Improved Models of Distortion Cost for Statistical Machine Translation

Spence Green, Michel Galley, and Christopher D. Manning

Stanford University

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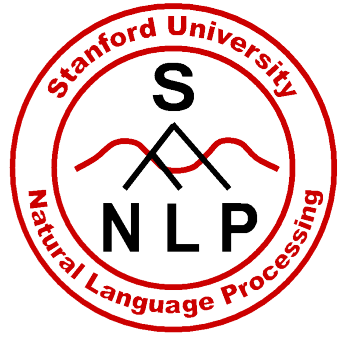

Motivation

Why phrase-based MT?

- Fast, simple, and scalable
- Good performance for many language pairs
  (Zollmann et al., 2008; Lopez, 2008; etc.)

Reordering in (baseline) phrase-based decoders controlled by:

- A distortion cost model
- A distortion limit

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Reordering in (baseline) phrase-based decoders controlled by:

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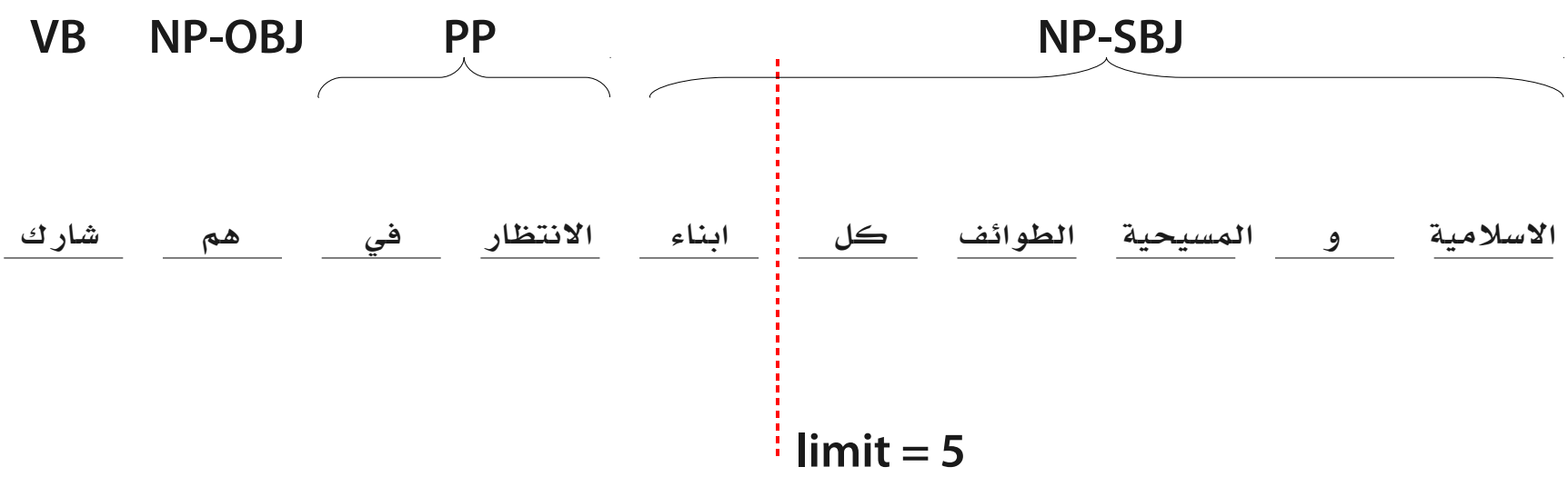
Cost model is poor, so a low distortion limit is typically used

Motivating Example

Gloss: **Followers of all of the Christian and Islamic sects engaged in waiting for them**



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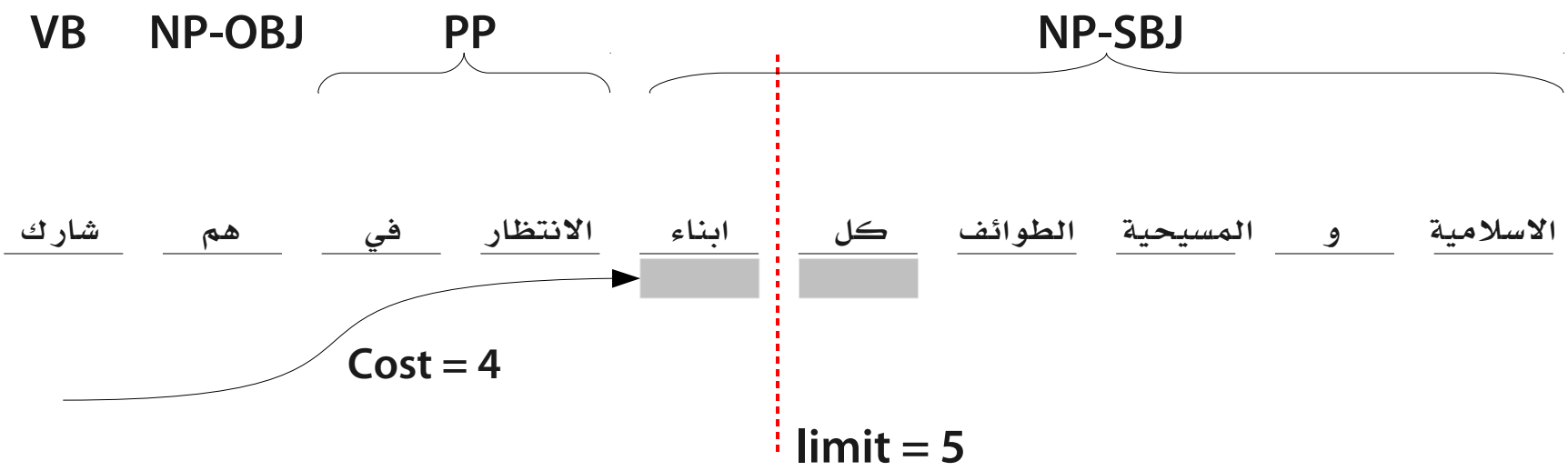

