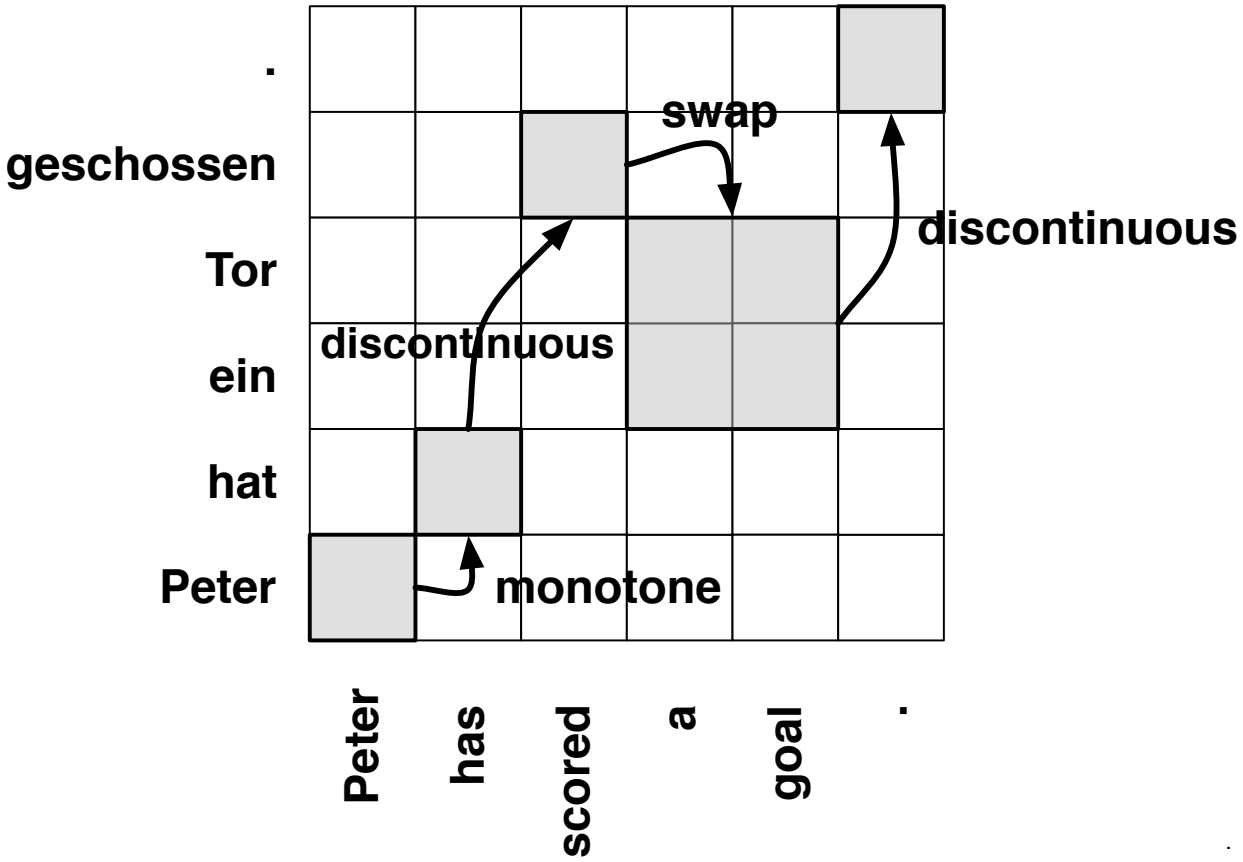

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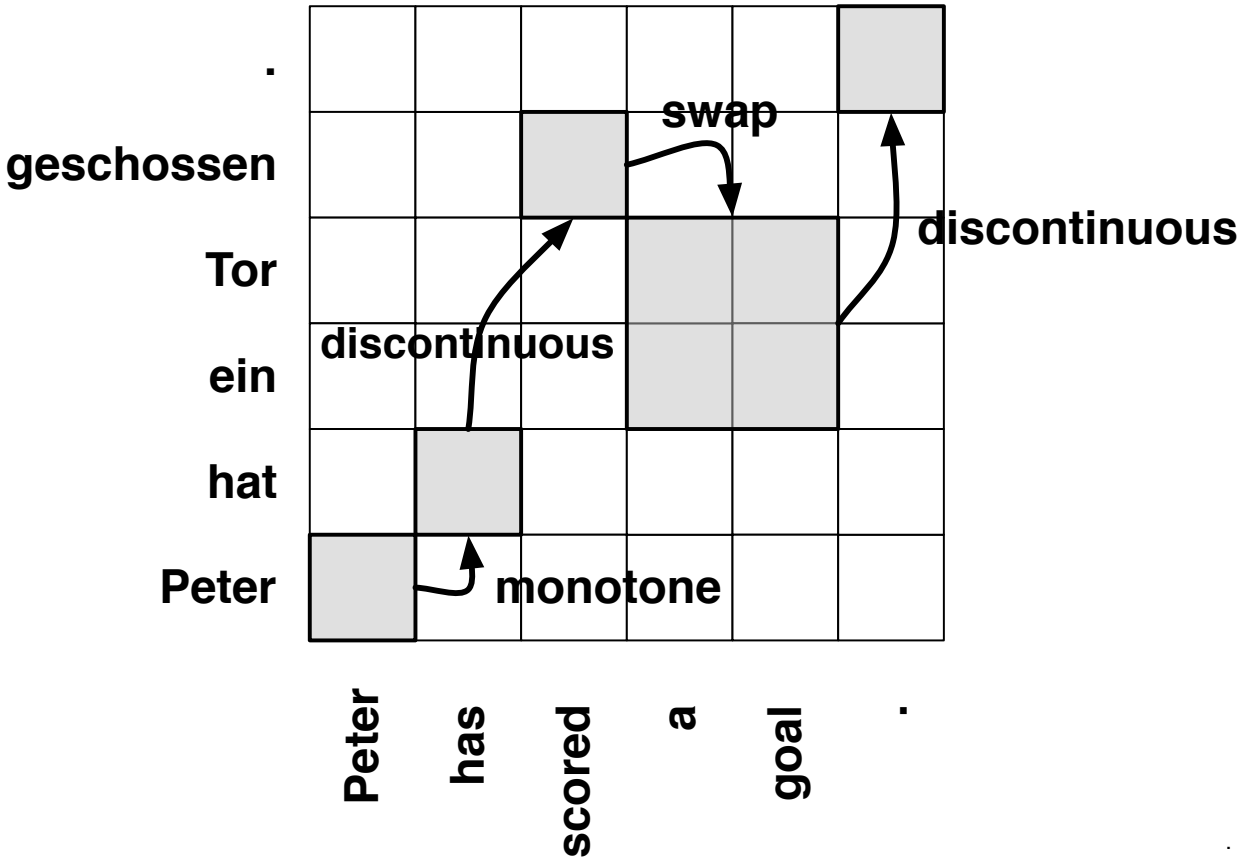
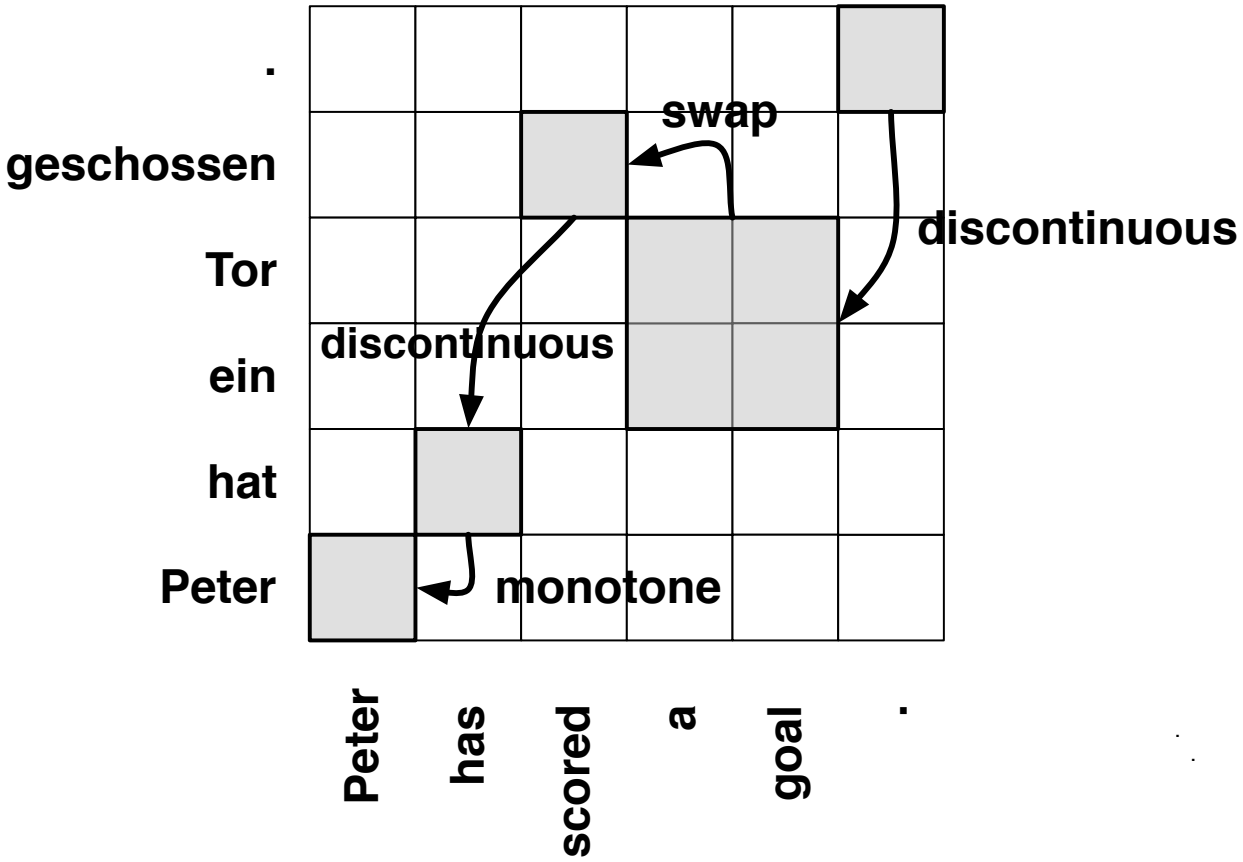


- Reordering probabilities are of the form: $p(o|(\bar{f},\bar{e}))$, where $o \in \{\text{monotone}, \text{discontinous}, \text{swap}\}$

Lexicalized Reordering



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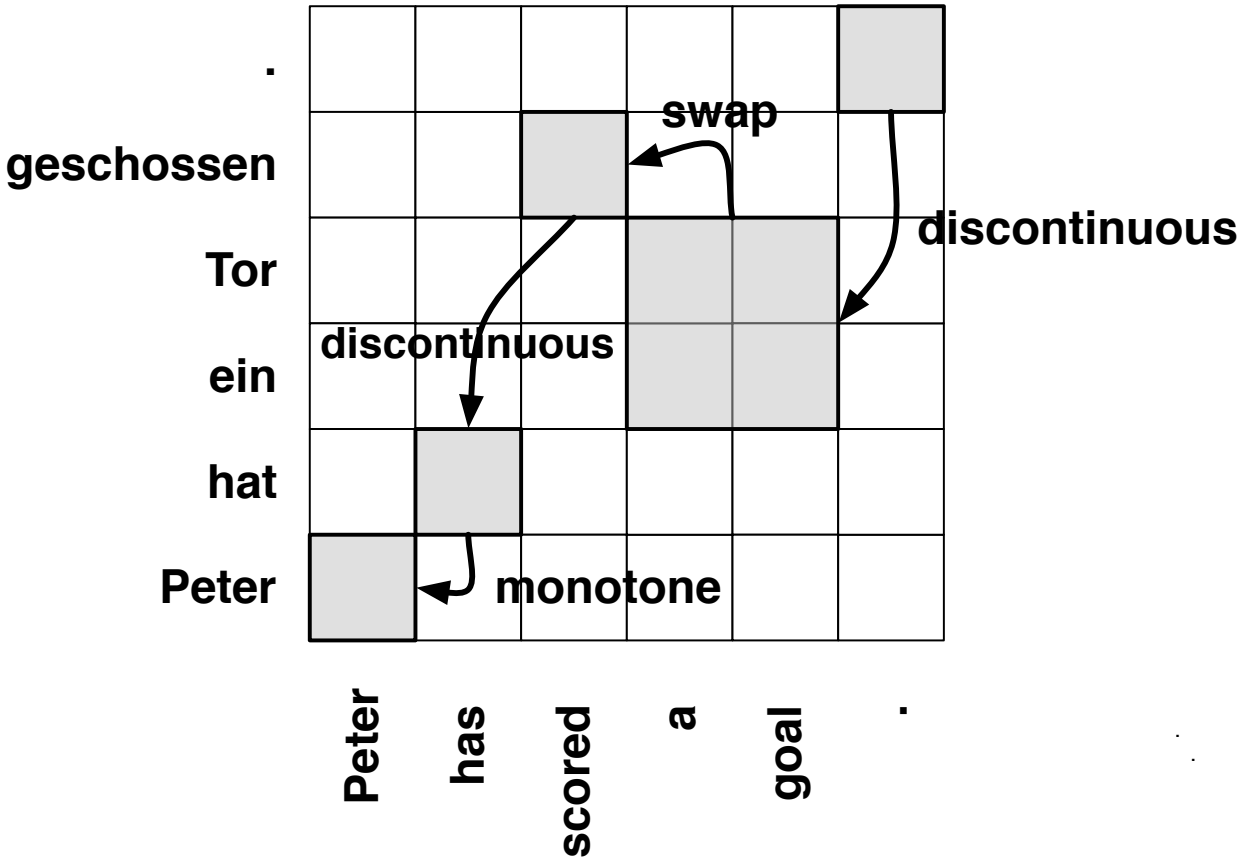


- We can also condition on the next phrase resulting in two different distributions: $p_{l \to r}(o|(\bar{f}, \bar{e}_i))$ and $p_{r \to l}(o|(\bar{f}', \bar{e}_{i+1}))$

Lexicalized Reordering

- Given two phrase applications: $(\bar{f}_i^j, \bar{e}_k^l)$ and $(\bar{f}_s^t, \bar{e}_{l+1}^m)$
- The orientation (o) of a reordering is
  - **monotone (m):** if $s = j+1$
  - **swap (s):** if $i = t+1$
  - **discontinuous (d):** otherwise
- Left-to-right reordering conditions on the previous phrase pair wrt the next phrase pair: $p_{l\to r}(o|(\bar{f}_i^j, \bar{e}_k^l))$
- Right-to-left reordering conditions on the next phrase pair wrt to the previous phrase pair: $p_{r\to l}(o|(\bar{f}_s^t, \bar{e}_{l+1}^m))$
- The total lexicalized reordering probability is the product of both orientations: $p_{LRM}(o|(\bar{f}_i^j, \bar{e}_k^l), (\bar{f}_s^t, \bar{e}_{l+1}^m))$
  $= p_{l\to r}(o|(\bar{f}_i^j, \bar{e}_k^l)) \cdot p_{r\to l}(o|(\bar{f}_s^t, \bar{e}_{l+1}^m))$

Lexicalized Reordering

- There are a number of ways to weight the contributions of reordering models
  - One weight for reordering: $p_{LRM}(o|(\bar{f}_i^j, \bar{e}_k^l), (\bar{f}_s^t, \bar{e}_{l+1}^m))^{\lambda_{LRM}}$
  - One weight for each direction:

    $p_{LRM}(o|(\bar{f}_i^j, \bar{e}_k^l), (\bar{f}_s^t, \bar{e}_{l+1}^m)) =$
    $p_{l\rightarrow r}(o|(\bar{f}_i^j, \bar{e}_k^l))^{\lambda_{l\rightarrow r}} \cdot p_{r\rightarrow l}(o|(\bar{f}_s^t, \bar{e}_{l+1}^m))^{\lambda_{r\rightarrow l}}$
  - One weight for each direction and orientation:

    $p_{LRM}(o|(\bar{f}_i^j, \bar{e}_k^l), (\bar{f}_s^t, \bar{e}_{l+1}^m)) =$
    $p_{l\rightarrow r}(o|(\bar{f}_i^j, \bar{e}_k^l))^{\lambda_{l\rightarrow r(o)}} \cdot p_{r\rightarrow l}(o|(\bar{f}_s^t, \bar{e}_{l+1}^m))^{\lambda_{r\rightarrow l(o)}}$
- Experimental results show that individual weights for each direction and orientation lead to the best performance
  - Downside: 6 weight parameters instead of 2 (or 1) need to be estimated

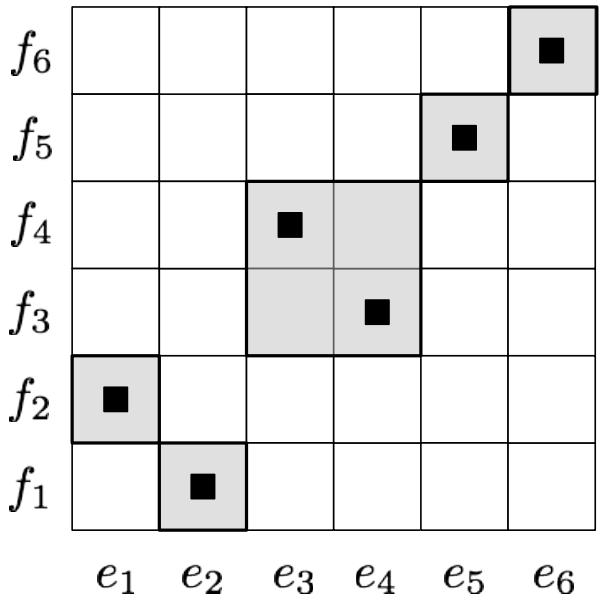
Estimating LRMs

- Lexicalized reordering models are estimated similarly to the way phrase translation models are estimated
- Using maximum likelihood, we can define

$$p_{r\to l}(o|(\bar{f},\bar{e})) = \frac{c_{r\to l}(o,(\bar{f},\bar{e}))}{\sum_{o\in O} c_{r\to l}(o,(\bar{f},\bar{e}))}$$

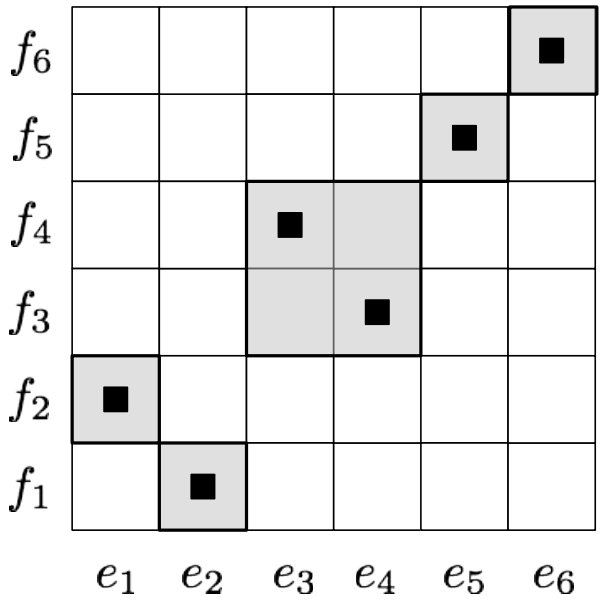
- How do we collect the event counts $c_{r\to l}(o,(\bar{f},\bar{e}))$?

Estimating LRMs



- Here we focus on the phrase pair $(\bar{f}, \bar{e}) = ((f_3 f_4), (e_3 e_4))$

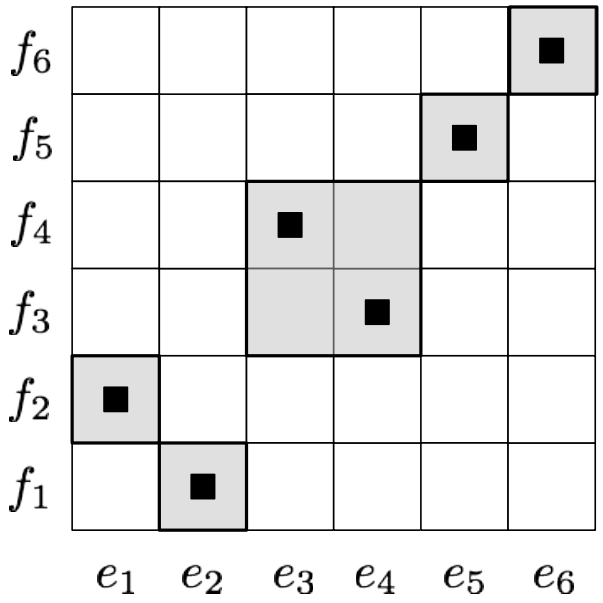
Estimating LRMs



- Here we focus on the phrase pair $(\bar{f}, \bar{e}) = ((f_3 f_4), (e_3 e_4))$

  $c_{r \to l}(d, (\bar{f}, \bar{e}))++$

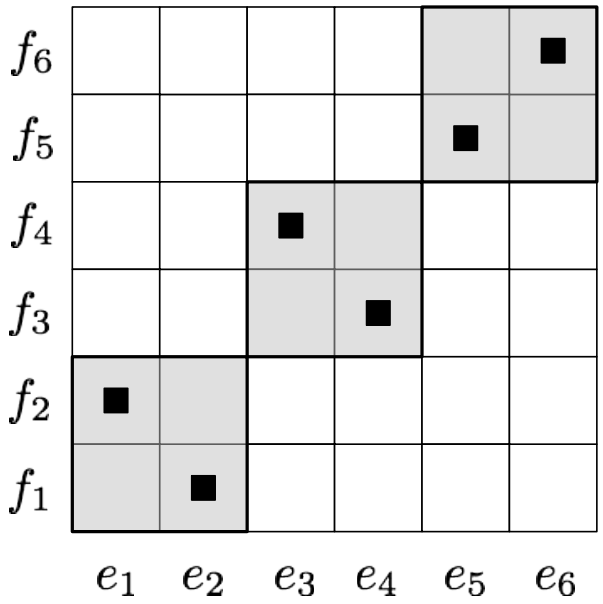
Estimating LRMs



- Here we focus on the phrase pair $(\bar{f}, \bar{e}) = ((f_3 f_4), (e_3 e_4))$

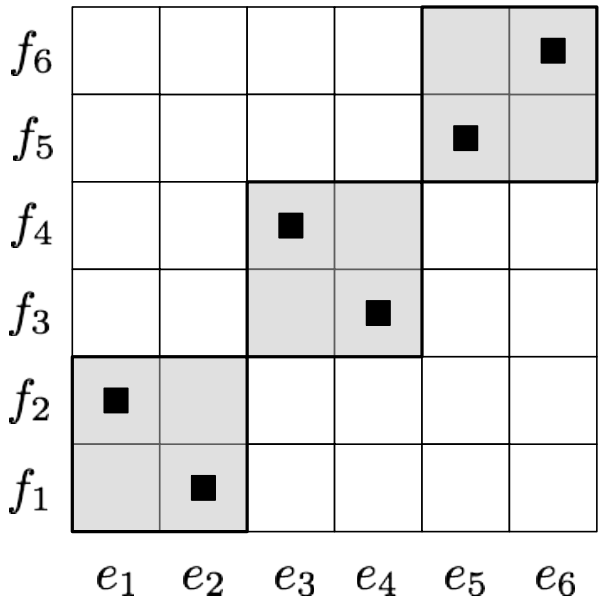
$$c_{r \to l}(d, (\bar{f}, \bar{e})) + +$$
$$c_{l \to r}(m, (\bar{f}, \bar{e})) + +$$

Estimating LRMs



- How about different phrase extractions?

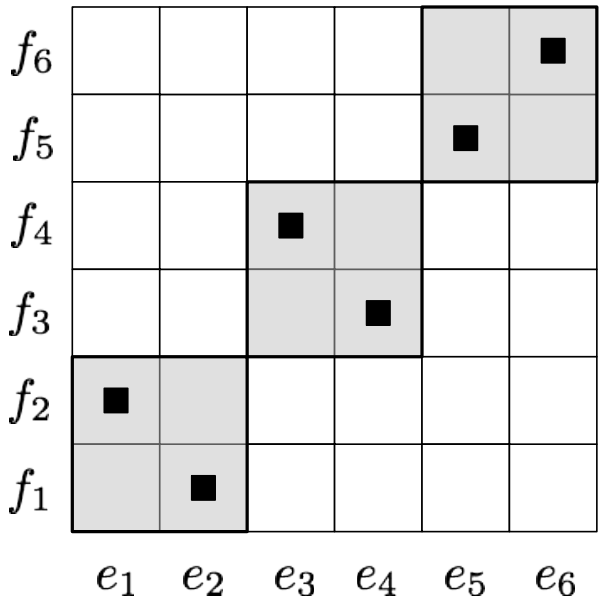
Estimating LRMs



- How about different phrase extractions?

$$c_{r \to l}(m, (\bar{f}, \bar{e})) + +$$

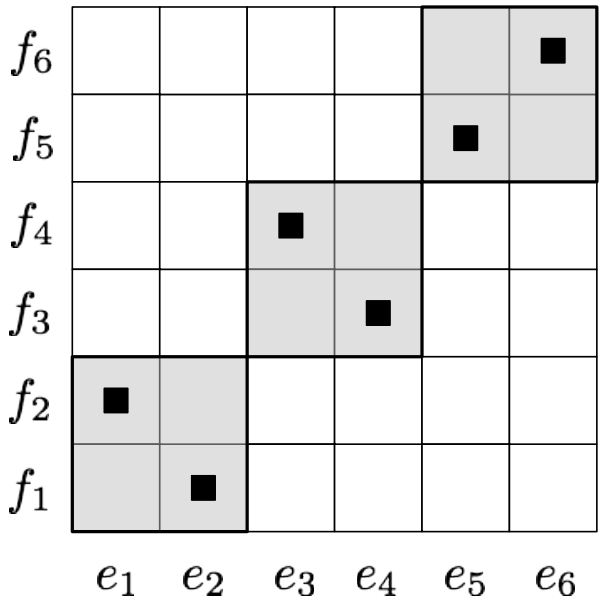
Estimating LRMs



- How about different phrase extractions?

$$c_{r\to l}(m,(\bar{f},\bar{e}))++$$
$$c_{l\to r}(m,(\bar{f},\bar{e}))++$$

Estimating LRMs



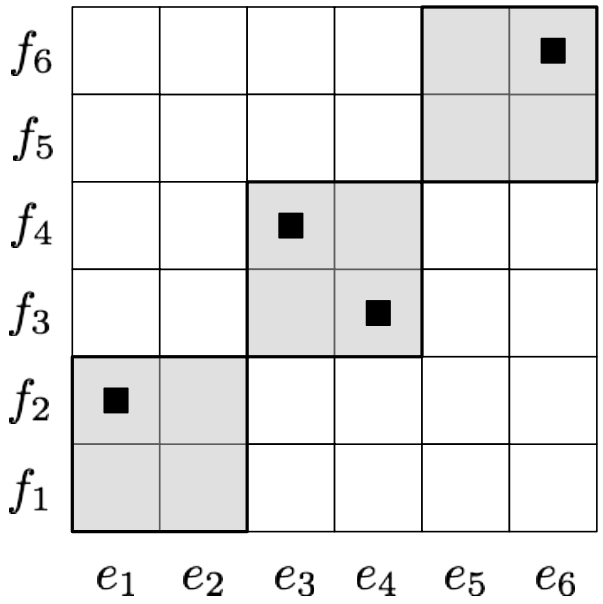
- How about different phrase extractions?

  $c_{r\to l}(m,(\bar{f},\bar{e}))++$
  $c_{l\to r}(m,(\bar{f},\bar{e}))++$

  In addition to

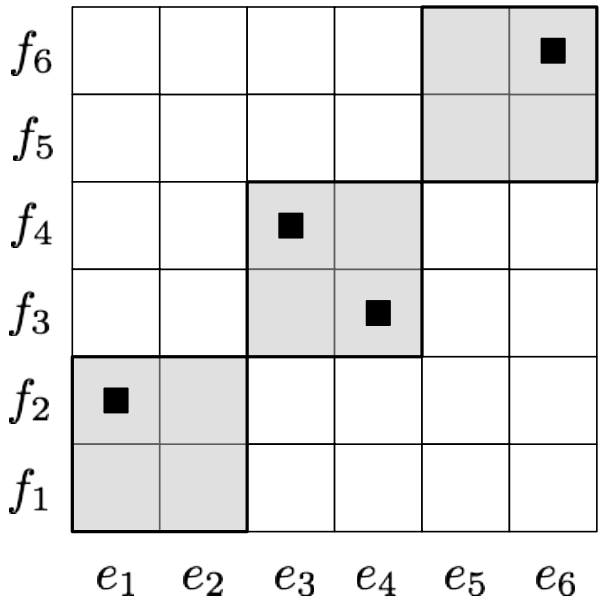
  $c_{r\to l}(d,(\bar{f},\bar{e}))++$
  $c_{l\to r}(m,(\bar{f},\bar{e}))++$?

Estimating LRMs



- How about phrases involving unaligned words?

