Machine Translation: Searching for Good Translations

Introduction to Natural Language Processing
Computer Science 585—Fall 2009
University of Massachusetts Amherst

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Search

What's the best translation
(under our model)?

Search

- Even if we know the right words in a translation, there are *n*! permutations.

$10! = 3{,}626{,}800$ $20! \approx 2.43 \times 10^{18}$ $30! \approx 2.65 \times 10^{32}$

- We want the translation that gets the highest score under our model
  - Or the best *k* translations
  - Or a random sample from the model's distribution
- But **not** in *n*! time!

Search in Phrase Models

Deshalb haben wir allen Grund , die Umwelt in die Agrarpolitik zu integrieren

Translate in target language order to ease language modeling.

Search in Phrase Models

Deshalb haben wir allen Grund , die Umwelt in die Agrarpolitik zu integrieren

That is why we have

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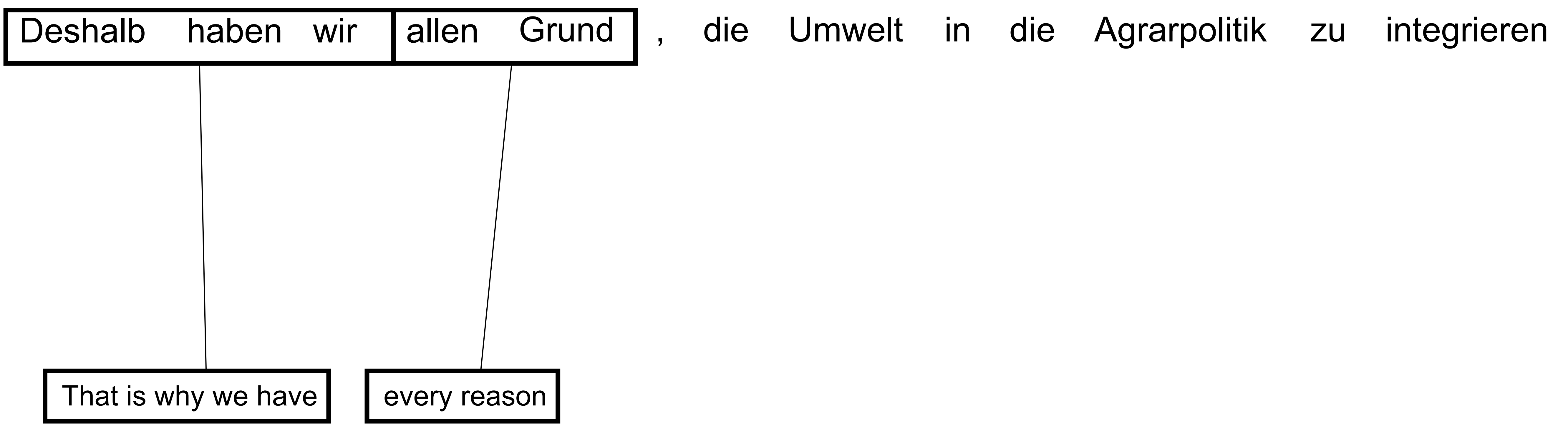

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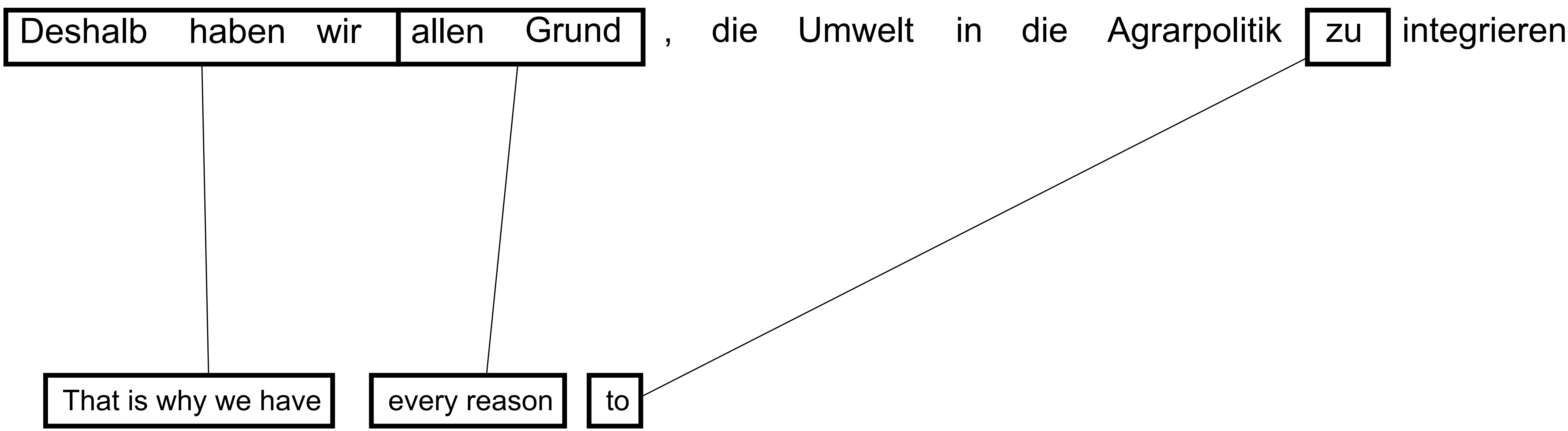

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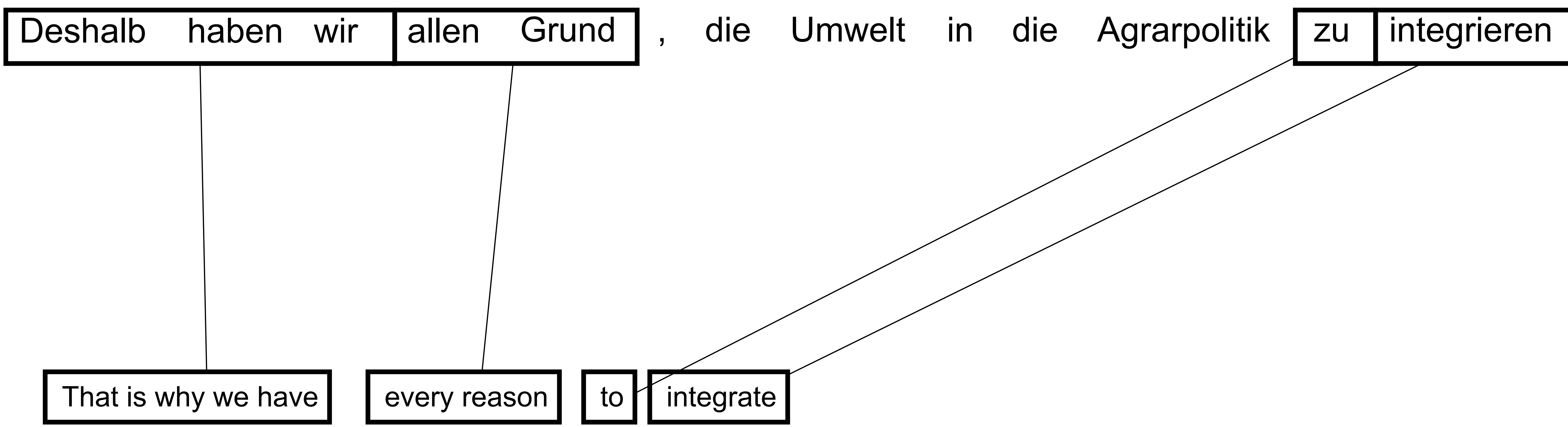

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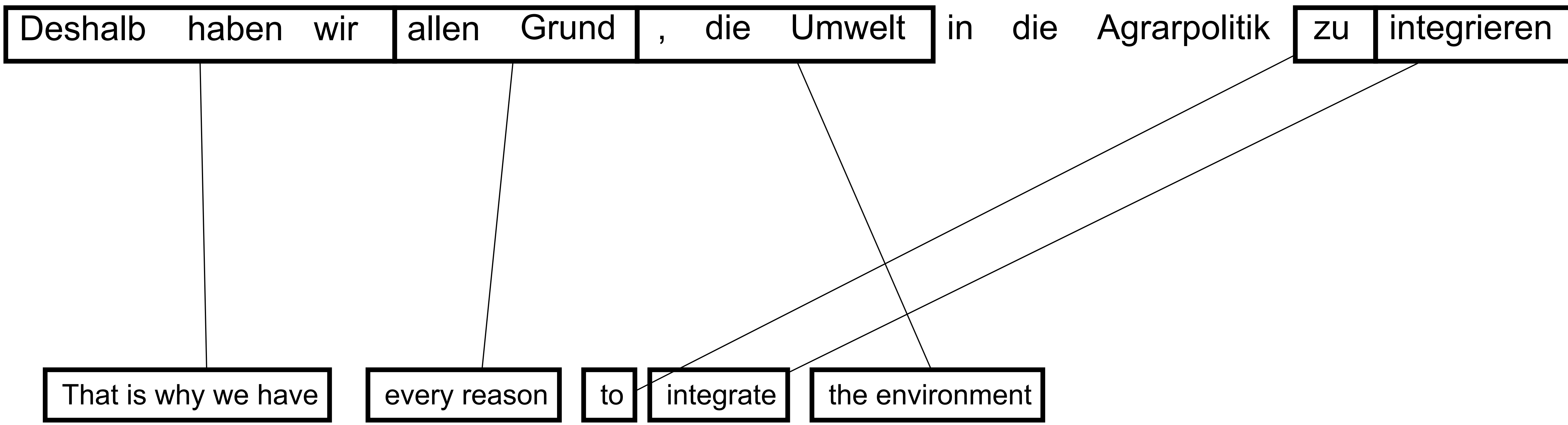