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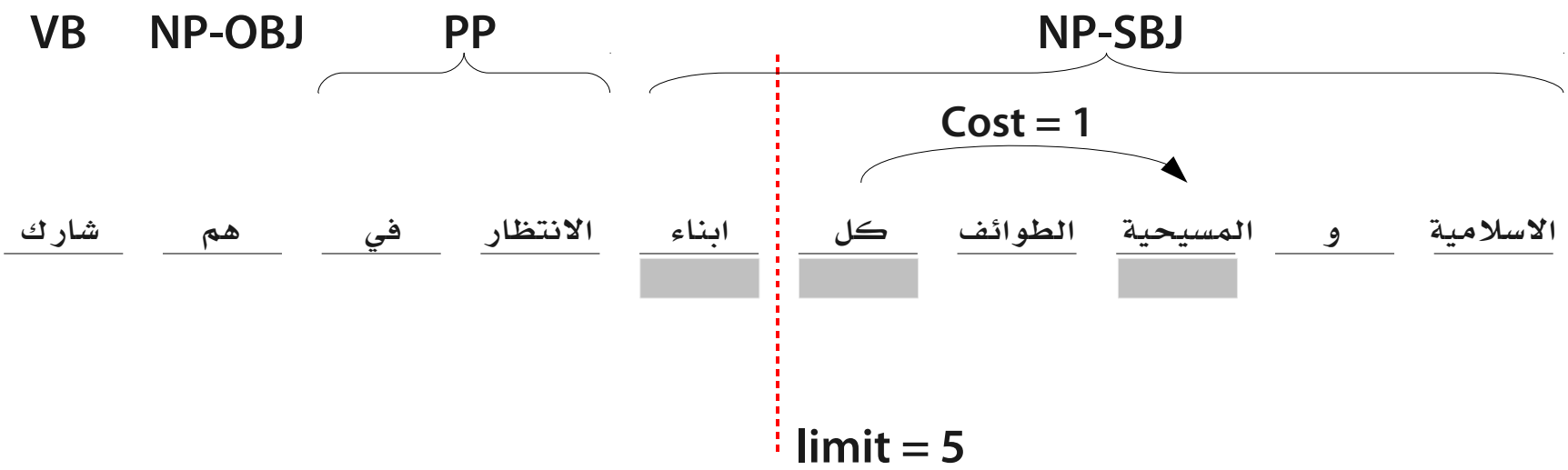

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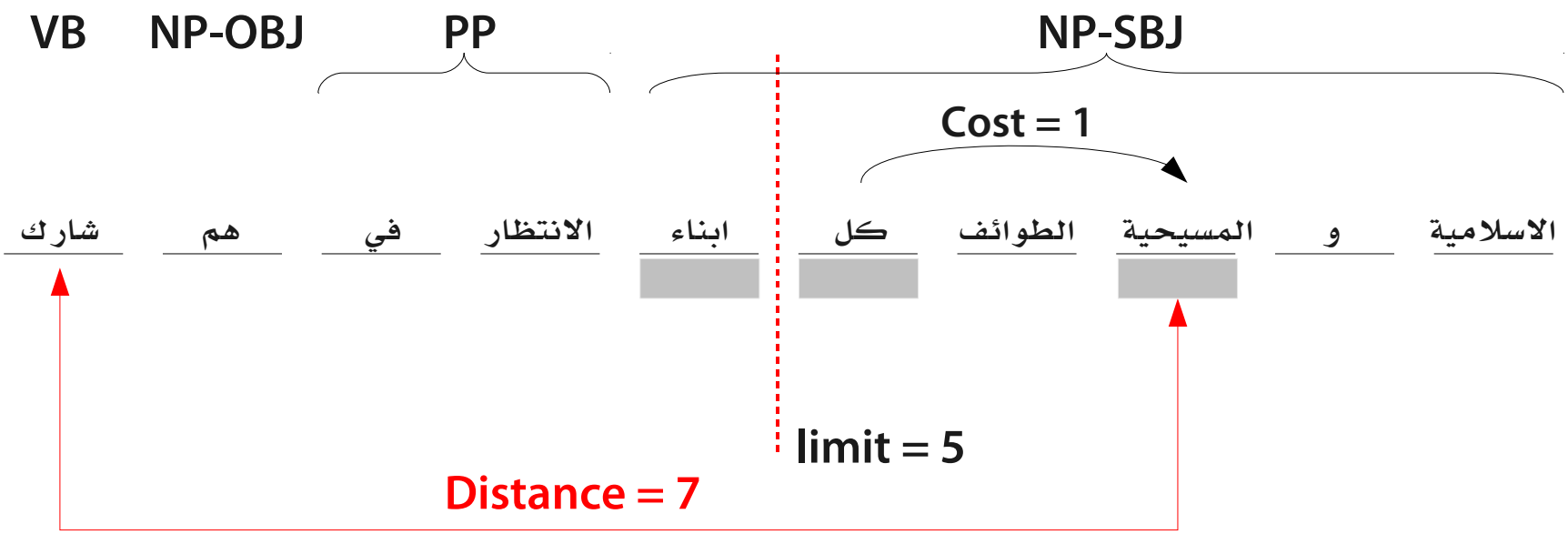