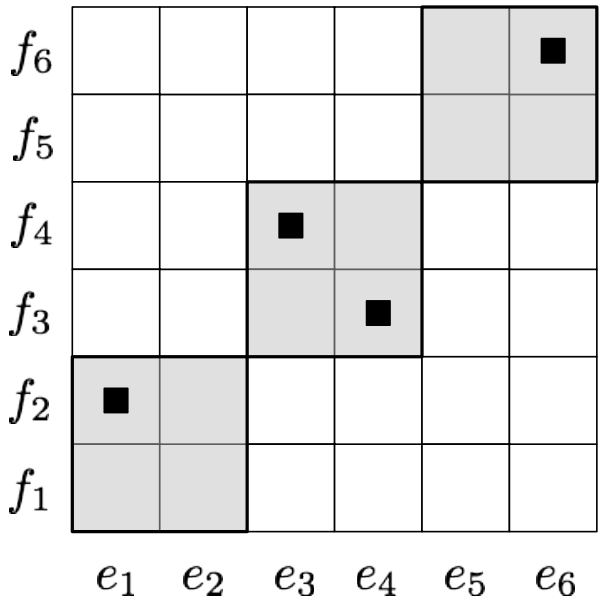
Estimating LRMs



- How about phrases involving unaligned words?

$$c_{r \to l}(m, (\bar{f}, \bar{e})) + +$$

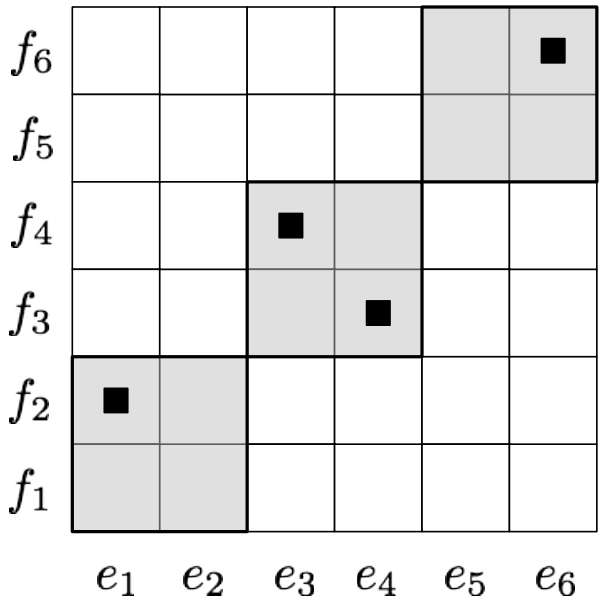
Estimating LRMs



- How about phrases involving unaligned words?

$$c_{r \to l}(m, (\bar{f}, \bar{e})) + +$$
$$c_{l \to r}(m, (\bar{f}, \bar{e})) + +$$

Estimating LRMs



- How about phrases involving unaligned words?

$$c_{r\to l}(m,(\bar{f},\bar{e}))++$$
$$c_{l\to r}(m,(\bar{f},\bar{e}))++$$

Or

$$c_{r\to l}(m,(\bar{f},\bar{e}))+=0$$
$$c_{l\to r}(m,(\bar{f},\bar{e}))+=0\ ?$$

Estimating LRMs

- There are two types of counting reordering events
  - **Word based:** consider only the word alignments surrounding the current phrase
  - **Phrase based:** consider the phrases surrounding the current phrase
- Given a sentence word alignment A, in the word-based orientation estimation approach $c_{r\rightarrow l}(o,(\bar{f},\bar{e}))++$ if
  - **o=m** and $(\text{left}(\bar{f})-1,\text{left}(\bar{e})-1)\in A$
  - **o=s** and $(\text{right}(\bar{f})+1,\text{left}(\bar{e})-1)\in A$
  - **o=d** and $\exists j:(j,\text{left}(\bar{e})-1)\in A$
    where $\text{left}(\cdot)/\text{right}(\cdot)$ is the left-/rightmost position of a phrase
- $c_{l\rightarrow r}(o,(\bar{f},\bar{e}))++$ if
  - **o=m** and $(\text{right}(\bar{f})+1,\text{right}(\bar{e})+1)\in A$
  - **o=s** and $(\text{left}(\bar{f})-1,\text{right}(\bar{e})+1)\in A$
  - **o=d** and $\exists j:(j,\text{right}(\bar{e})+1)\in A$

Estimating LRMs

- Phrase-based orientation estimation only considers the phrases next to the current phrase
- $c_{r \to l}(o, (\bar{f}, \bar{e})) + +$ if
  - **o=m** and $\exists (\bar{f}', \bar{e}') : \text{right}(\bar{e}') = \text{left}(\bar{e}) - 1 \wedge \text{right}(\bar{f}') = \text{left}(\bar{f}) - 1$
  - **o=s** and $\exists (\bar{f}', \bar{e}') : \text{right}(\bar{e}') = \text{left}(\bar{e}) - 1 \wedge \text{left}(\bar{f}') = \text{right}(\bar{f}) + 1$
  - **o=d** and $\exists (\bar{f}', \bar{e}') : \text{right}(\bar{e}') = \text{left}(\bar{e}) - 1$
- $c_{l \to r}(o, (\bar{f}, \bar{e})) + +$ if
  - **o=m** and $\exists (\bar{f}', \bar{e}') : \text{left}(\bar{e}') = \text{right}(\bar{e}) + 1 \wedge \text{left}(\bar{f}') = \text{right}(\bar{f}) + 1$
  - **o=s** and $\exists (\bar{f}', \bar{e}') : \text{left}(\bar{e}') = \text{right}(\bar{e}) - 1 \wedge \text{right}(\bar{f}') = \text{left}(\bar{f}) - 1$
  - **o=d** and $\exists (\bar{f}', \bar{e}') : \text{left}(\bar{e}') = \text{right}(\bar{e}) + 1$

Smoothing LRMs

- Using maximum likelihood estimation

$$p_{r\to l}(o|(\bar{f},\bar{e})) = \frac{c_{r\to l}(o,(\bar{f},\bar{e}))}{\sum_{o\in O} c_{r\to l}(o,(\bar{f},\bar{e}))}$$

  leads to overfitting on the training data

- Therefore simple additive smoothing is commonly applied:

$$p_{r\to l}(o|(\bar{f},\bar{e})) = \frac{\sigma p_{r\to l}(o)+c_{r\to l}(o,(\bar{f},\bar{e}))}{\sigma+\sum_{o\in O} c_{r\to l}(o,(\bar{f},\bar{e}))}$$

  where σ is a small constant (e.g., 0.5)

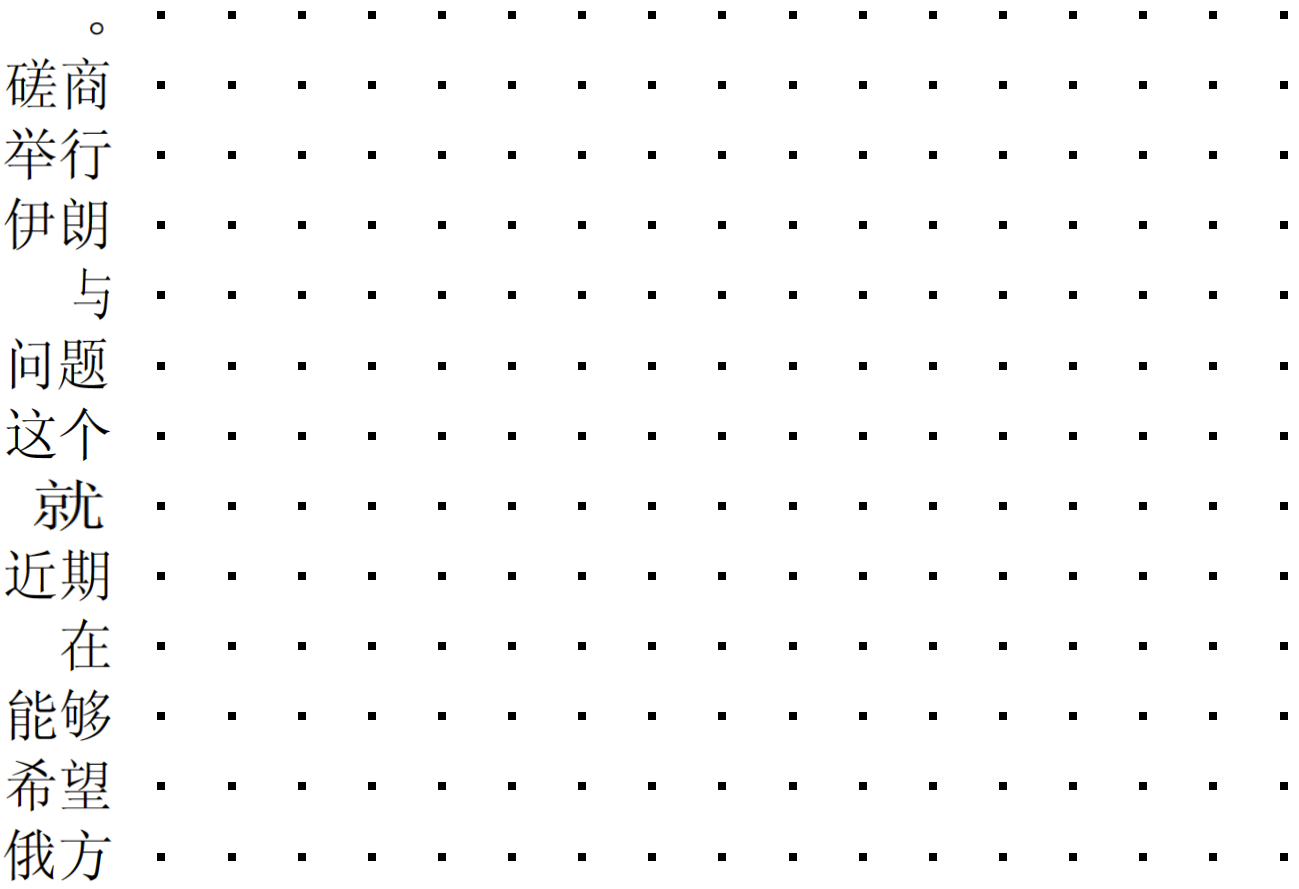
$$p_{r\to l}(o) = \frac{\sum_{(\bar{f},\bar{e})} c_{r\to l}(o,(\bar{f},\bar{e}))}{\sum_{o\in O}\sum_{(\bar{f},\bar{e})} c_{r\to l}(o,(\bar{f},\bar{e}))}$$

- The smoothed variant of $p_{l\to r}(o|(\bar{f},\bar{e}))$ is defined analoguously

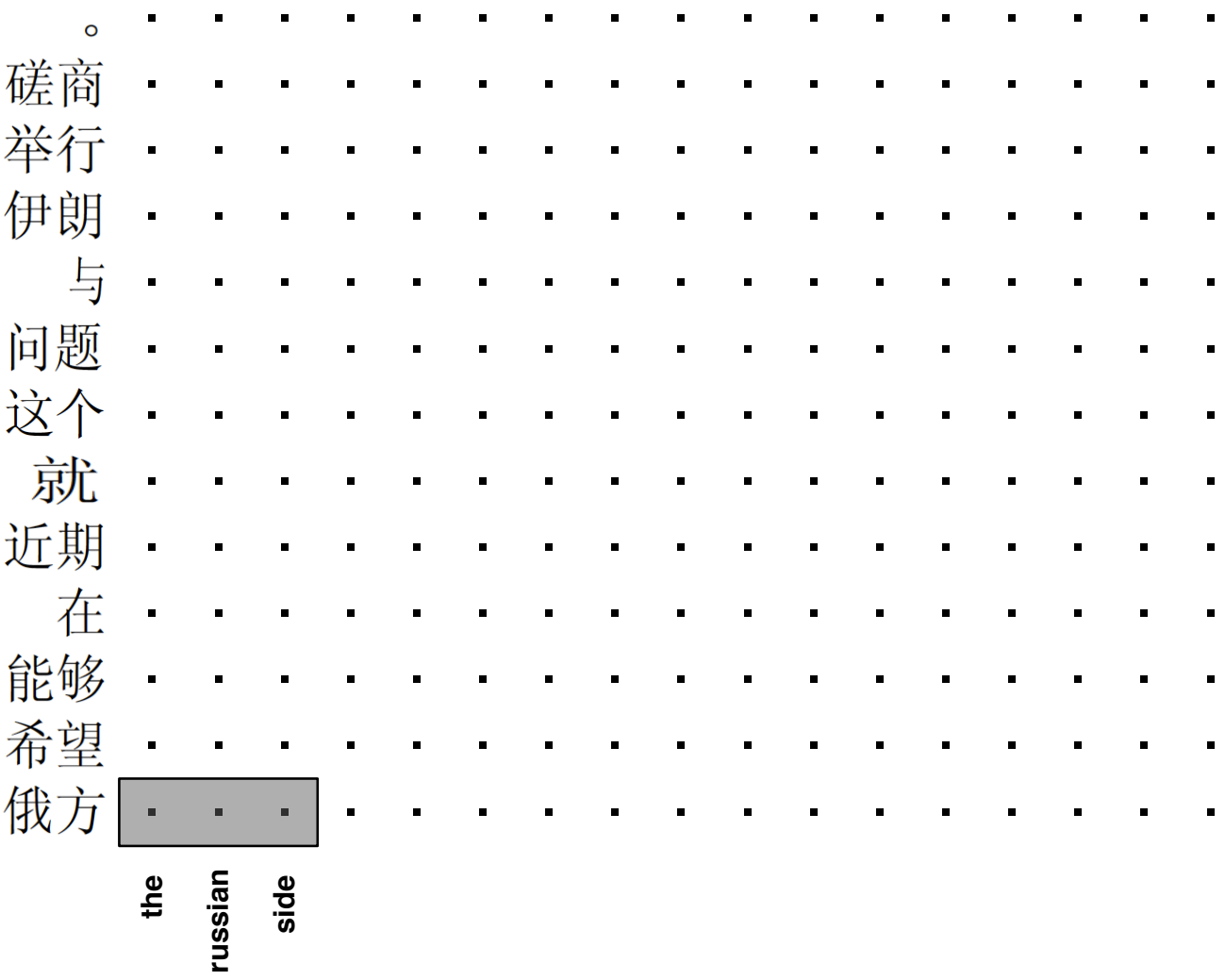
Using LRMs During Decoding

- The phrase-based estimation allows for consider multiple extractions, and therefore multiple orientations, wrt the previous $(r \rightarrow l)$ and next phrases $((l \rightarrow r)$
  - This is not the case during decoding!
- During decoding the $r \rightarrow l$ orientations are computed with the respect to the one phrase pair applied in the previous state
  - Even though an alternative derivation might have lead to different phrase applications
- Note that an additional constraint has to be respected for two states s_i and s_j to be recombinable
  - the current phrase pair of s_i and s_j has to be identical
  - Can be weakened to: $\forall_{o \in O} : p_{l \rightarrow r}(o|(\bar{f}_j, \bar{e}_j)) = p_{l \rightarrow r}(o|(\bar{f}_i, \bar{e}_i))$

Hierarchical Reordering



Hierarchical Reordering



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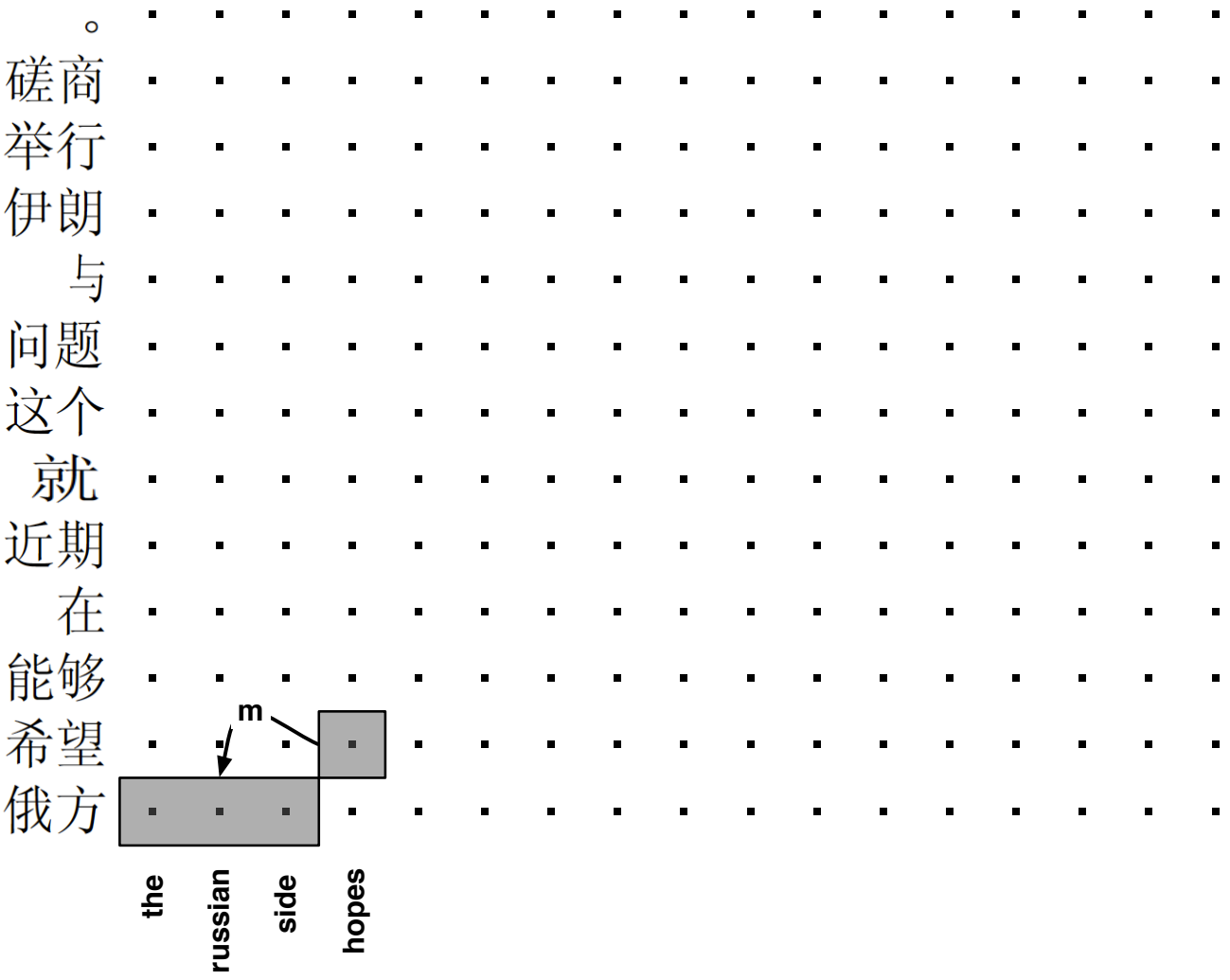
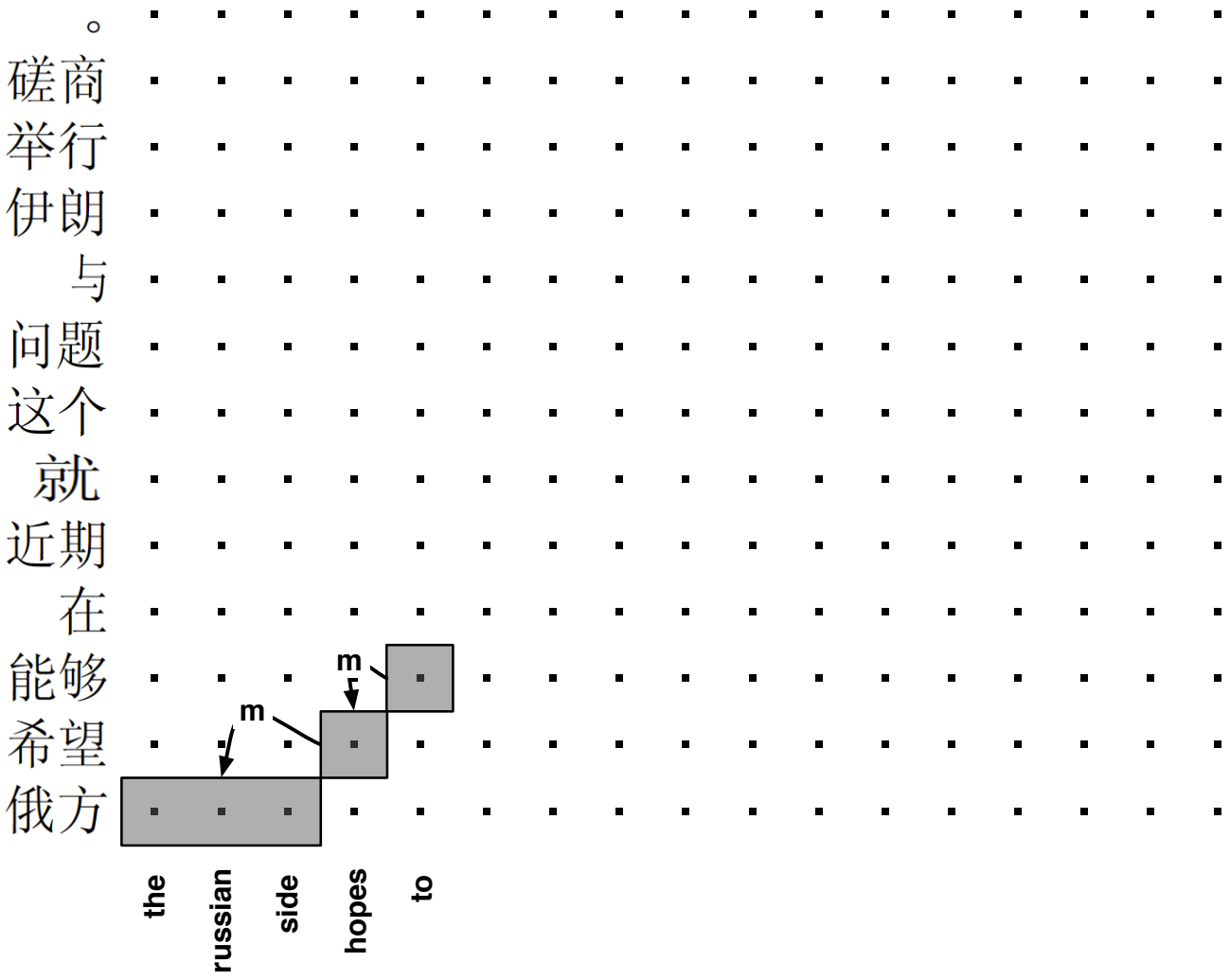


Hierarchical Reordering



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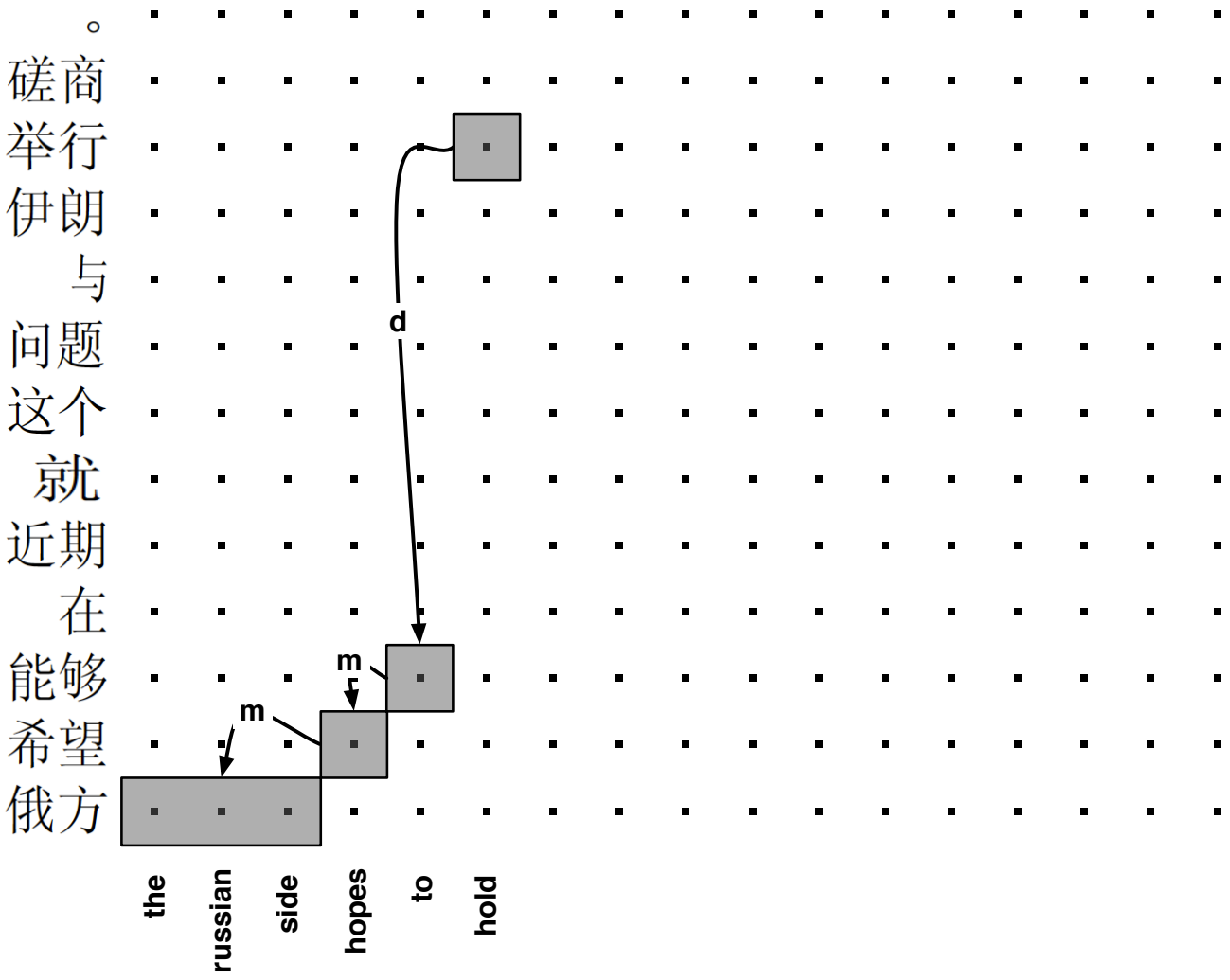

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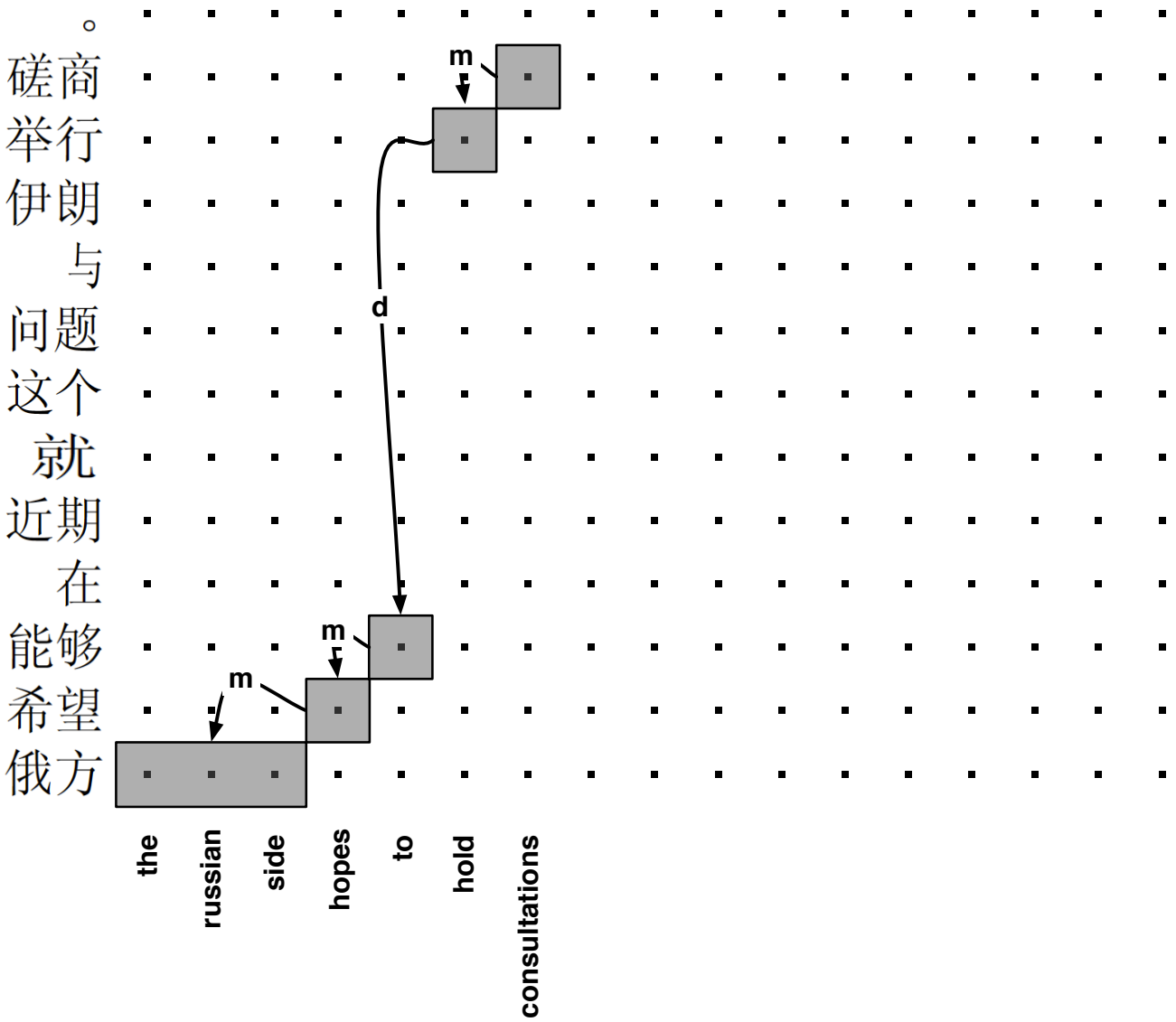

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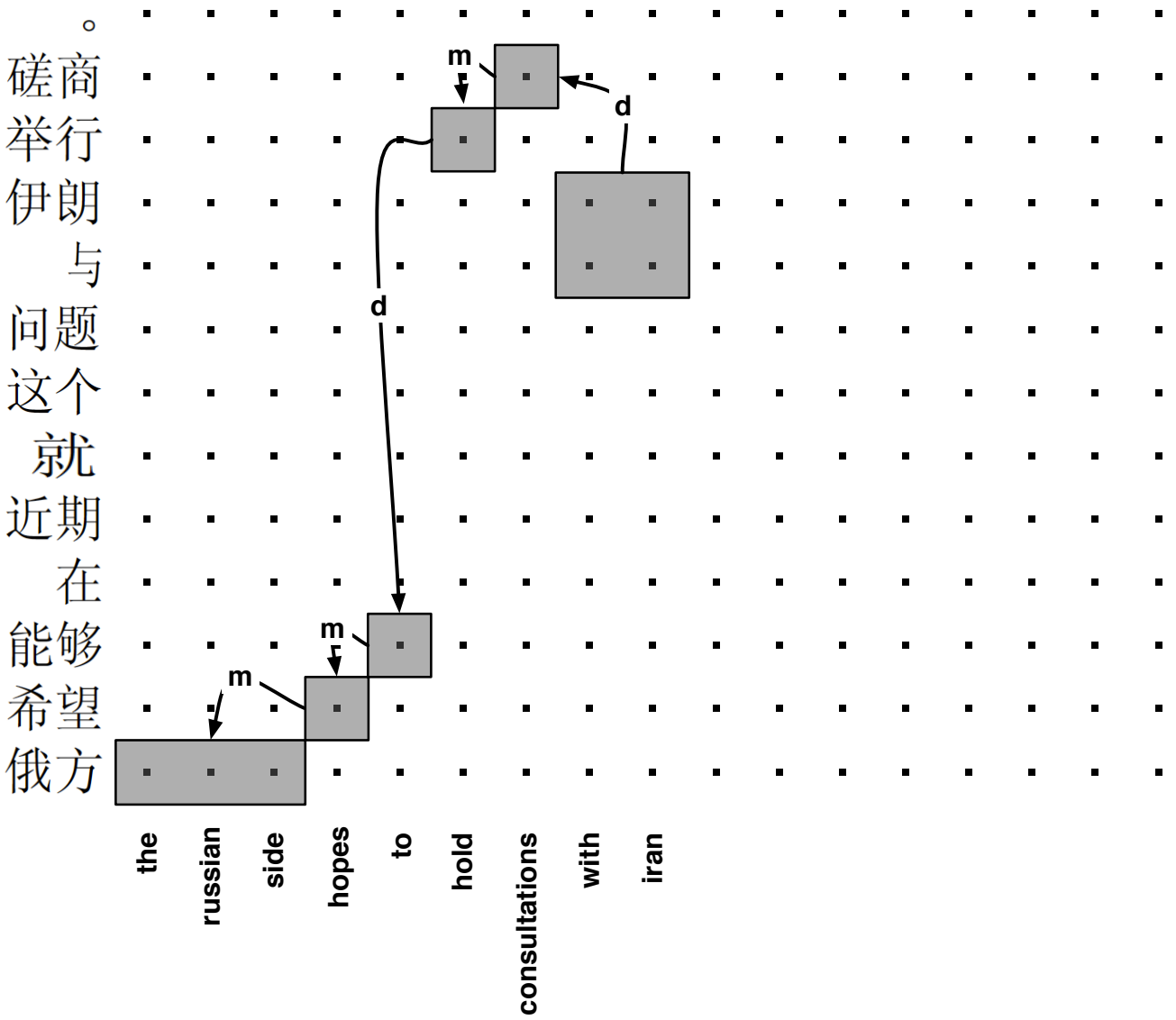

