Source-side Dependency Tree Reordering Models with Subtree Movements and Constraints

Nguyen Bach, Qin Gao and Stephan Vogel

Carnegie Mellon University

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International Center for Advanced Communication Technologies

Carnegie Mellon

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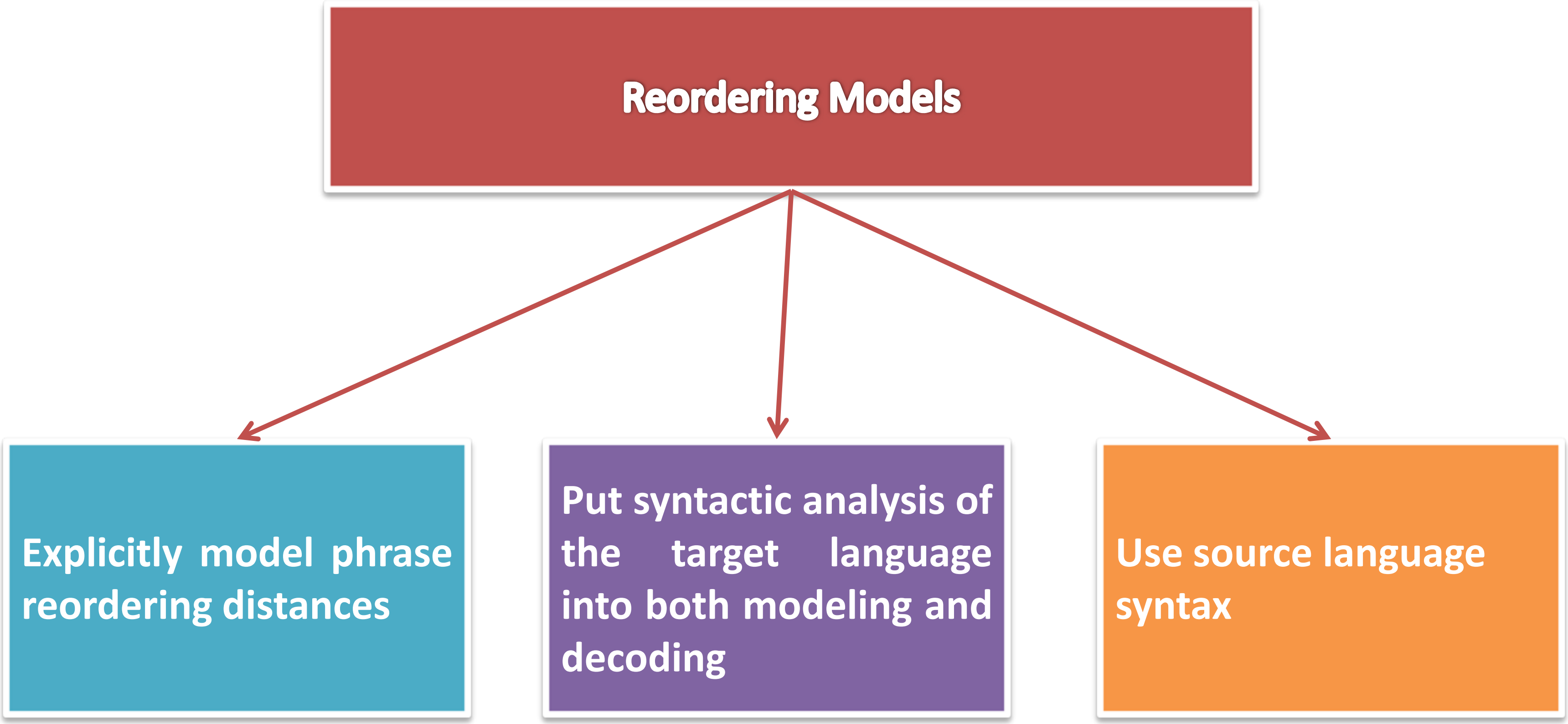
Overview

- We introduce **source-side dependency tree reordering models**
  - Inspired by **lexicalized reordering model** (Koehn et. al 2005) , **hierarchical dependency translation** (Shen et. al, 2008) and **cohesive decoding** (Cherry, 2008)
- We model reordering events of phrases associated with source-side dependency trees
  - **Inside/Outside subtree movements** efficiently capture the statistical distribution of the subtree-to-subtree transitions in training data
  - Utilize subtree movements directly at the decoding time alongside with **cohesive constraints** to guide the search process
  - Improvements are shown in English-Spanish and English-Iraqi tasks

Outline

- **Background & Motivations**
- Source-side dependency tree reordering models
  – Modeling
  – Training
  – Decoding
- Experiments & Analysis
- Conclusions

Background of Reordering Models



Reordering Models

- **Explicitly model phrase reordering distances**
  - Distance-based (Och, 2002; Koehn et.al., 2003)
  - Lexicalized phrase (Tillmann, 2004; Koehn, et.al., 2005; Al-Onaizan and Papineni, 2006)
  - Hierarchical phrase (Galley and Manning, 2008)
  - MaxEnt classifier (Zens and Ney, 2006; Xiong, et.al., 2006; Chang, et. al., 2009)
- **Put syntactic analysis of the target language into both modeling and decoding**
  - Direct model target language constituents movement in either constituency trees (Yamada and Knight, 2001; Galley et.al., 2006; Zollmann et.al., 2008) or dependency trees (Quirk, et.al., 2005)
  - Hierarchical phrase-based (Chiang, 2005; Shen et. al., 2008)
- **Use source language syntax**
  - Preprocessing with syntactic reordering rules (Xia and McCord, 2004; Collins et.al., 2005; Rottmann and Vogel, 2007; Wang et.al., 2007; Xu et.al. 2009)
  - Use syntactical analysis to provide multiple source sentence reordering options through word lattices (Zhang et.al., 2007; Li et.al., 2007; Elming, 2008).

Reordering Models

Explicitly model phrase reordering distances

Put syntactic analysis of the target language into both modeling and decoding

Use source language syntax

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Source-side **Dependency Tree** **Reordering Models**

with Subtree Movements and Constraints

What are the differences?

- Instead of using flat word structures to extract reordering events, utilize **source-side dependency structures**
  - Provide more linguistic cues for reordering events
- Instead of using pre-defined reordering patterns, learn **reordering feature distributions** from training data
  - Capture reordering events from real data
- Instead of preprocessing the data, **discriminatively train** the reordering model via MERT
  - Tighter integration with the decoder

Cohesive Decoding

- A cohesive decoding (Cherry, 08; Bach et. al., 09) is forcing the cohesive constraint:
  - *When the decoder begins translation any part of a source subtree, it must cover all words under that subtree before it can translate anything outside.*

- Source-side dependency tree reordering models
  - Efficiently capture the statistical distribution of the subtree-to-subtree transitions in training data.
  - Directly utilize it at the decoding time to guide the search process.

Outline

- Background of Reordering Models
- **Source-side dependency tree reordering models**
  - **Modeling**
  - **Training**
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- Conclusions

Lexicalized Reordering Models (Tillmann, 2004; Koehn, et.al., 2005; Al-Onaizan & Papineni, 2006)

$$p(O \mid e, f) = \prod_{i=1}^{n} p(o_i \mid \bar{e}_i, \bar{f}_{a_i}, a_{i-1}, a_i)$$

where

f is the input sentence;

$e = (\bar{e}_1, \ldots, \bar{e}_n)$ is the target language phrases;

$a = (a_1, \ldots, a_n)$ is phrase alignments;

$\bar{f}_{a_i}$ is a source phrase which has a translated phrase $\bar{e}_i$ defined by an alignment a_i;

O is orientation phrase sequence; each o_i has a value over 3 possibles (M, S,D);

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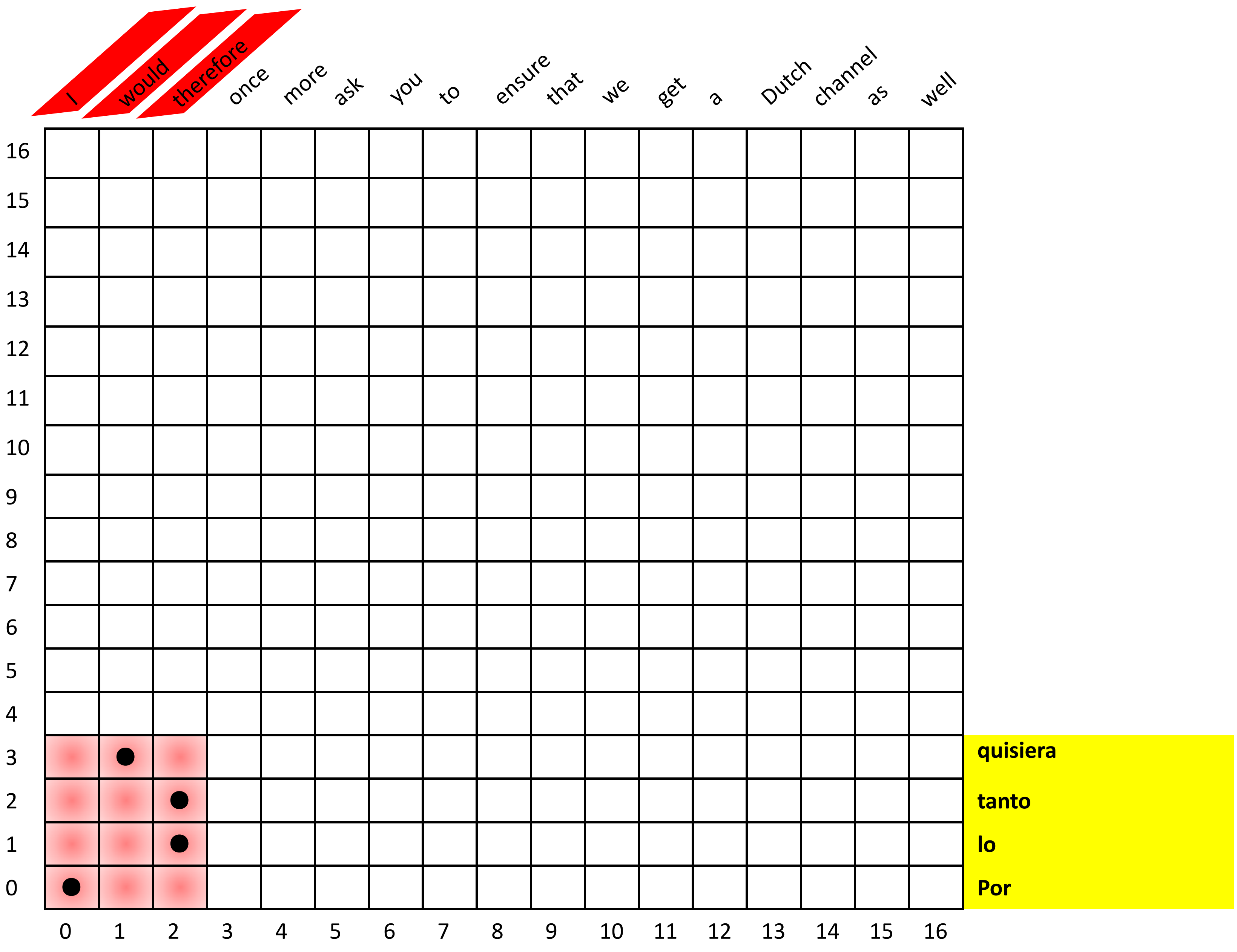