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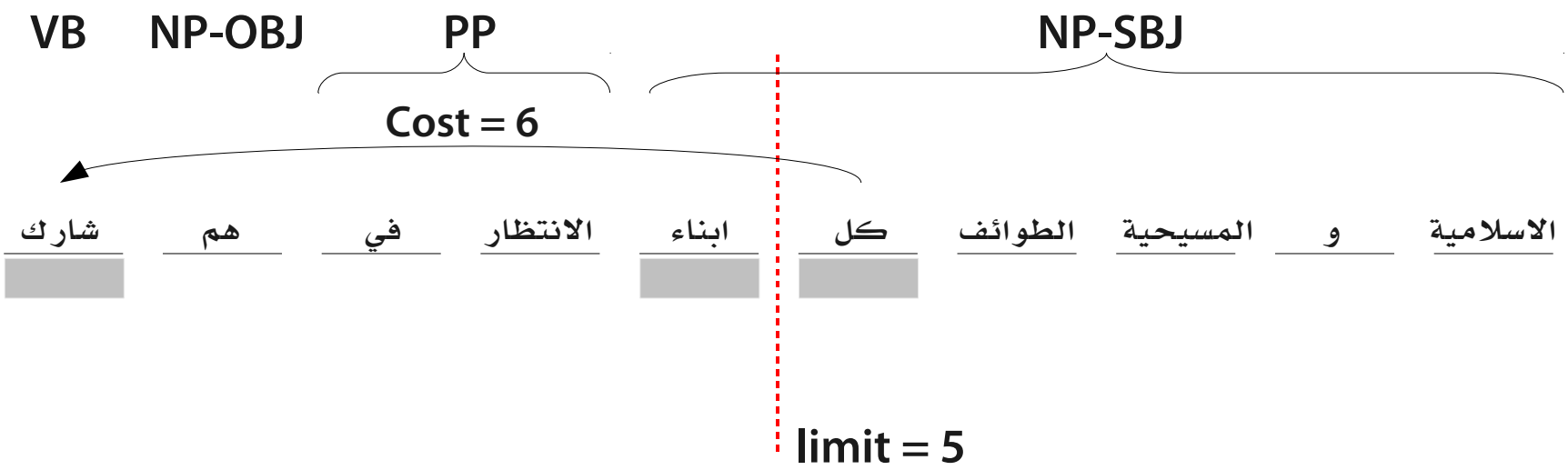

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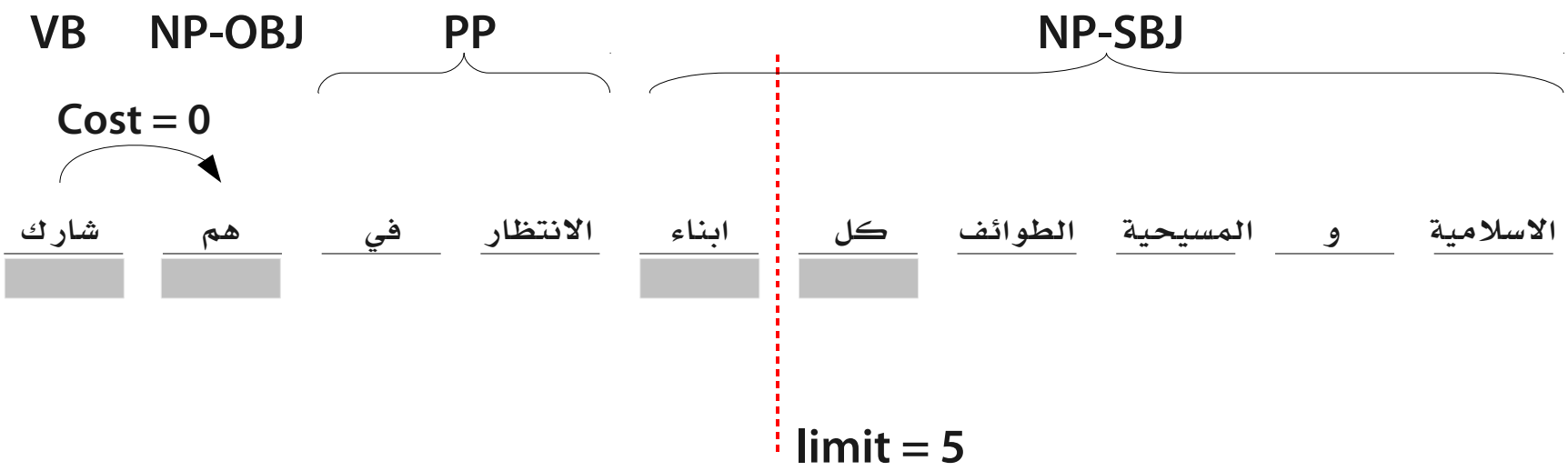

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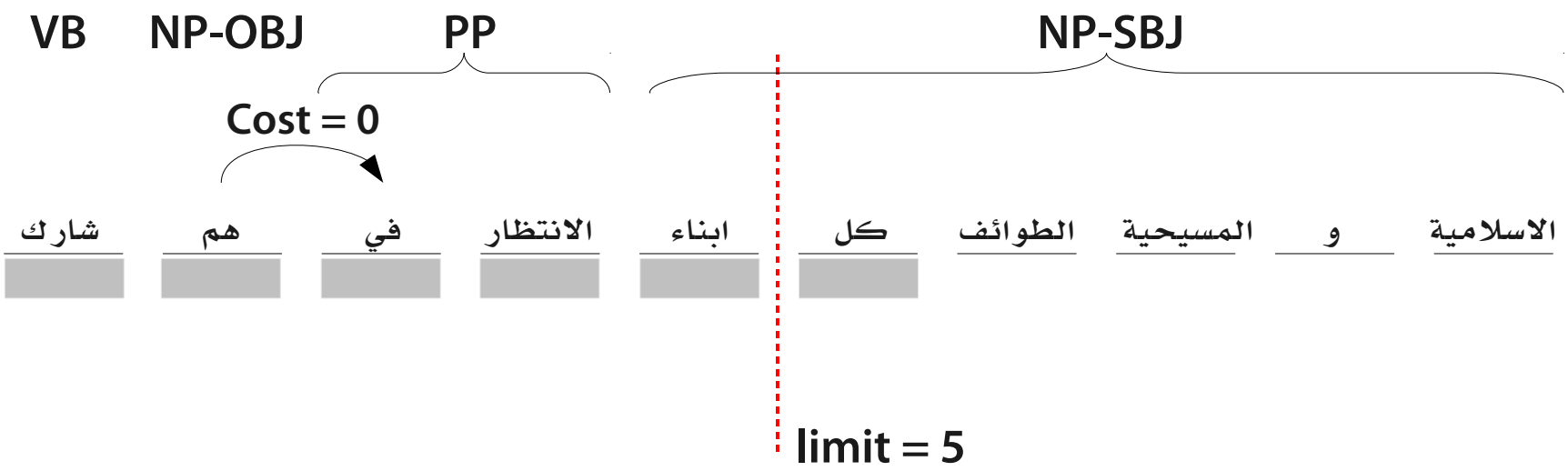

Hypothesis: Followers of all engaged them in waiting ...