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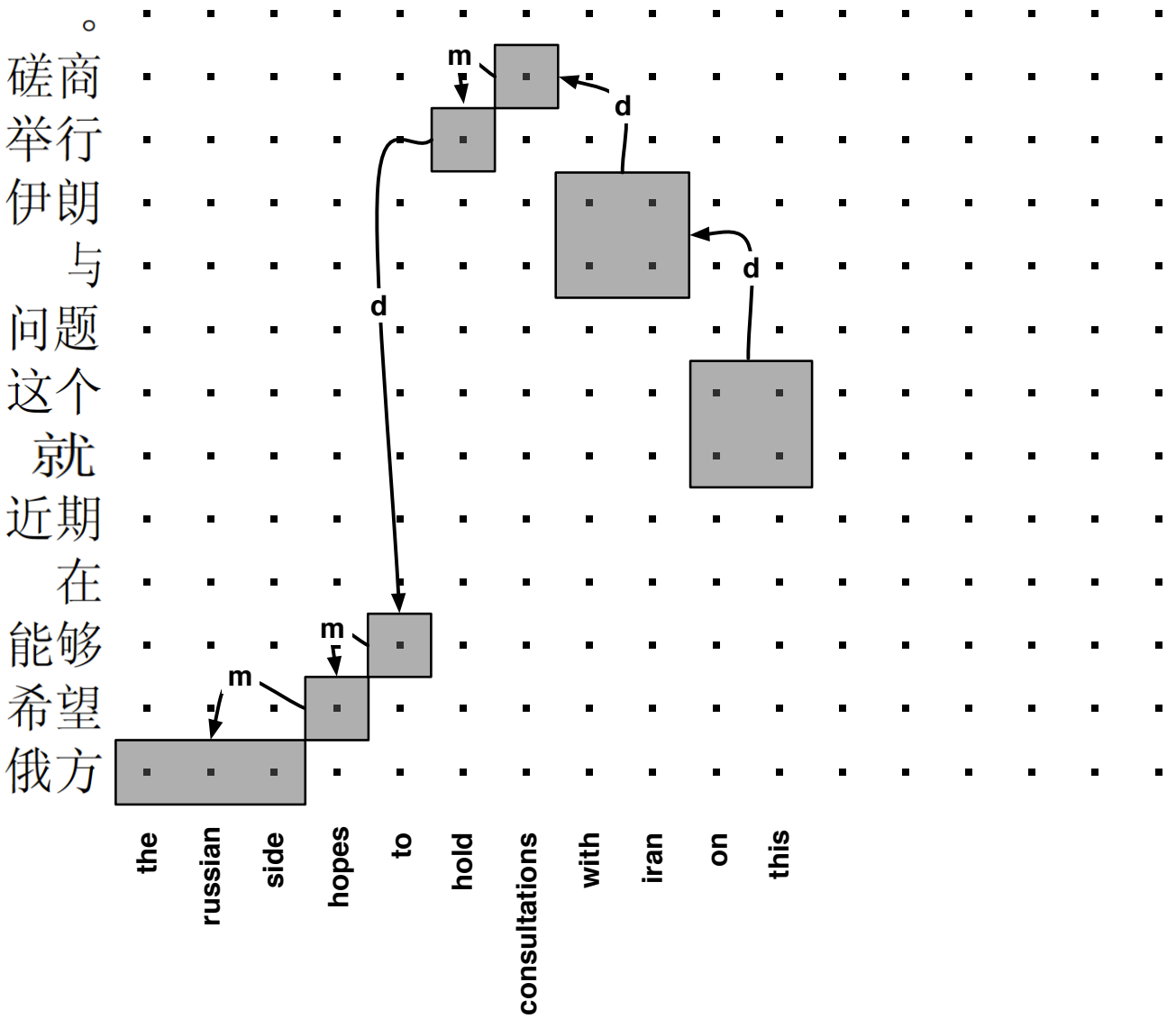

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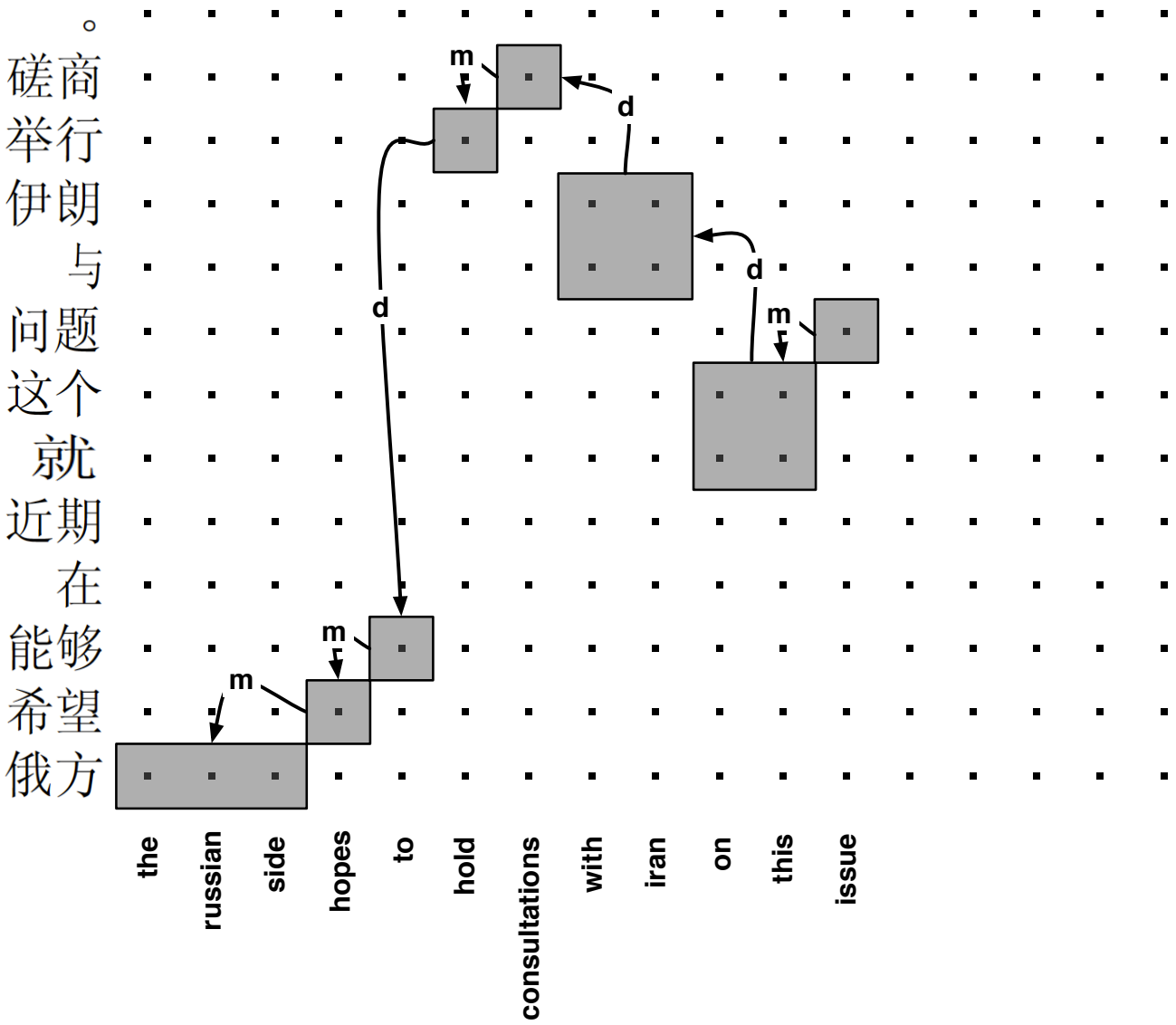

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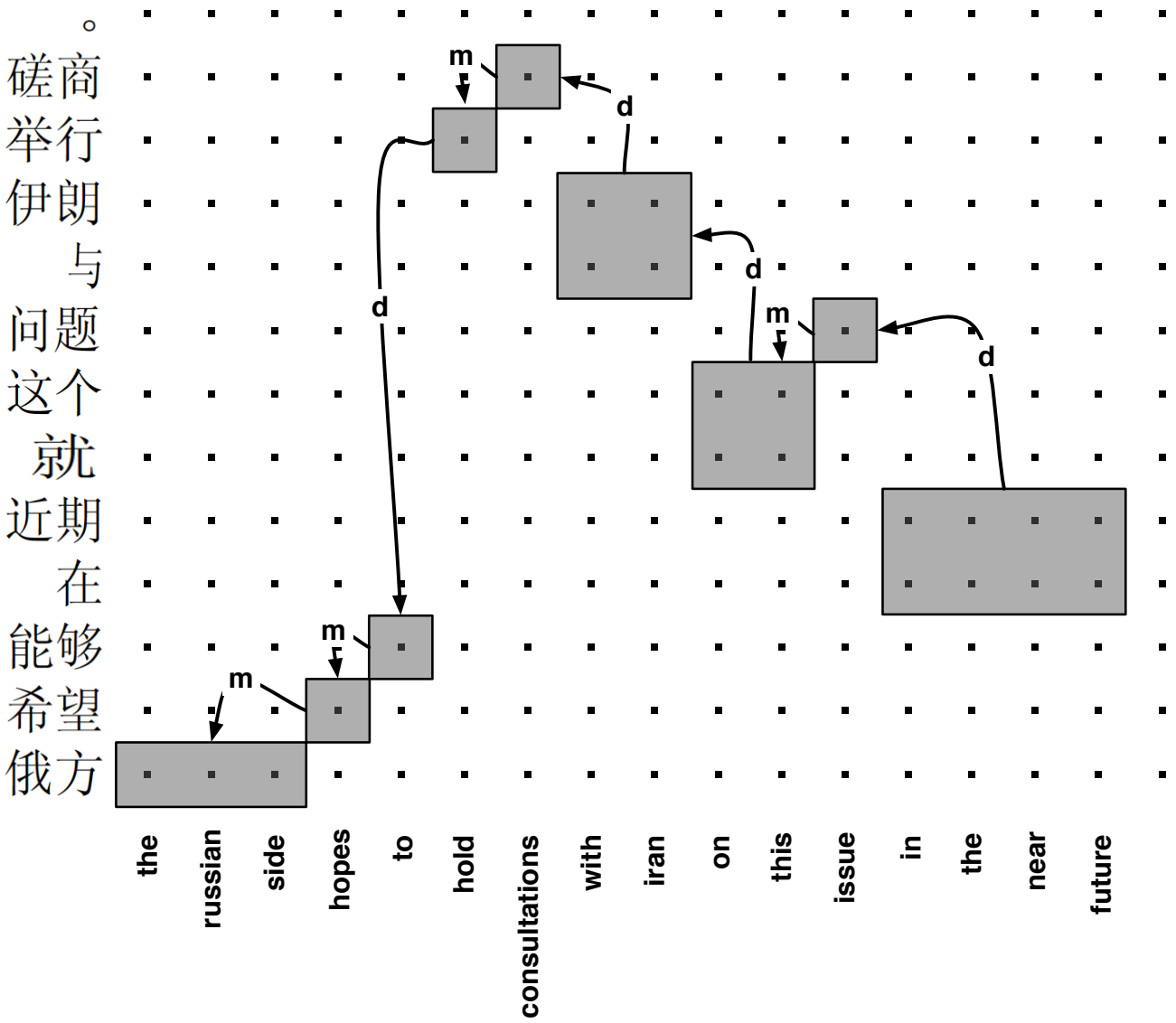

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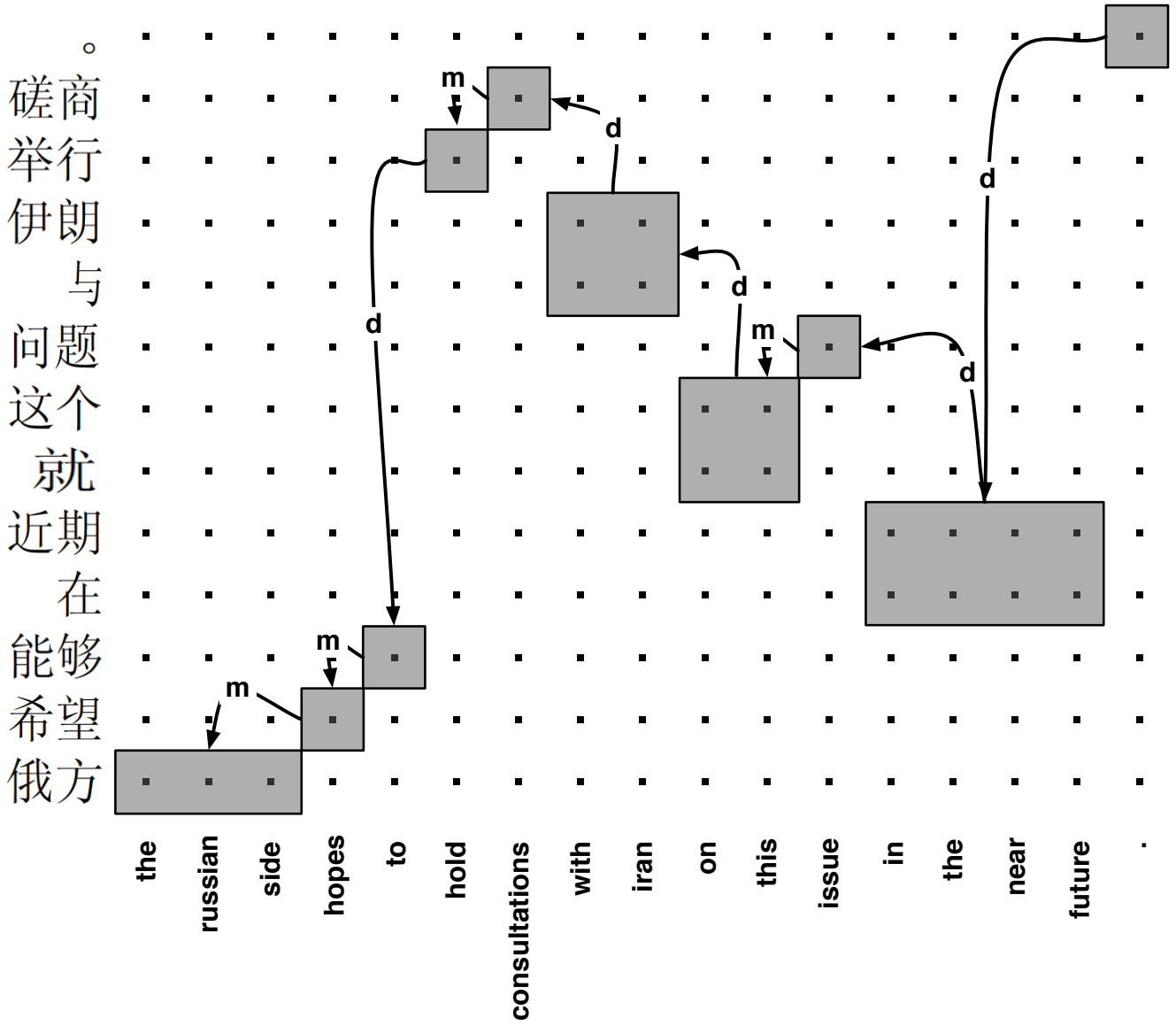

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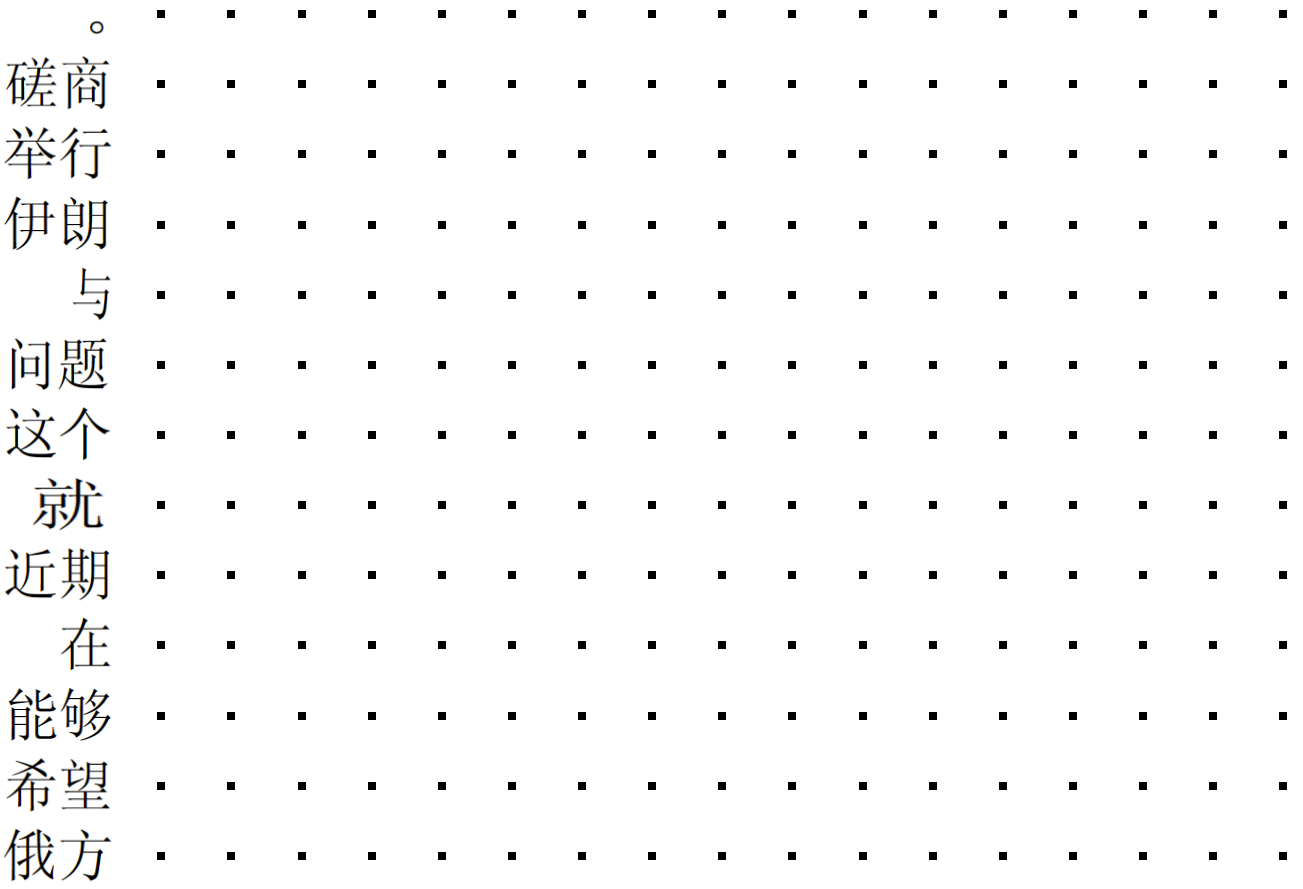

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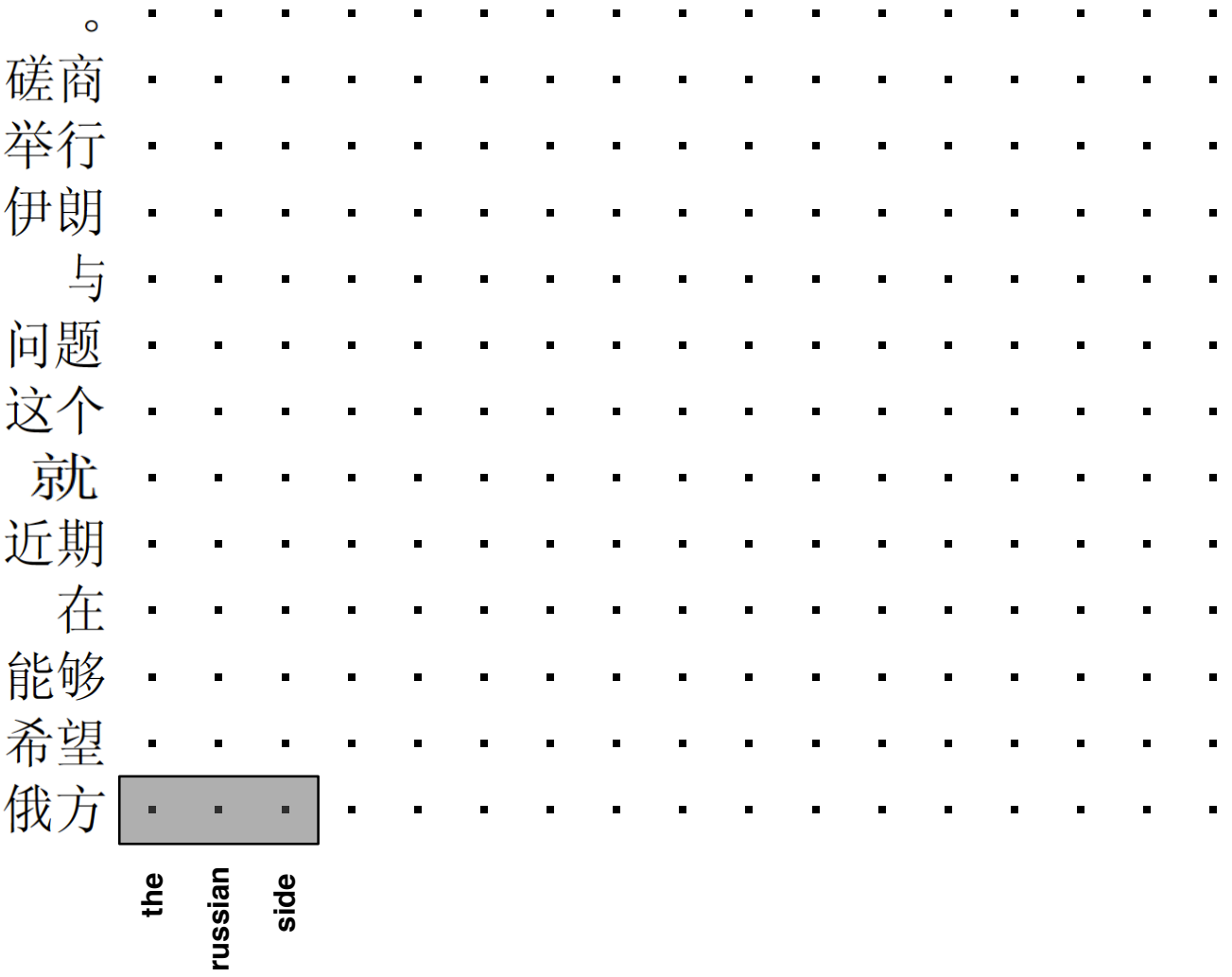

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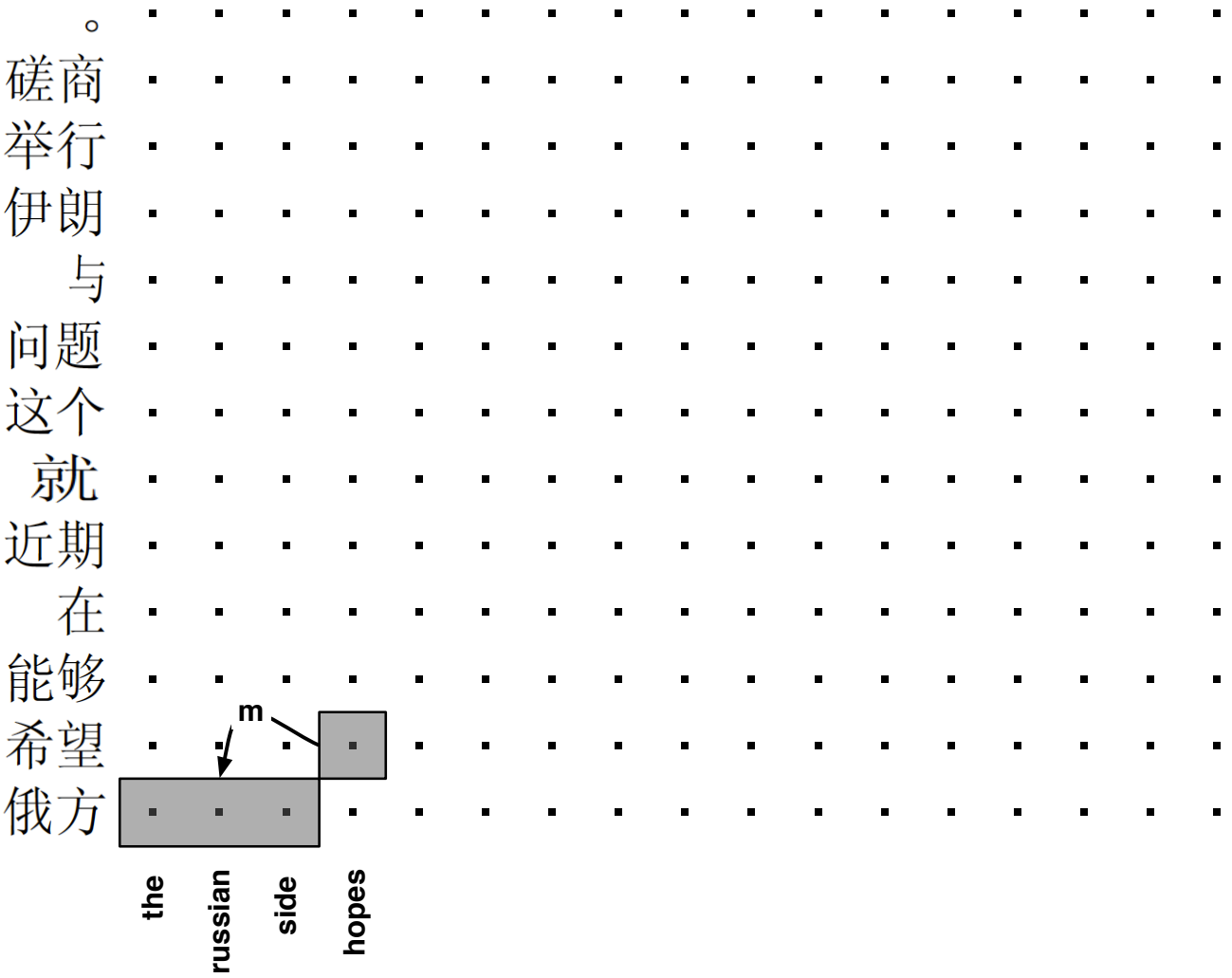

Hierarchical Reordering

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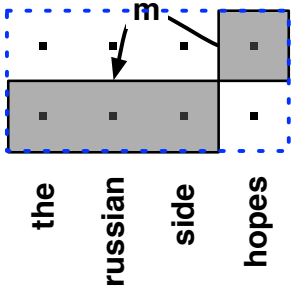

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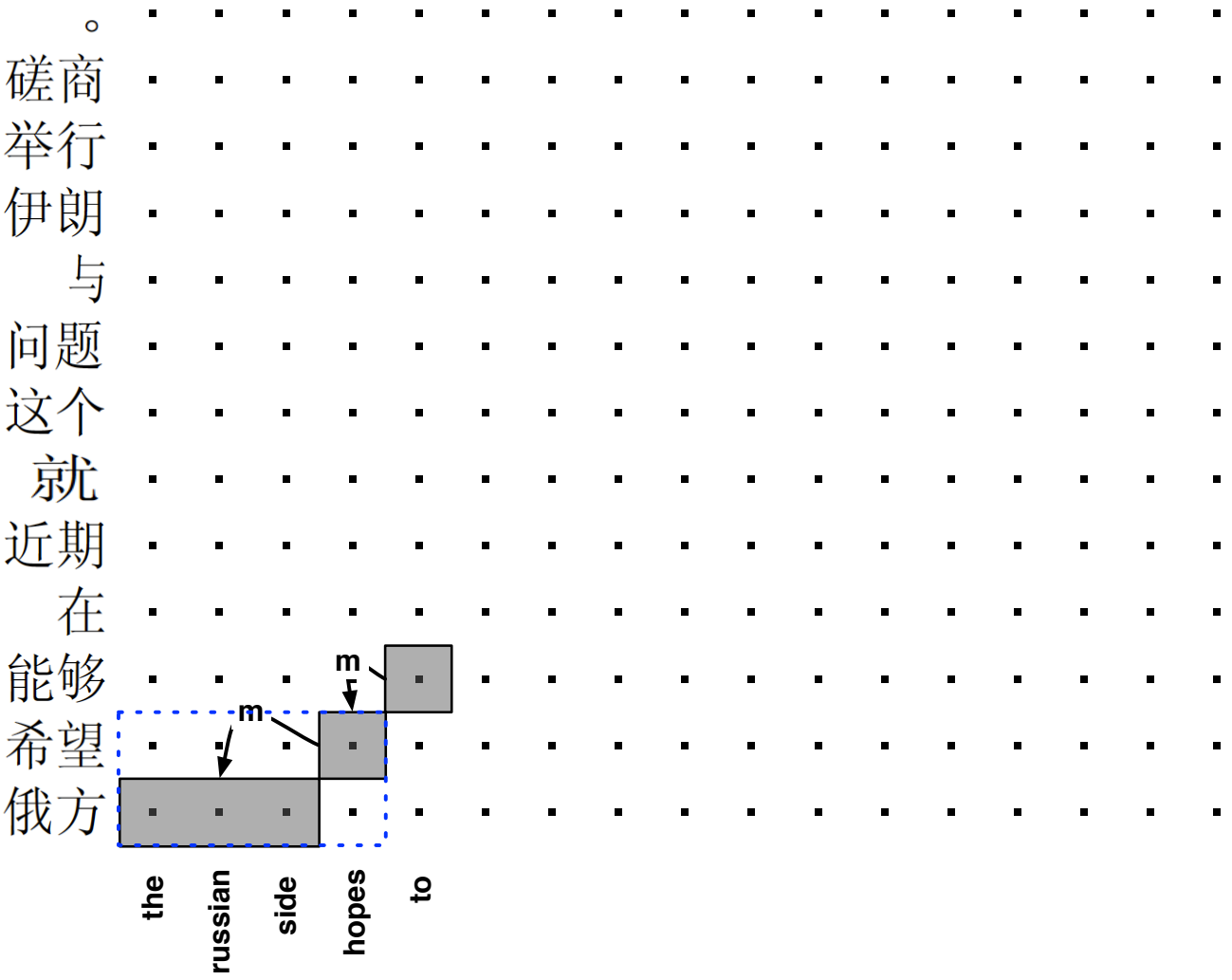