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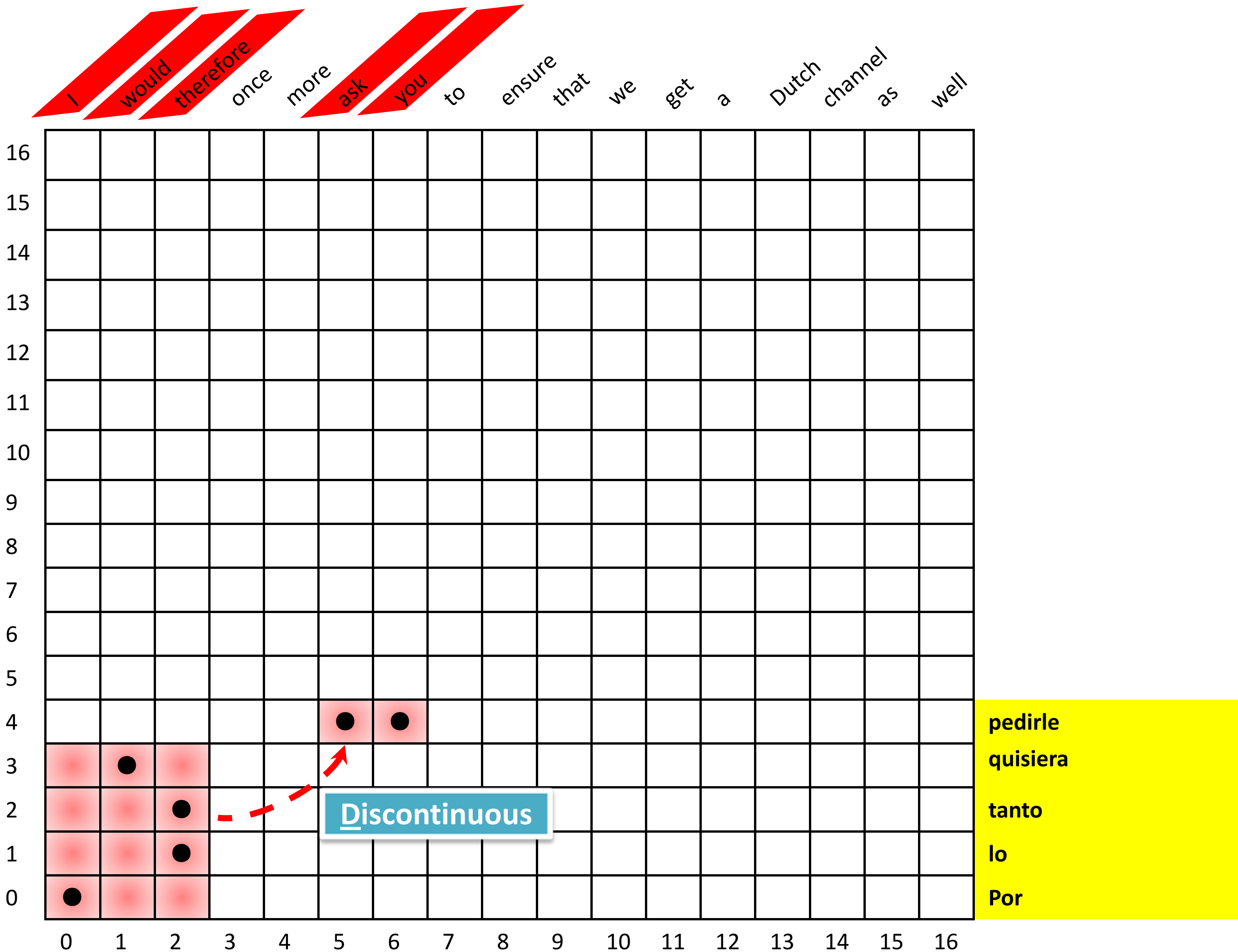

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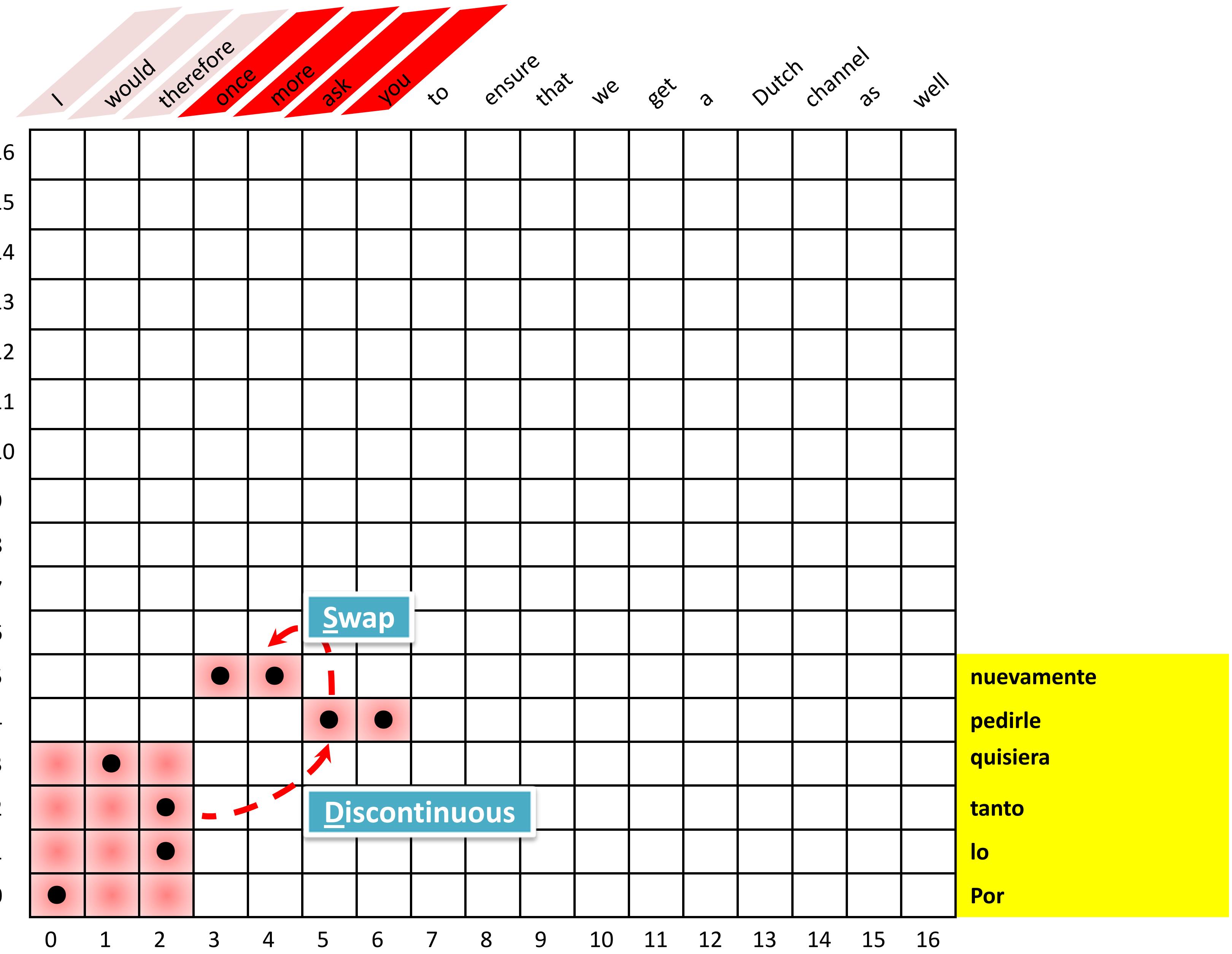

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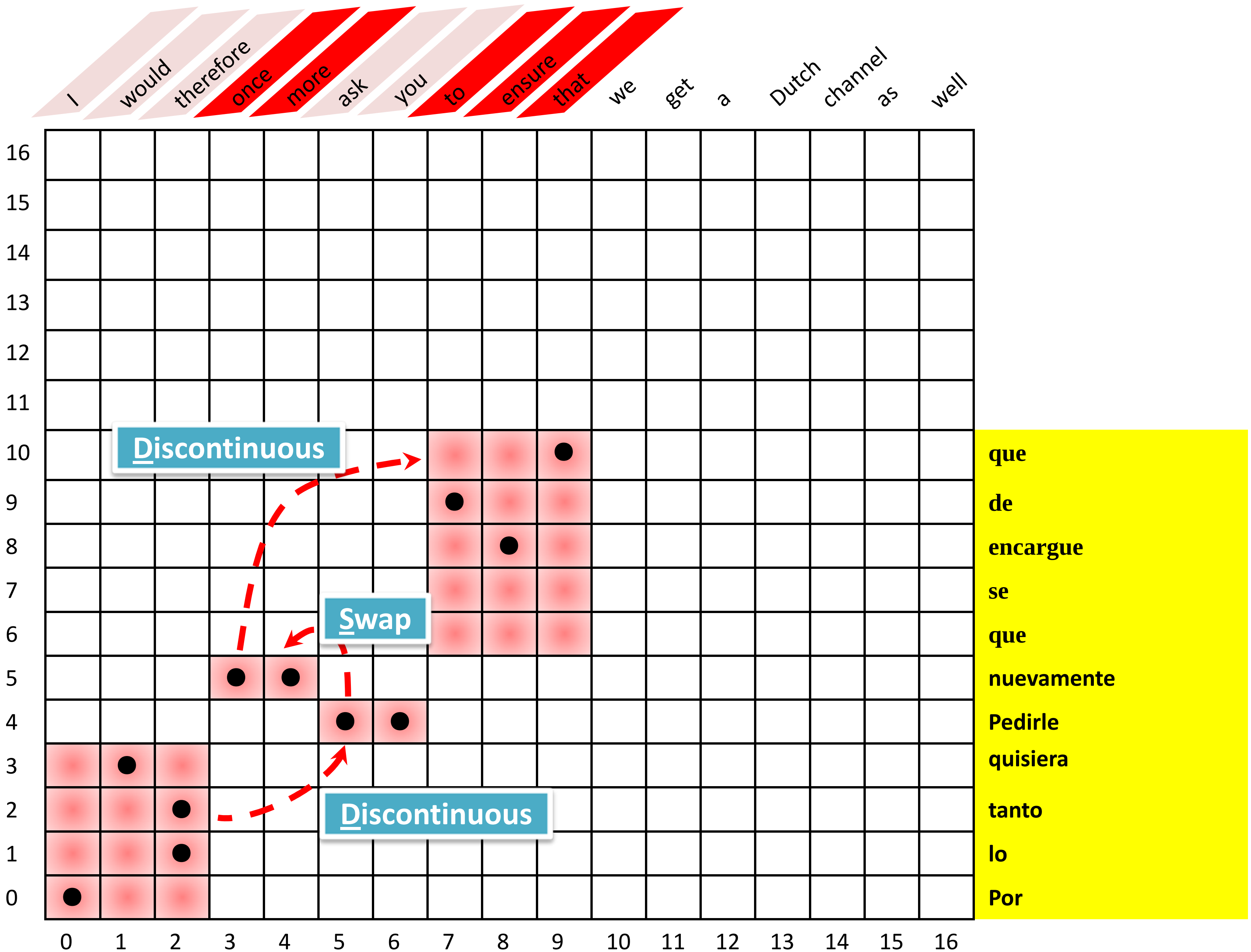
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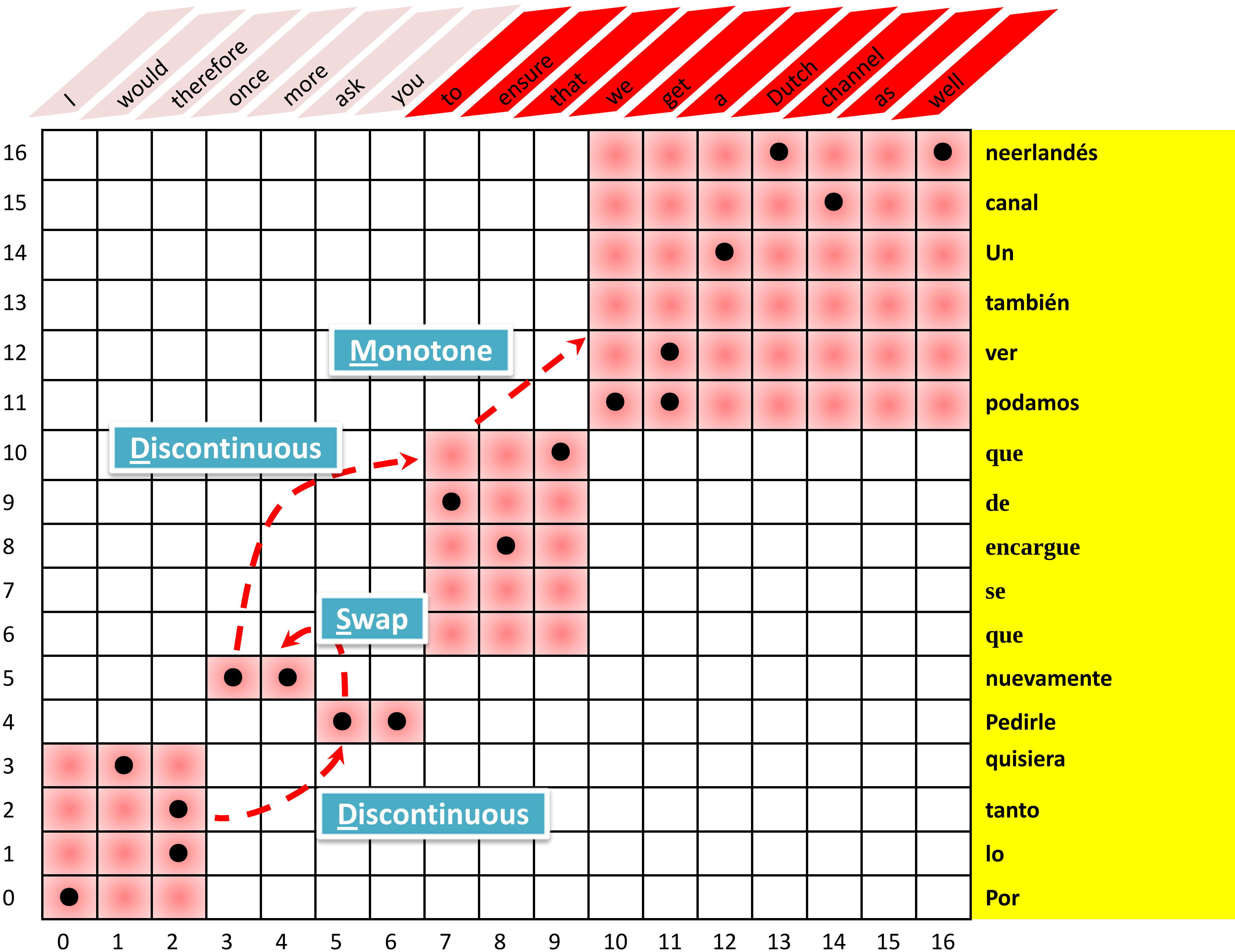