Distortion Limit v. Distortion Cost

Cost is a *soft* constraint

- Does **not** prune the search space
- Feature in the log-linear decoder framework

Limit is a *hard* constraint

- Prunes translations from the search space

Distortion Limit v. Distortion Cost

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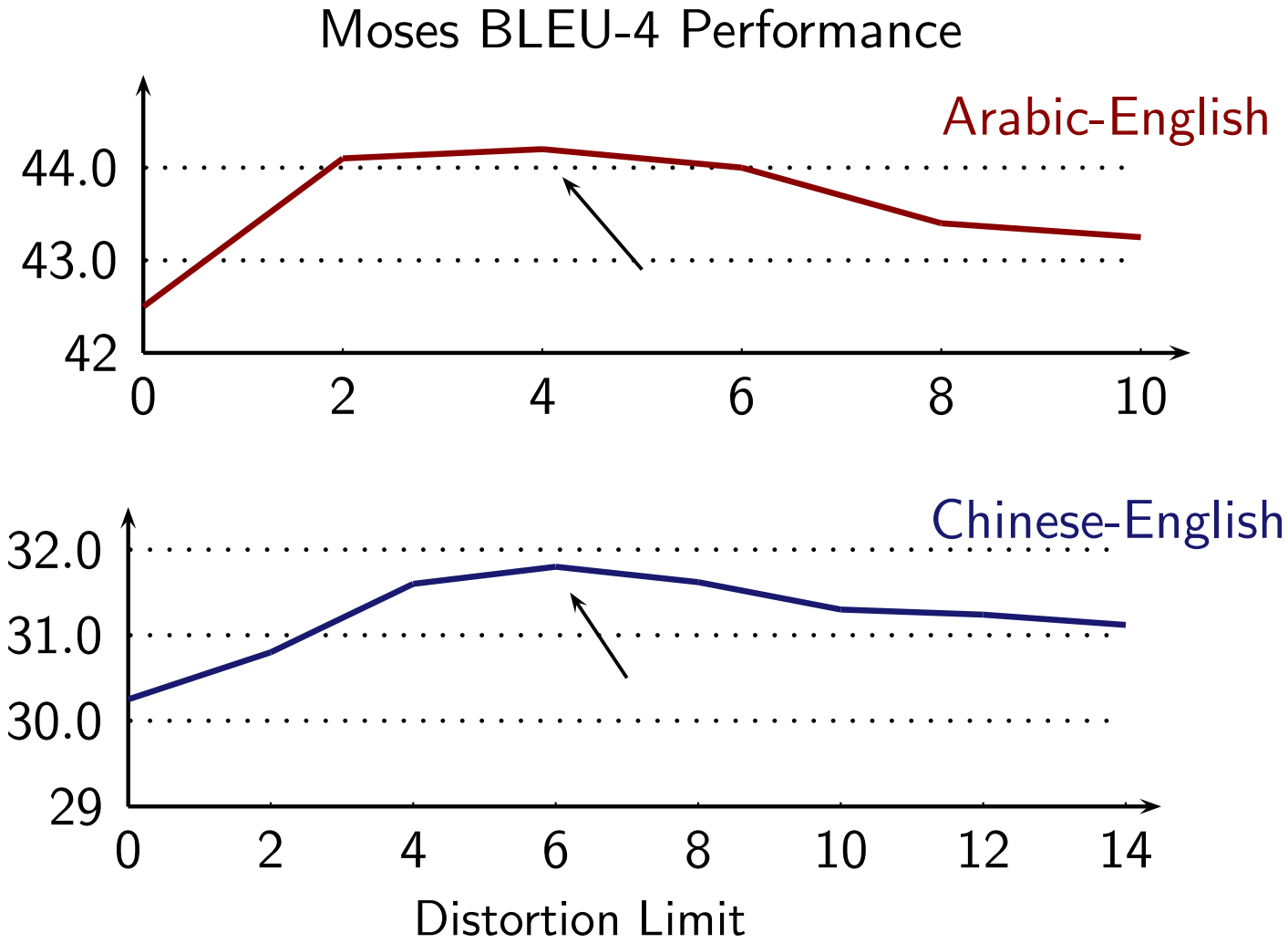
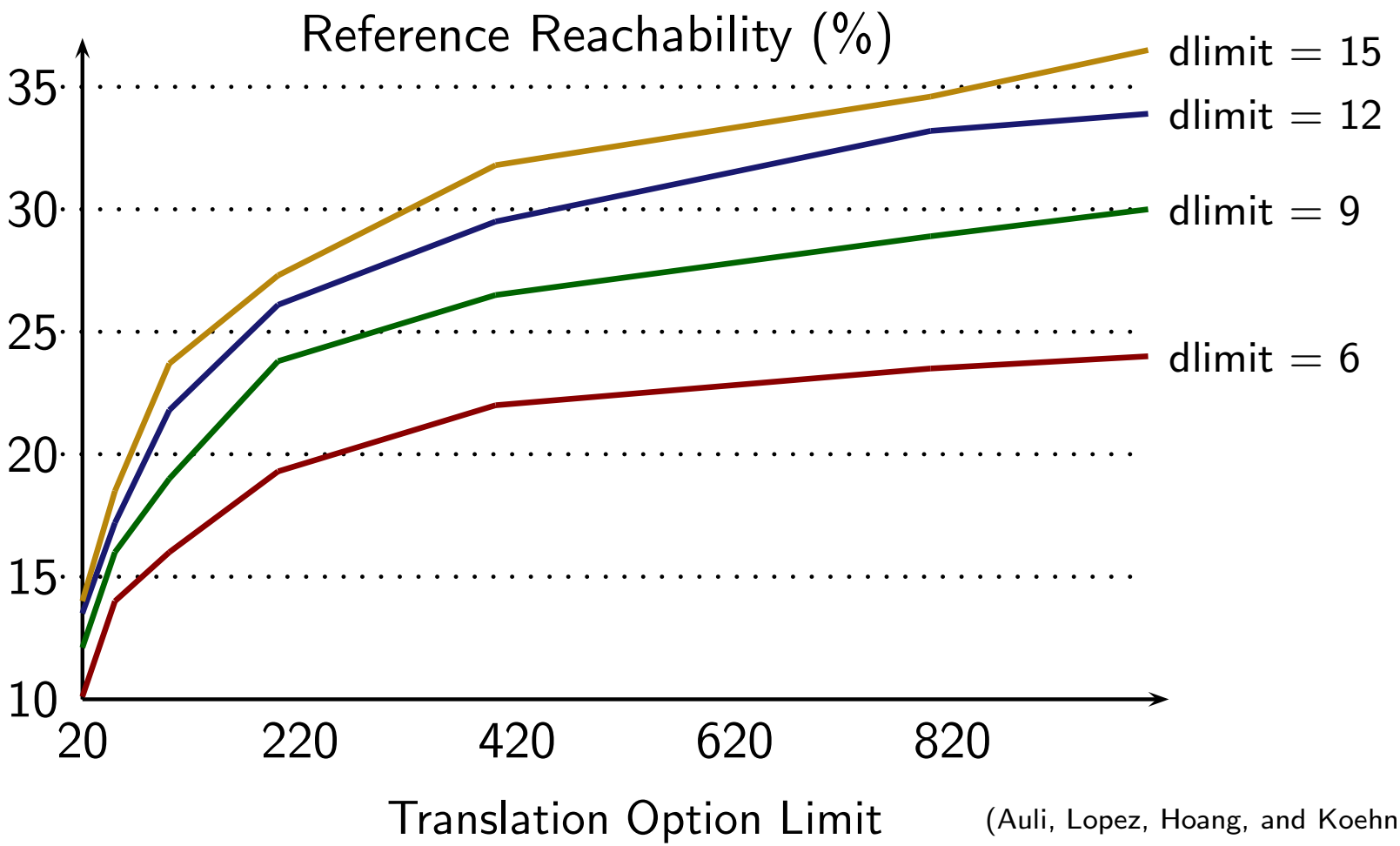
For Moses, low(er) distortion limit improves translation quality!