Hierarchical Reordering

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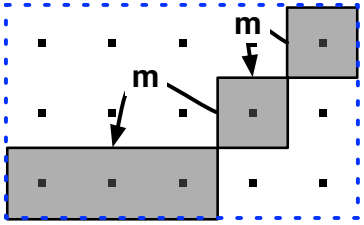

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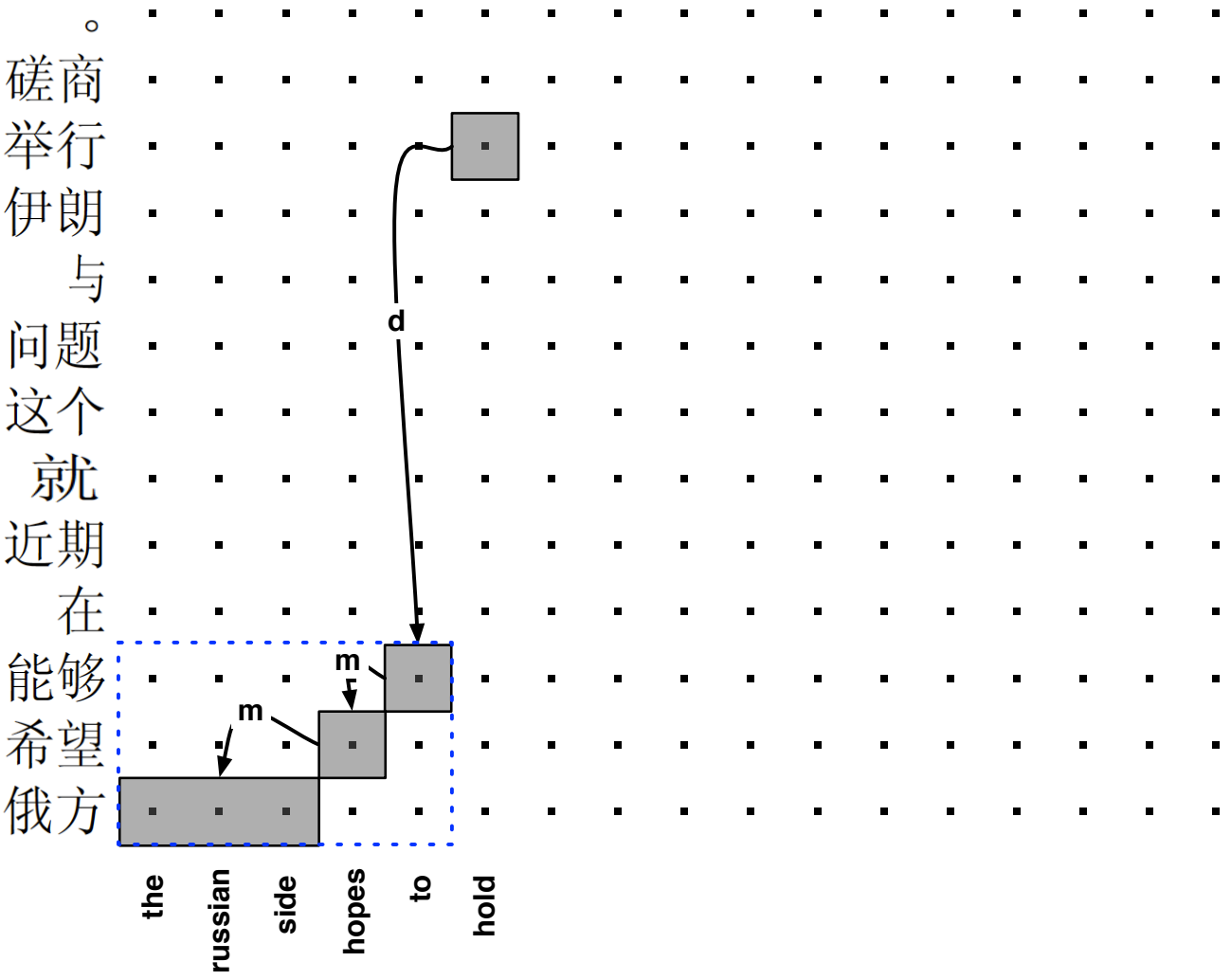
Hierarchical Reordering



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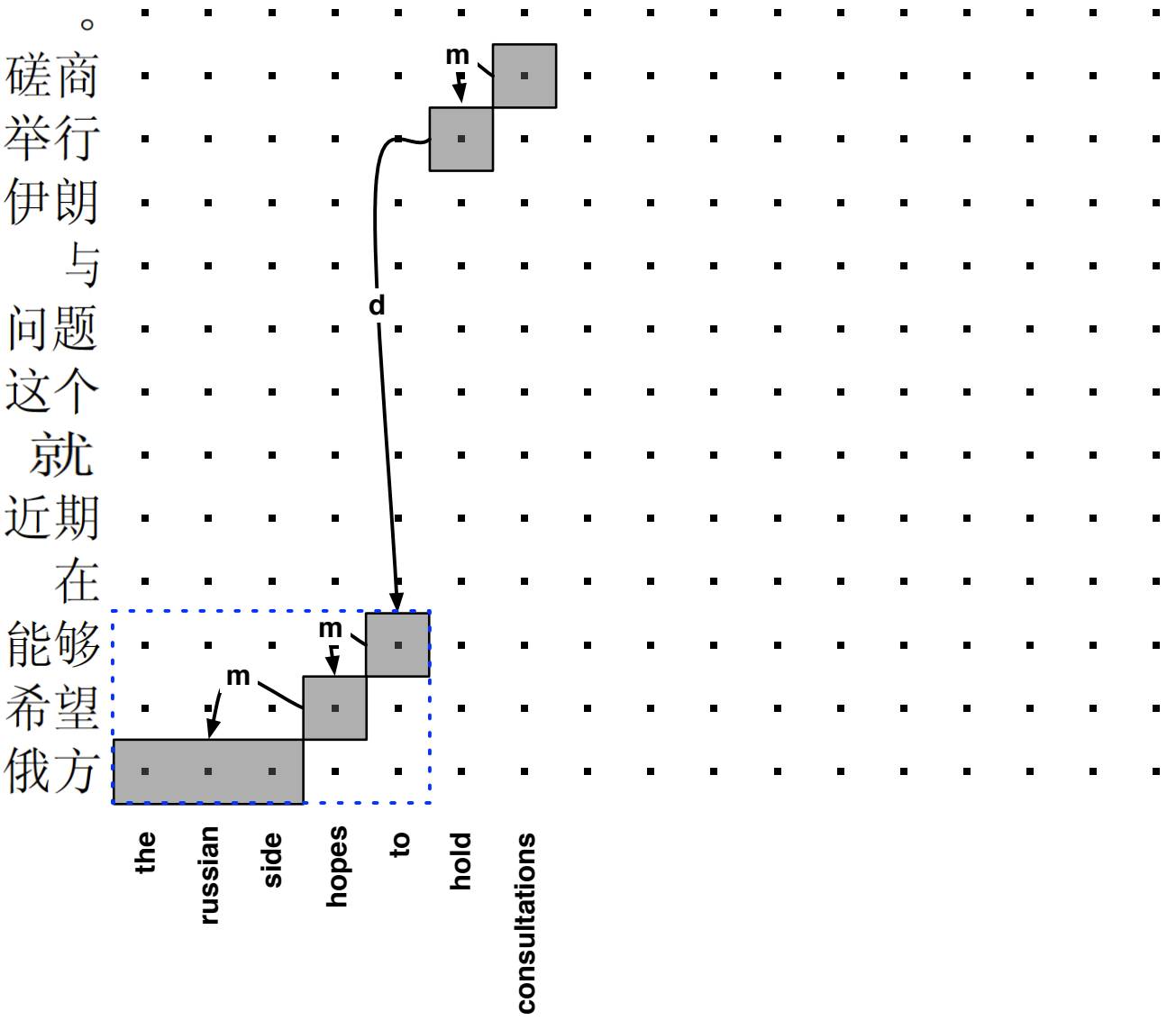

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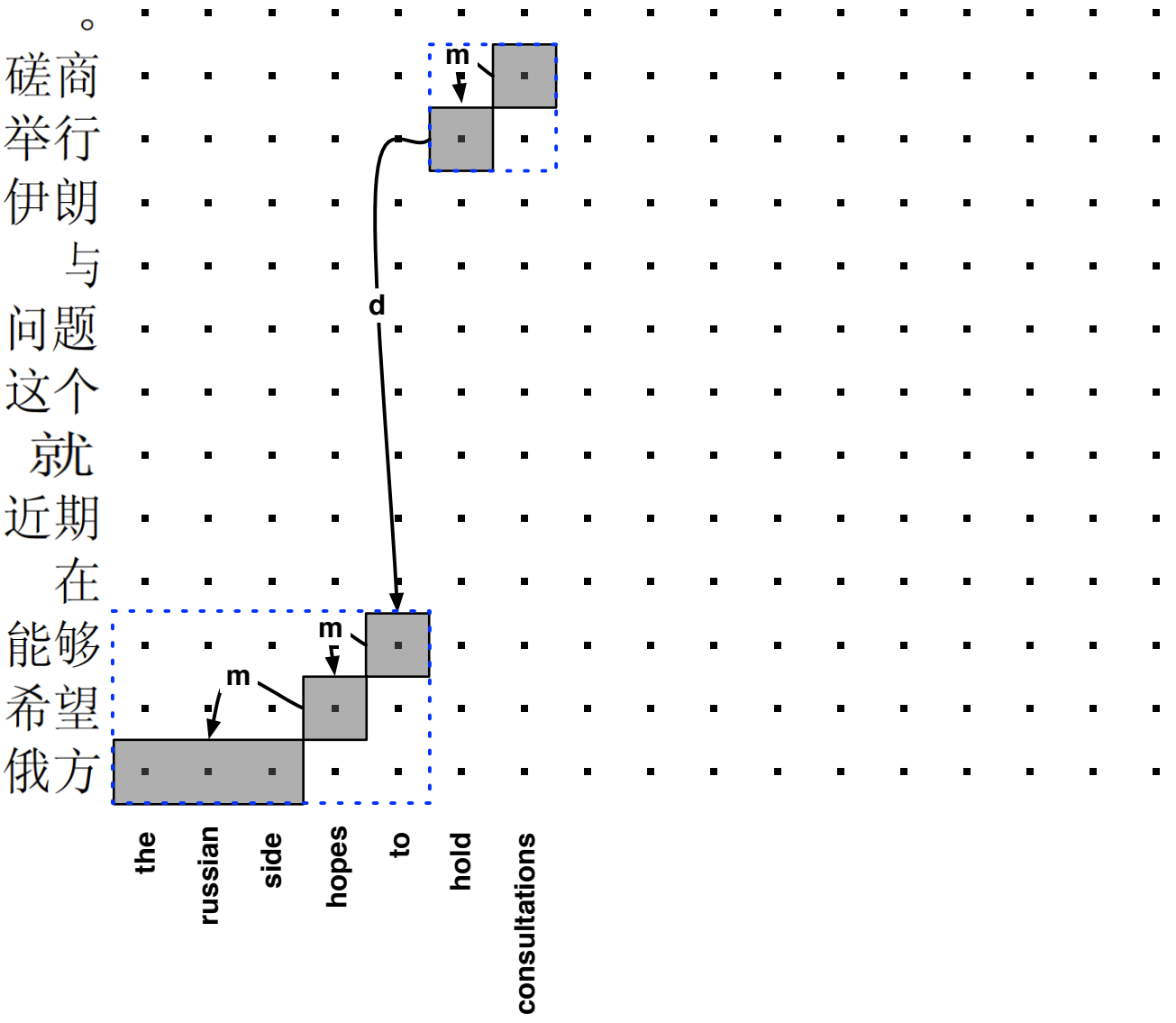

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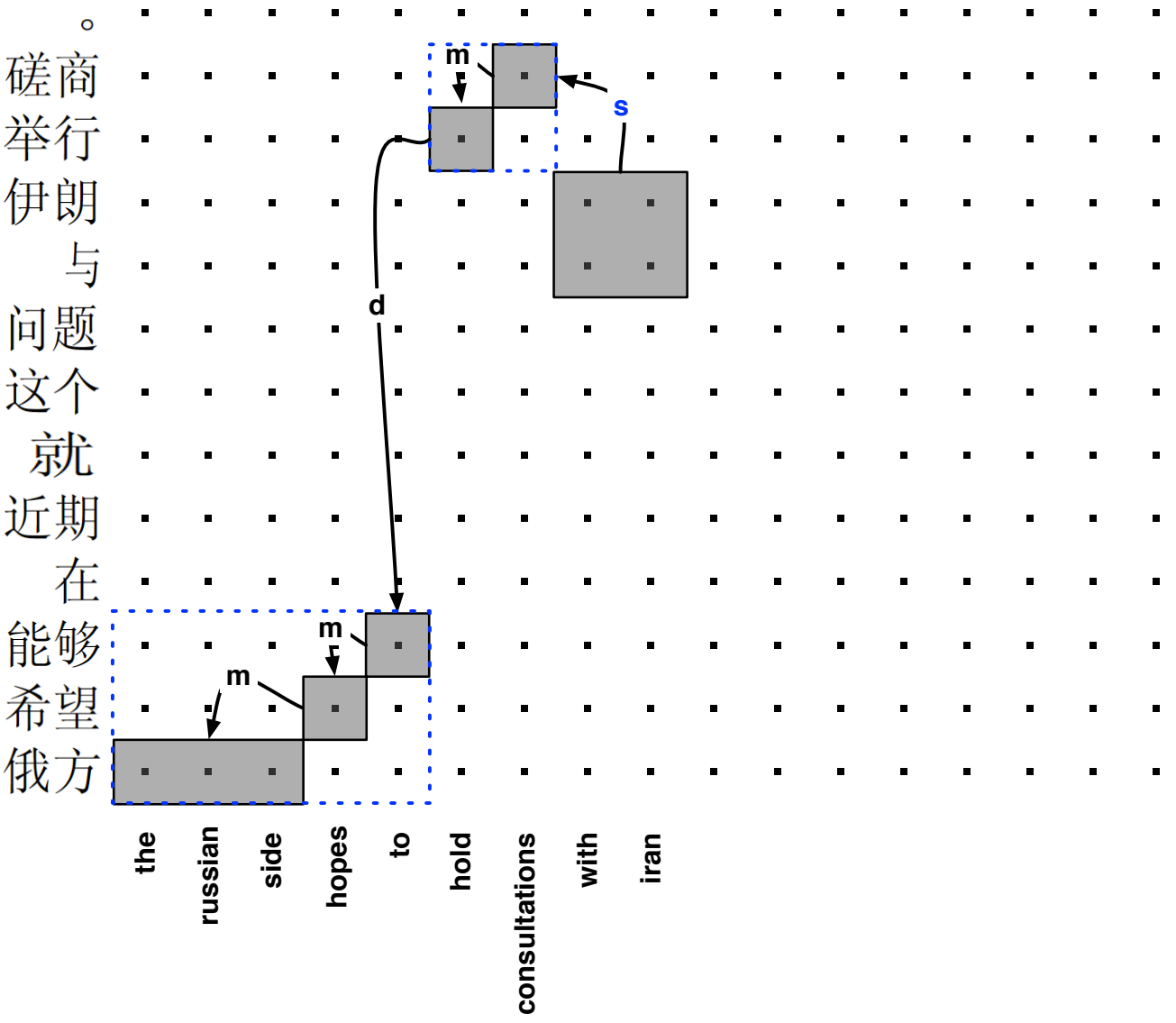

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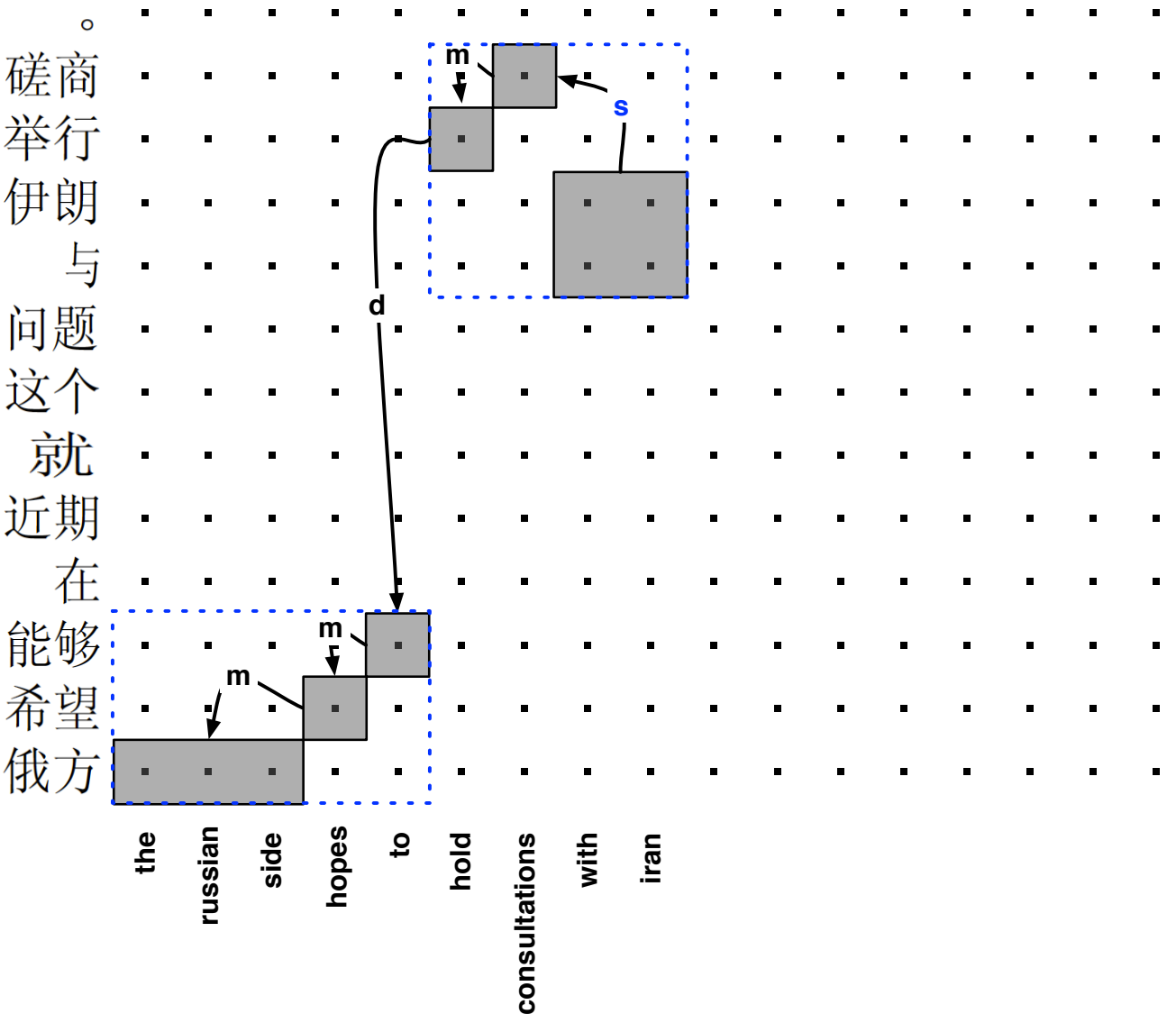

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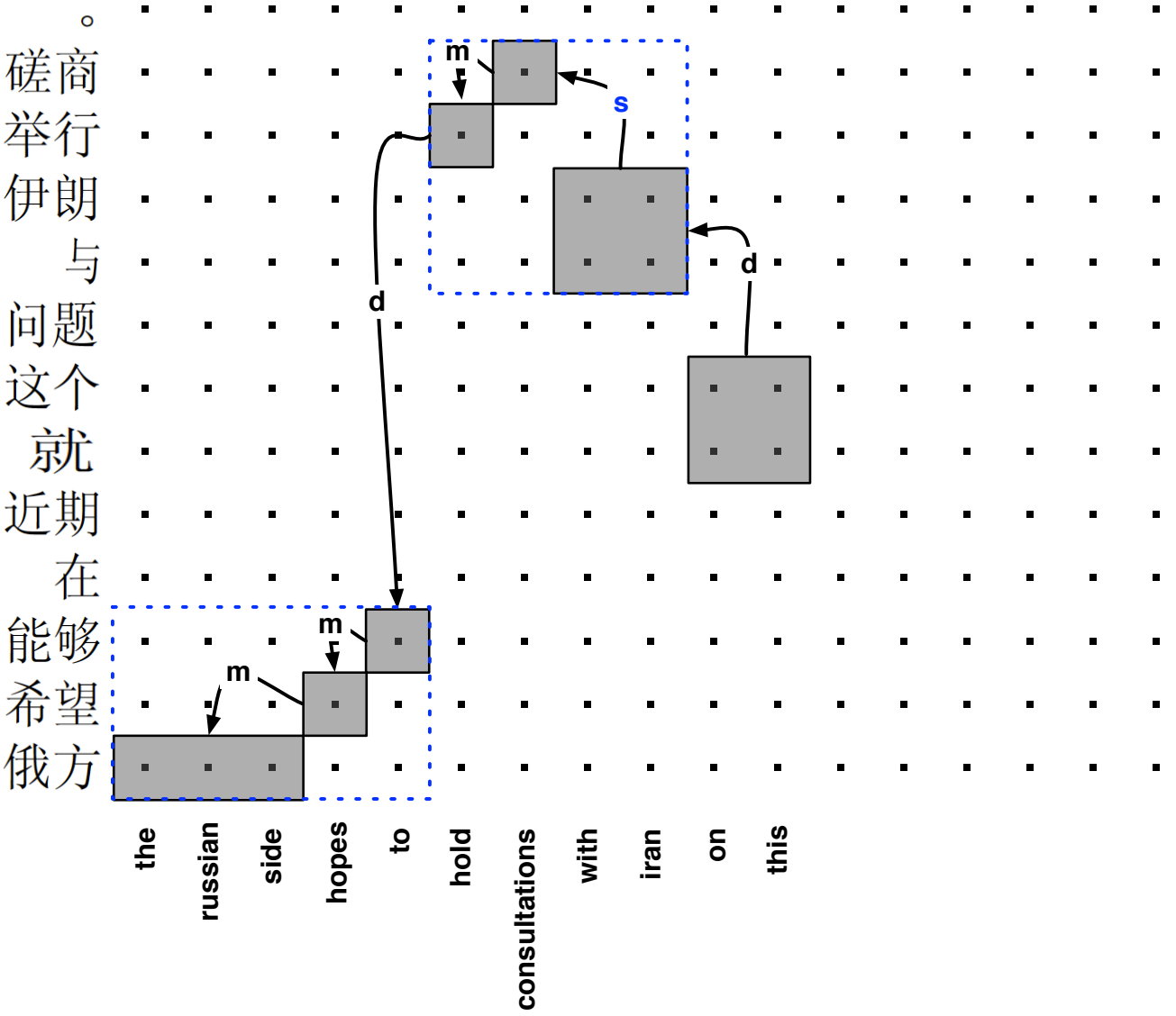

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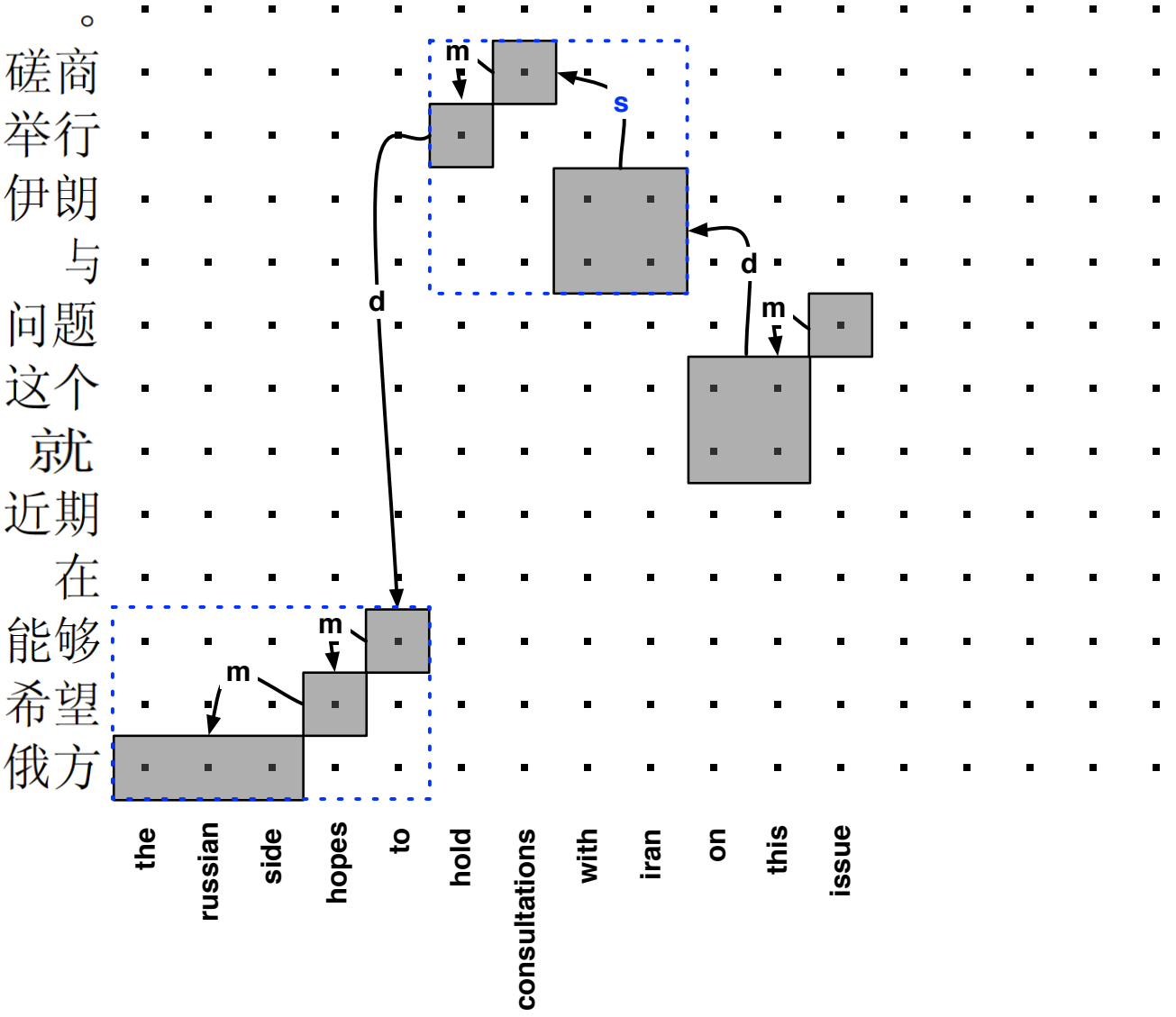

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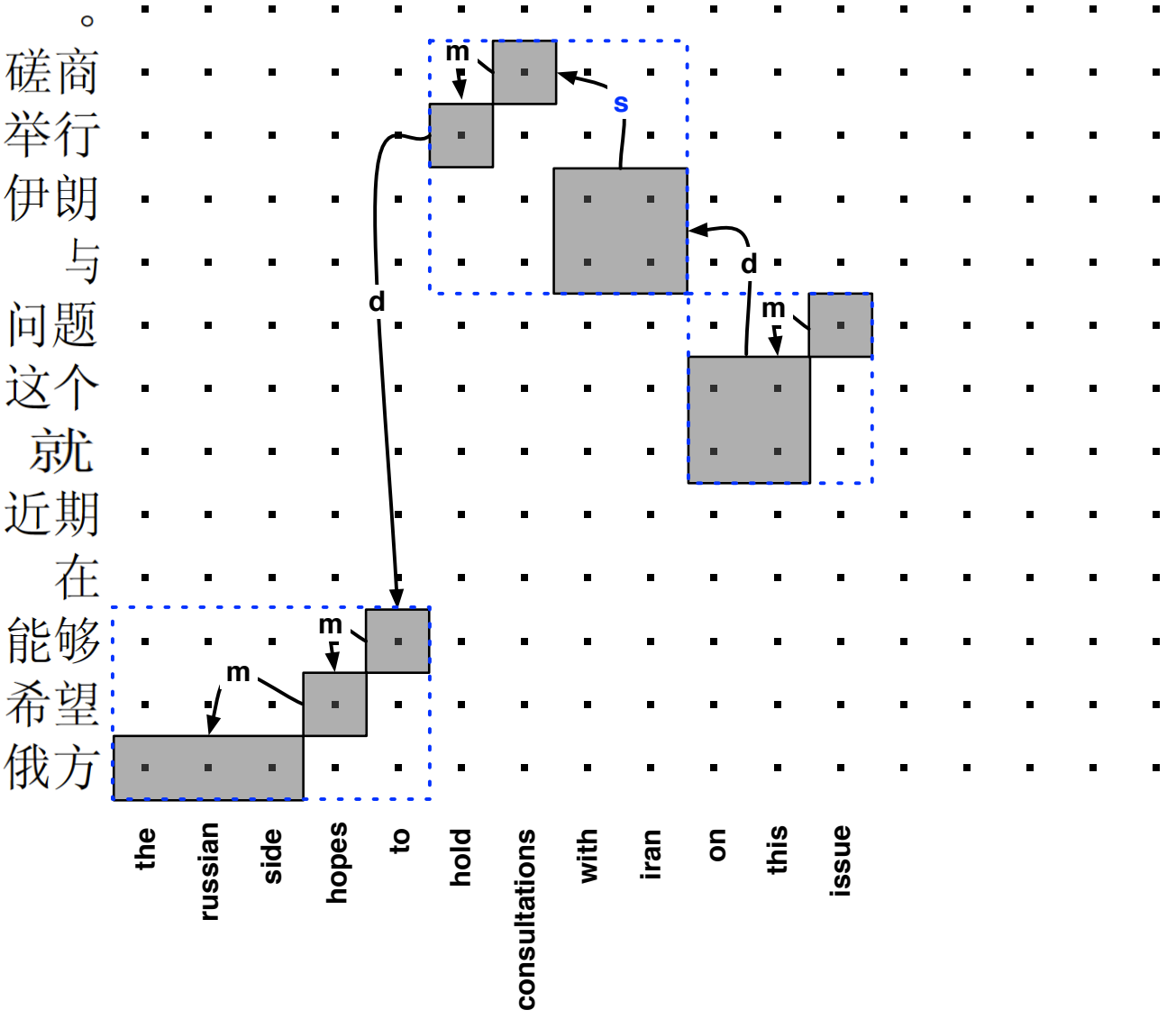