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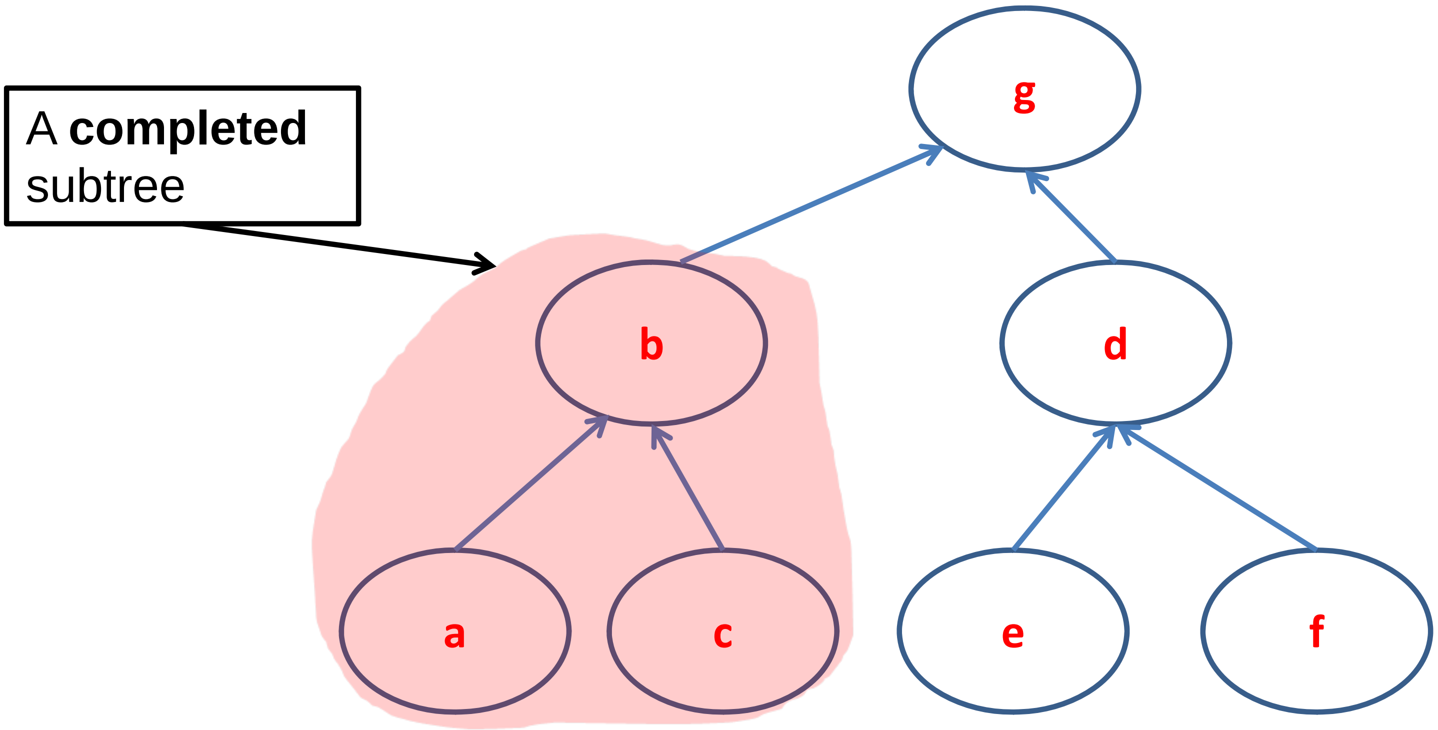
Pros & Cons of Lexicalized Reordering Models

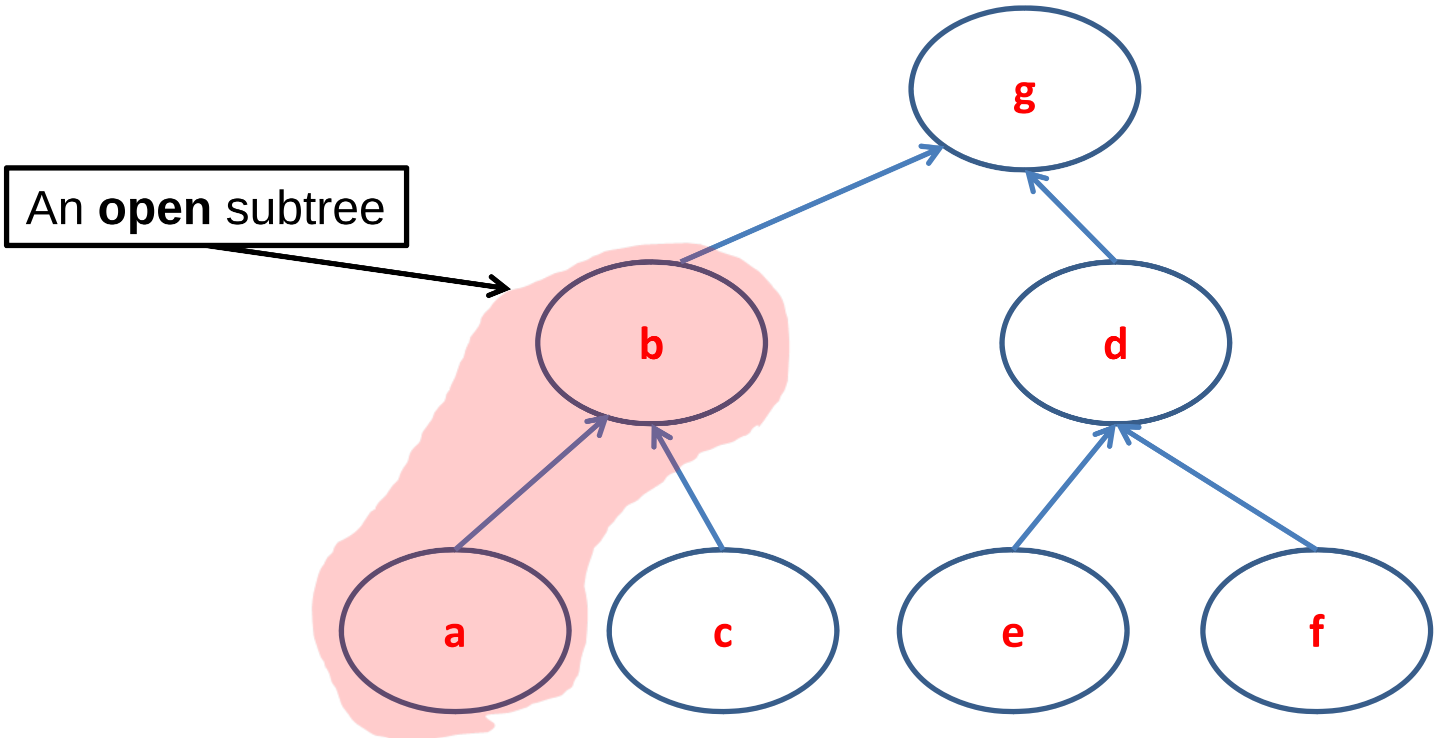
- Pros
  - intuitively model flat word movements
  - well-defined for phrase-based framework
- Cons
  - No linguistics structures
  - Need alignment matrix to determine movements

Completed/Open subtrees



All words under a node have been translated then we call a ***completed*** *subtree*

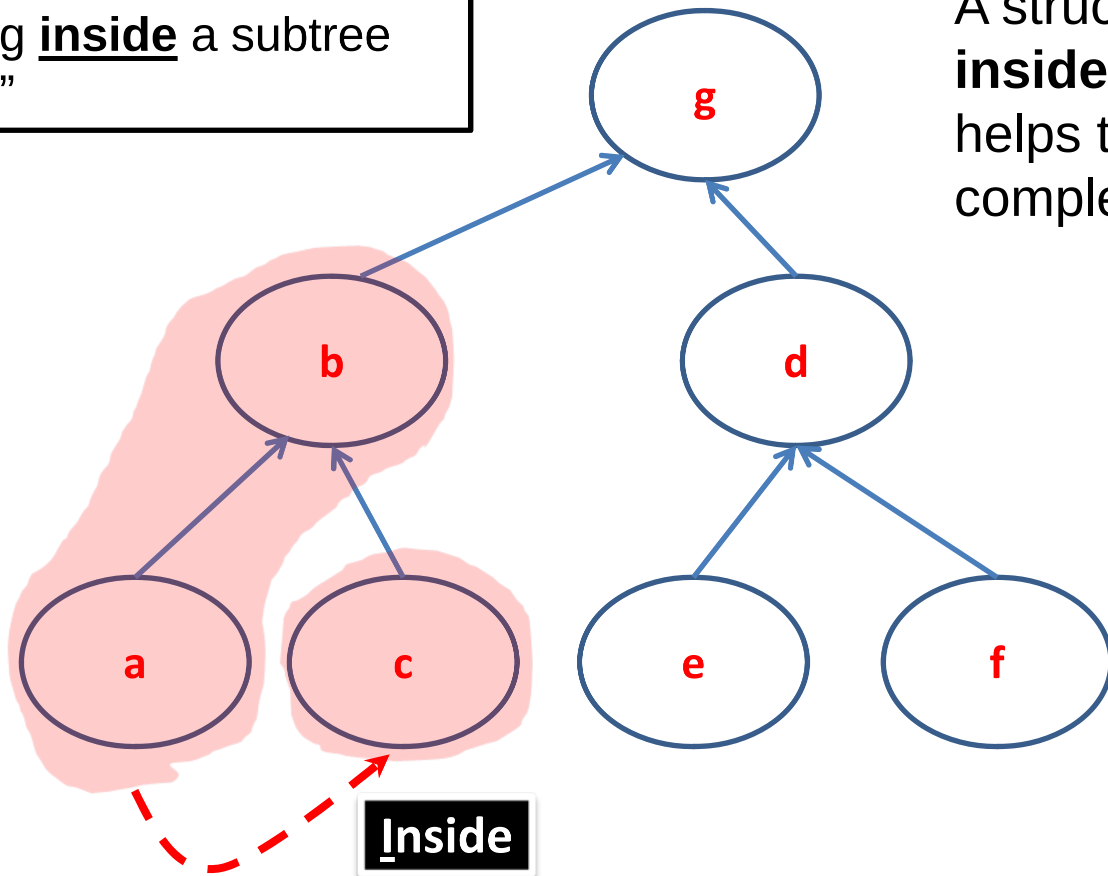
Completed/Open subtrees



A subtree that has begun translation but not yet complete, an ***open*** subtree

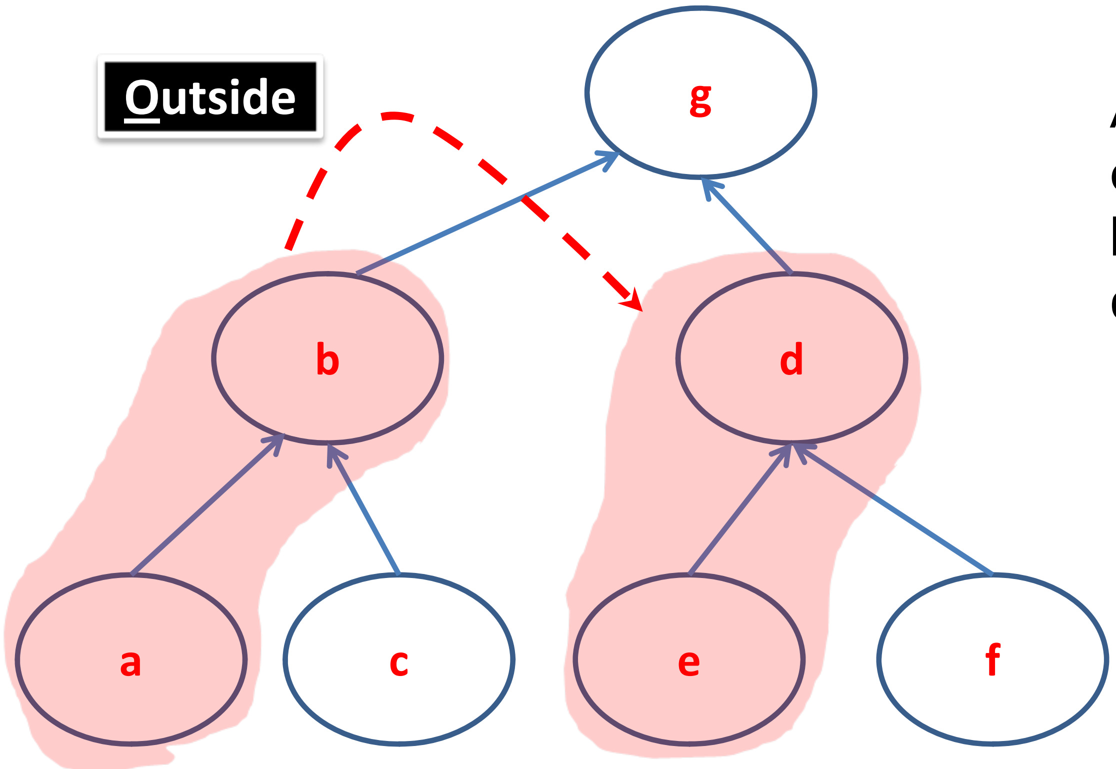
Inside/Outside subtree movements

“c” is moving **inside** a subtree rooted at “b”