Translation Quality Decreases at High Distortion Limits



Hard Constraints Reduce Reference Reachability



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

A New Distortion Cost Model

Guide search *without* hard constraints

- Maintain baseline performance at high distortion limits
- Solution: Improve heuristic search with future cost estimation (Moore and Quirk, 2007)

Encourage linguistically-approriate reorderings

- Solution: Transition-based discriminative distortion model

Worst-case $O(n)$ cost computation

- Maintain linear running time of decoding!

Search Errors at High Distortion Limits

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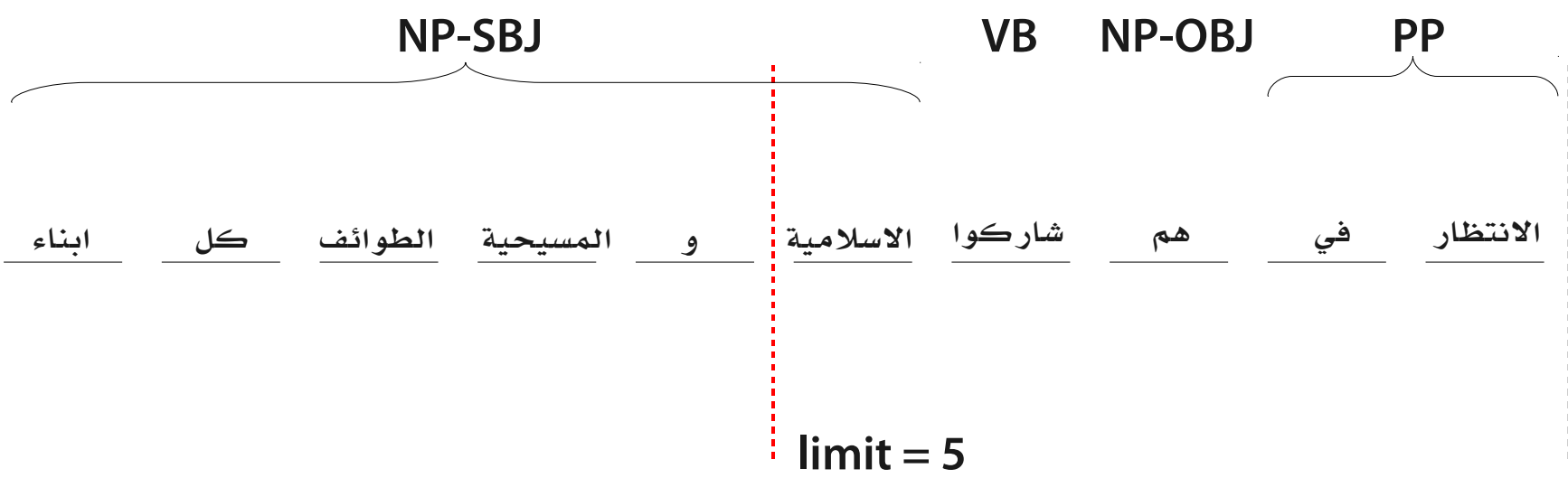