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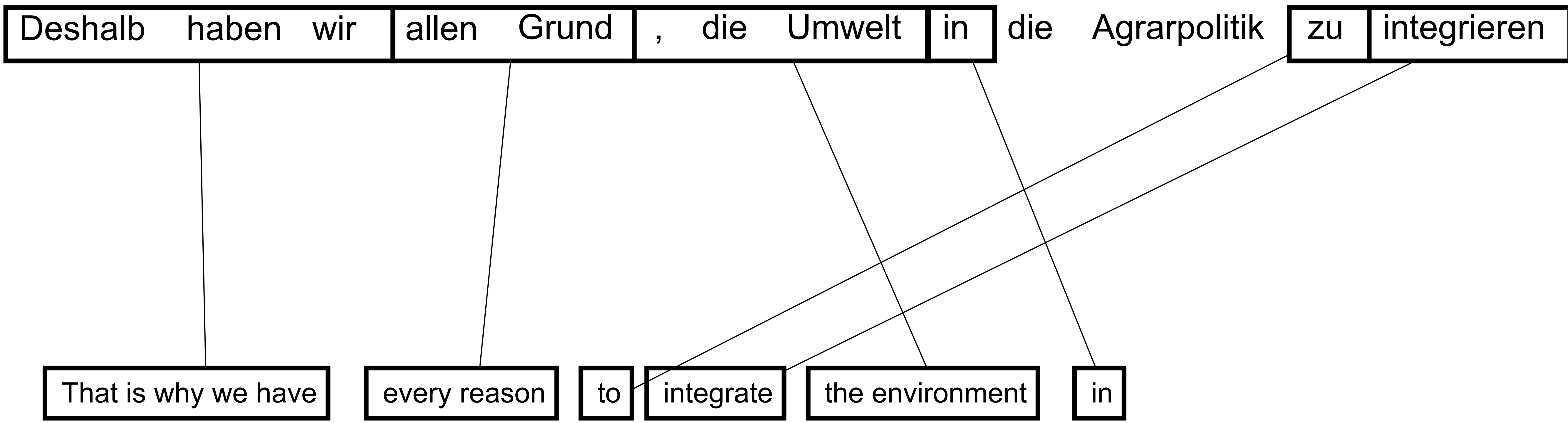

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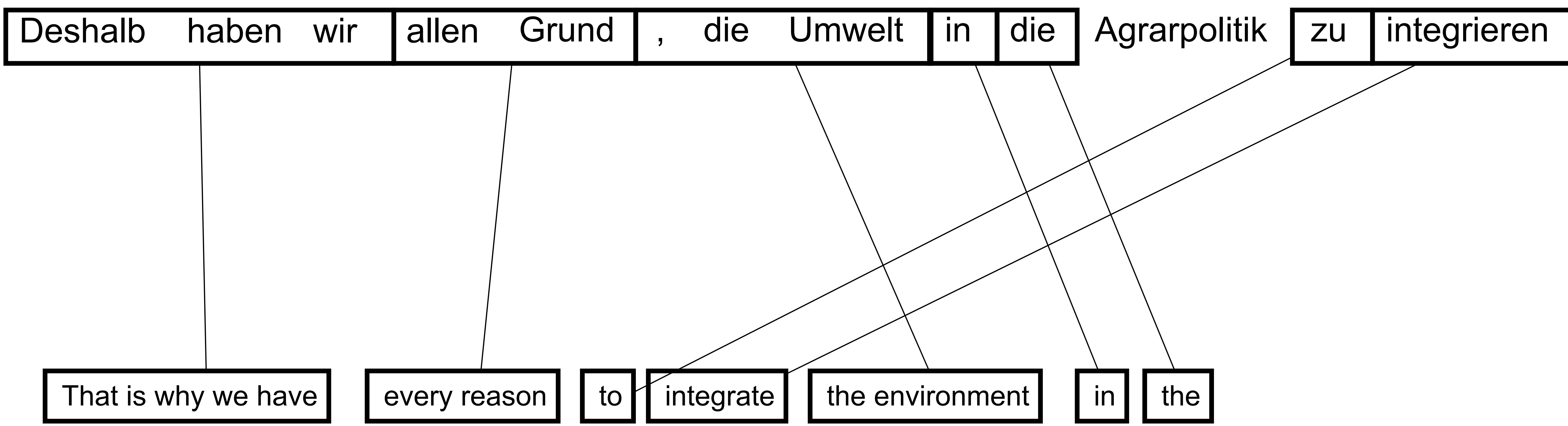

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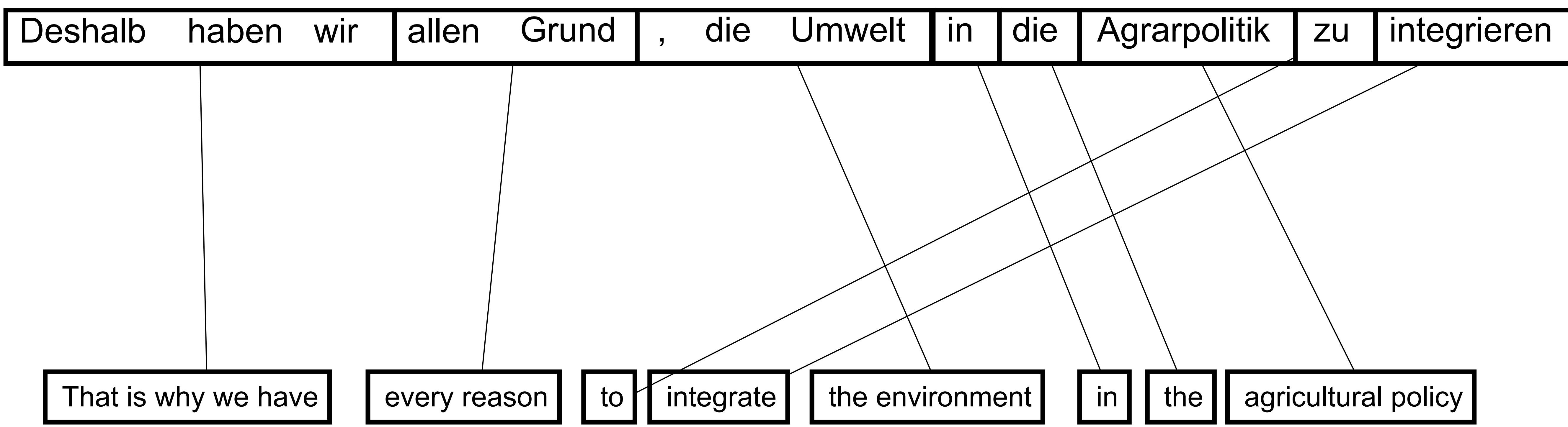

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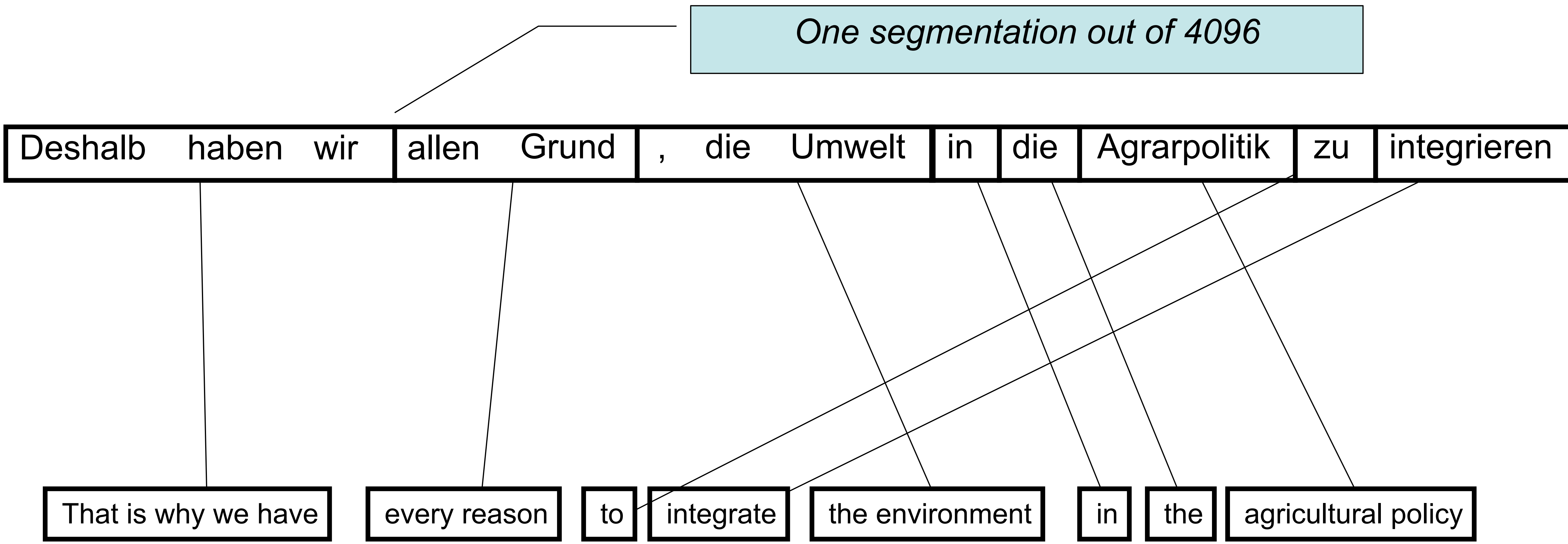