A structure is moving **inside** a subtree if it helps the subtree to be completed or less open

Inside/Outside subtree movements



A structure is moving **outside** a subtree if it leaves the subtree to be open

"d e" is moving **<u>outside</u>** a subtree rooted at "b"

Source-side Dependency Tree (SDT) Reordering Models

$$p(D \mid e, f) = \prod_{i=1}^{n} p(d_i \mid \bar{e}_i, \bar{f}_{a_i}, a_i, s_{i-1}, s_i)$$

where

f is the input sentence;

$e = (\bar{e}_1, \ldots, \bar{e}_n)$ is the target language phrases;

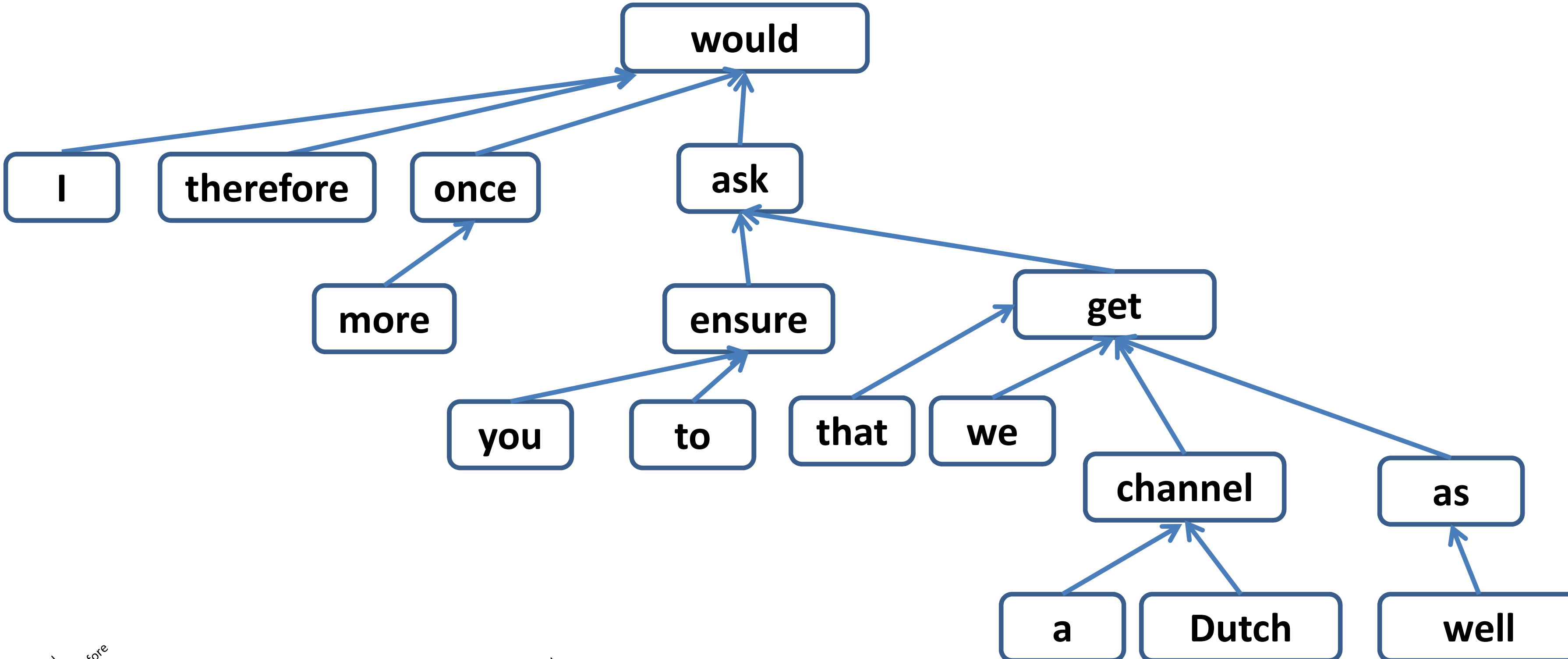
$a = (a_1, \ldots, a_n)$ is phrase alignments ;

$\bar{f}_{a_i}$ is a source phrase which has a translated phrase $\bar{e}_i$ defined by an alignment a_i;

s_i and $s_{i\text{-}1}$ are dependency structures of source phrases $\bar{f}_{\mathrm{a_i}}$ and $\bar{f}_{\mathrm{a_{i\text{-}1}}}$;

D represents the sequence of syntactic phrase movements over source dependency tree;

each $d_i = \{I, O\}$;



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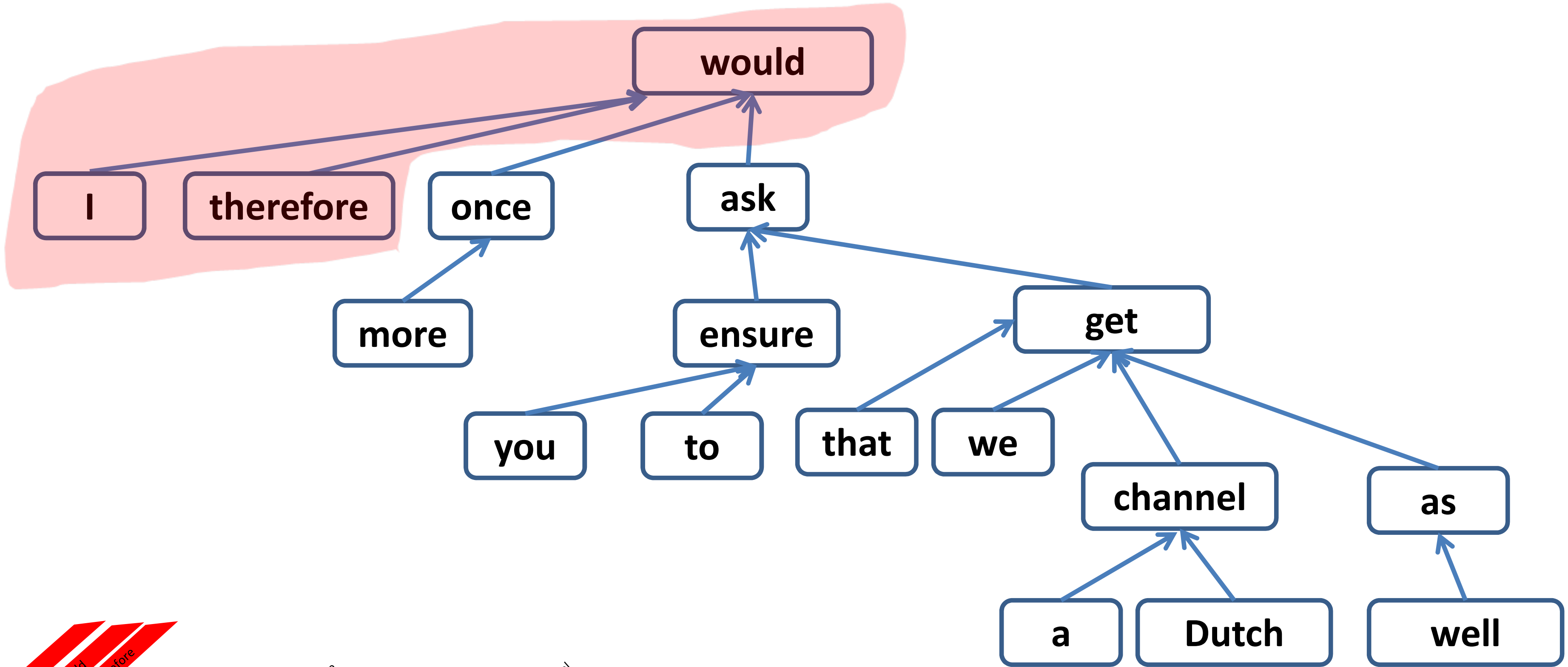
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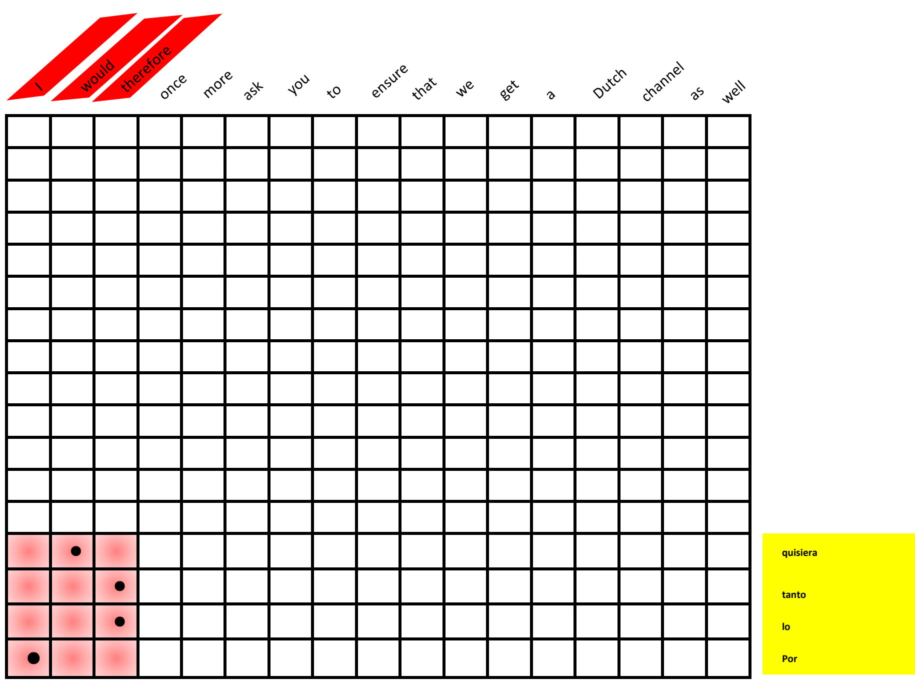
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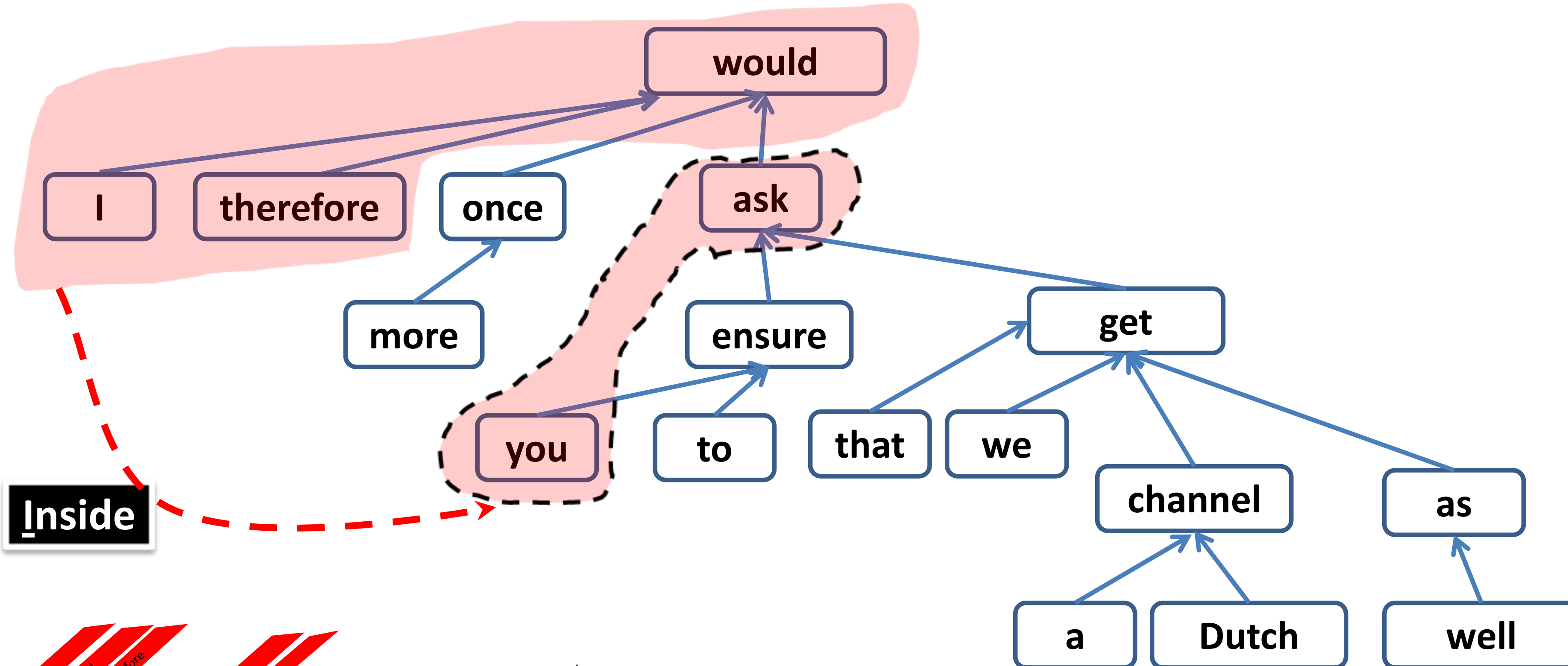