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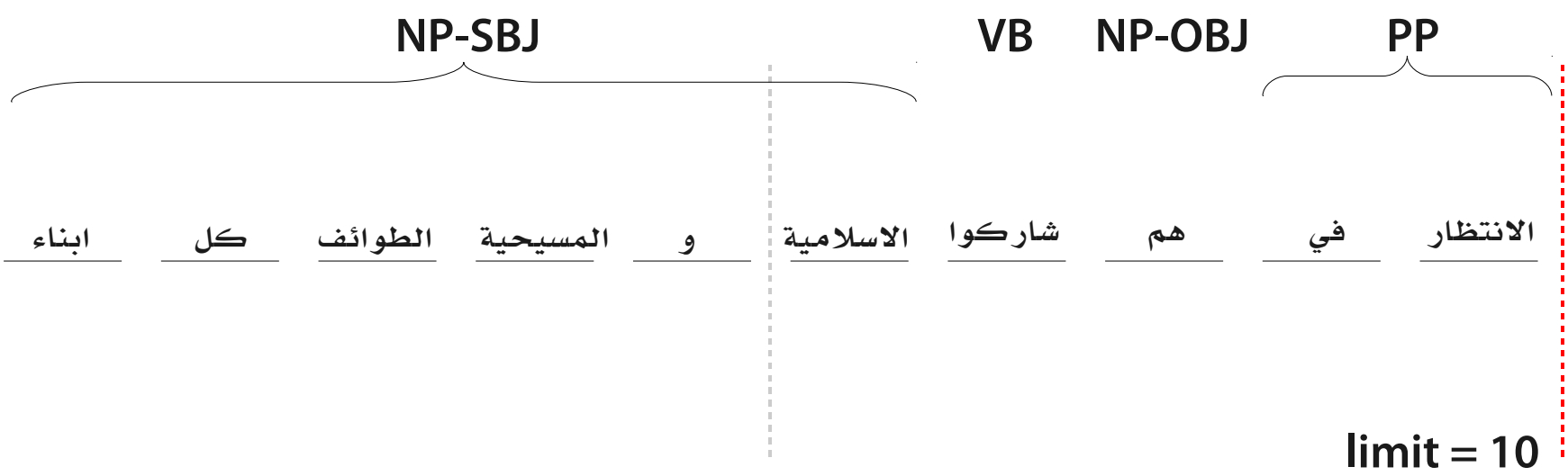

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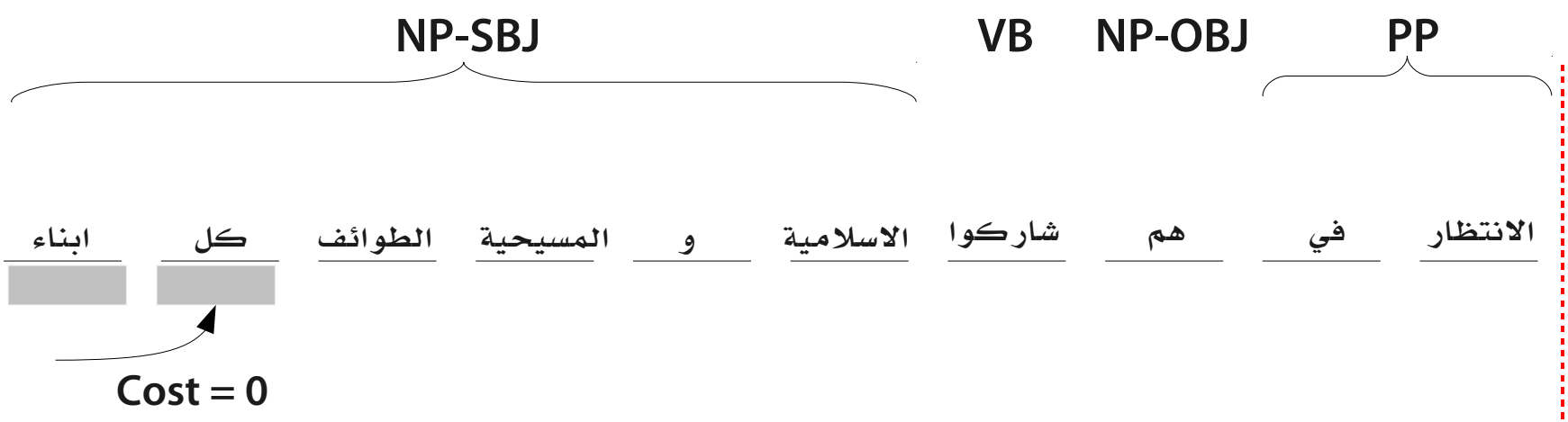

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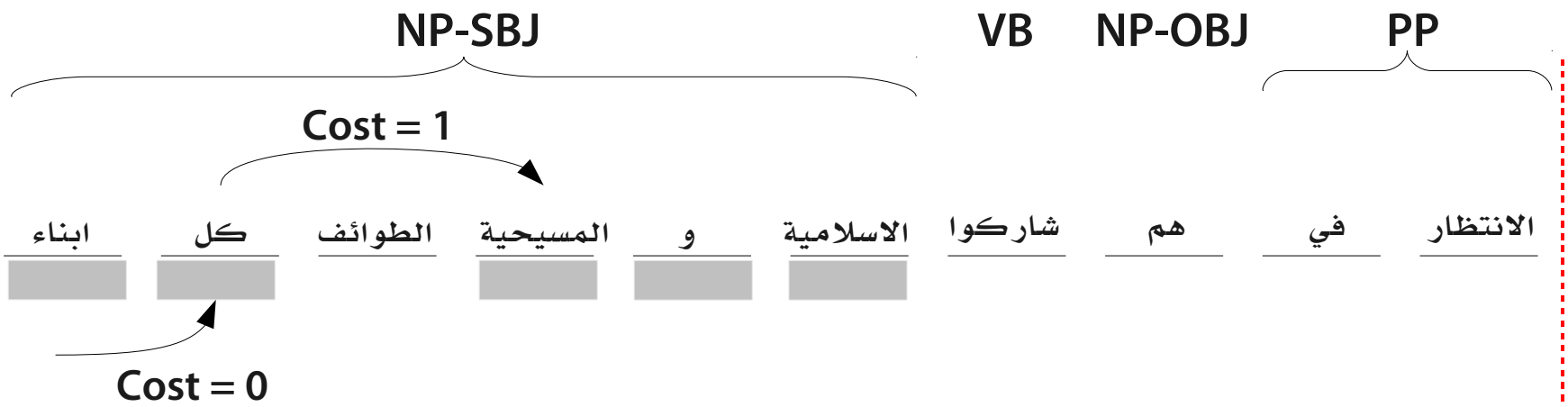