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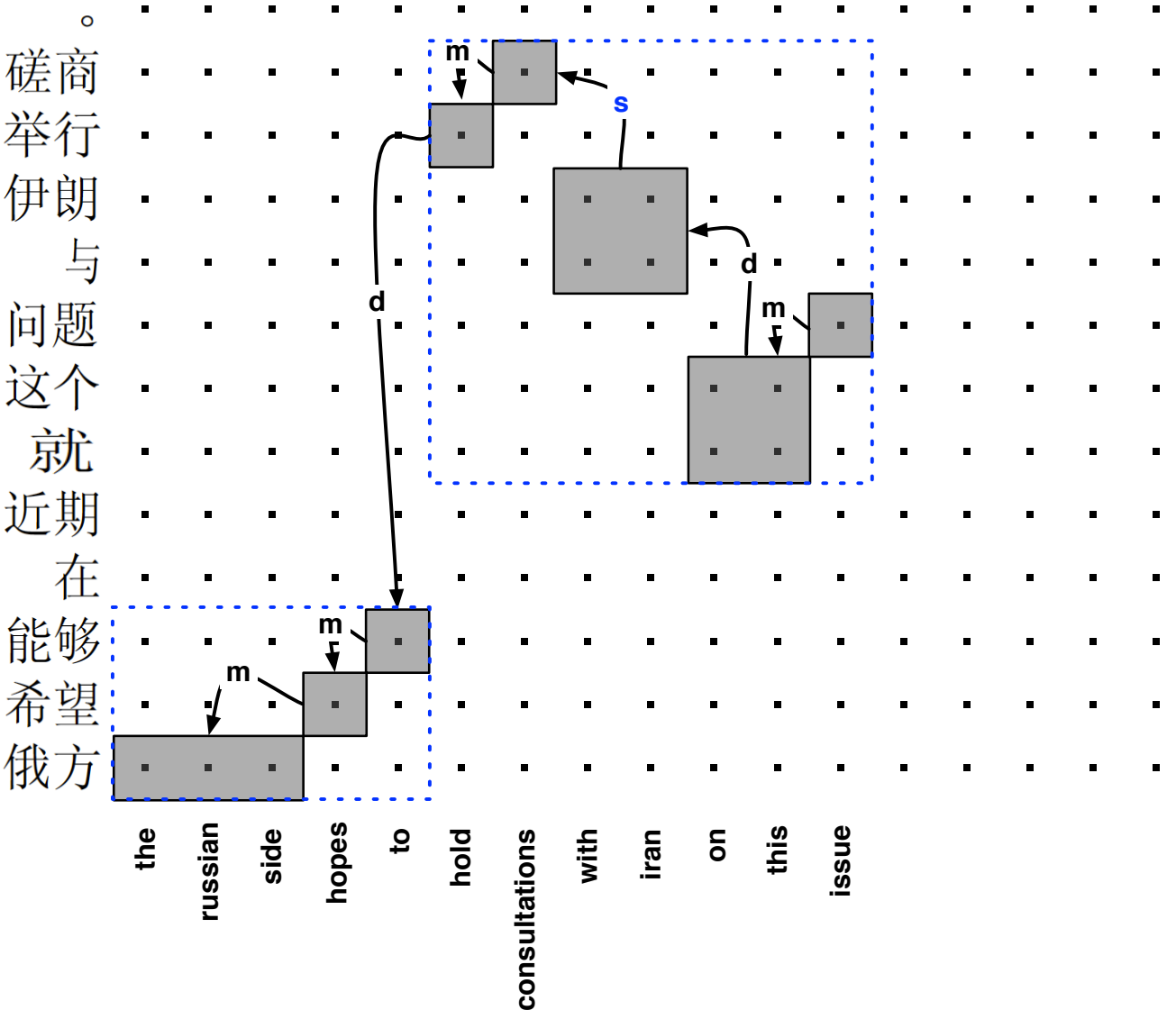

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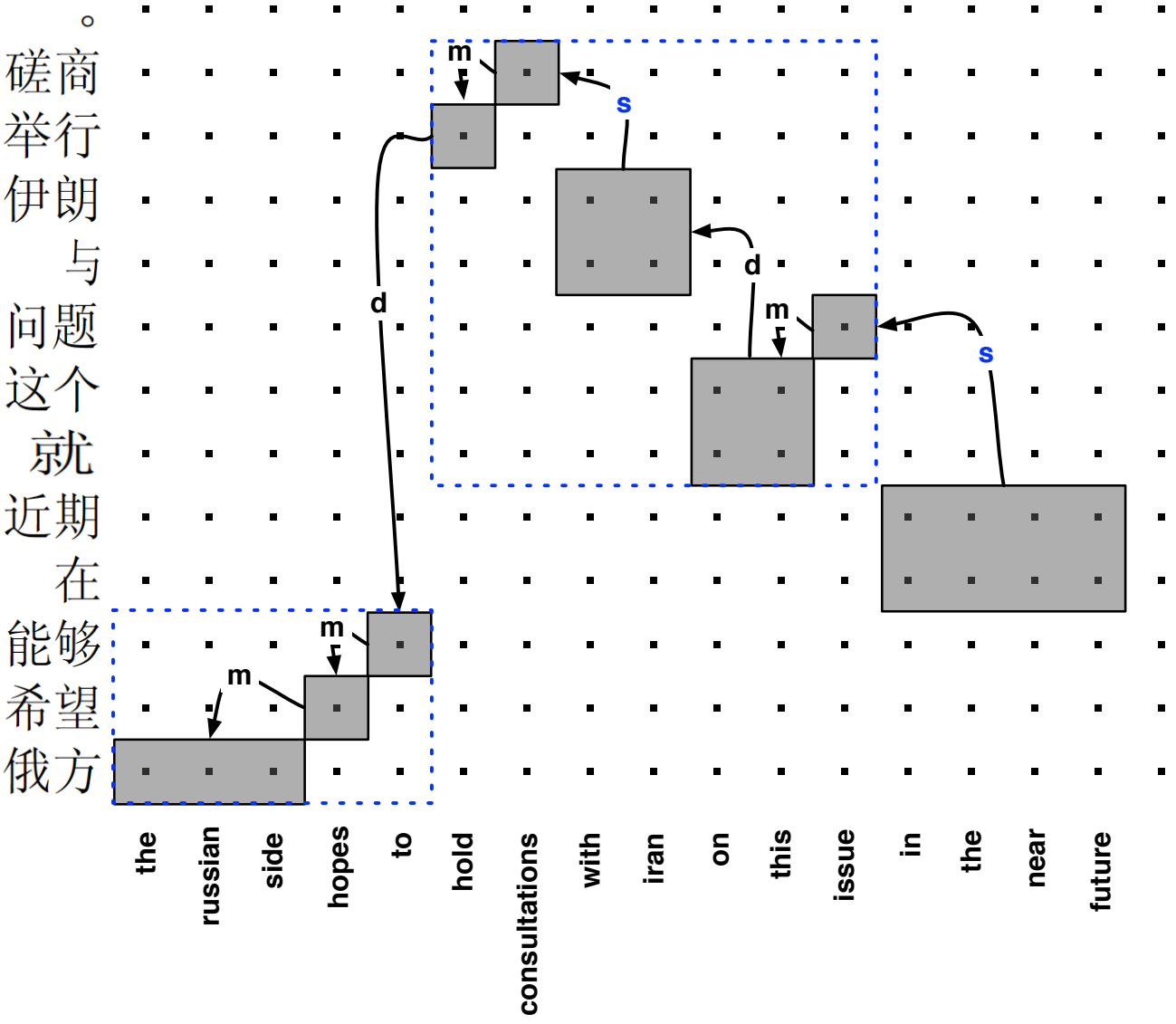

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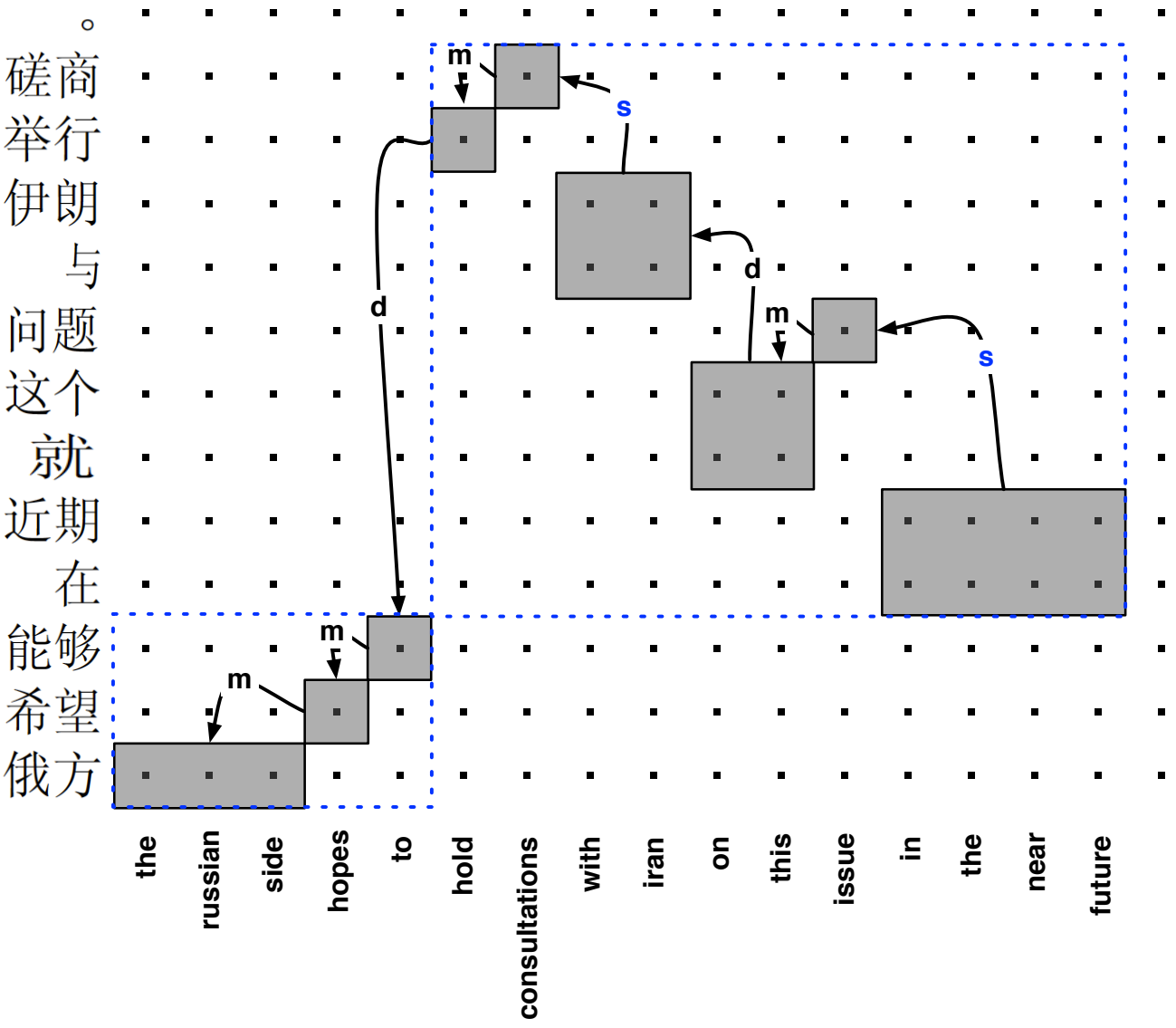
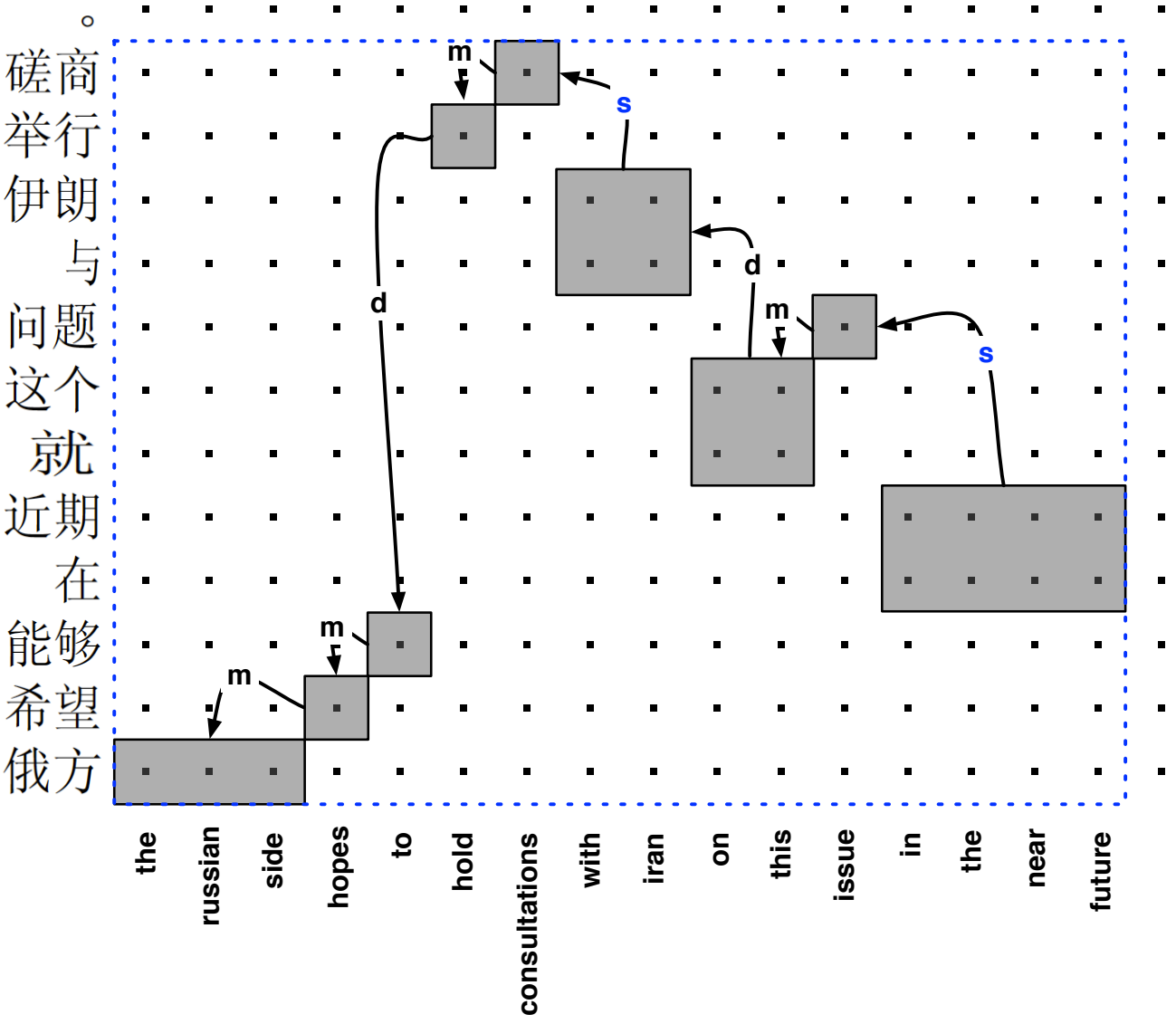


Hierarchical Reordering



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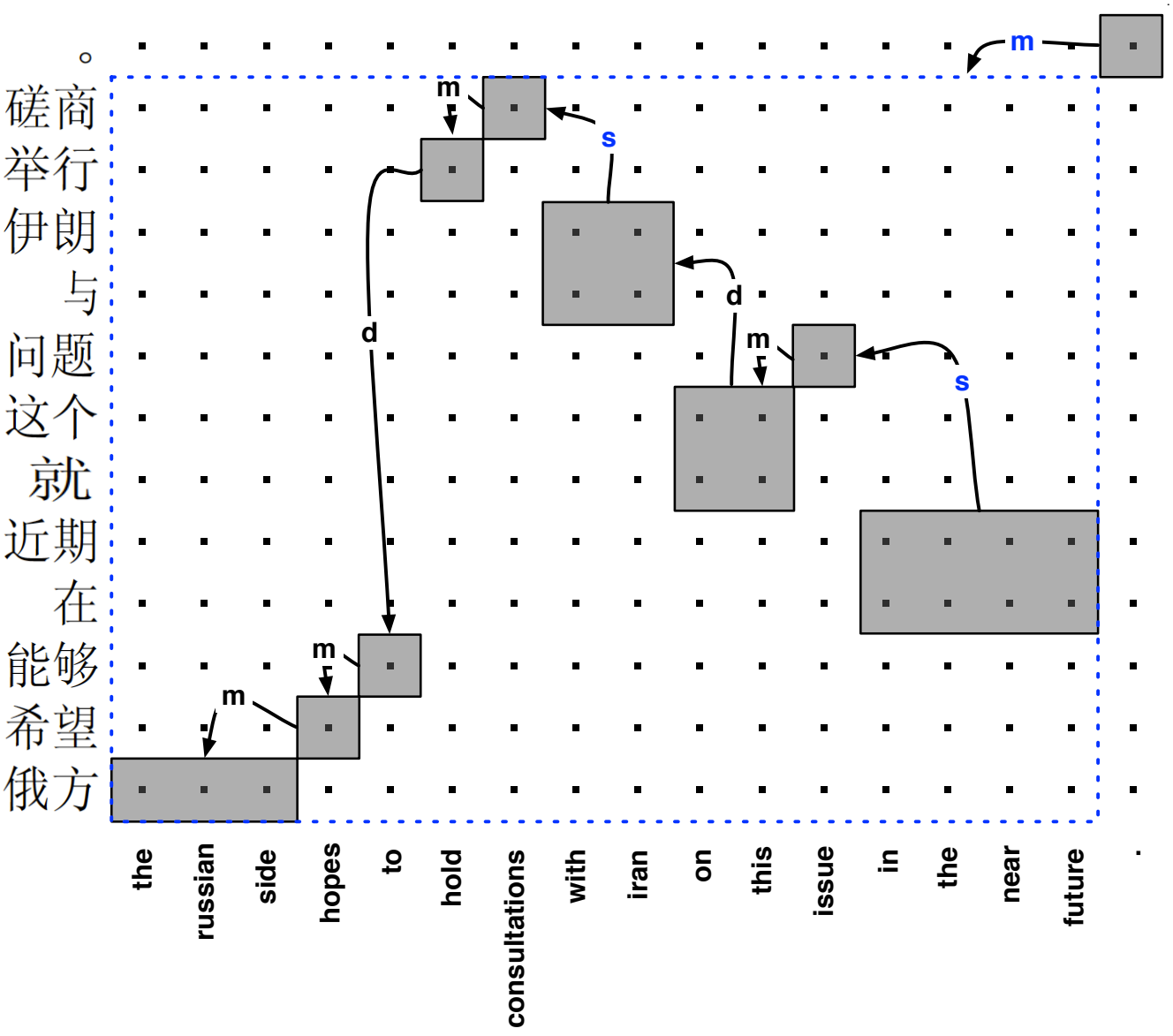
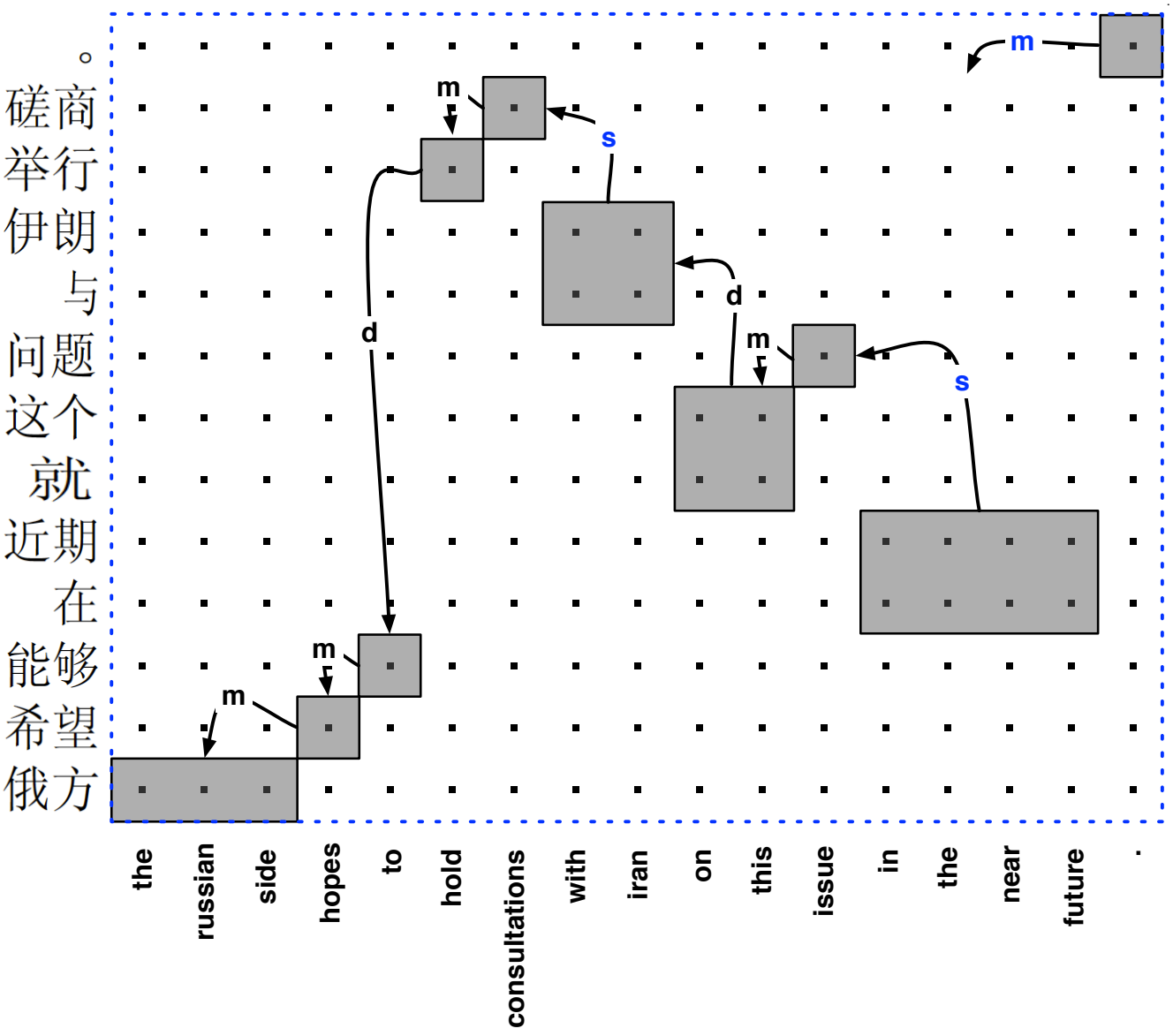


Hierarchical Reordering



Hierarchical Reordering

- Hierarchical Reordering Models introduced by Galley and Manning (2008)
- Phrase-based alternative to hierarchical reordering found in syntax-based and hierarchical SMT systems
- Translations are still generated from left to right (no chart decoding)
- Hierarchical grouping of phrase applications realized as a shift-reduce (SR) parser
  - Reductions are carried out *before* shifts
- Hypothesis (states) contain a stack of foreign phrase spans
  - Additional criteria for recombination
- Hierarchical reordering often used in combination with lexicalized reordering (and linear distortion)

Hierarchical Reordering: SR-Parsing

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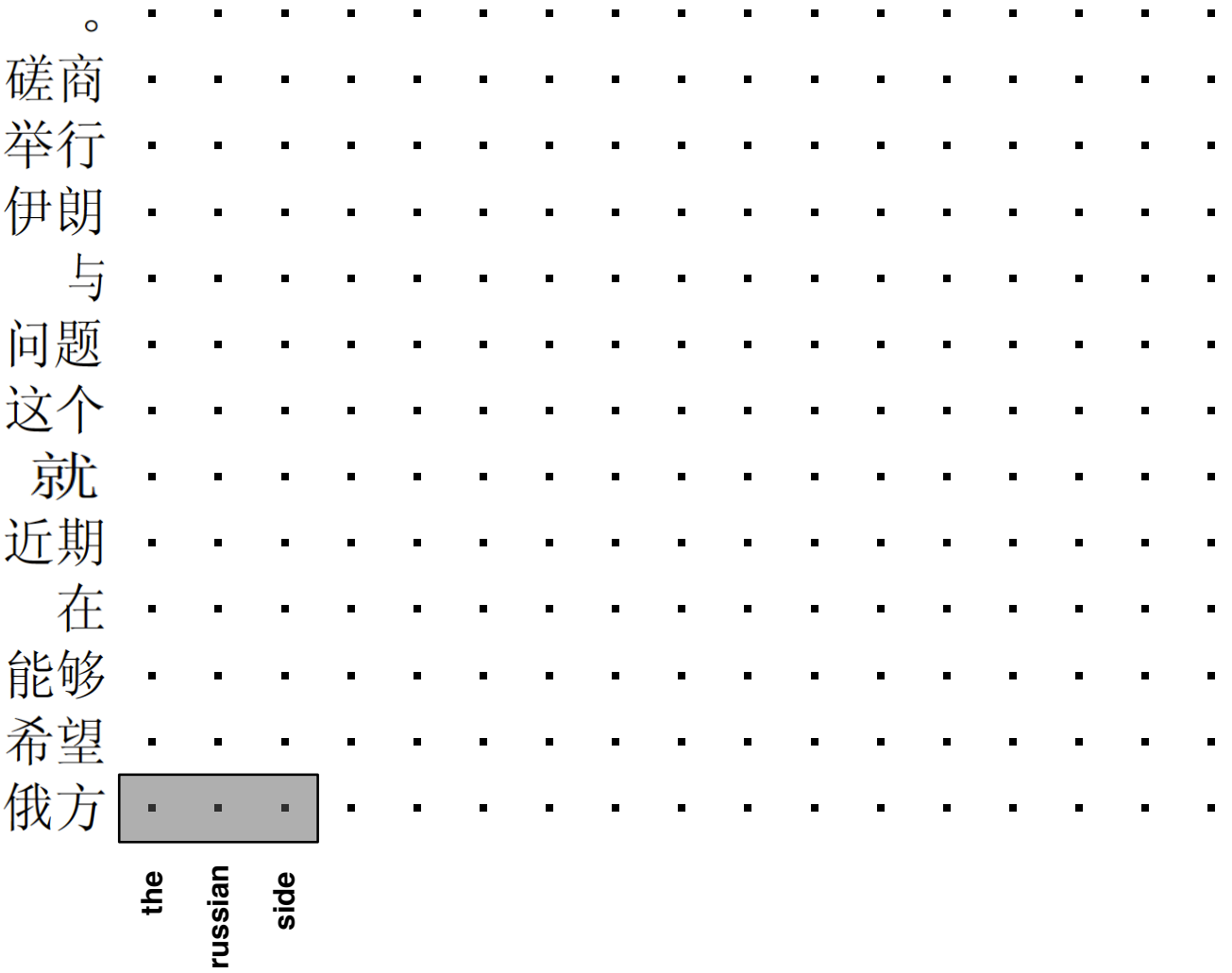
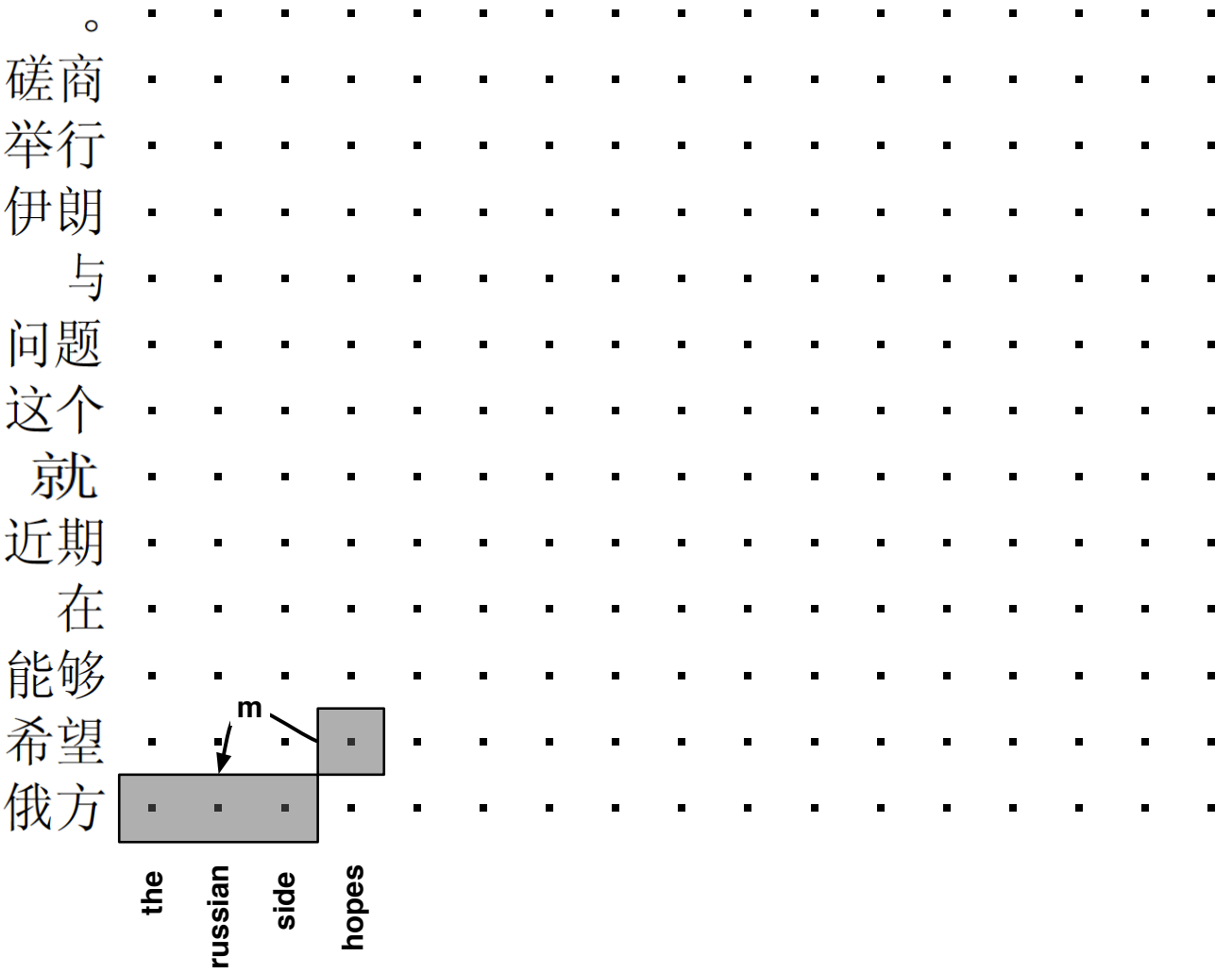
Hierarchical Reordering: SR-Parsing