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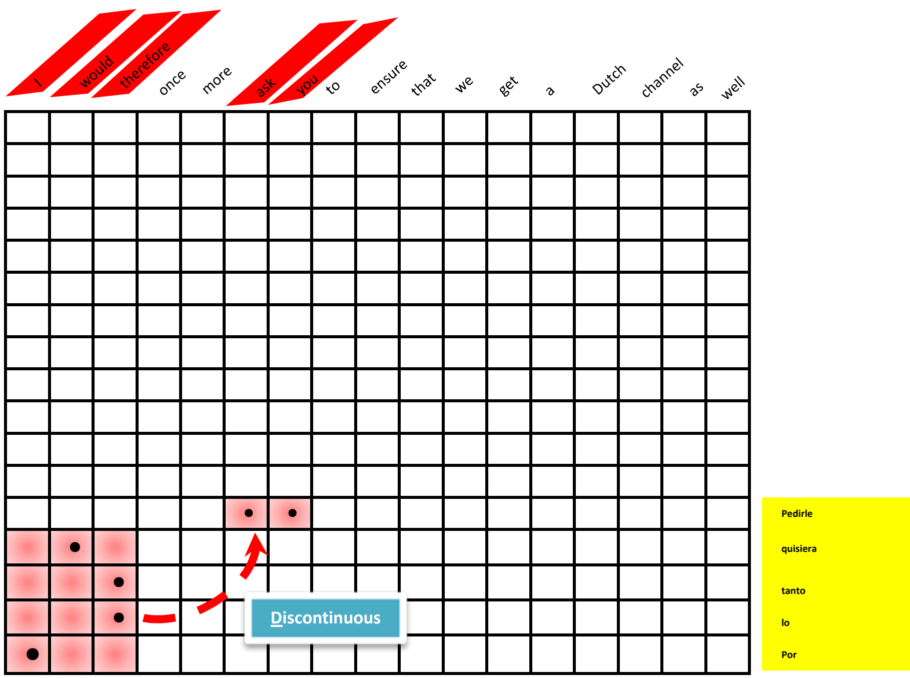

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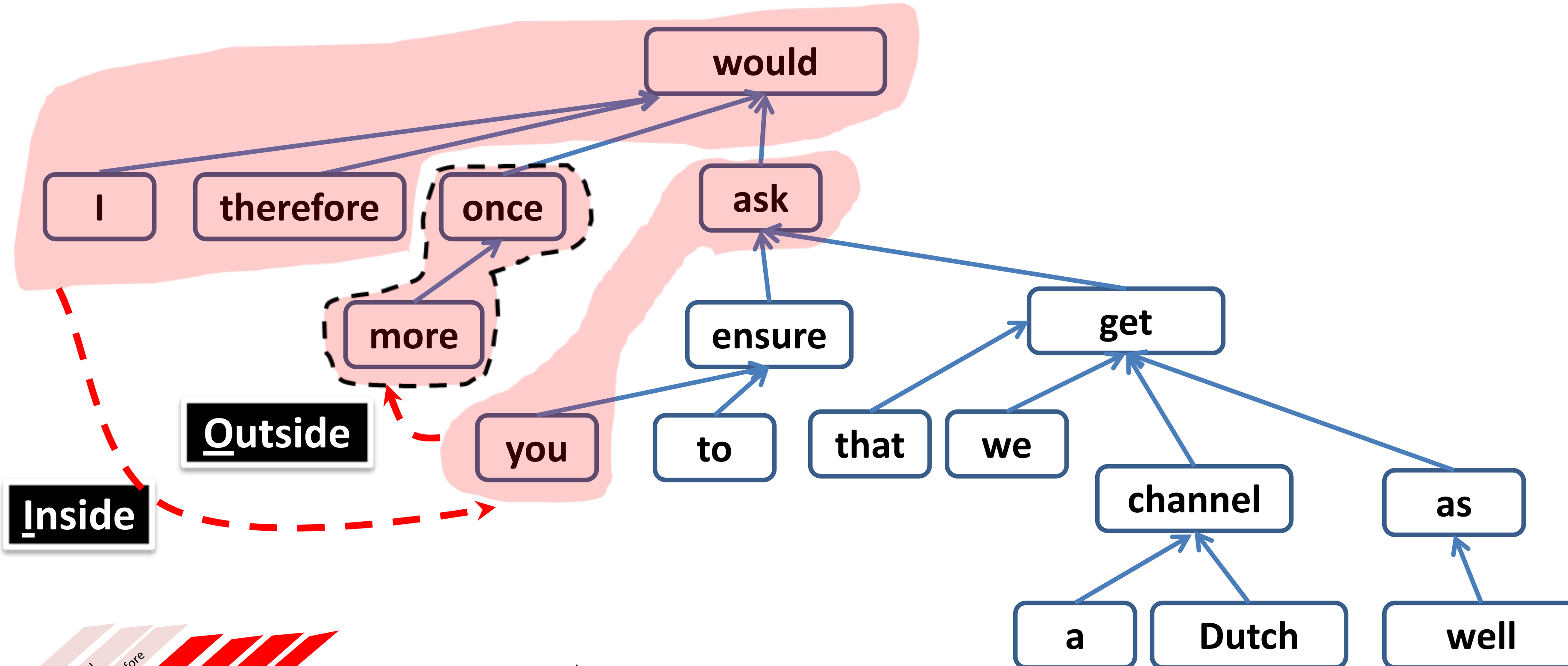

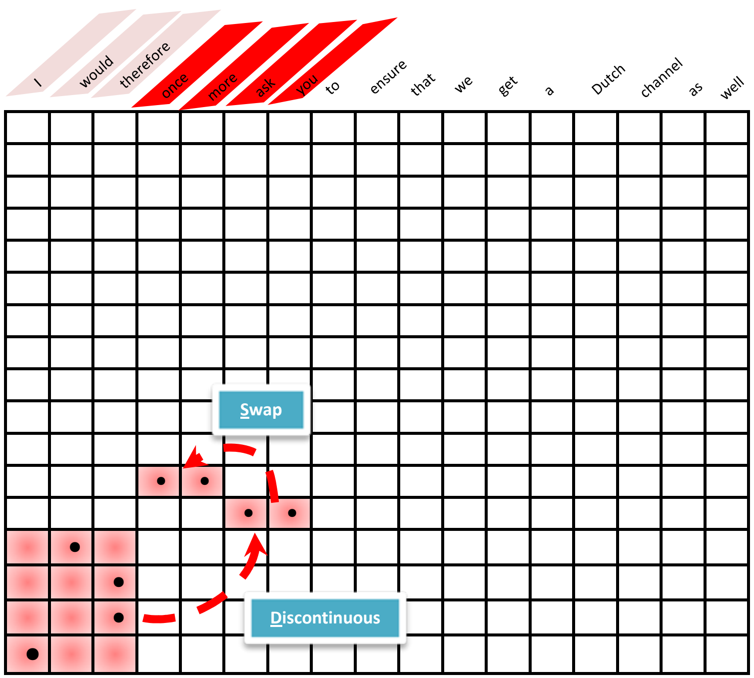

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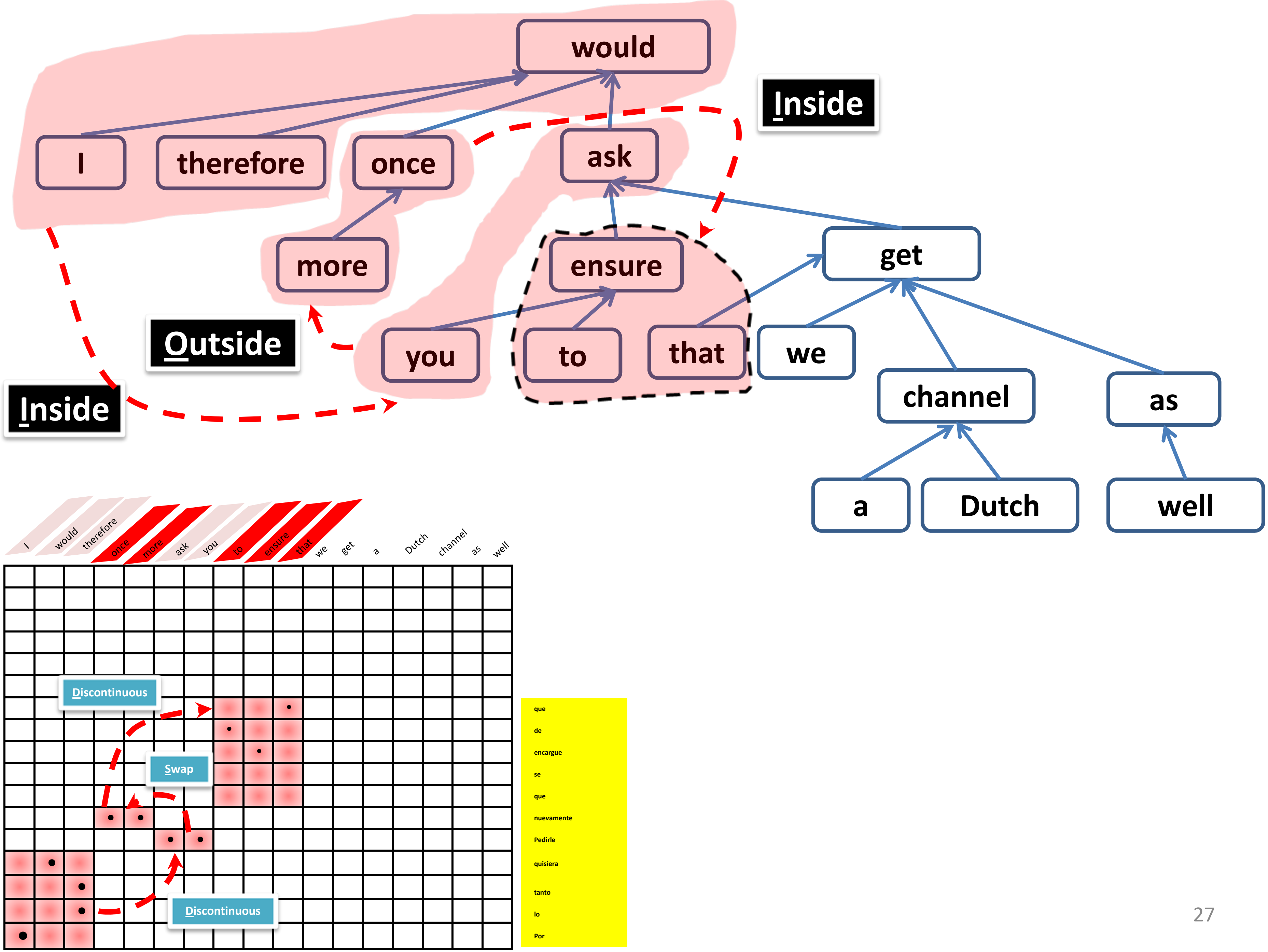