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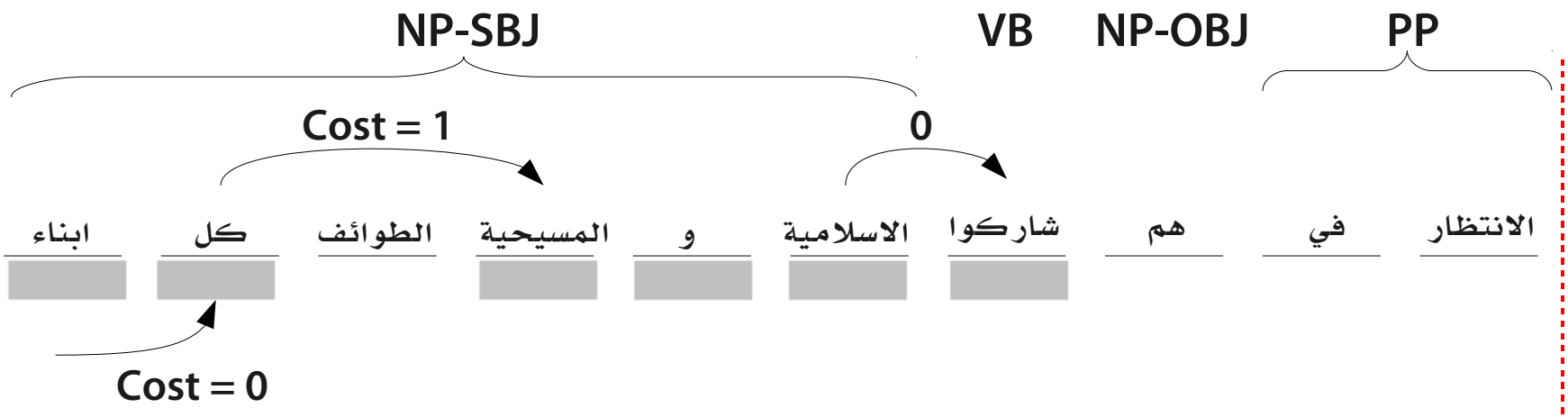

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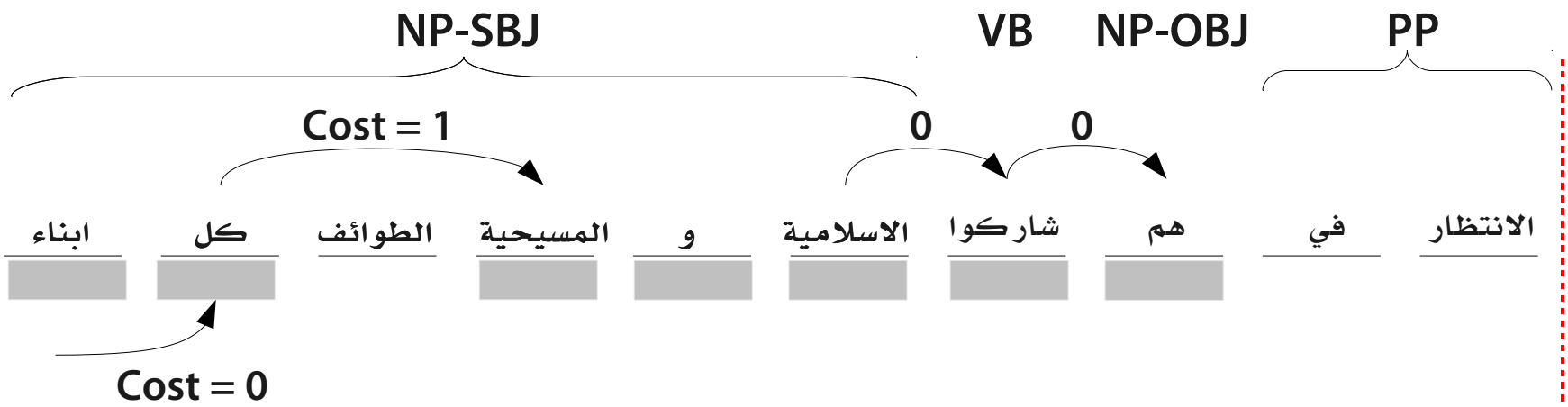

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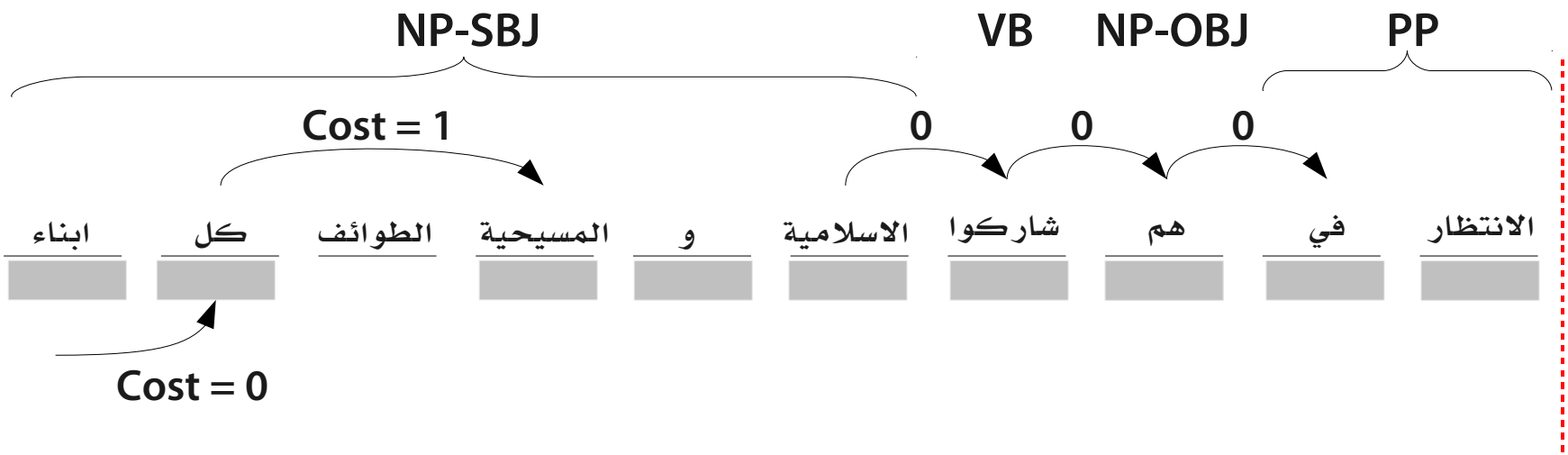