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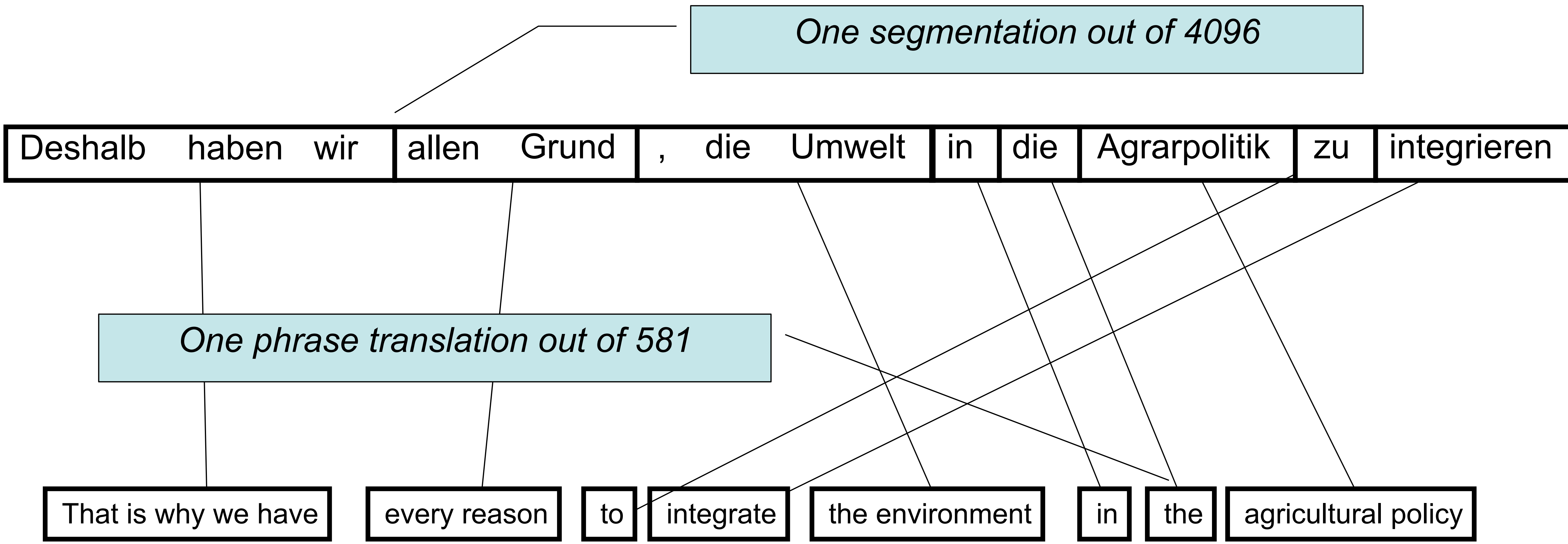

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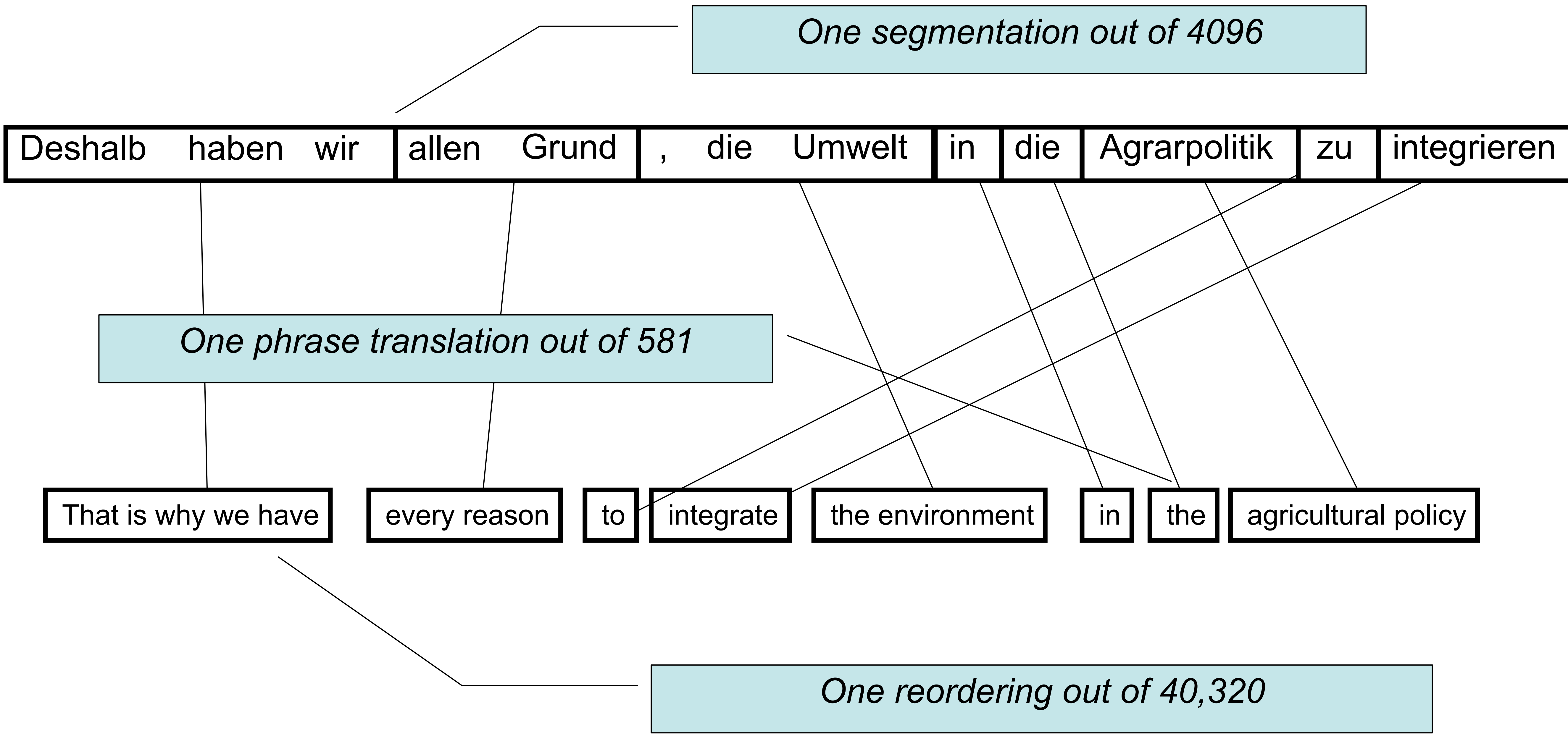

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And many, many more…even before reordering

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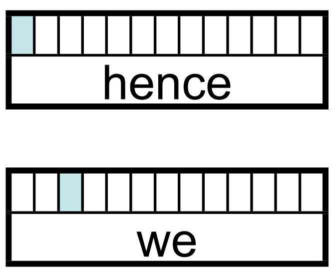

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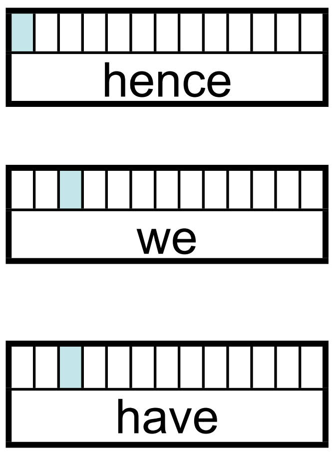

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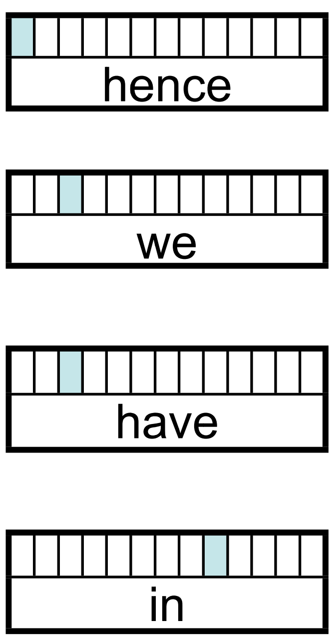

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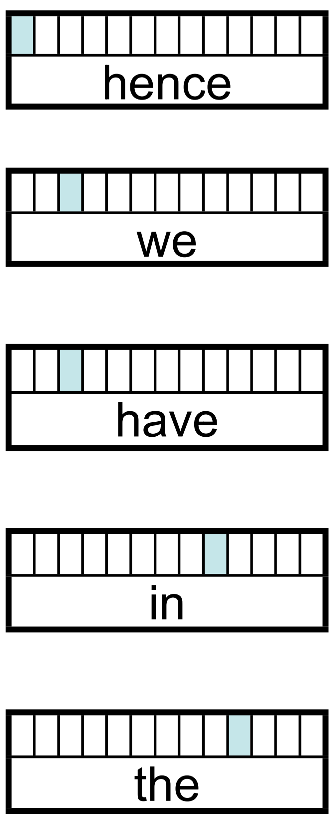

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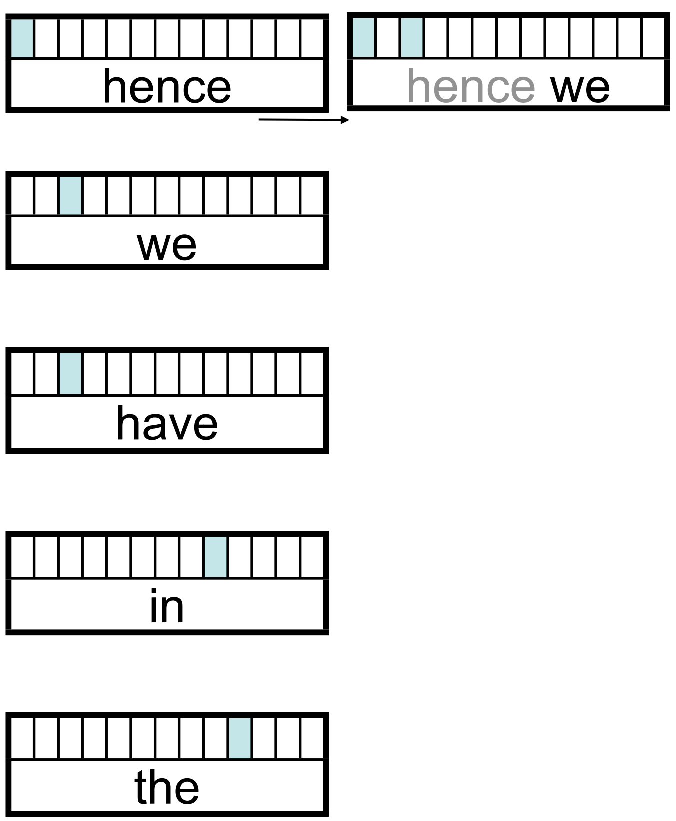