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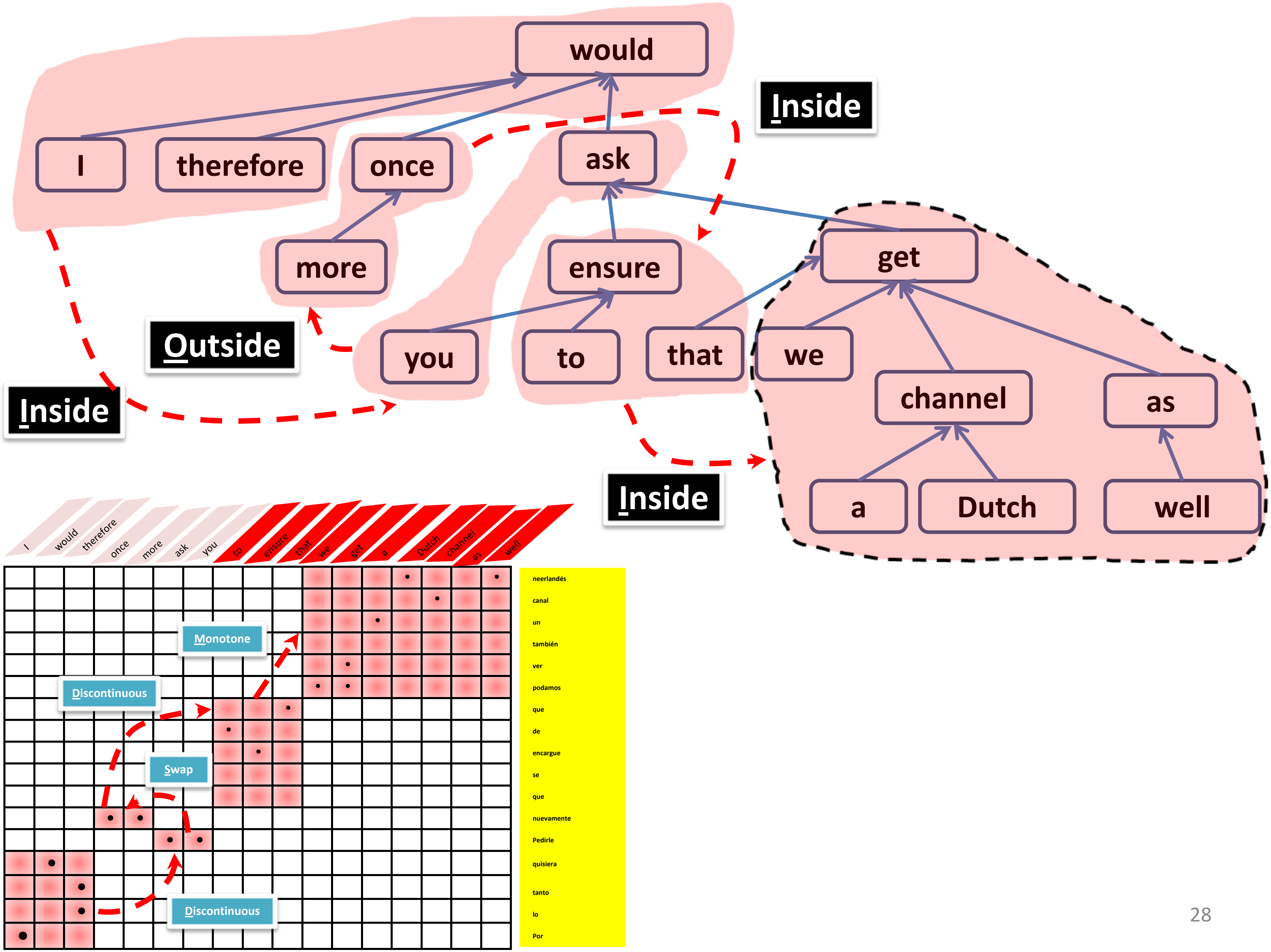
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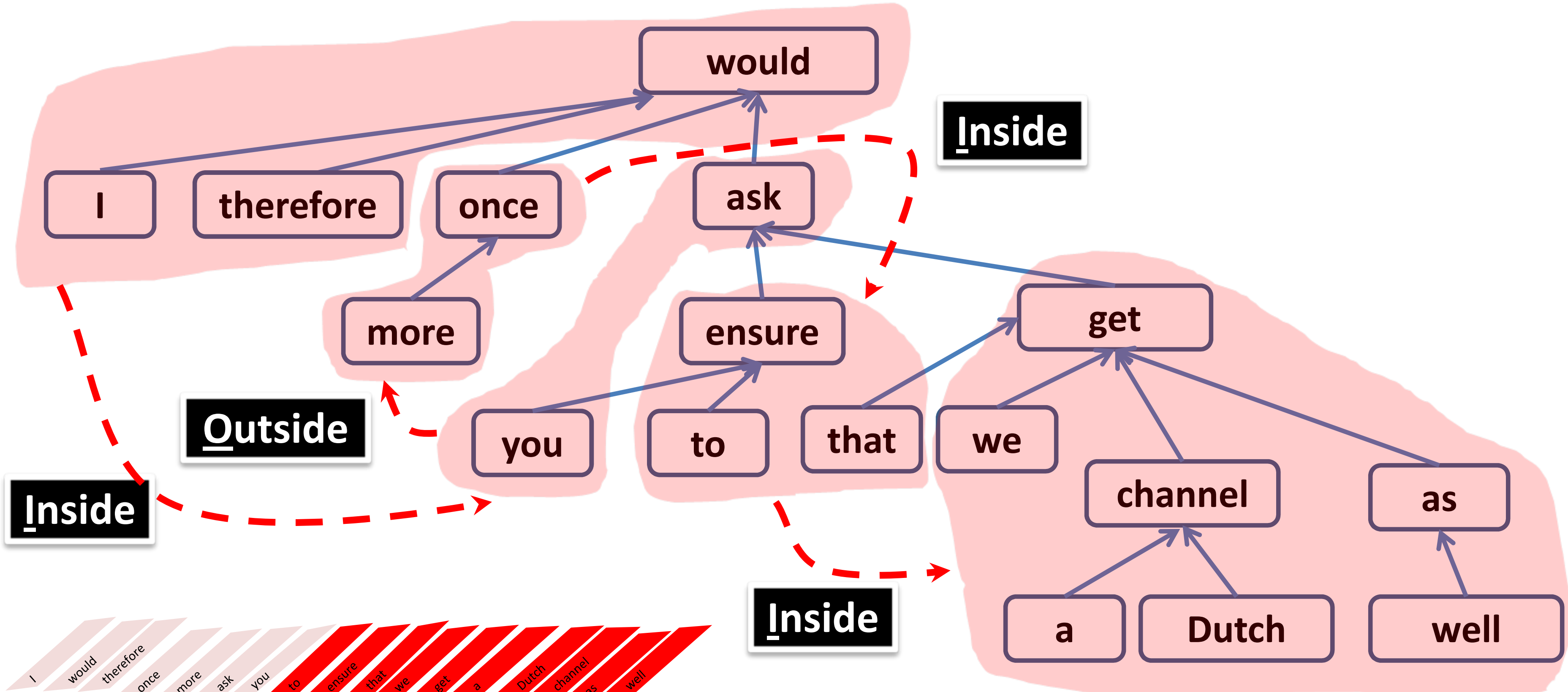

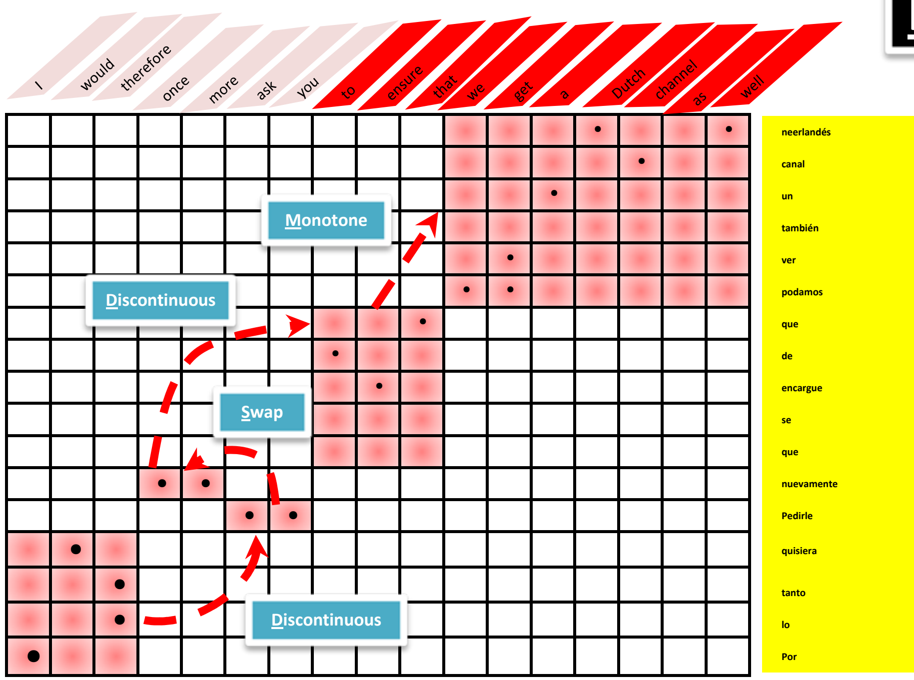

Source-side Dependency Tree R.M.

Inside | Outside | Inside | Inside

Lexicalized R.M.

Discontinuous | Swap | Discontinuous | Monotone

Extended Source-side Dependency Tree (SDT) Reordering Models

$$p(D \mid e, f) = \prod_{i=1}^{n} p((o\_d)_i \mid \bar{e}_i, \bar{f}_{a_i}, a_i, a_{i-1}, s_{i-1}, s_i)$$

where

f is the input sentence;

$e = (\bar{e}_1, ..., \bar{e}_n)$ is the target language phrases;

$a = (a_1, ..., a_n)$ is phrase alignments ;

$\bar{f}_{a_i}$ is a source phrase which has a translate d phrase $\bar{e}_i$ defined by an alignment a_i;

s_i and s_{i-1} are dependency structures of source phrases $\bar{f}_{a_i}$ and $\bar{f}_{a_{i-1}}$;

D represents the sequence of syntactic phrase movements over source dependency tree;

each $(o\_d)_i = \{M\_I, S\_I, D\_I, M\_O, S\_O, D\_O\}$;

Extended Source-side Dependency Tree (SDT) Reordering Models

$p($

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$e = (\bar{e}_1, \ldots$

$a = (a_1, \ldots$

$\bar{f}_{a_i}$ is a s

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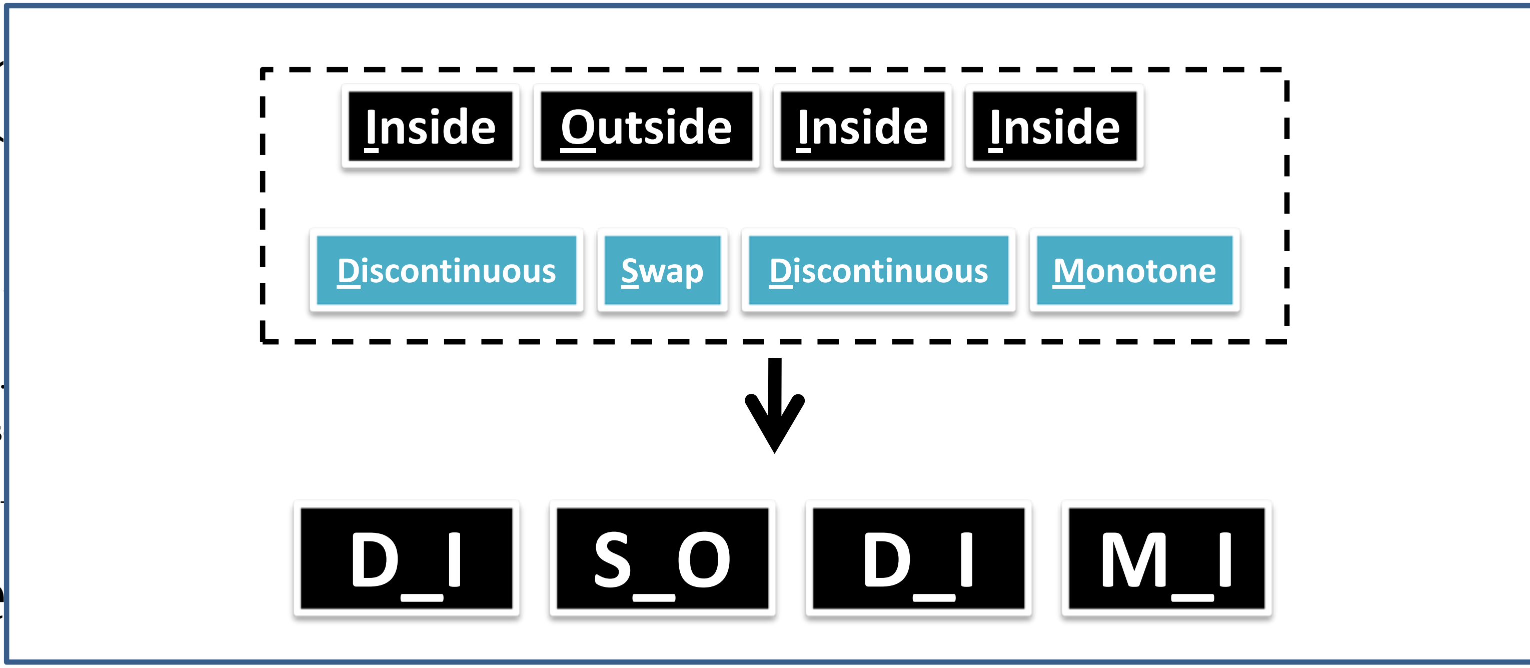

D re ts

over source dependency tree;

each $(o\_d)_i = \{M\_I, S\_I, D\_I, M\_O, S\_O, D\_O\}$;