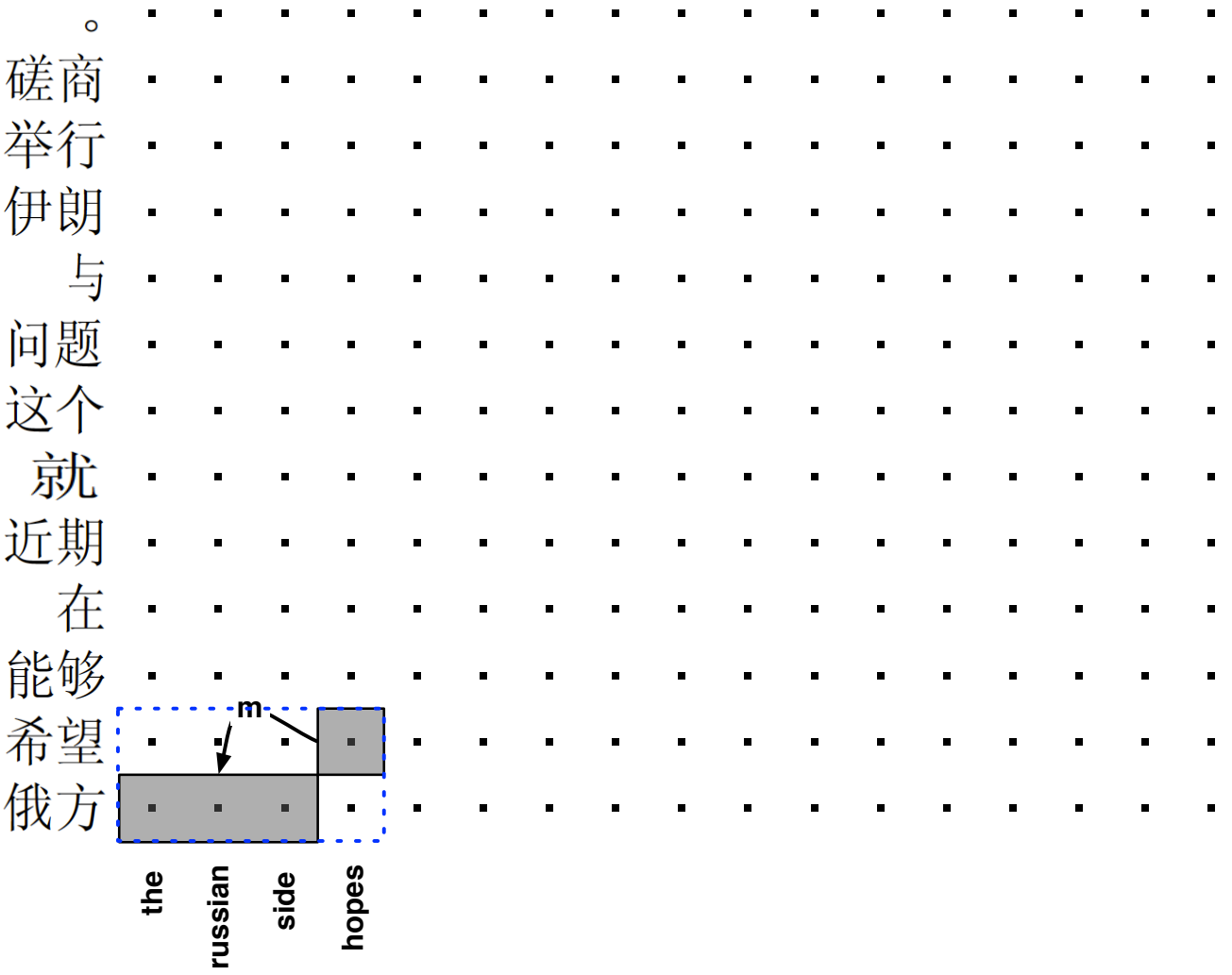
s [1]

Hierarchical Reordering: SR-Parsing



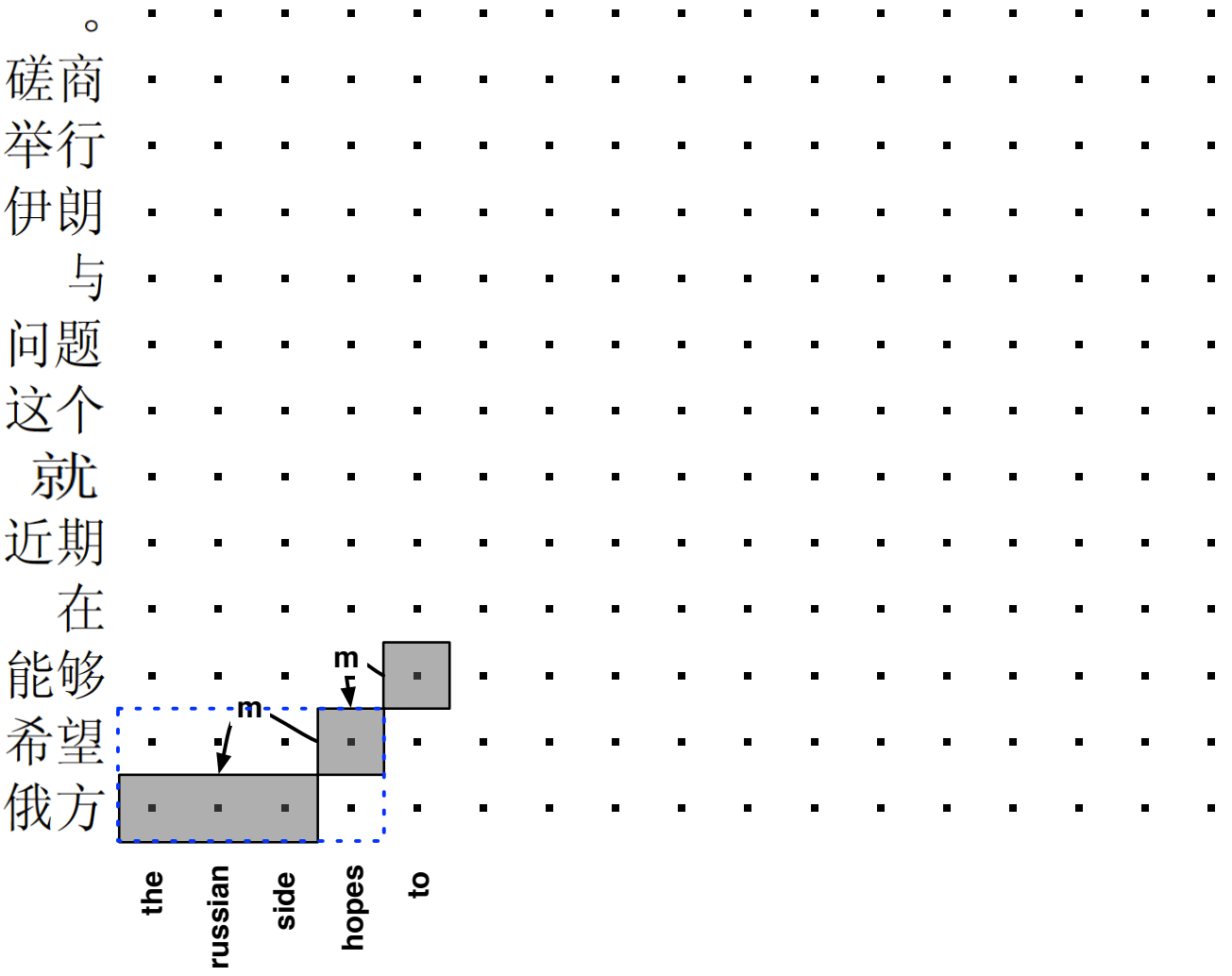
s [1]
s [2], [1]

Hierarchical Reordering: SR-Parsing



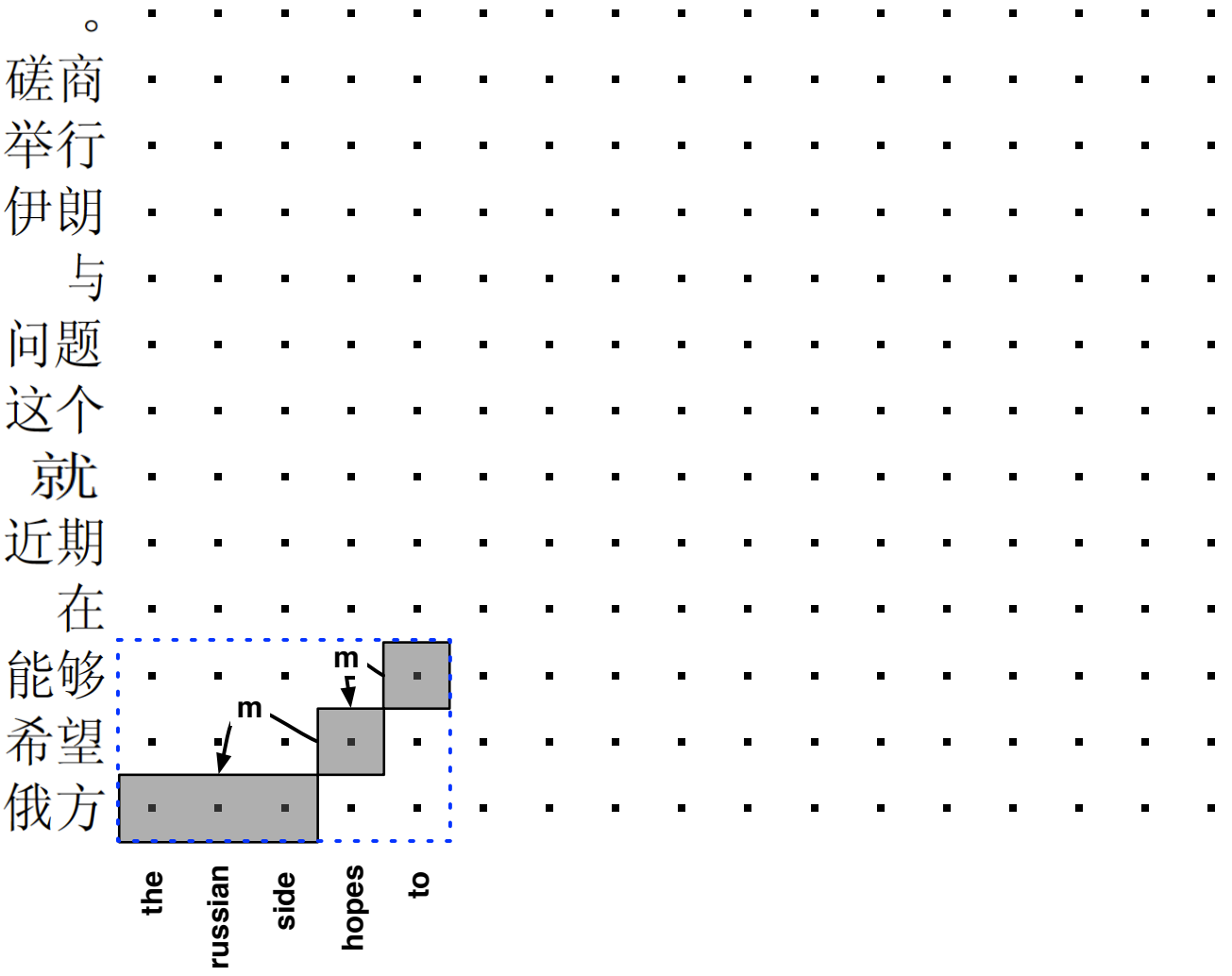
s [1]
s [2], [1]
r [1–2]

Hierarchical Reordering: SR-Parsing



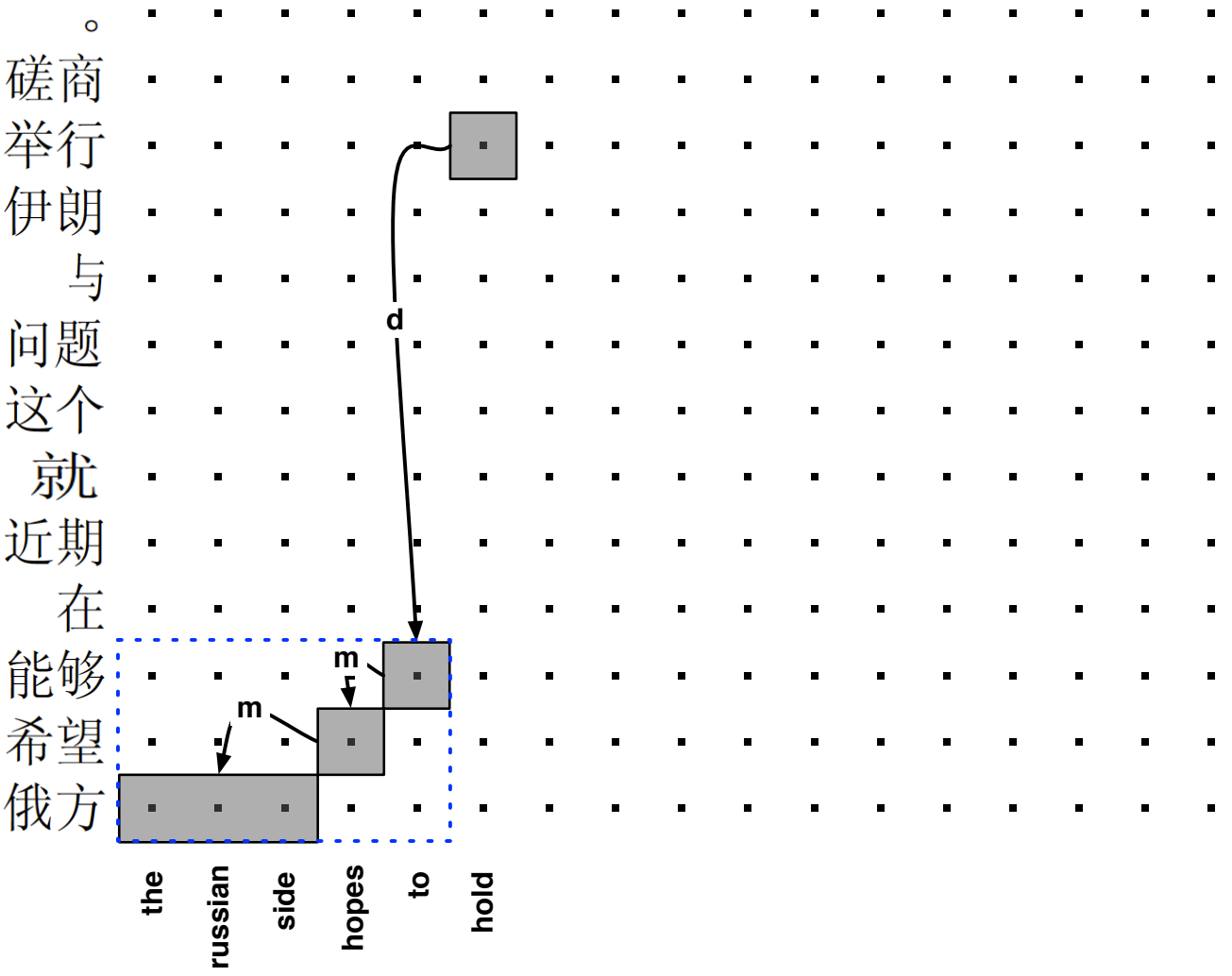
s [1]
s [2], [1]
r [1–2]
s [3], [1–2]

Hierarchical Reordering: SR-Parsing



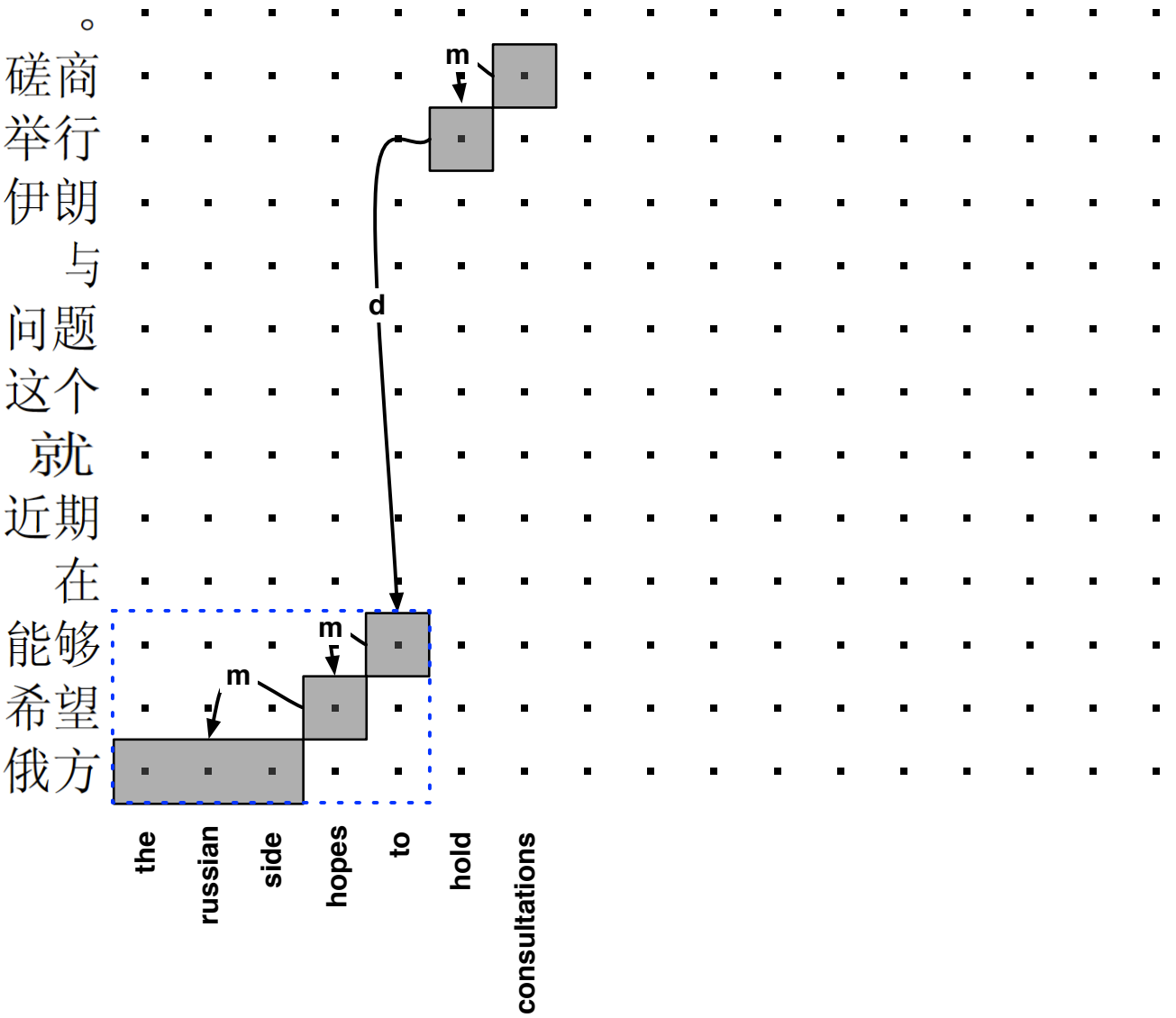
s [1]
s [2], [1]
r [1–2]
s [3], [1–2]
r [1–3]

Hierarchical Reordering: SR-Parsing



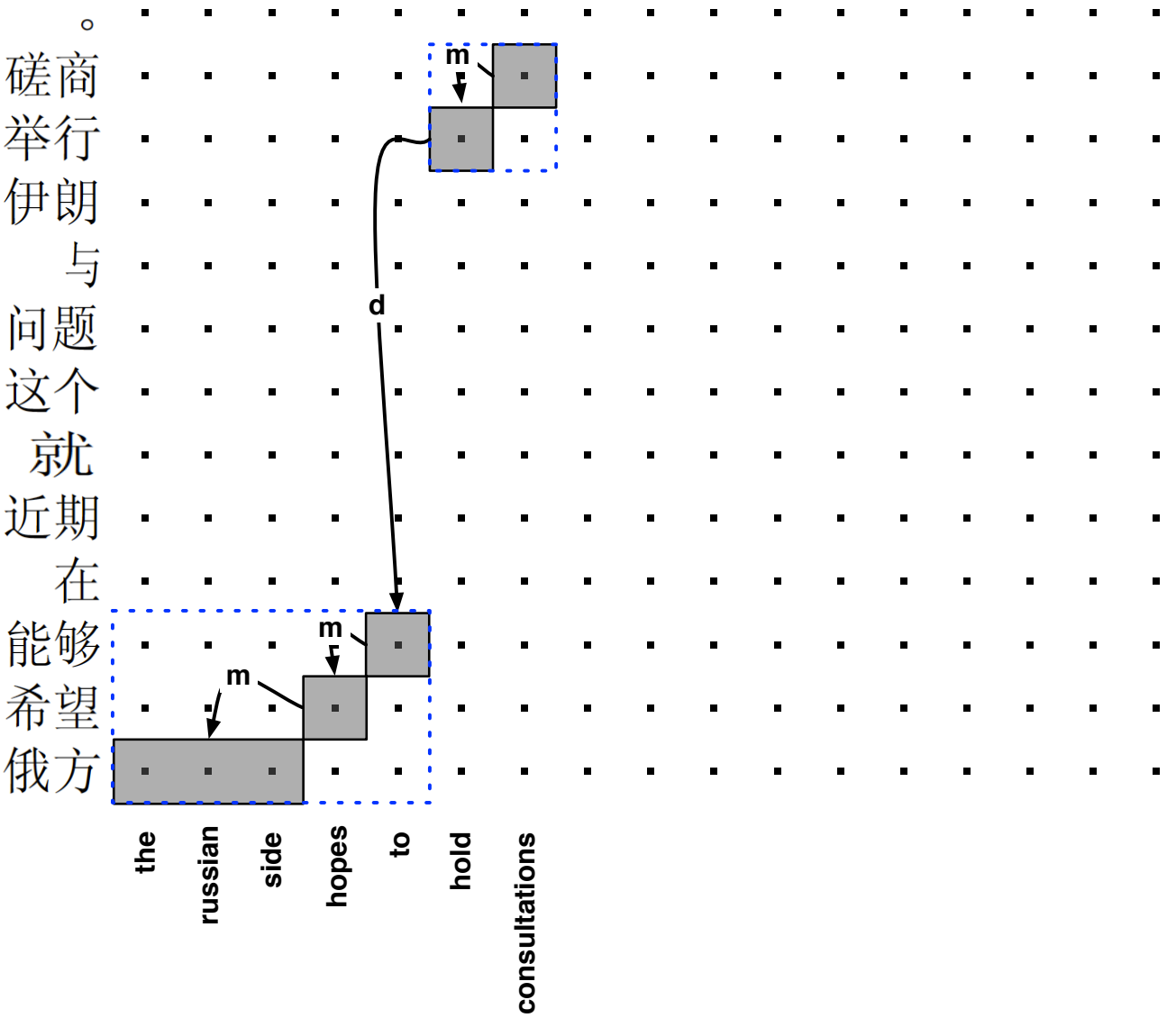
s [1]
s [2], [1]
r [1–2]
s [3], [1–2]
r [1–3]
s [11], [1–3]

Hierarchical Reordering: SR-Parsing



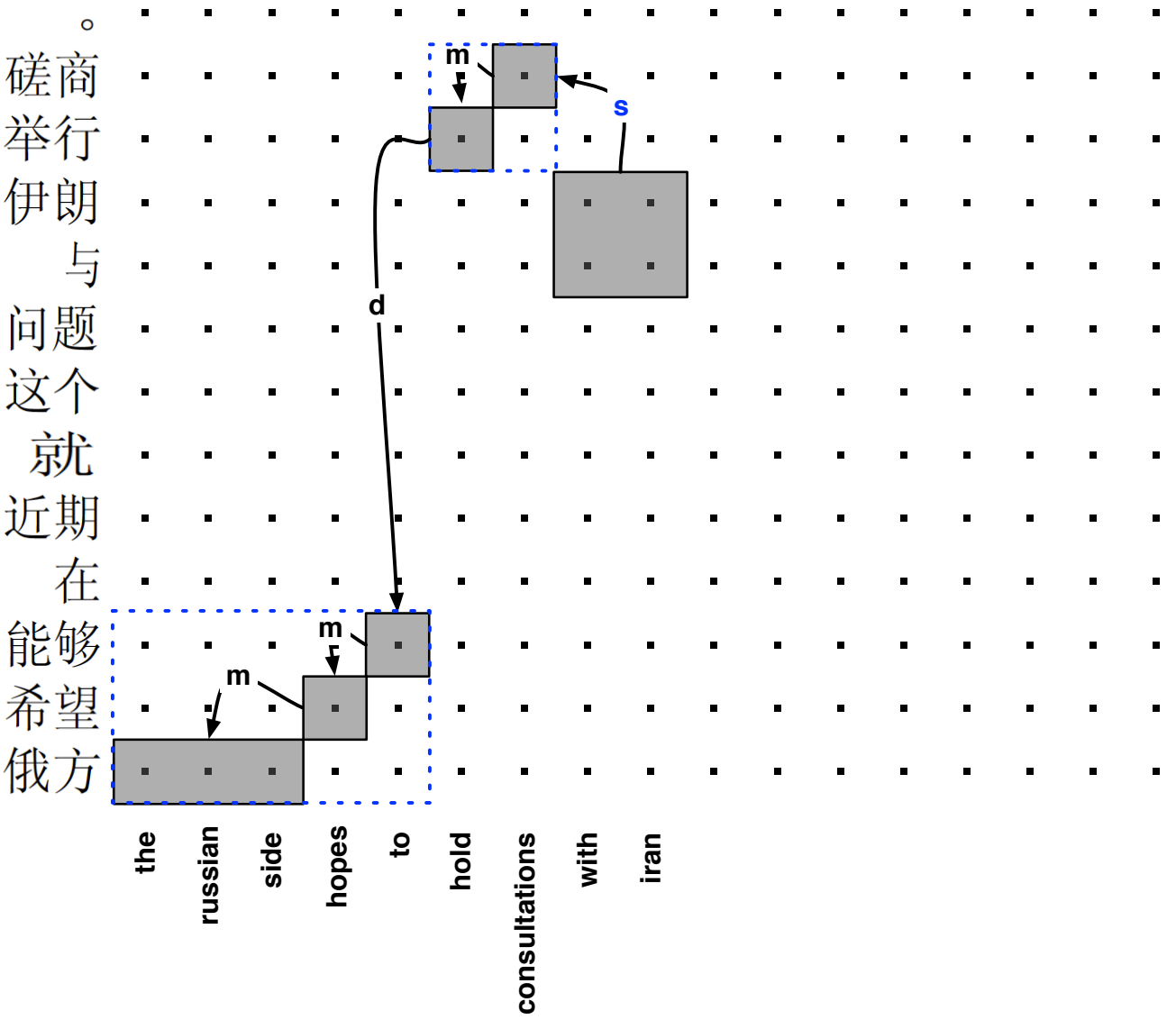
s [1]
s [2], [1]
r [1–2]
s [3], [1–2]
r [1–3]
s [11], [1–3]
s [12], [11], [1–3]

Hierarchical Reordering: SR-Parsing



s [1]
s [2], [1]
r [1–2]
s [3], [1–2]
r [1–3]
s [11], [1–3]
s [12], [11], [1–3]
r [11–12], [1–3]

Hierarchical Reordering: SR-Parsing



s [1]
s [2], [1]
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r [11–12], [1–3]
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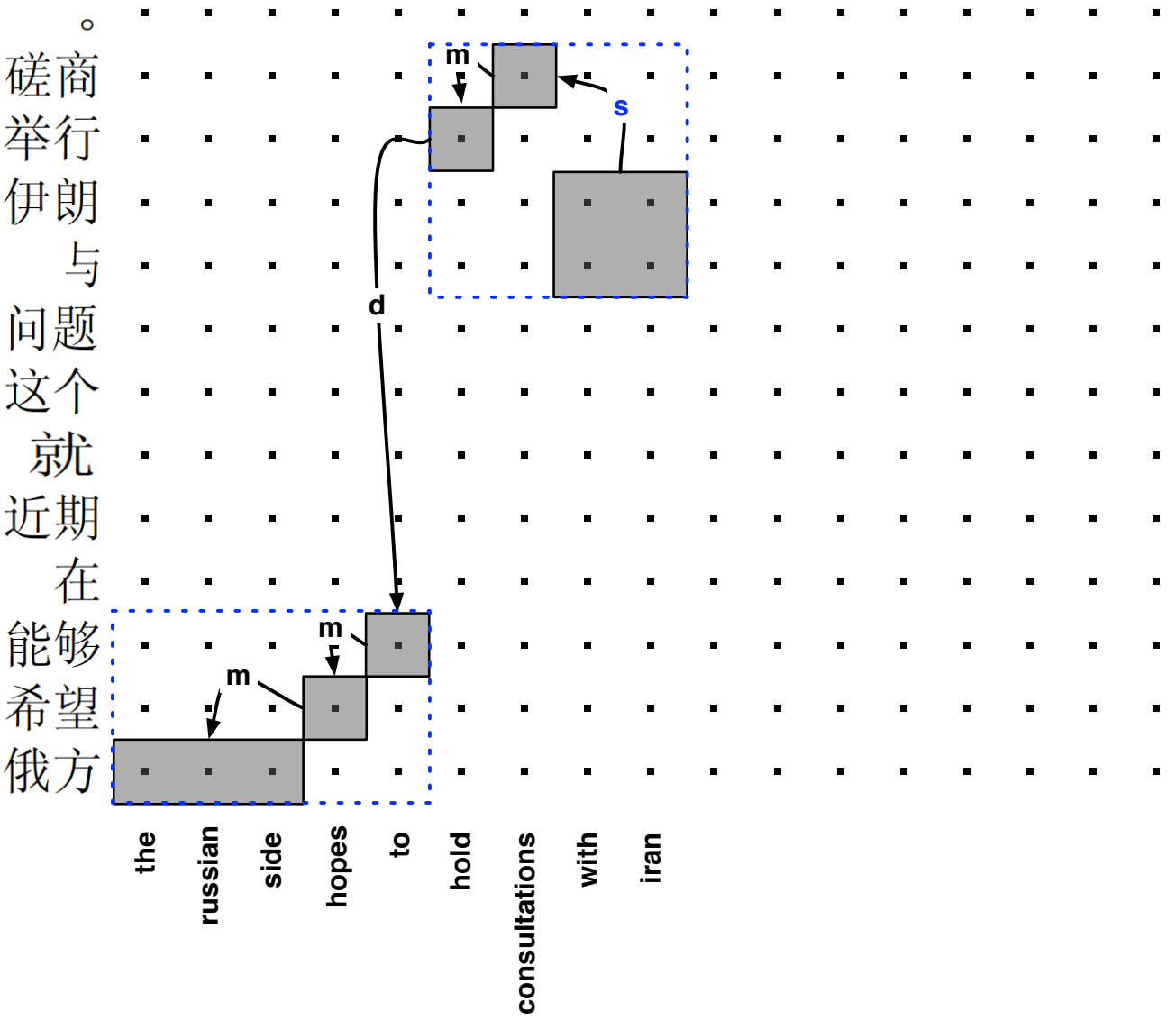
Hierarchical Reordering: SR-Parsing