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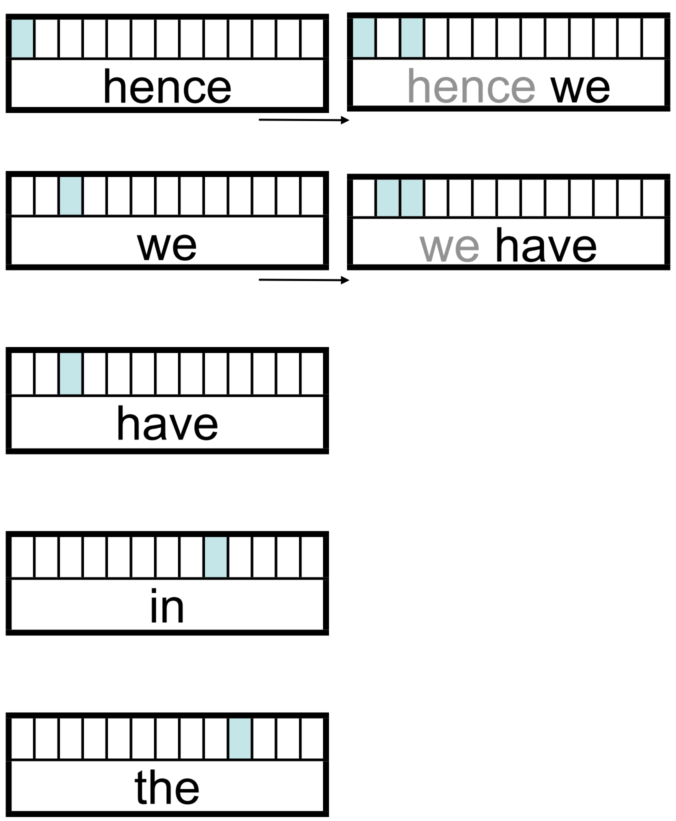

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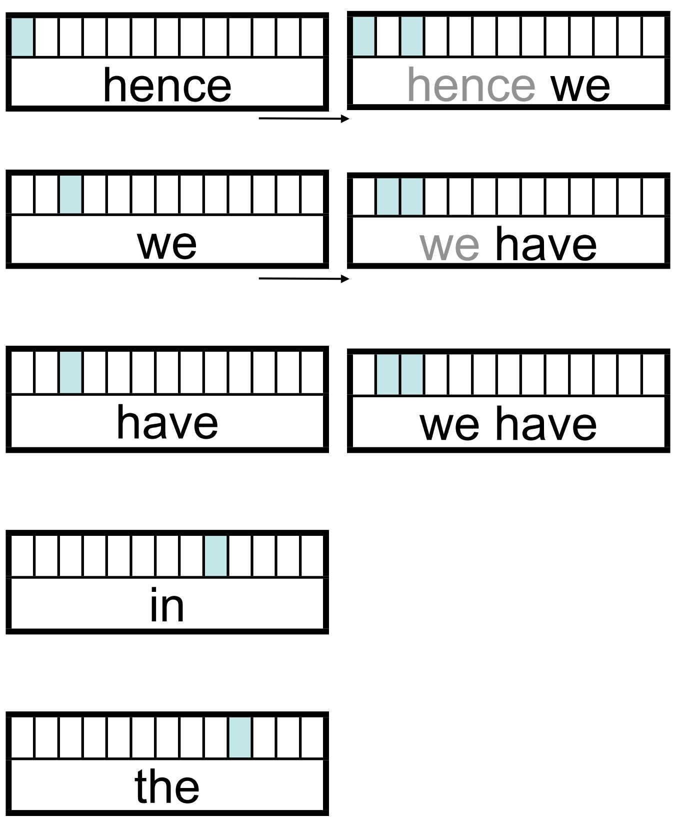

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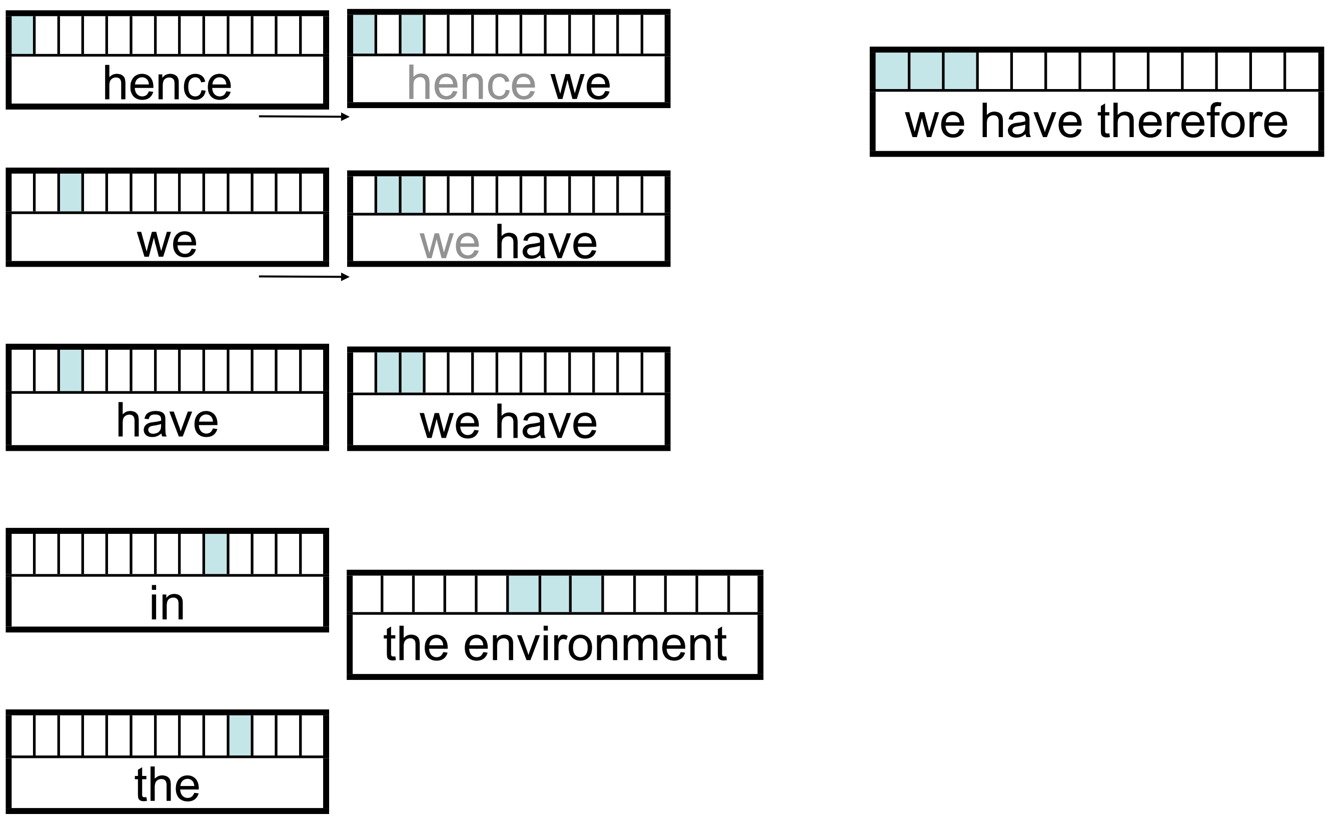