Training

- Obtain dependency parse of the source side
- Given a sentence pair and the source side dependency tree
  – Phrase extraction: also extract source dependency structures of phrase pairs
  – Identify Inside/Outside movement by using *Interruption Check Algorithms* (Bach et.al., 2009)

Training

DO: a **joint probability** of subtree movements and lexicalized orientations

$$p((o_j\_d_k) \mid \overline{e_i}, \bar{f}_{a_i}, o_j, d_k) = \frac{count(o_j\_d_k) + \gamma}{\sum_k \sum_j (count(o_j\_d_k) + \gamma)}$$

DOD: conditioned on subtree movements

$$p((o_j\_d_k) \mid \overline{e_i}, \bar{f}_{a_i}, d_k) = \frac{count(o_j\_d_k) + \gamma}{\sum_k (count(o_j\_d_k) + \gamma)}$$

DOO: conditioned on lexicalized orientations

$$p((o_j\_d_k) \mid \overline{e_i}, \bar{f}_{a_i}, o_j) = \frac{count(o_j\_d_k) + \gamma}{\sum_j (count(o_j\_d_k) + \gamma)}$$

Decoding

- Without cohesive constraints
  - Having no information about the source dependency tree information during the decoding time
  - Consider **both** subtree movements, and add them up to the translation model costs

- With cohesive constraints
  - The source dependency tree is available during the decoding time
  - Only consider **either** inside or outside movement, depending on the output of the interruption check algorithm

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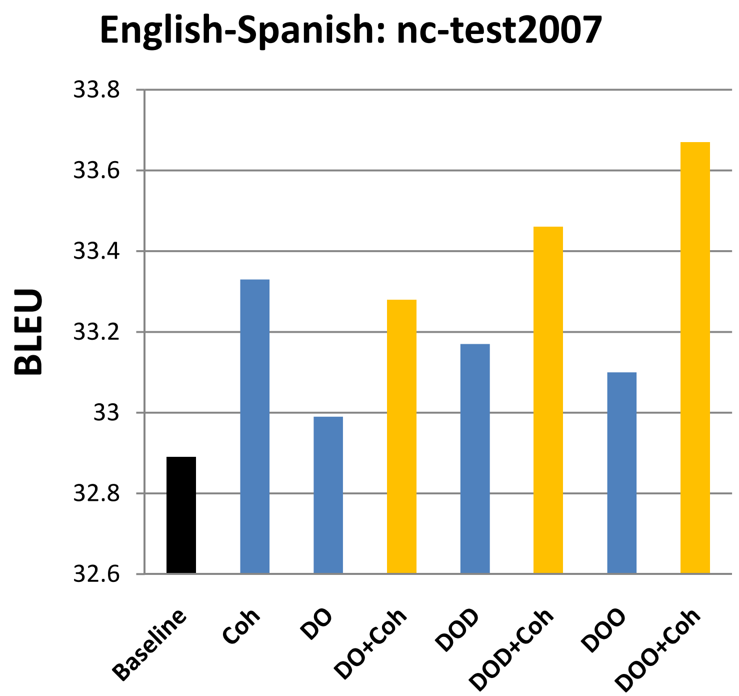
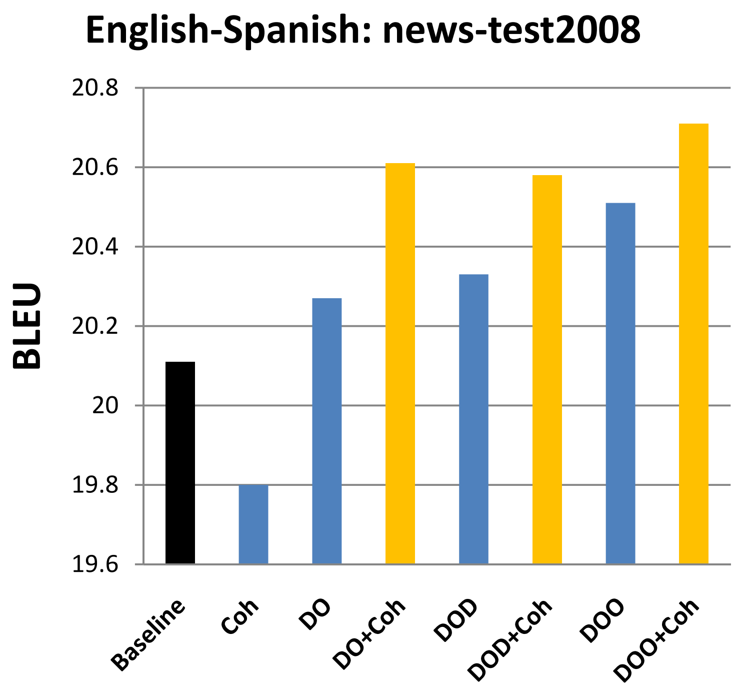
Experiments setups

- **Baseline**: a phrase-based MT with lexicalized reordering model
- **Coh**: using cohesive constraints
- **DO** / **DOD** / **DOO**: using source-side dependency tree (SDT) reordering model with different parameter estimations
- **DO+Coh** / **DOD+Coh** / **DOO+Coh**: decoding with both SDT reordering model and cohesive constraints.

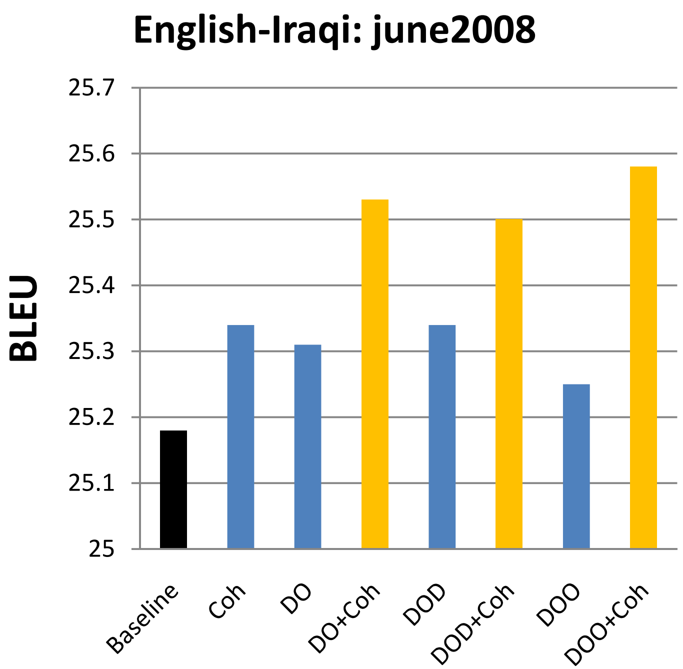
English-Spanish (Europarl)

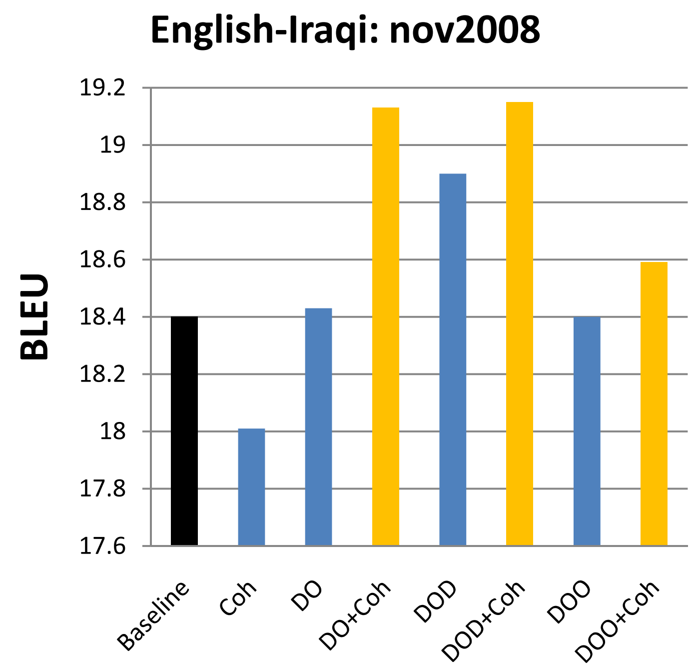




- Source-side dependency tree reordering models and cohesive constraints obtained **improvements** over the lexicalized reordering models.

English-Iraqi (TransTac)



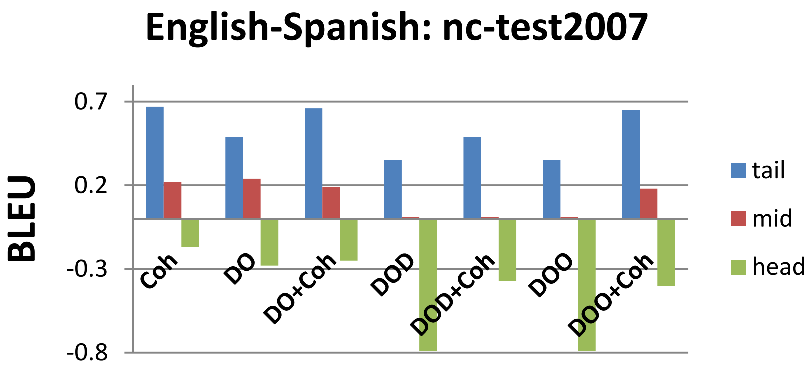


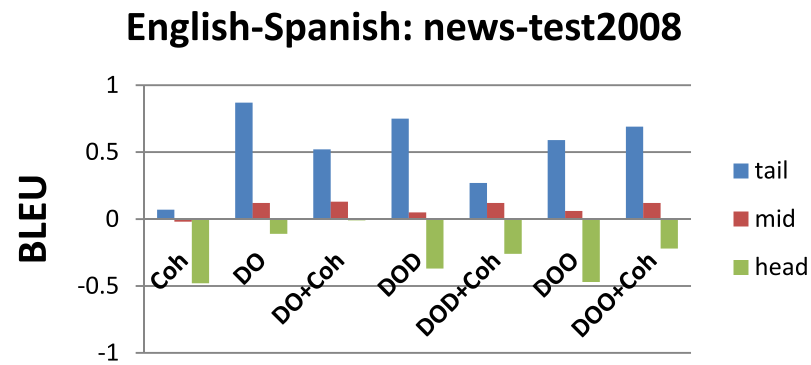
- Decoding with both source-side dependency tree reordering models and cohesive constraints often obtain the best performance.

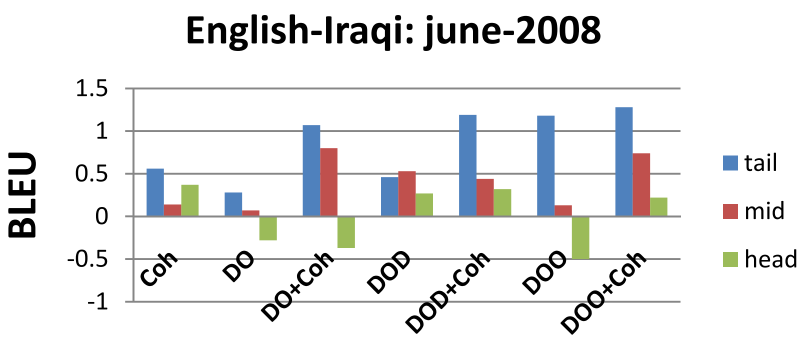
Where are improvements coming from?

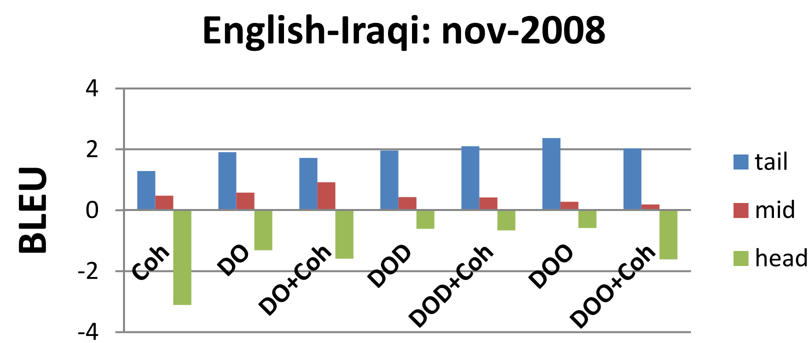
Test set breakdown

- Divide the test sets into three portions based on sentence-level TER of the baseline system
- μ and σ are mean and standard deviation of the whole test set
- **Head**, **Tail** and **Mid** as the sentence whose score is lower than μ-1/2 σ, higher than μ+1/2 σ and the rest









	june-08	nov-08	nc-test2007	news-test2008
Head	7.92	6.27	20.39	13.07
Mid	12.31	11.09	28.07	22.78
Tail	13.91	14.08	35.29	25.33

What is the most significant effect the source-tree reordering models contribute?