s [1]
s [2], [1]
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r [1–3]
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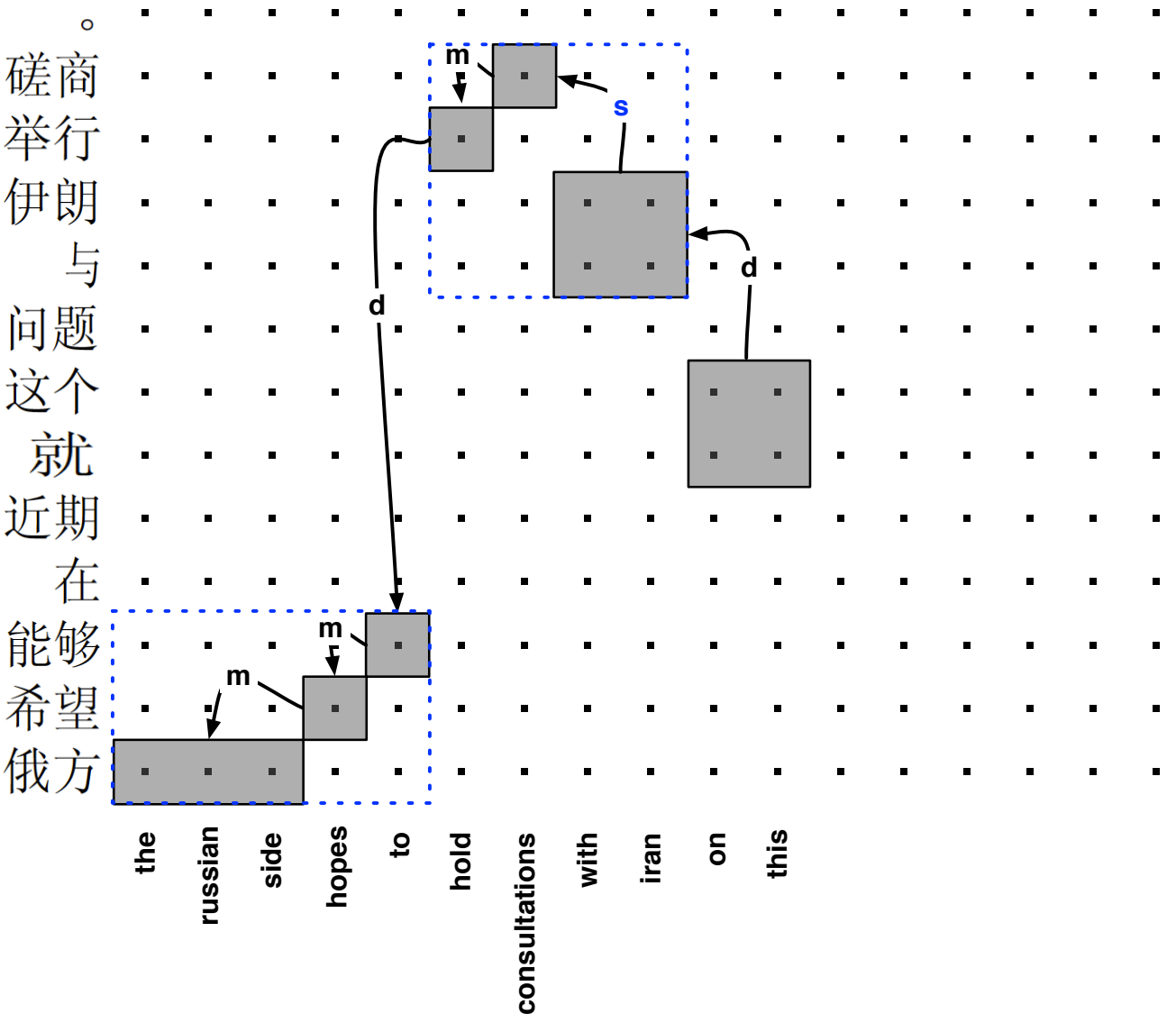
Hierarchical Reordering: SR-Parsing



s [1]
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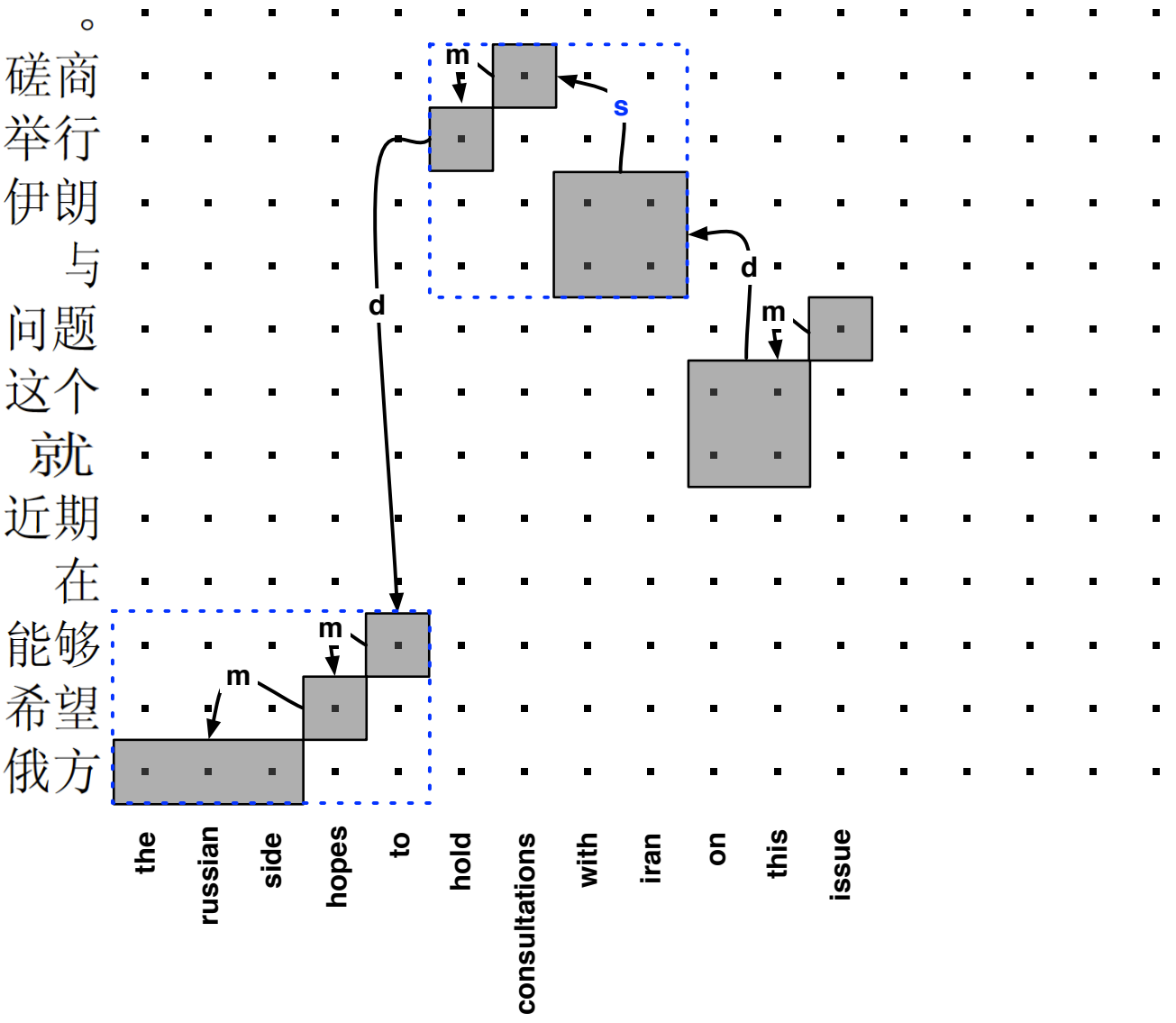
s [9–10], [11–12], [1–3]
r [9–12], [1–3]
s [6–7], [9–12], [1–3]

Hierarchical Reordering: SR-Parsing



s [1]
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r [1–3]
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s [12], [11], [1–3]
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s [9–10], [11–12], [1–3]
r [9–12], [1–3]
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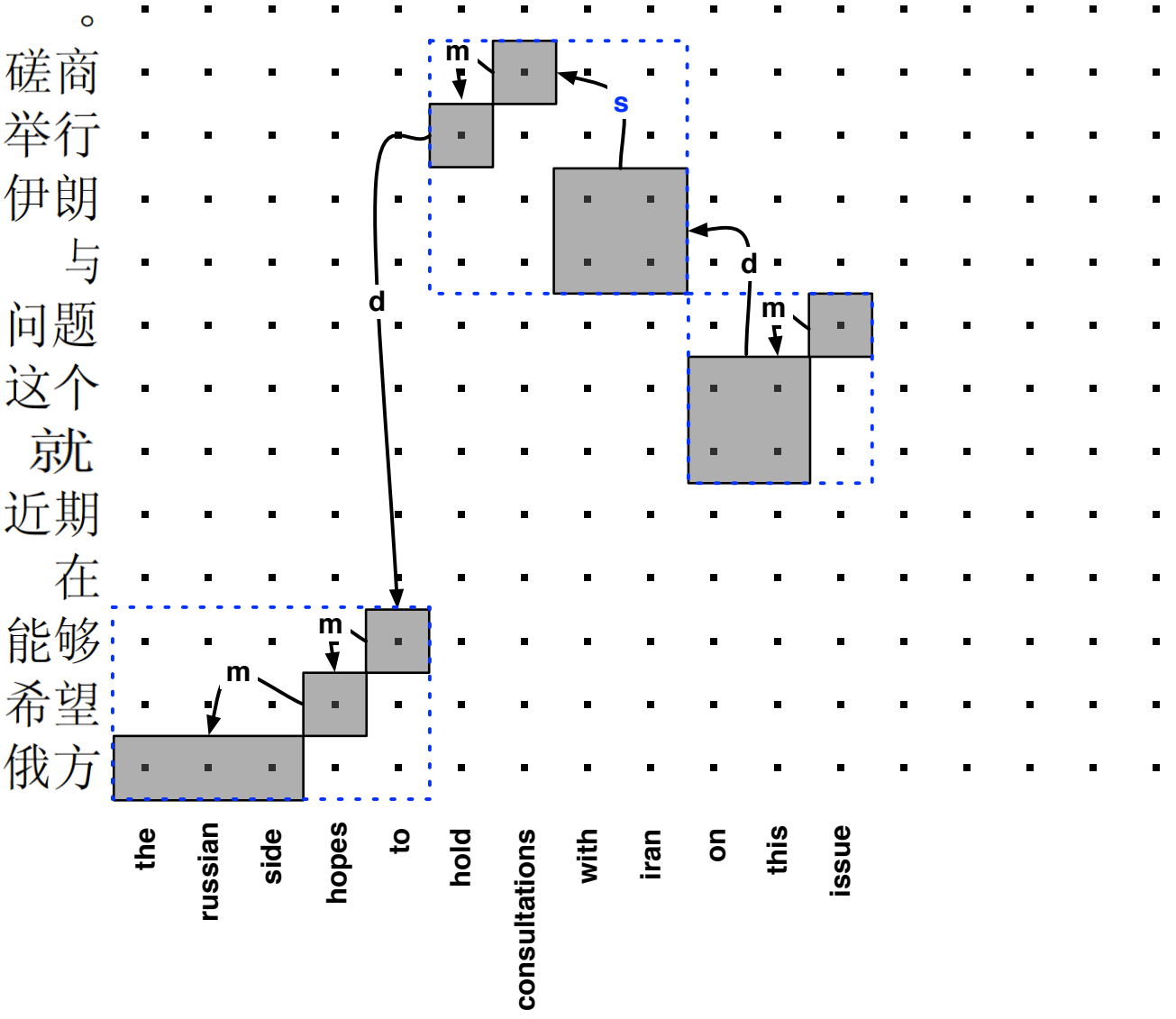
s [8], [6–7], [9–12], [1–3]

Hierarchical Reordering: SR-Parsing



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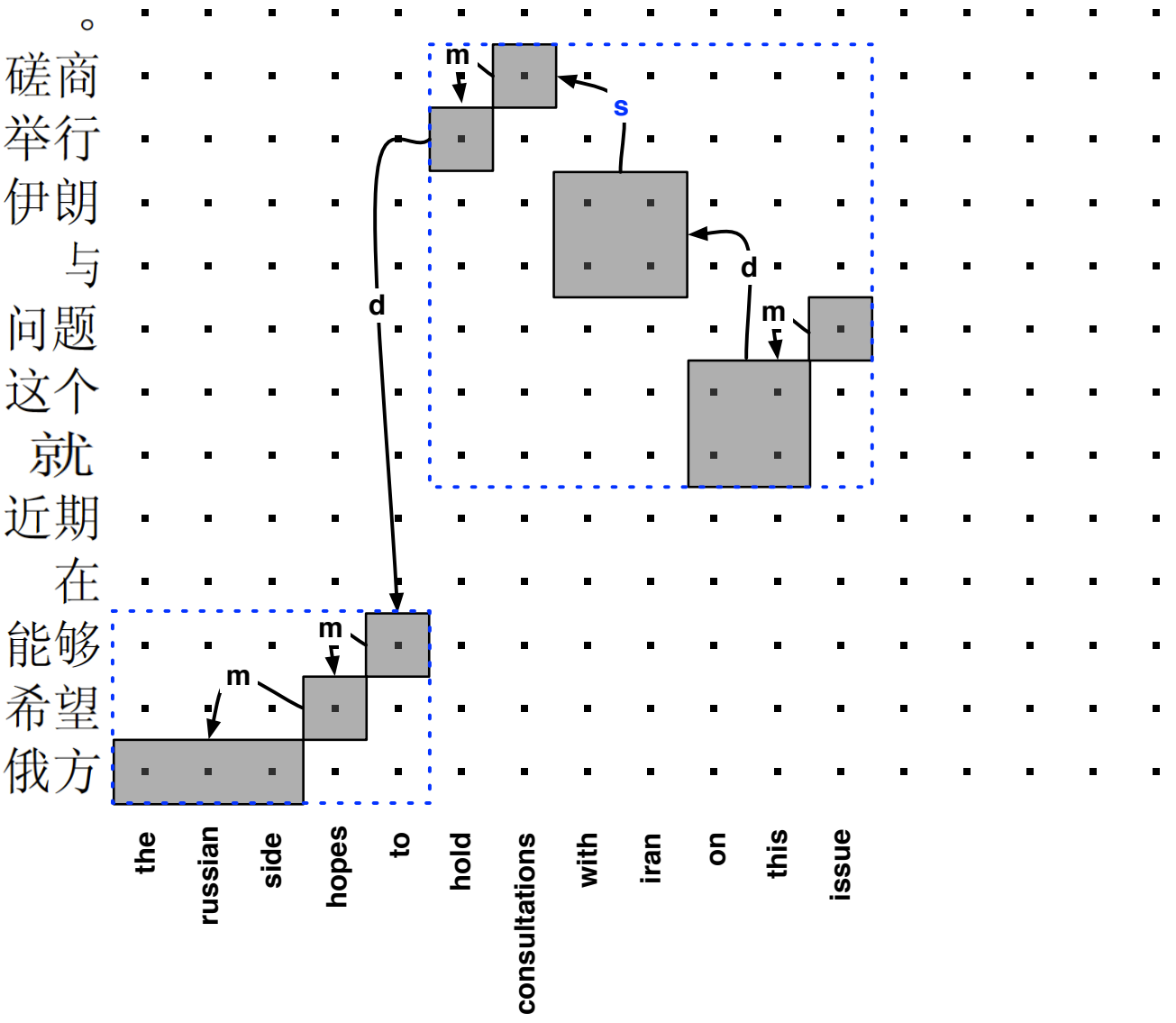
Hierarchical Reordering: SR-Parsing



s [1]
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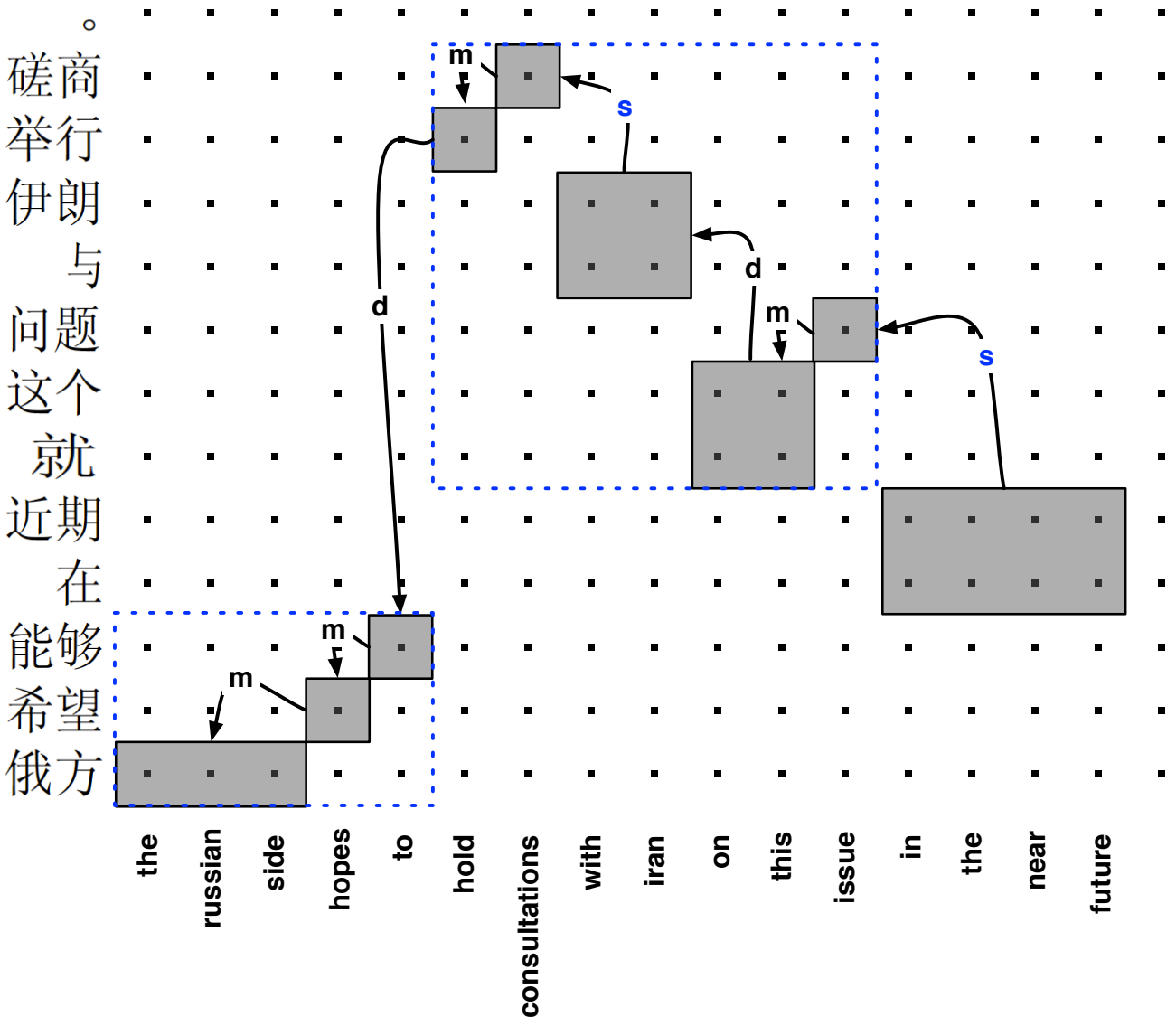
r [6–12], [1–3]

Hierarchical Reordering: SR-Parsing



s [1]
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s [12], [11], [1–3]
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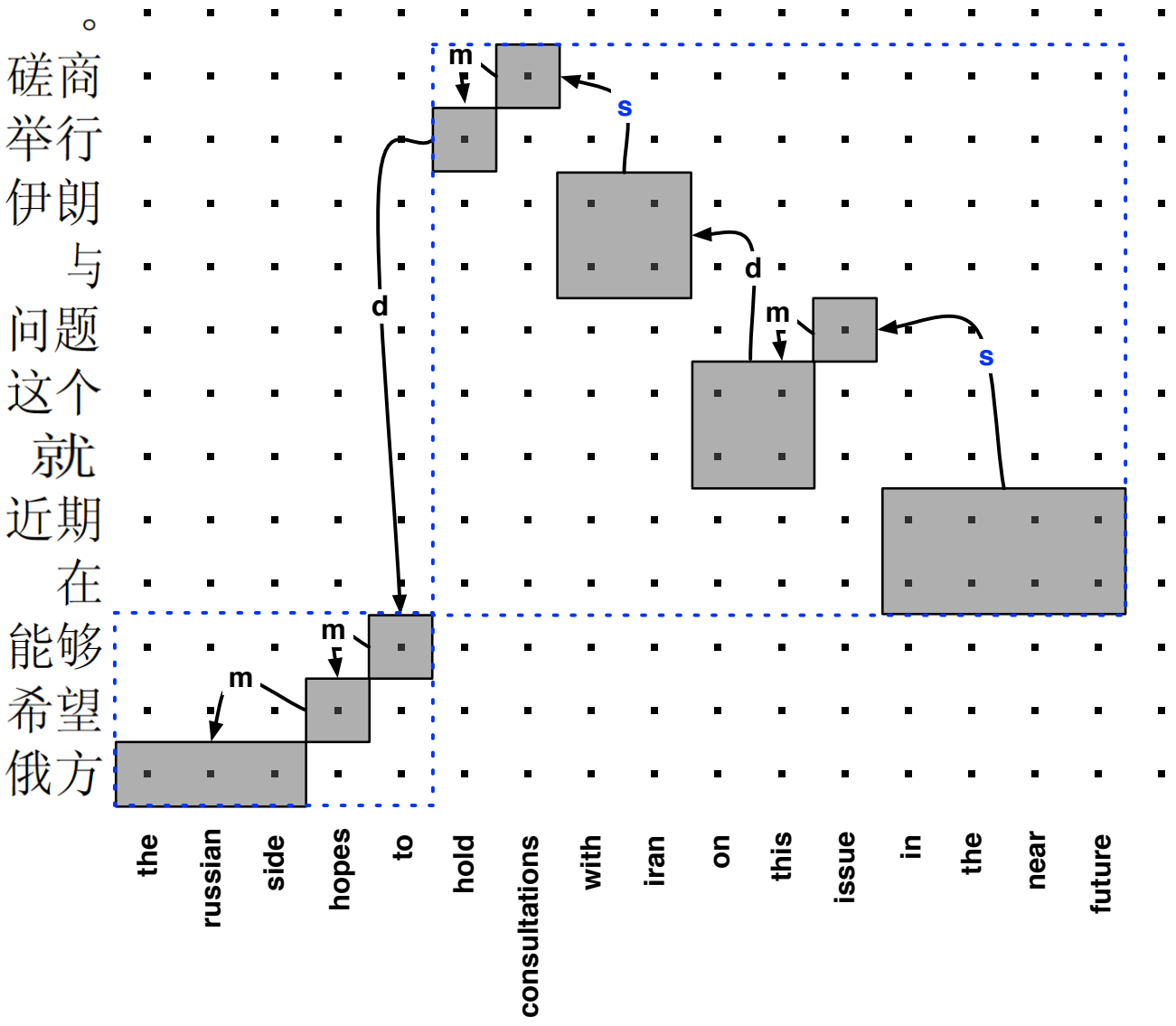
r [6–12], [1–3]
s [4–5], [6–12], [1–3]

Hierarchical Reordering: SR-Parsing



s [1]
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r [1–3]
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s [12], [11], [1–3]
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s [8], [6–7], [9–12], [1–3]
r [6–8], [9–12], [1–3]
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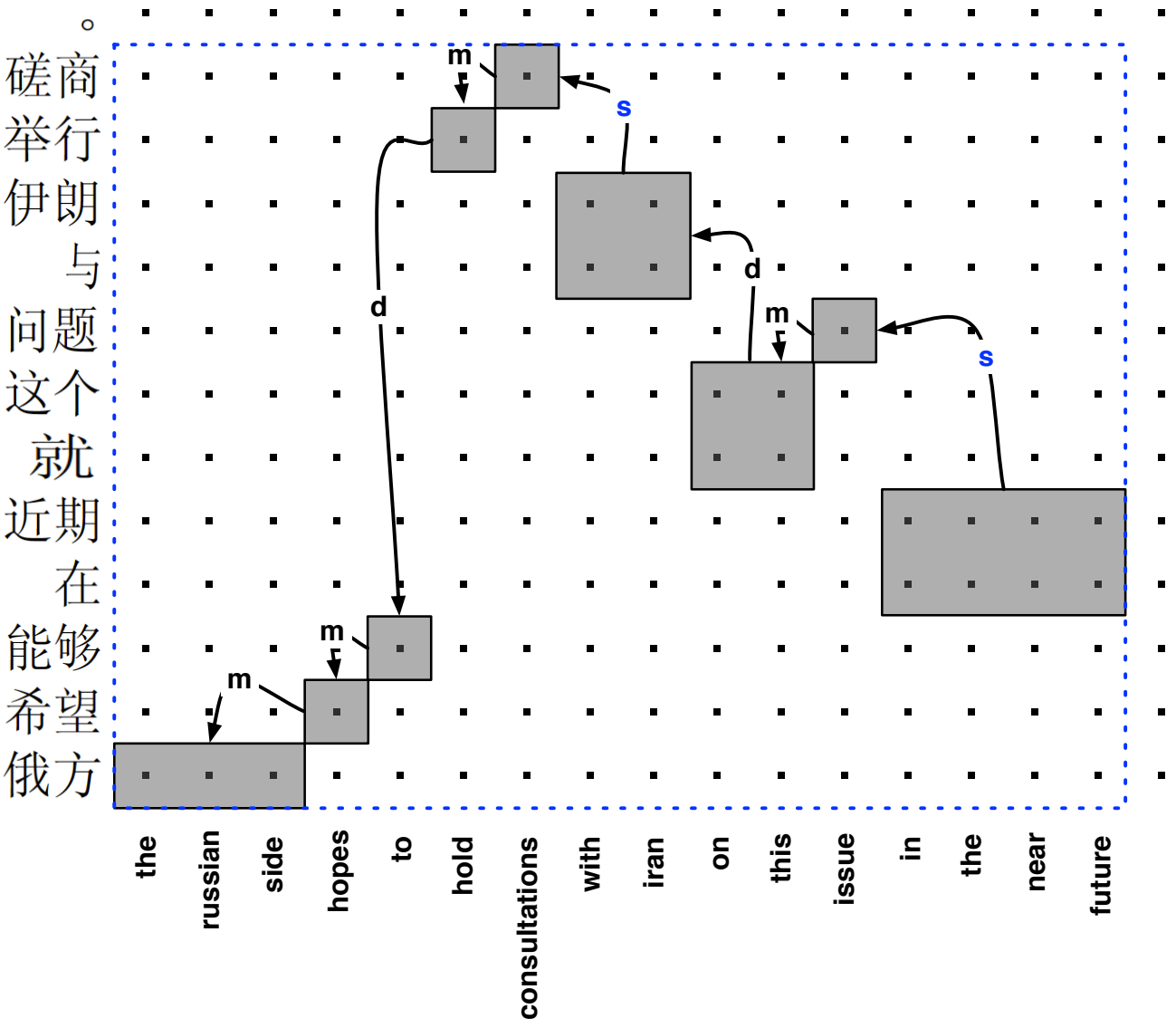
r [4–12], [1–3]

Hierarchical Reordering: SR-Parsing



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r [1–2]
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s [9–10], [11–12], [1–3]
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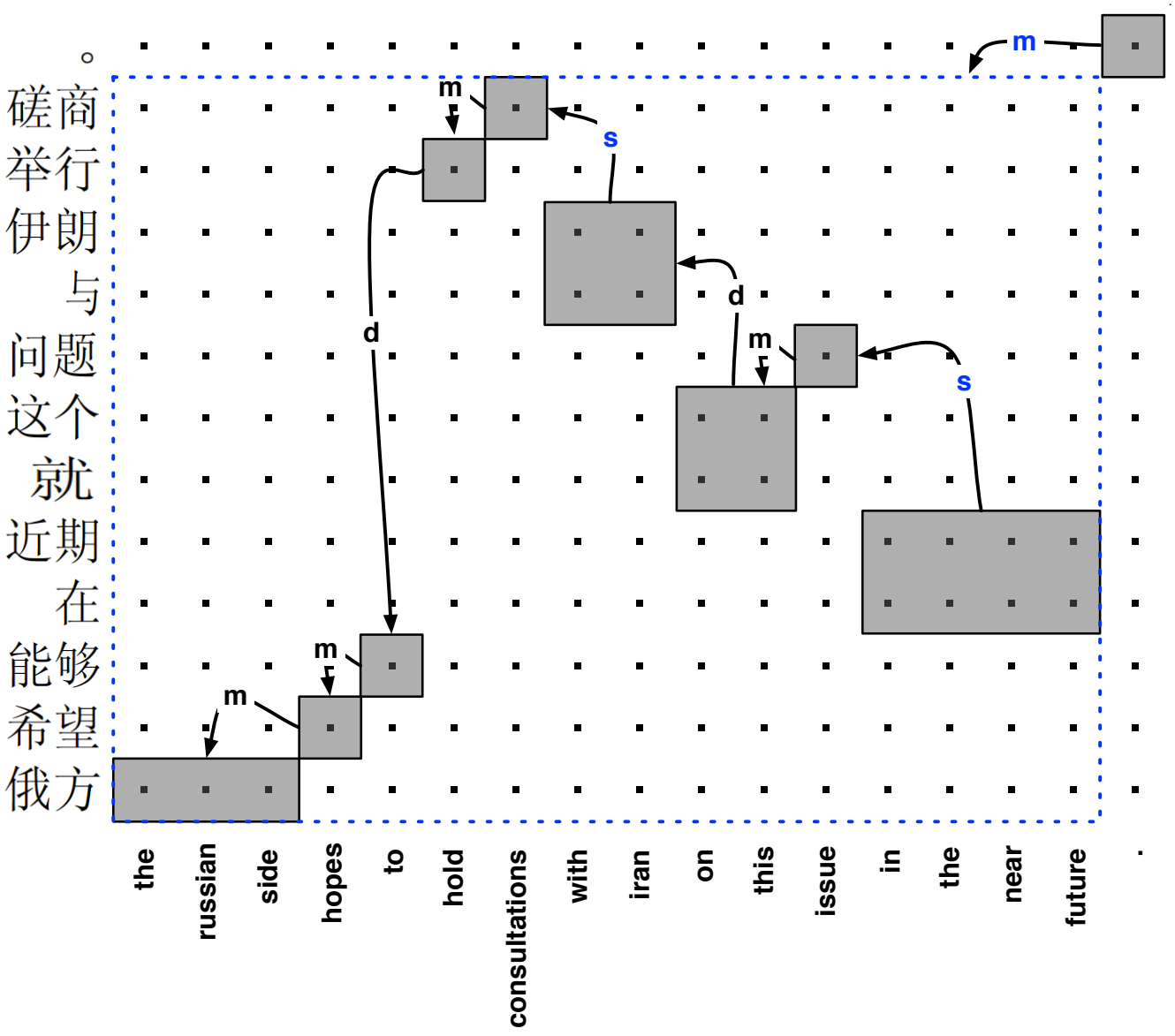
r [1–12]