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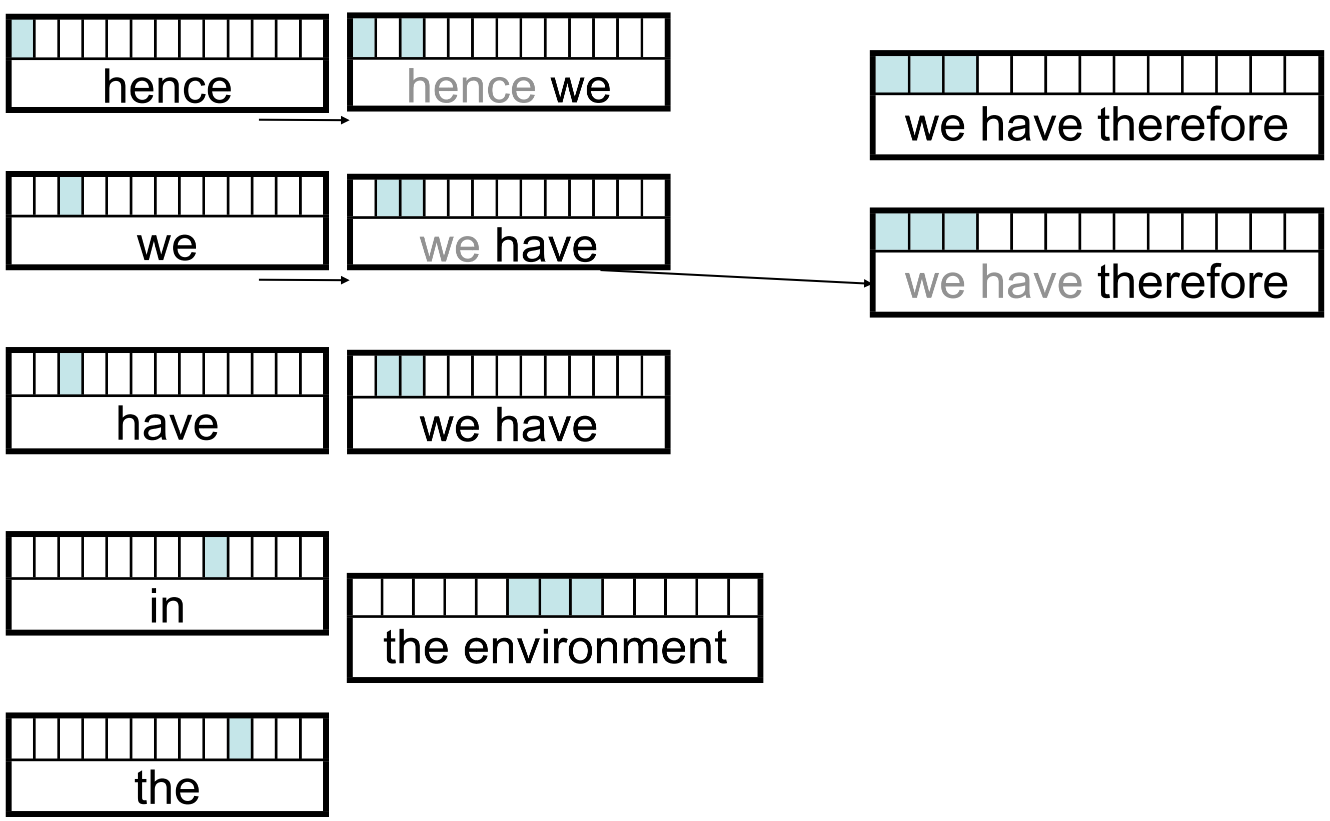

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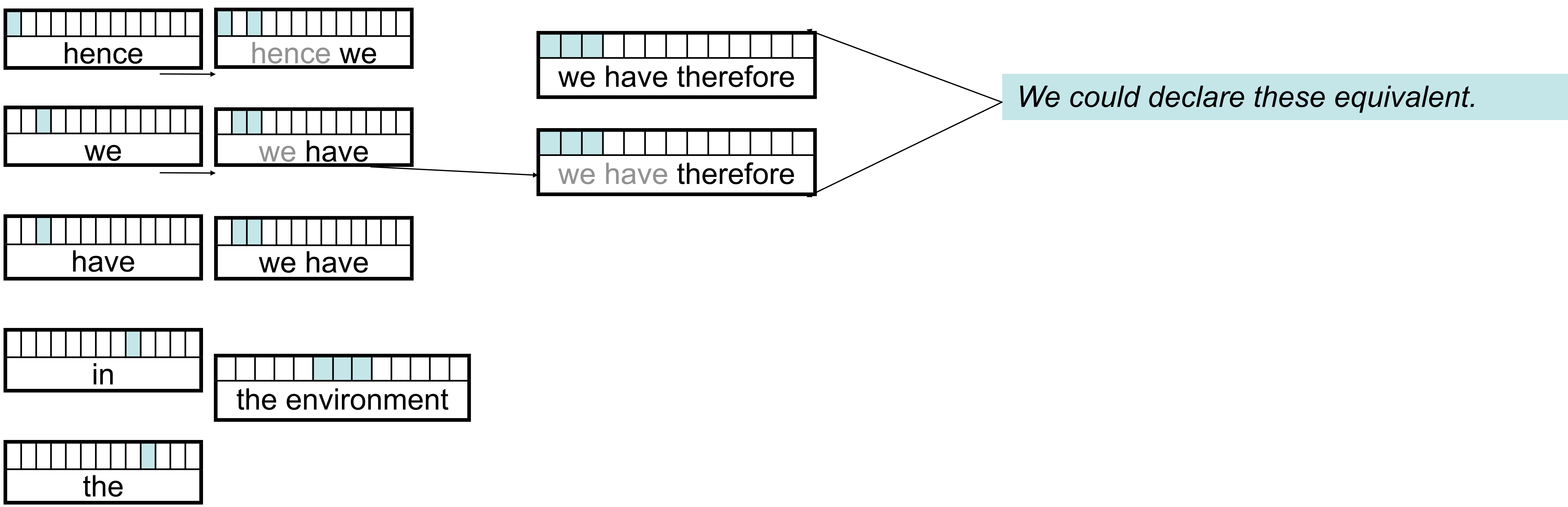

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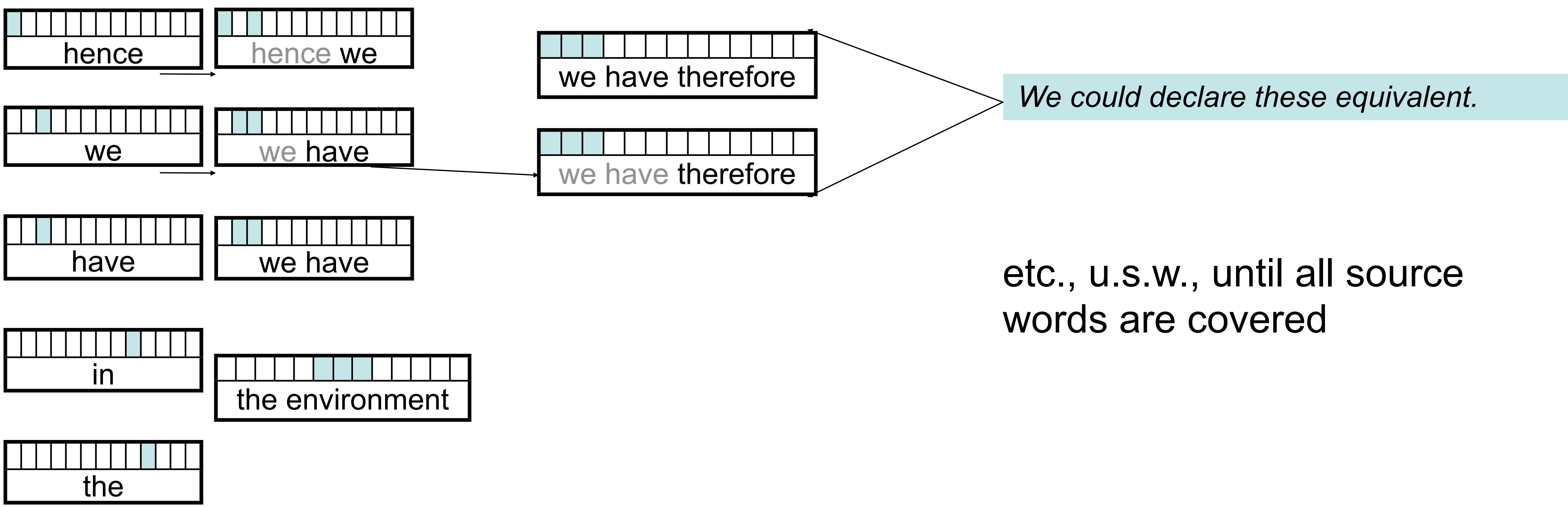


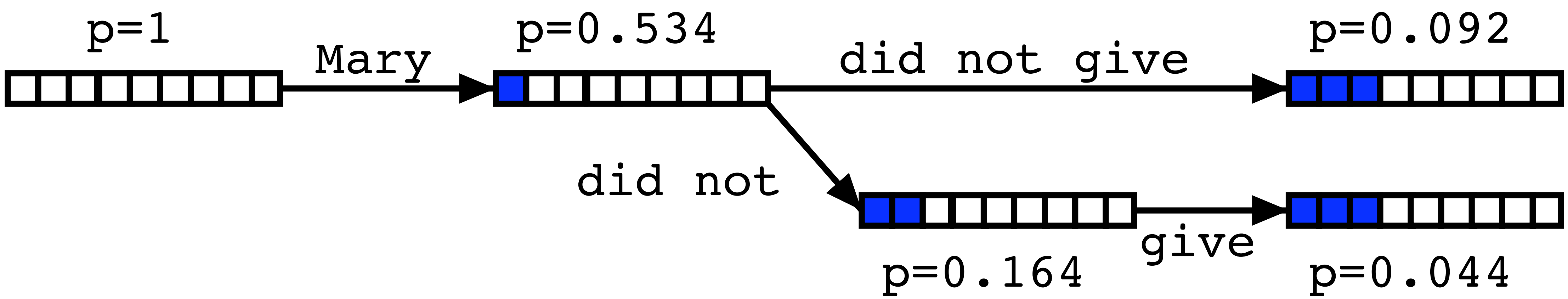
etc., u.s.w., until all source words are covered

Search in Phrase Models

- Many ways of segmenting source
- Many ways of translating each segment
- *Restrict* model class: phrases >, e.g., 7 words, no long-distance reordering
- *Recombine* equivalent hypotheses
- *Prune* away unpromising partial translations or we'll run out of space and/or run too long
  - How to compare partial translations?
  - Some start with easy stuff: "in", "das", ...
  - Some with hard stuff: "Agrarpolitik", "Entscheidungsproblem", …