Numbers of Reorderings

	nc-test2007	news-test2008	june-2008	nov-2008
Baseline	1507	1684	39	24
Coh	2045	**2903**	46	21
DO	**2189**	2113	97	58
DO+Coh	1929	1900	155	88
DOD	1735	2592	123	60
DOD+Coh	2070	2021	148	**90**
DOO	1735	1785	164	49
DOO+Coh	1818	1959	**247**	66

- More reorderings can be generated without losing performance.
- The source-tree reordering models provide a more discriminative mechanism to estimate reordering events.
- Reordering is more language-specific than general translation models, and the conditions for a reordering event to happen vary among languages.

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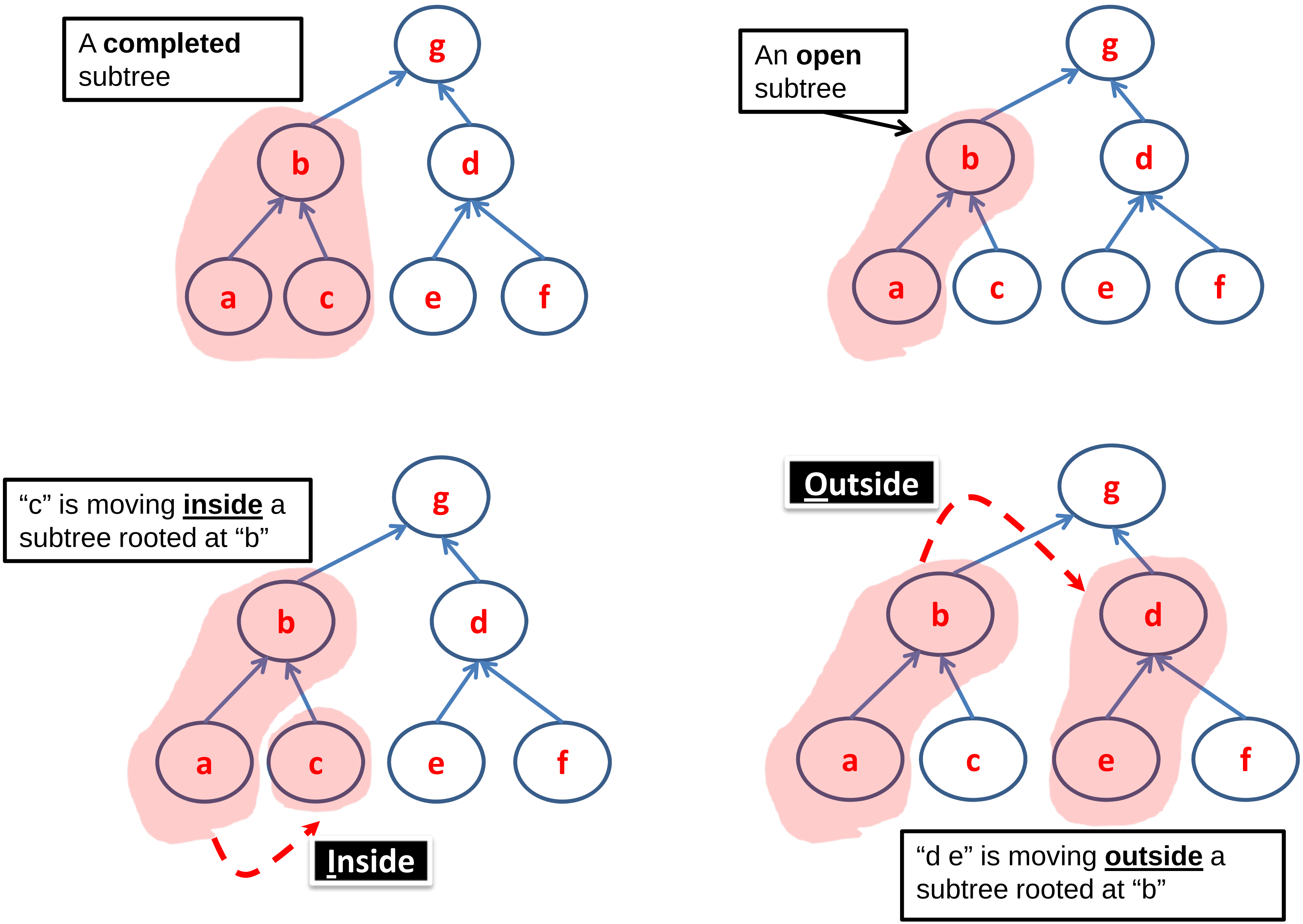
Conclusions & Future Work

- Conclusions
  - Source-side dependency tree reordering models are helpful
    - Model reordering event with **Inside/Outside** subtree movements
  - The effectiveness was shown when comparing with a strong reordering model
  - Obtained improvements with 2 language pairs and also covered a training corpus sizes, ranging from 500K up to 1.3M sentence pairs
- Future work
  - A hierarchical source side dependency reordering model: extend Galley&Manning (2008).
  - Packed-forest dependency tree reordering models

Back up


A **completed** subtree
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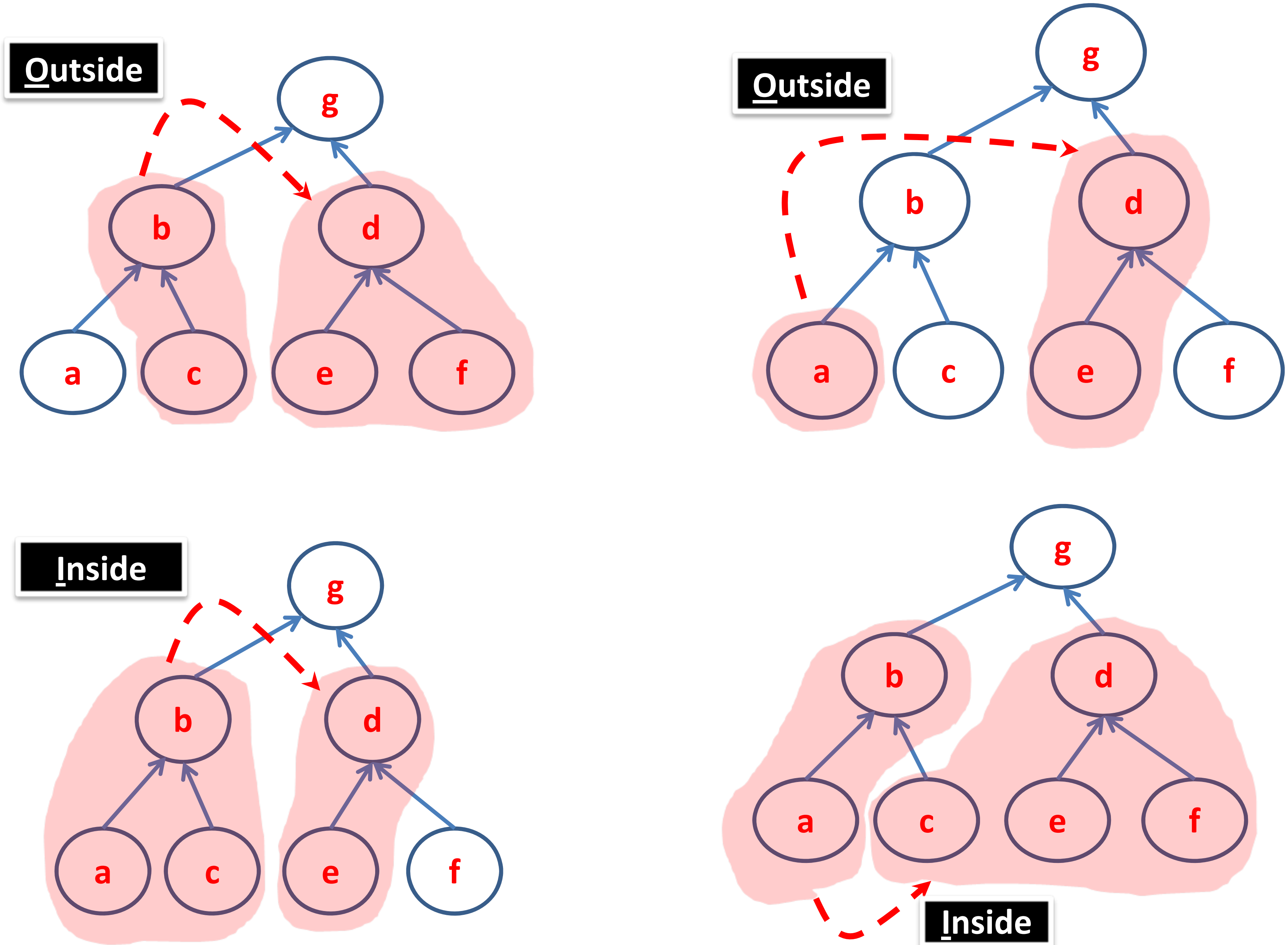
e
f
“c” is moving **inside** a subtree rooted at “b”
g
b
d
a
c
e
f
Inside
Outside
g
b
d
a
c
e
f
“d e” is moving **outside** a subtree rooted at “b”


Outside
g
b
d
a
c
e
f
Outside
g
b
d
a
c
e
f
Inside
g
b
d
a
c
e
f
g
b
d
a
c
e
f
Inside

What do you mean by introducing Inside/Outside notions?

- The movement of the **subtree inside** or **outside** a source subtree can be viewed as the decoder is leaving from the **previous** source state to the **current** source state.

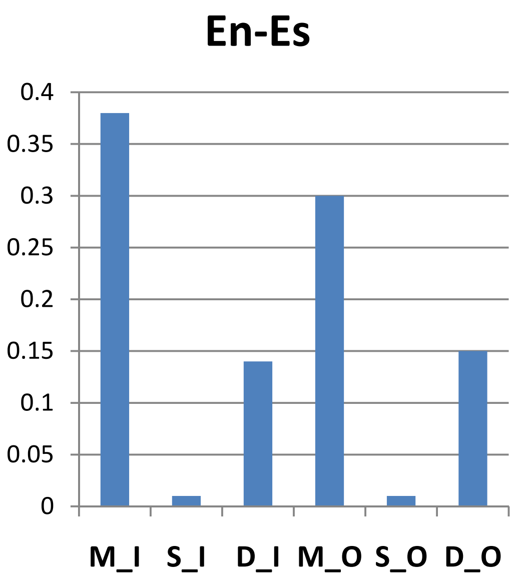
- Tracking facts about the **subtree-to-subtree transitions** observed in the source side of word-aligned training data.

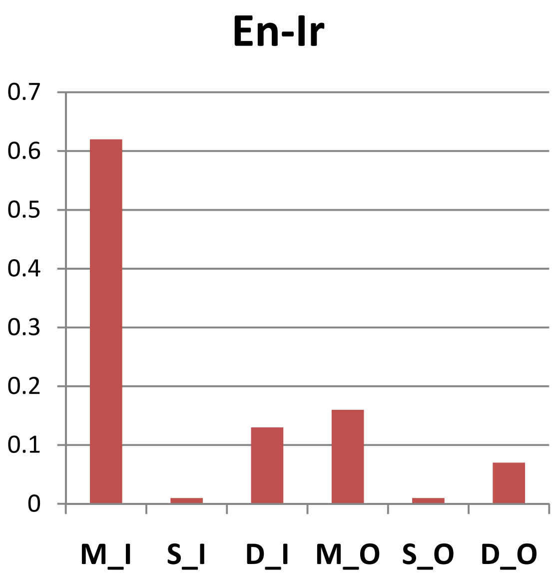
	Lexicalized	Source-tree
ask you # pedirle	dis swap	D_I *
ask you # pedirle	mono mono	M_I
ask you # pedirle	mono mono	M_O
once more # nuevamente	swap dis	S_O *
once more # nuevamente	dis swap	D_O
once more # nuevamente que	swap dis	S_O

inside and outside probabilities for phrase "***ask you***"- "***pedirle***" according to three parameter estimation methods

	M_I	S_I	D_I	M_O	S_O	D_O
DO	0.691	0.003	0.142	0.119	0.009	0.038
DOD	0.827	0.003	0.17	0.719	0.053	0.228
DOO	0.854	0.25	0.79	0.146	0.75	0.21

Distributions of Reordering Events





Observed **monotone** & **inside** (**M_I**) movements more often than other categories

Reordering Models

- Explicitly model phrase reordering distances
  - Distance-based (Och, 2002; Koehn et.al., 2003)
  - Lexicalized phrase (Tillmann, 2004; Koehn, et.al., 2005; Al-Onaizan and Papineni, 2006)
  - Hierarchical phrase (Galley and Manning, 2008)
  - MaxEnt classifier (Zens and Ney, 2006; Xiong, et.al., 2006; Chang, et. al., 2009)
- Put syntactic analysis of the target language into both modeling and decoding
- Use source language syntax

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- Put syntactic analysis of the target language into both modeling and decoding
  - Direct model target language constituents movement in either constituency trees (Yamada and Knight, 2001; Galley et.al., 2006; Zollmann et.al., 2008) or dependency trees (Quirk, et.al., 2005)
  - Hierarchical phrase-based (Chiang, 2005; Shen et. al., 2008)
- Use source language syntax