Hierarchical Reordering: SR-Parsing



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s [2], [1]
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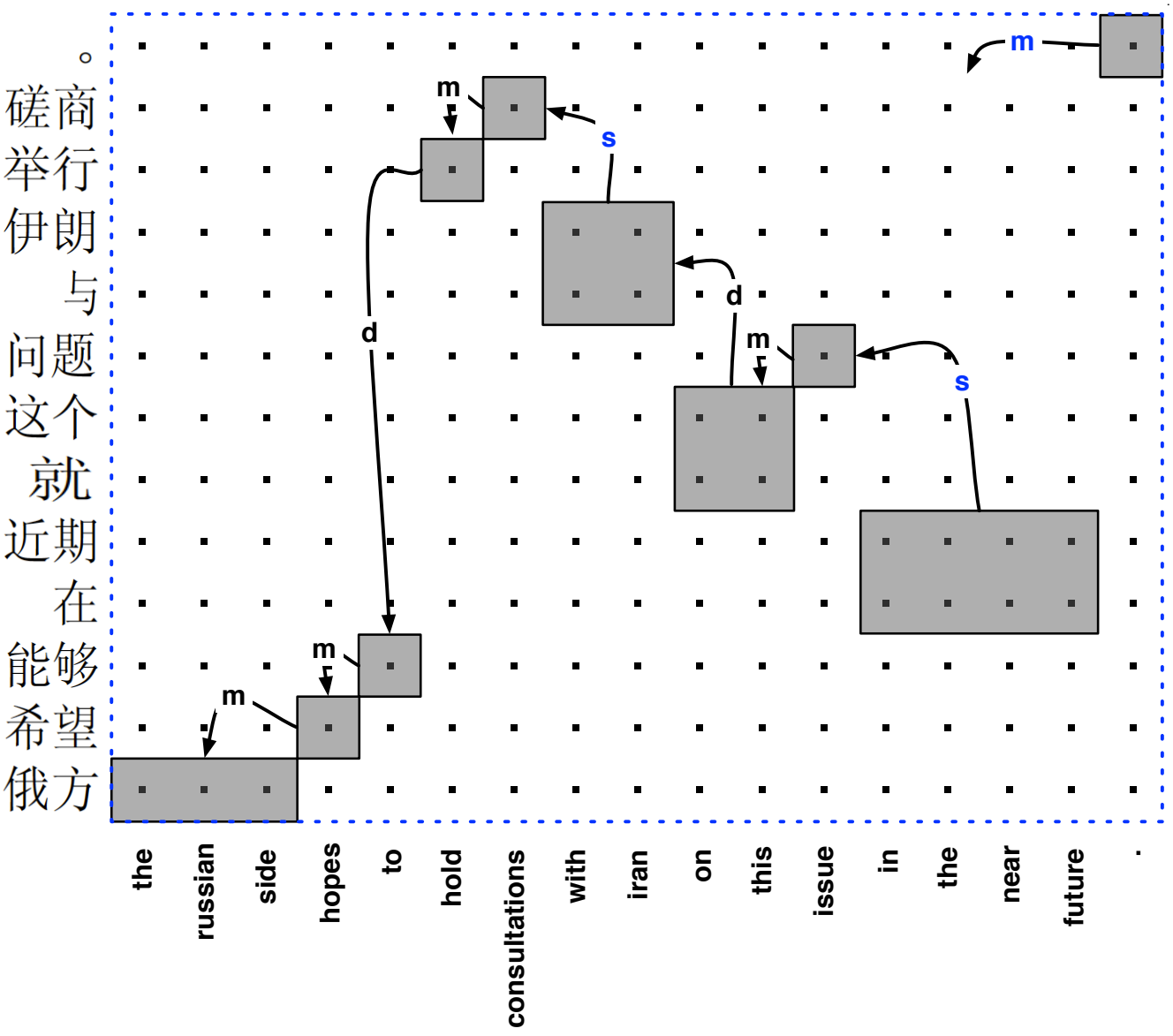
s [13], [1–12]

Hierarchical Reordering: SR-Parsing



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s [8], [6–7], [9–12], [1–3]
r [6–8], [9–12], [1–3]
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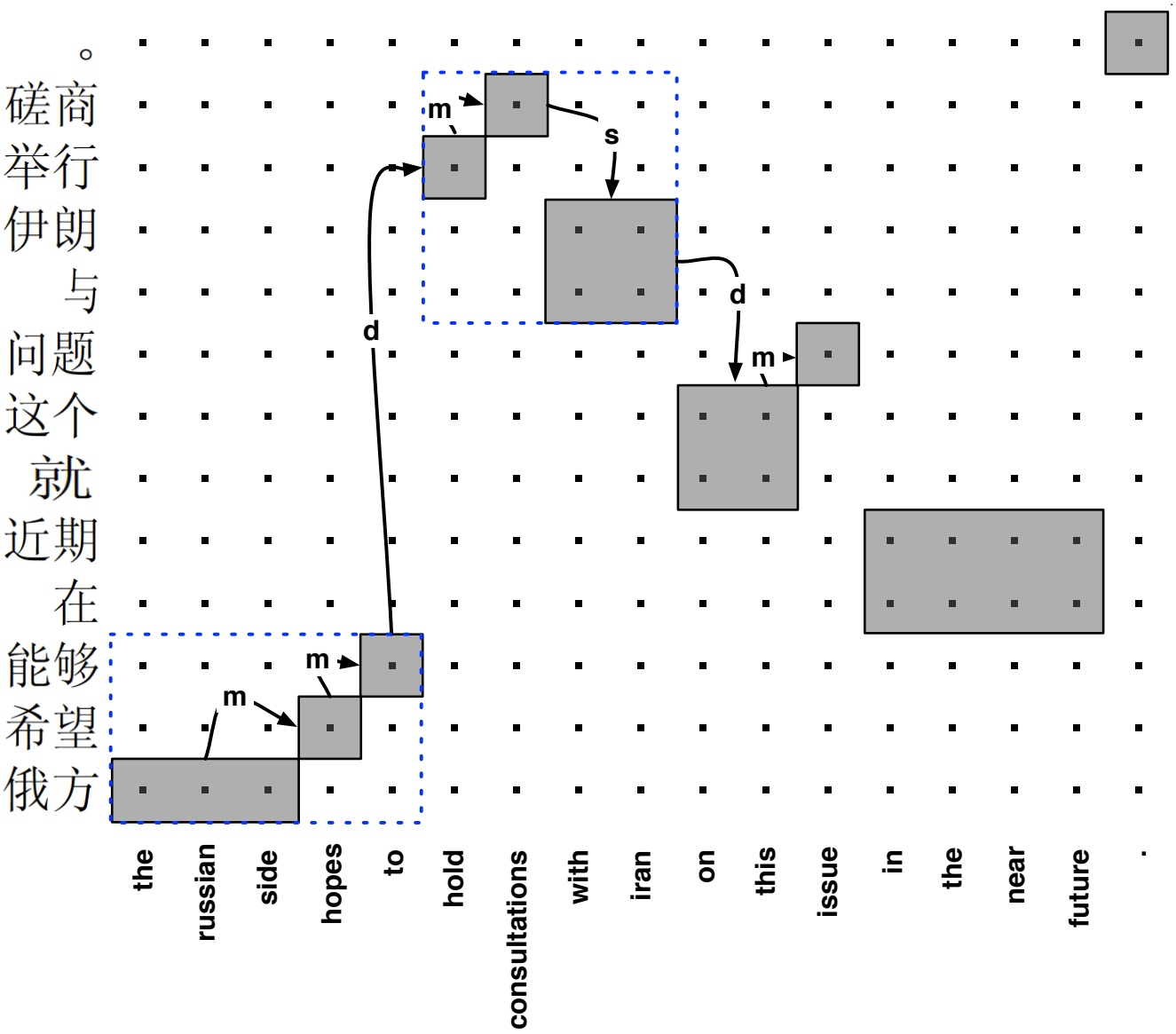
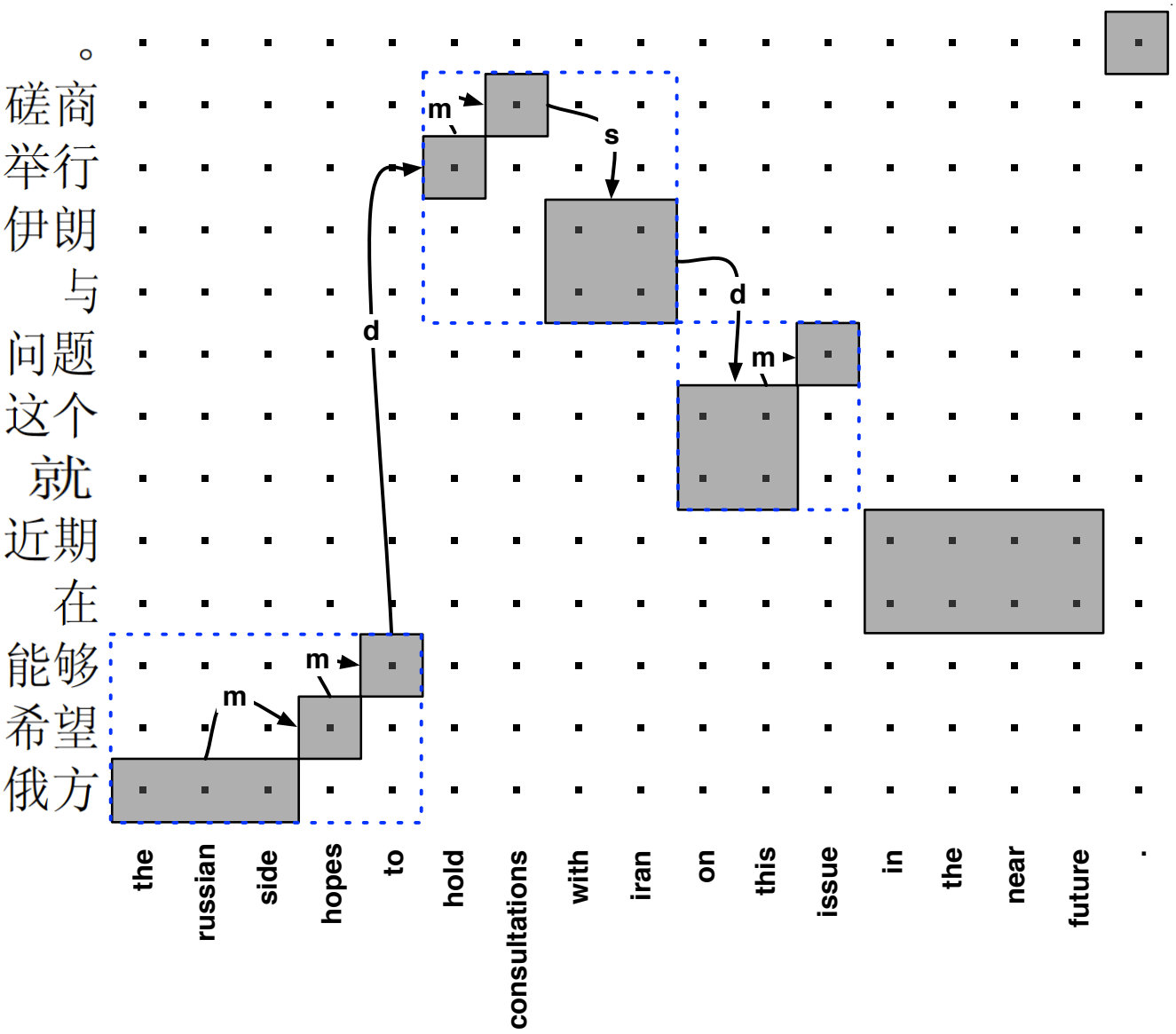
s [4–5], [6–12], [1–3]
r [4–12], [1–3]
r [1–12]
s [13], [1–12]
r [1–13]

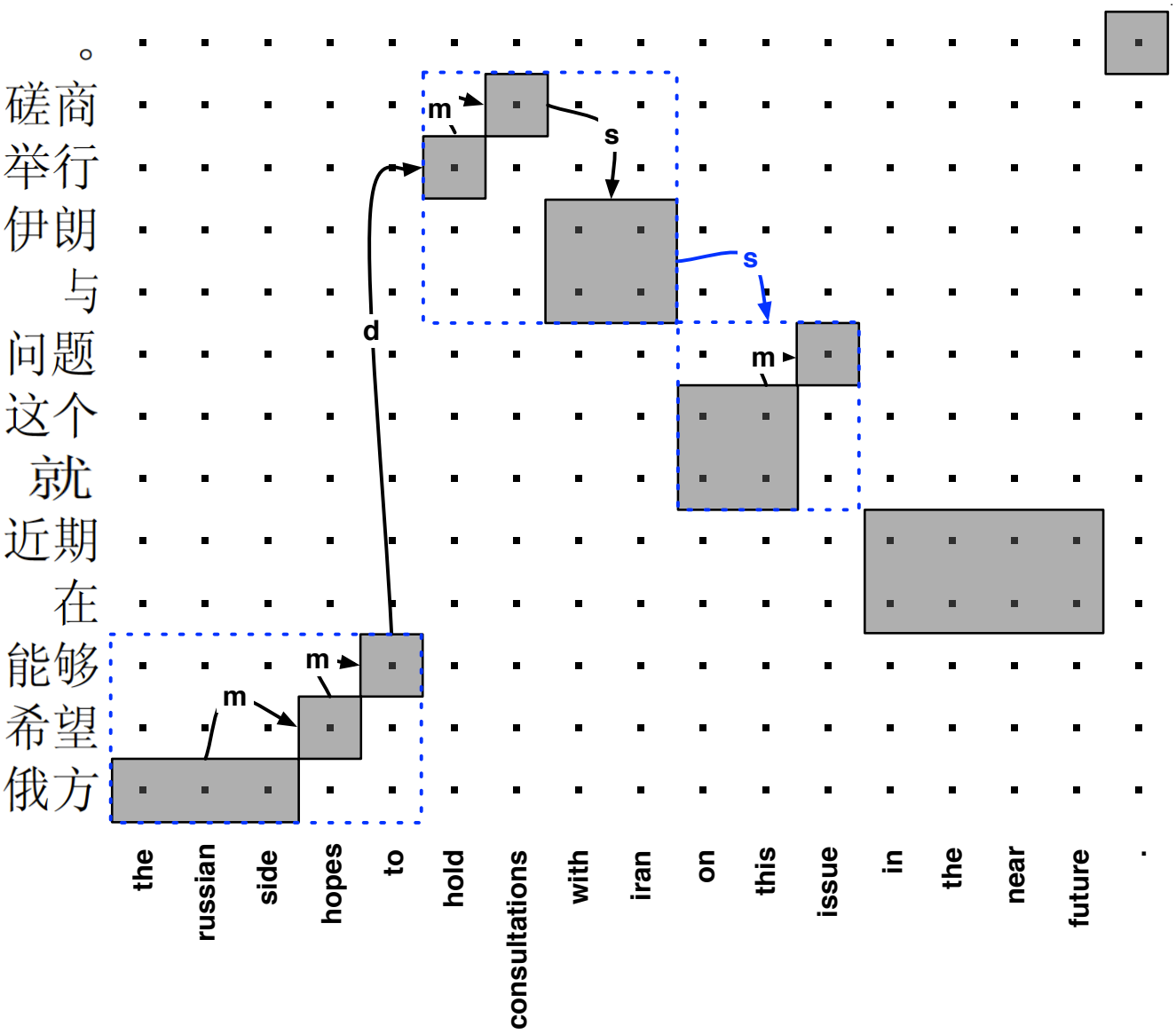
Hierarchical Reordering: Left-to-Right



Hierarchical Reordering: Left-to-Right



Hierarchical Reordering: Left-to-Right



Hierarchical Reordering: Left-to-Right

- Estimation of left-to-right orientations is difficult as we don't know how future phrases applications can be grouped into larger hierarchical phrases
- Left-to-right orientations are approximated
  - Future (block) orientations that are impossible are ignored
  - The remaining orientations are used in the following order of preference:
    - monotone
    - swap
    - discontinuous

Estimation of HRMs

- HRM orientation estimation is achieved similarly to LRM orientation estimation
- For each sentence in the word-aligned parallel corpus we extract two sets of phrase
  - (PP_n): Phrases of maximum length n, which are the phrases that are used during decoding
  - (PP_∞): Phrases of maximum length ∞, which are the phrases wrt which we compute the orientations of the phrases in (PP_n)
- For each phrase pair $(\bar{f}, \bar{e}) \in PP_n$: $c_{r \to l}(o, (\bar{f}, \bar{e})) + +$
  - if **o=m** and $\exists (\bar{f}', \bar{e}') \in PP_\infty : \text{right}(\bar{e}') = \text{left}(\bar{e}) - 1 \wedge \text{right}(\bar{f}') = \text{left}(\bar{f}) - 1$
  - else if **o=s** and $\exists (\bar{f}', \bar{e}') \in PP_\infty : \text{right}(\bar{e}') = \text{left}(\bar{e}) - 1 \wedge \text{left}(\bar{f}') = \text{right}(\bar{f}) + 1$
  - else if **o=d** and $\exists (\bar{f}', \bar{e}') \in PP_\infty : \text{right}(\bar{e}') = \text{left}(\bar{e}) - 1$
- $c_{l \to r}(o, (\bar{f}, \bar{e})) + +$ is estimated analogously

ITG Constraints

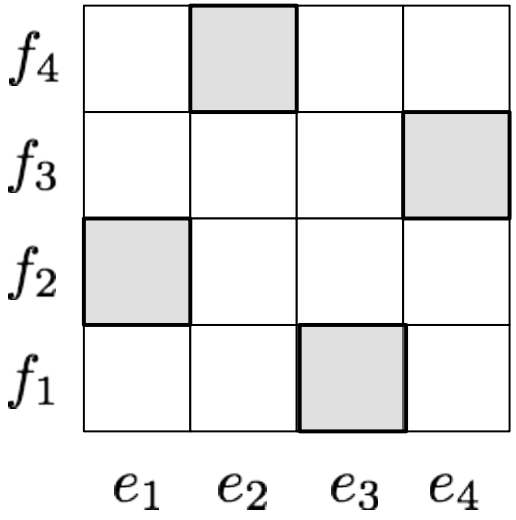
- Inversion Transduction Grammar (ITG) constraints date back to automata theory
- Given a foreign sentence f and a derivation d that yields a translation e of f, we say that derivation d does violate the ITG constraints if d can be rewritten as f: $d \rightarrow_R^* f$ using a rewrite rules of the form
  - $\bar{e} \rightarrow \text{trans}(\bar{e})$
  - $f_1 f_2 \rightarrow f_1 \oplus f_2$
  - $f_1 f_2 \rightarrow f_2 \oplus f_1$
- It is argued that translations should not violate ITG constraints

ITG Constraints

- The shift operation puts one element on the top of the stack
- The reduce operation reduces the top two elements of the stack to one element
  - This can be generalized to n-reduction where the top m $(m \leq n)$ elements can be reduced
  - 2-reduction most commonly used
  - The bigger n the more computations required

ITG Constraints

- Consider the following derivation:



- What n-reduction is required for the decoder to be able to generate this derivation?
- Hierarchical reordering can still produce translations violating ITG constraints
  - Final resulting stack will not be of the form $[0-J-1]$ where J is the length of the foreign sentence

ITG Constraints

- We would like to be able to identify ITG violations as early as possible during decoding
- The approach of Zens et al. (2004) uses the coverage vector
- Let $\bar{f}_i^j$ and $\bar{f}_k^l$ be the previously and currently translated foreign phrases. ITG constraints are violated if
  - $j < k$ and $\exists n : j < n < k-1$ where $\text{cov}(n) = 0$ and $\text{cov}(n+1) = 1$
  - $l < i$ and $\exists n : l < n < i-1$ where $\text{cov}(n) = 1$ and $\text{cov}(n+1) = 0$

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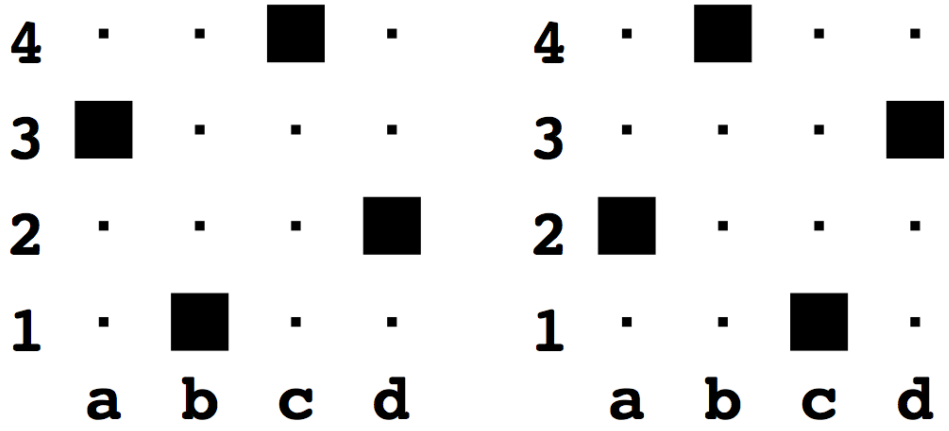
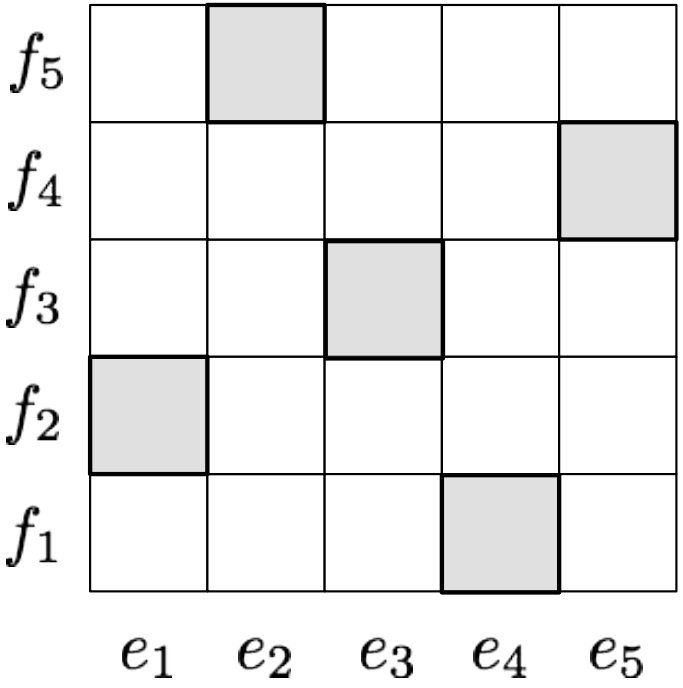


ITG Constraints

- The coverage vector based approach to ITG violation detection does work correctly for ITG violations involving 4 phrases, but misses higher-order violations



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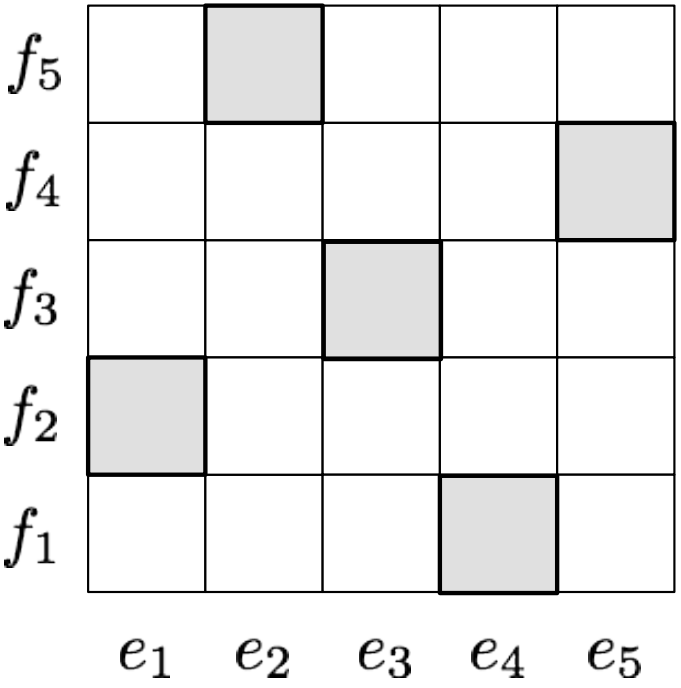
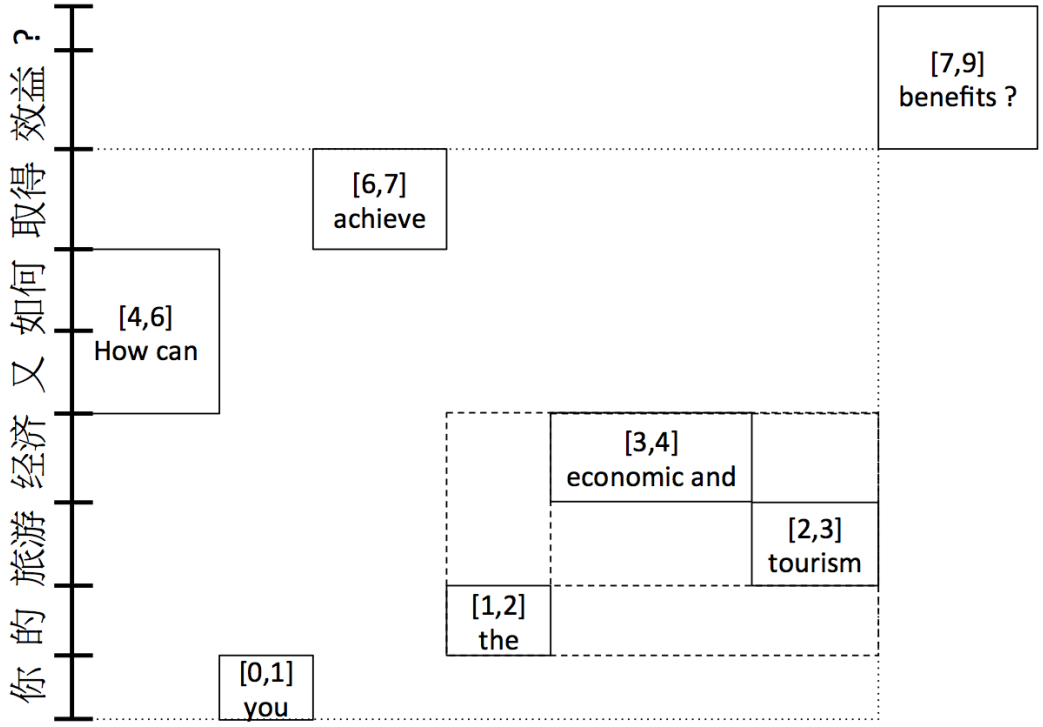


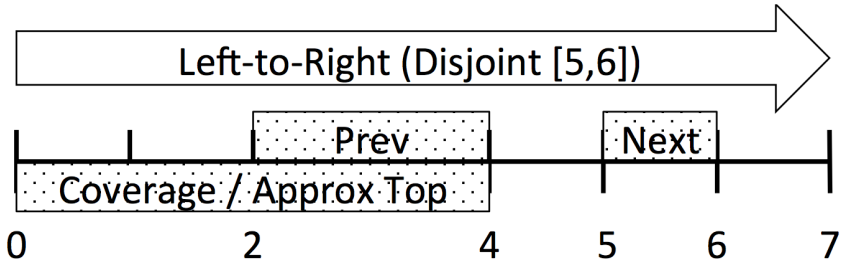


Hierarchical Reordering without Stacks

- Maintaining a stack for each hypothesis and performing shift-reduce parsing further burdens the decoder
- Cherry et al. (2012) proposed an approximation of hierarchical reordering without stacks and shift-reduce parsing
- Reordering orientations are computed with respect to the top element of the stack
  - The top element is a previously shifted element
  - or the result of multiple reduce steps
- The 'true' top element $[i-j]$ can be approximated as the sub-span $[k-l]$ of the coverage vector s.t.
  - for the previously translated foreign phrase $\bar{f}_m^n$: $k \leq m \leq n \leq l$
  - for each n, s.t. $k \leq n \leq l$: $\text{cov}(n) = 1$
  - $k = 0$ or $\text{cov}(k-1) = 0$ and $l = J$ or $\text{cov}(l+1) = 0$ ($J =$ length of foreign sentence -1)
- Most of the times: $k = i$ and $l = j$

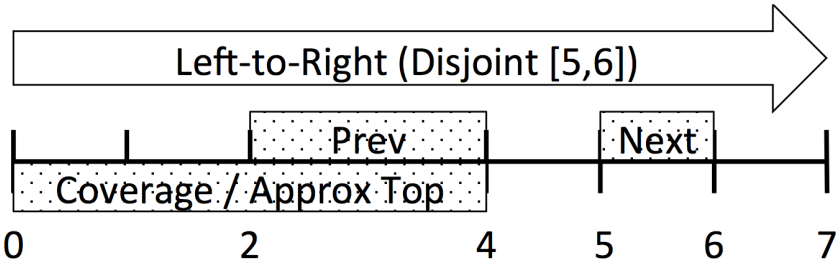
Hierarchical Reordering without Stacks

- Example for right-to-left orientations:

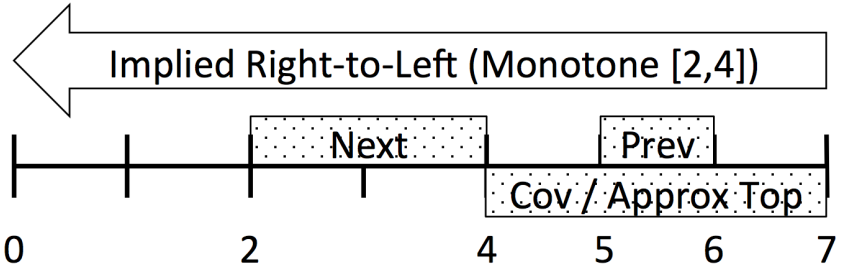


Hierarchical Reordering without Stacks

- Example for right-to-left orientations:



- We can also approximate the left-to-right orientations where the 'true' top element $[i-j]$ can be approximated as the sub-span $[k-l]$ of the coverage vector s.t.
  - for the currently translated foreign phrase $\bar{f}_m^n$: $k \leq m \leq n \leq l$
  - for each s, s.t. $k \leq s < m$ or $n < s \leq l$: $\mathrm{cov}(n) = 0$
  - $k = 0$ or $\mathrm{cov}(k-1) = 1$ and $l = J$ or $\mathrm{cov}(l+1) = 1$
- Example for left-to-right orientations:



Impact of ITG Violations

- Experimental results from Cherry et al. (2012)

	BLEU			NIST 08 Complexity Counts						Speed
Method	nist04	nist06	nist08	> 2	4	5	6	7	≥ 8	sec/sent
LRM	38.00	33.79	27.12	241	146	40	32	12	11	3.187
HRM 2-red	38.53	34.20	27.57	176	113	31	20	8	4	3.353
HRM apprx	38.58	34.09	27.60	280	198	41	26	13	2	3.231
HRM *-red	38.39	34.22	27.41	328	189	71	34	20	14	3.585
HRM itg	38.70	34.26	27.33	0	0	0	0	0	0	3.274

- HRM 2-red (Galley and Manning, 2008) operates as a soft ITG constraint (leading to fewer ITG violations)
- Overall weak correlation between MT quality (as measured by BLEU) and number of ITG violations

Recap

- Distortion limit and distortion constraints
  - linear distortion limit
  - IBM constraints
- Lexicalized reordering modeling
  - Orientation probabilities
  - Estimation of orientation probabilities
- Hierarchical Reordering modeling
  - Shift-Reduce parsing with stacks
  - ITG constraints
  - Approximated HRMs using coverage vectors