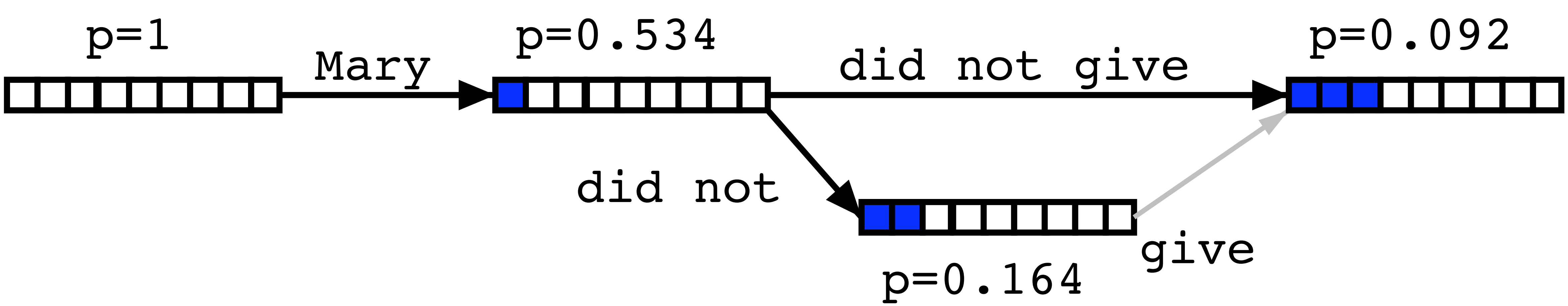
Hypothesis Recombination

- Different paths to the same partial translation



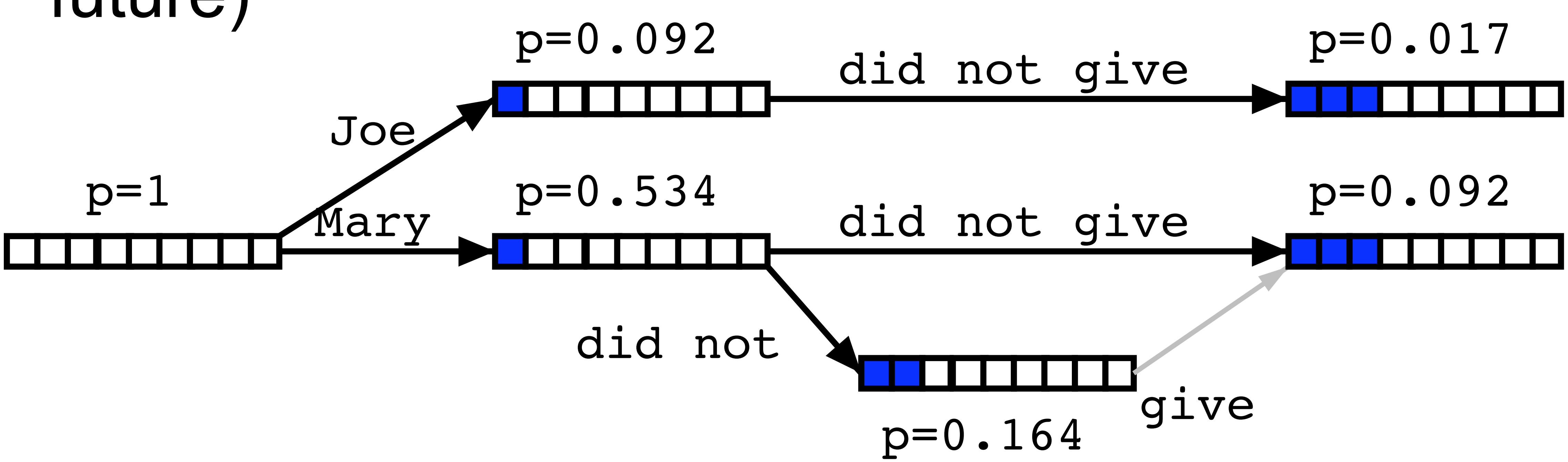
Hypothesis Recombination

- Different paths to the same partial translation
- Combine paths
  - –Drop weaker path
  - –Keep backpointer to weaker path (for lattice or n-best generation)



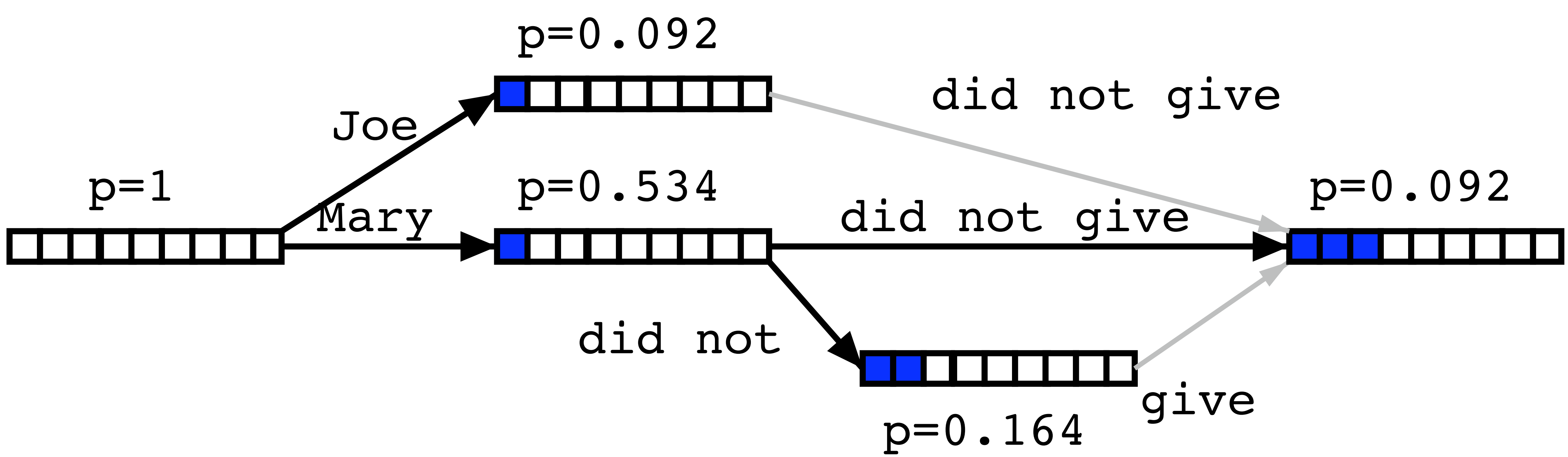
Hypothesis Recombination

- Recombined hypotheses do not have to match completely
- Weaker path can be dropped if
  - –Last n target words match (for n+1-gram lang. model)
  - –Source coverage vectors match (same best future)



Hypothesis Recombination

- Combining partially matching hypotheses



Pruning

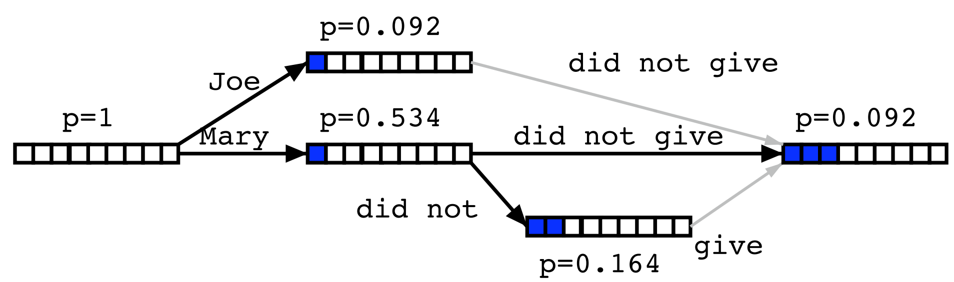
- Hypothesis recombination is *not su cient*

  Heuristically *discard* weak hypotheses early

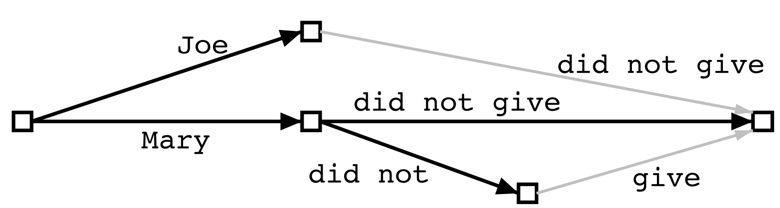
- Organize Hypothesis in **stacks**, e.g. by
  - *same* foreign words covered
  - *same number* of foreign words covered
  - *same number* of English words produced

- Compare hypotheses in stacks, discard bad ones
  - **histogram pruning**: keep top n hypotheses in each stack (e.g., $n = 100$)
  - **threshold pruning**: keep hypotheses that are at most times the cost of best hypothesis in stack (e.g., $= 0.001$)

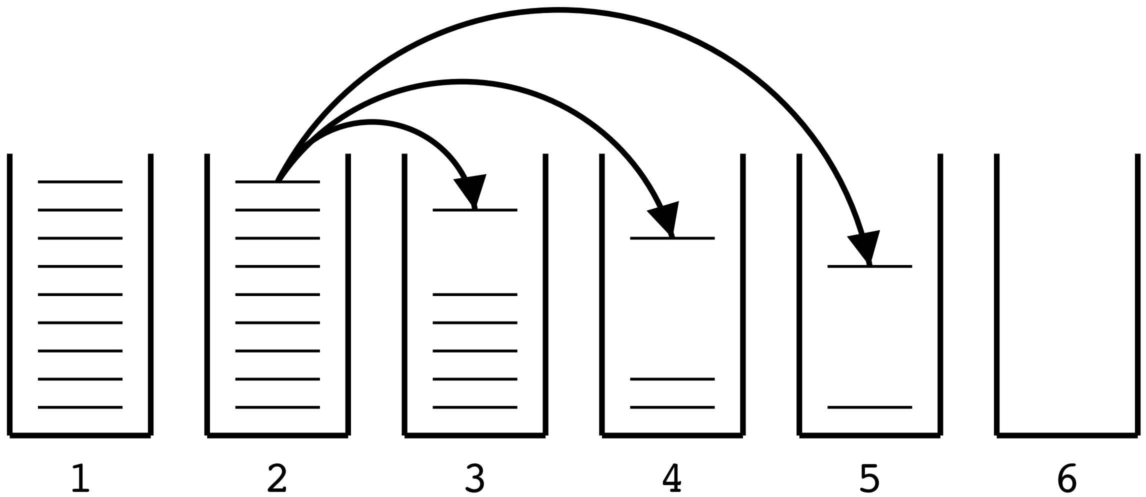
Word Lattice Generation



- **Search graph** can be easily converted into a **word lattice**
  - can be further mined for **n-best lists**
    enables **reranking** approaches
    enables **discriminative training**



Hypothesis Stacks



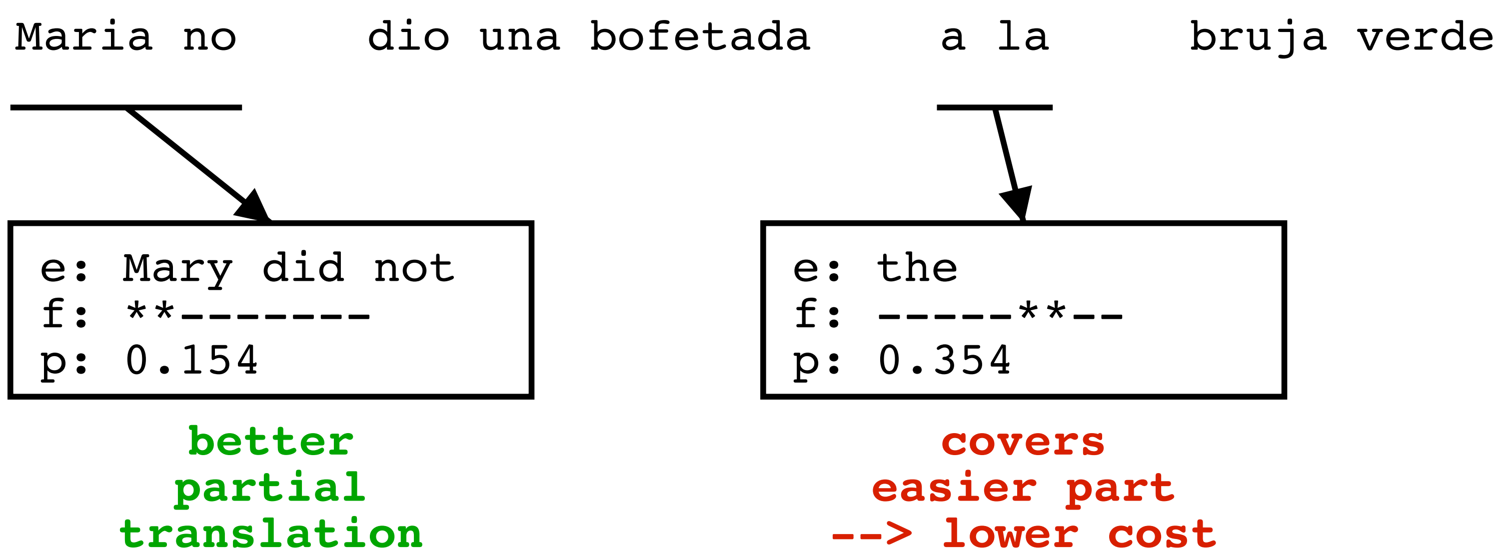
- Organization of hypothesis into stacks
  - here: based on *number of foreign words* translated
  - during translation all hypotheses from one stack are expanded
  - expanded Hypotheses are placed into stacks

Limits on Reordering

- Reordering may be **limited**
  - **Monotone** Translation: No reordering at all
  - Only phrase movements of at most *n* words
- Reordering limits *speed* up search (polynomial instead of exponential)
- Current reordering models are weak, so limits *improve* translation quality

Comparing Hypotheses

- Comparing hypotheses with *same number of foreign words* covered



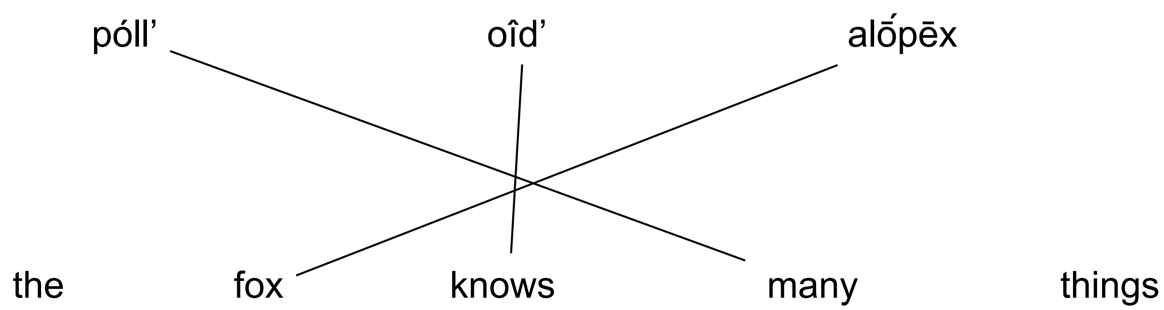
- Hypothesis that covers *easy part* of sentence is preferred

  Need to consider **future cost** of uncovered parts
  or: have one hypothesis stack per coverage vector

Synchronous Grammars

- Just like monolingual grammars except...
  - Each rule involves pairs (tuples) of nonterminals
  - Tuples of elementary trees for TAG, etc.
- First proposed for source-source translation in compilers
- Can be constituency, dependency, lexicalized, etc.
- Parsing speedups for monolingual grammar don't necessarily work
  - E.g., no split-head trick for lexicalized parsing
- Binarization less straightforward

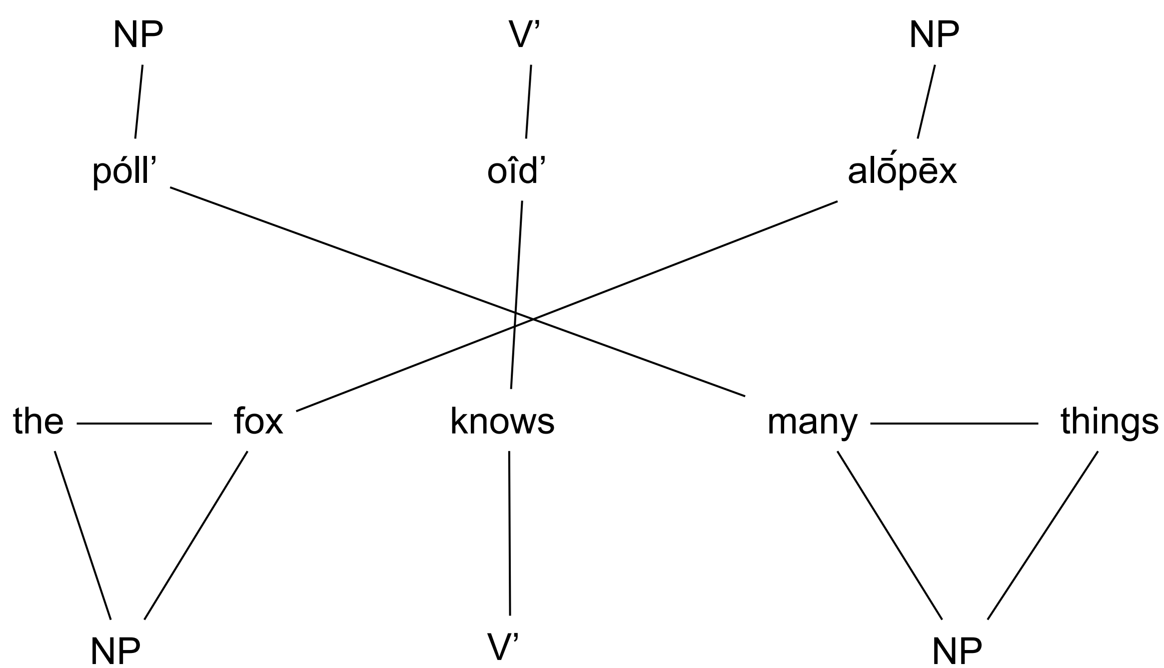
Bilingual Parsing



A variant of CKY chart parsing.

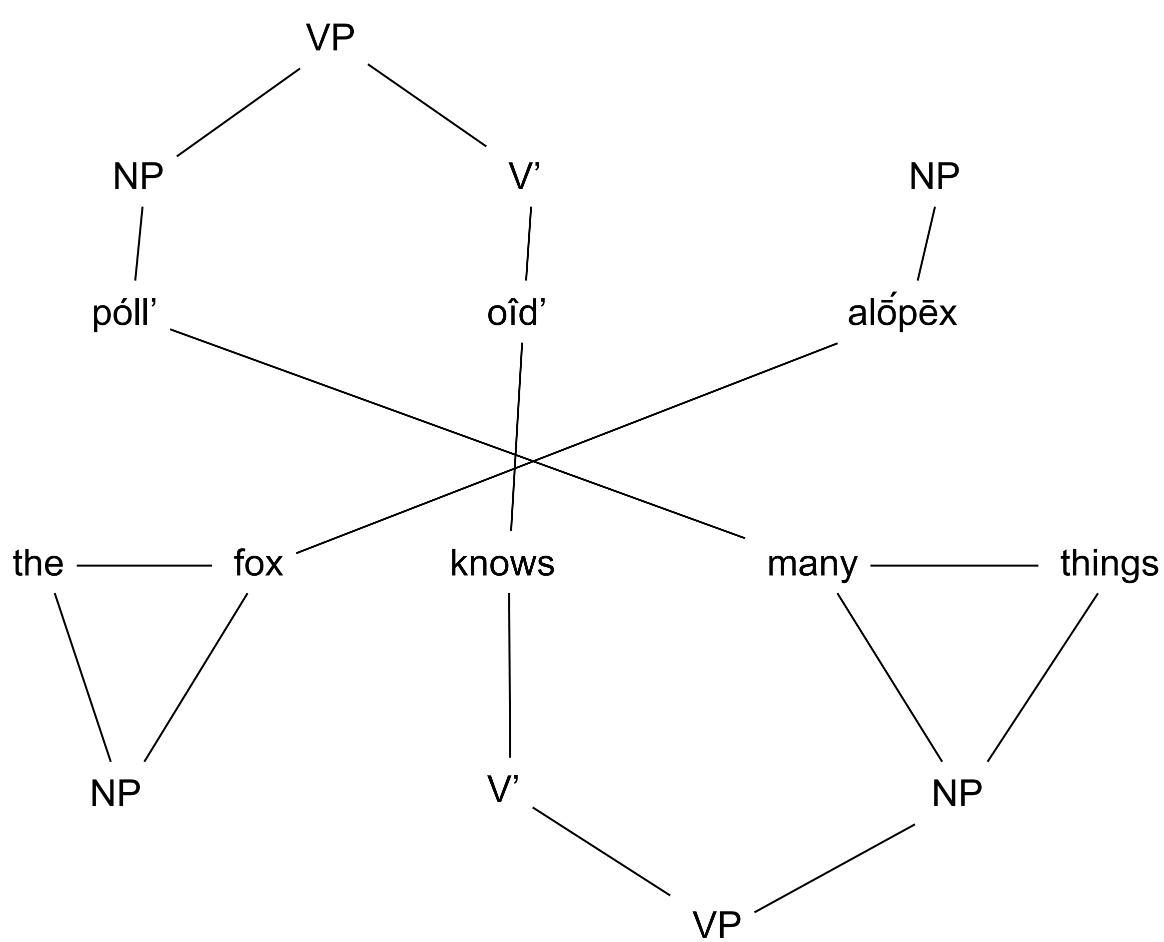
	póll’	oîd’	alṓpēx
the			
fox			NN/NN
knows		VB/VB	
many	JJ/JJ		
things			

Bilingual Parsing



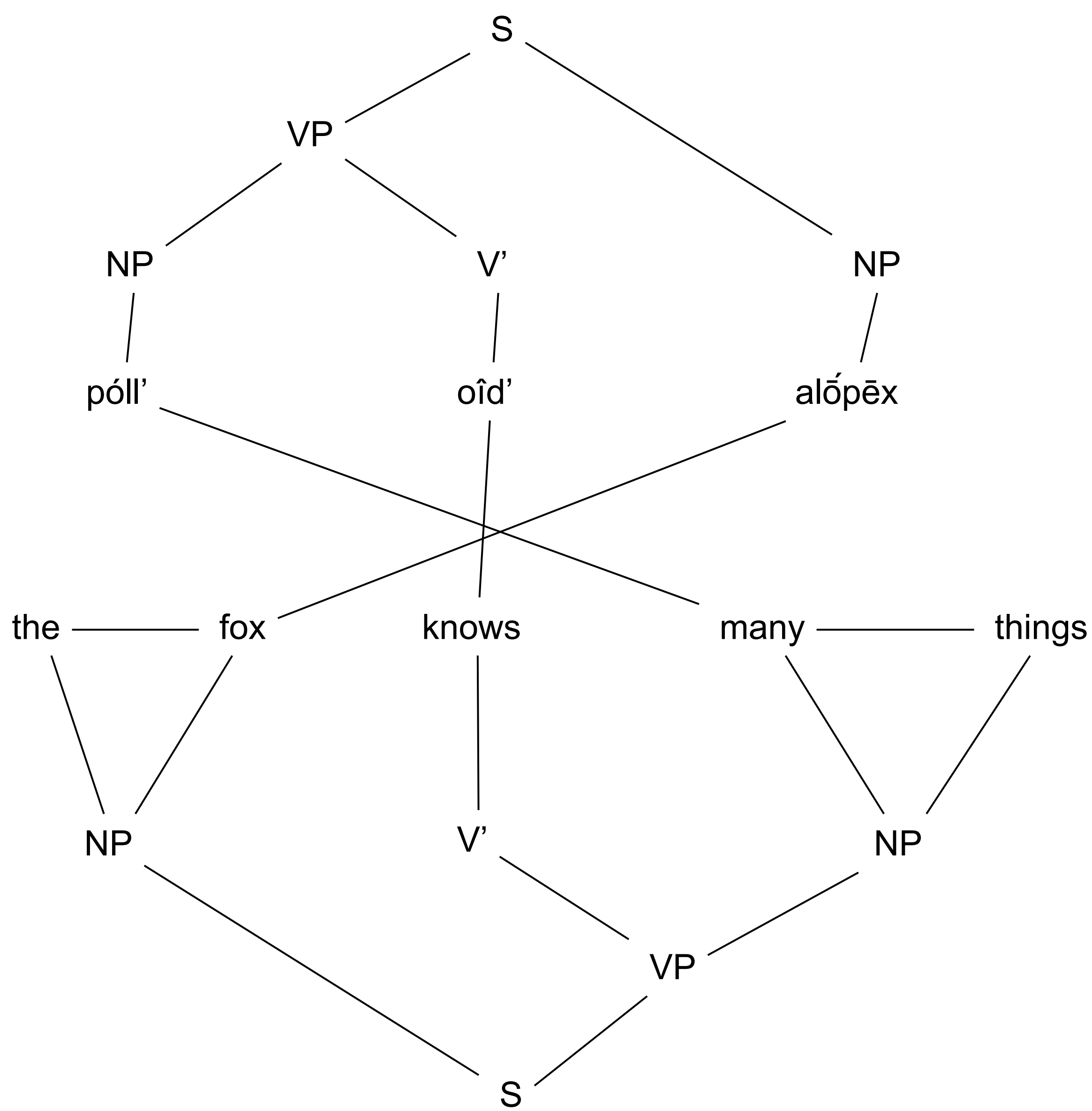
	póll’	oîd’	alṓpēx
the			NP/NP
fox			
knows		VP/VP	
many	NP/NP		
things			

Bilingual Parsing



<table>
<tr><th></th><th>póll’</th><th>oîd’</th><th>alṓpēx</th></tr>
<tr><td>the</td><td></td><td></td><td rowspan="2">NP/NP</td></tr>
<tr><td>fox</td><td></td><td></td></tr>
<tr><td>knows</td><td colspan="2" rowspan="3">VP/VP</td><td></td></tr>
<tr><td>many</td><td></td></tr>
<tr><td>things</td><td></td></tr>
</table>

Bilingual Parsing



	póll’	oîd’	alṓpēx
the			
fox			
knows		S/S	
many			
things			

MT as Parsing

- If we only have the source, parse it while recording all compatible target language trees.
- Runtime is also multiplied by a *grammar constant*: one string could be a noun and a verb phrase
- Continuing problem of multiple hidden configurations (trees, instead of phrases) for one translation.

What Makes Search Hard?

- What we really want: the best (highest-scoring) translation
- What we get: the best translation/phrase segmentation/alignment
  - Even summing over all ways of segmenting *one* translation is hard.
- Most common approaches:
  - Ignore problem
  - Sum over top *j* translation/segmentation/alignment triples to get top *k*<<j translations

Redundancy in *n*-best Lists

Source: Da ich wenig Zeit habe , gehe ich sofort in medias res .

as i have little time , i am immediately in medias res . | 0-1,0-1 2-2,4-4 3-4,2-3 5-5,5-5 6-7,6-7 8-8,8-8 9-9,9-9 10-10,10-10 11-11,11-11 12-12,12-12
as i have little time , i am immediately in medias res . | 0-0,0-0 1-1,1-1 2-2,4-4 3-4,2-3 5-5,5-5 6-7,6-7 8-8,8-8 9-9,9-9 10-10,10-10 11-11,11-11 12-12,12-12
as i have little time , i am in medias res immediately . | 0-1,0-1 2-2,4-4 3-4,2-3 5-5,5-5 6-7,6-7 8-8,9-9 9-9,10-10 10-10,11-11 11-11,8-8 12-12,12-12
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as i have little time , i am immediately in medias res . | 0-1,0-1 2-2,4-4 3-3,2-2 4-4,3-3 5-5,5-5 6-7,6-7 8-8,8-8 9-9,9-9 10-10,10-10 11-11,11-11 12-12,12-12
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as i have little time , i am immediately in medias res . | 0-0,0-0 1-1,1-1 2-2,4-4 3-4,2-3 5-5,5-5 6-6,7-7 7-7,6-6 8-8,8-8 9-9,9-9 10-10,10-10 11-11,11-11 12-12,12-12
as i have little time , i would immediately in medias res . | 0-1,0-1 2-2,4-4 3-4,2-3 5-5,5-5 6-6,7-7 7-7,6-6 8-8,8-8 9-9,9-9 10-10,10-10 11-11,11-11 12-12,12-12
because i have little time , i am immediately in medias res . | 0-0,0-0 1-1,1-1 2-2,4-4 3-4,2-3 5-5,5-5 6-7,6-7 8-8,8-8 9-9,9-9 10-10,10-10 11-11,11-11 12-12,12-12
as i have little time , i am immediately in medias res . | 0-1,0-1 2-2,4-4 3-3,2-2 4-4,3-3 5-5,5-5 6-6,7-7 7-7,6-6 8-8,8-8 9-9,9-9 10-10,10-10 11-11,11-11 12-12,12-12
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