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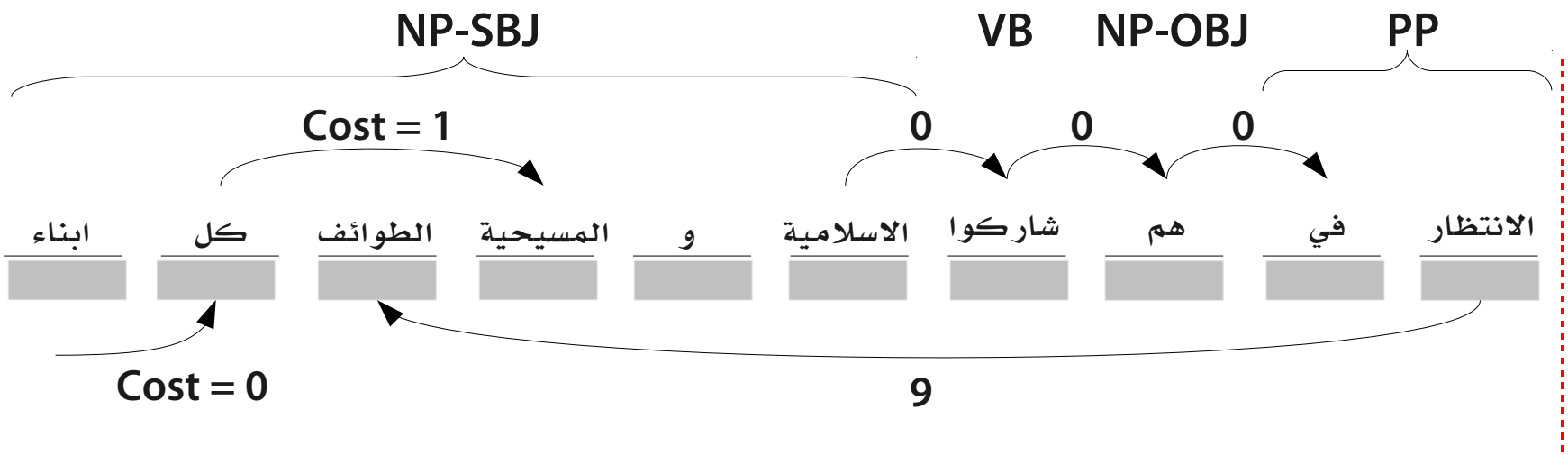

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An Admissible Future Cost Heuristic

$$
\begin{aligned}
s_j &\leftarrow \text{First } \textit{un}\text{covered source position} \\
s_{j'} &\leftarrow \text{First source position of phrase } p \\
\mathbf{C}_j &\leftarrow \text{Coverage set to the right of } s_j \\
D(s_{j'}, s_j) &\leftarrow \text{Linear distortion from } s_{j'} \text{ to } s_j
\end{aligned}
$$

When $j' > j$, the estimate is

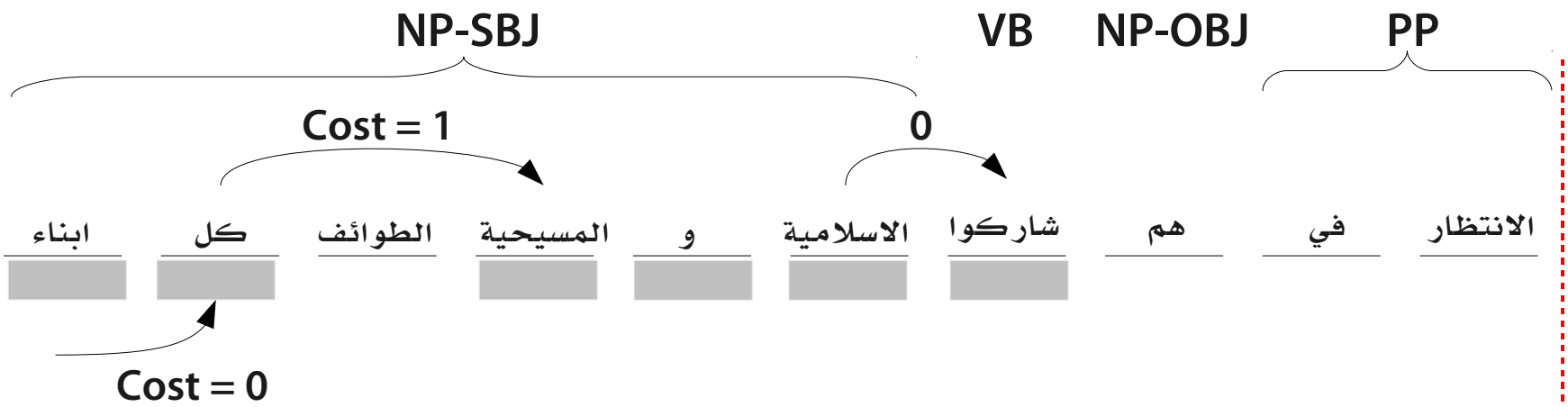
$$F = |\mathbf{C}_j| + D(s_{j'}, s_j)$$

Update the estimate at each translation step n

$$\Delta F = F_n - F_{n-1} \qquad n > 0$$

Linear Distortion with Future Cost

Gloss: Followers of all of the Christian and Islamic sects engaged in waiting for them



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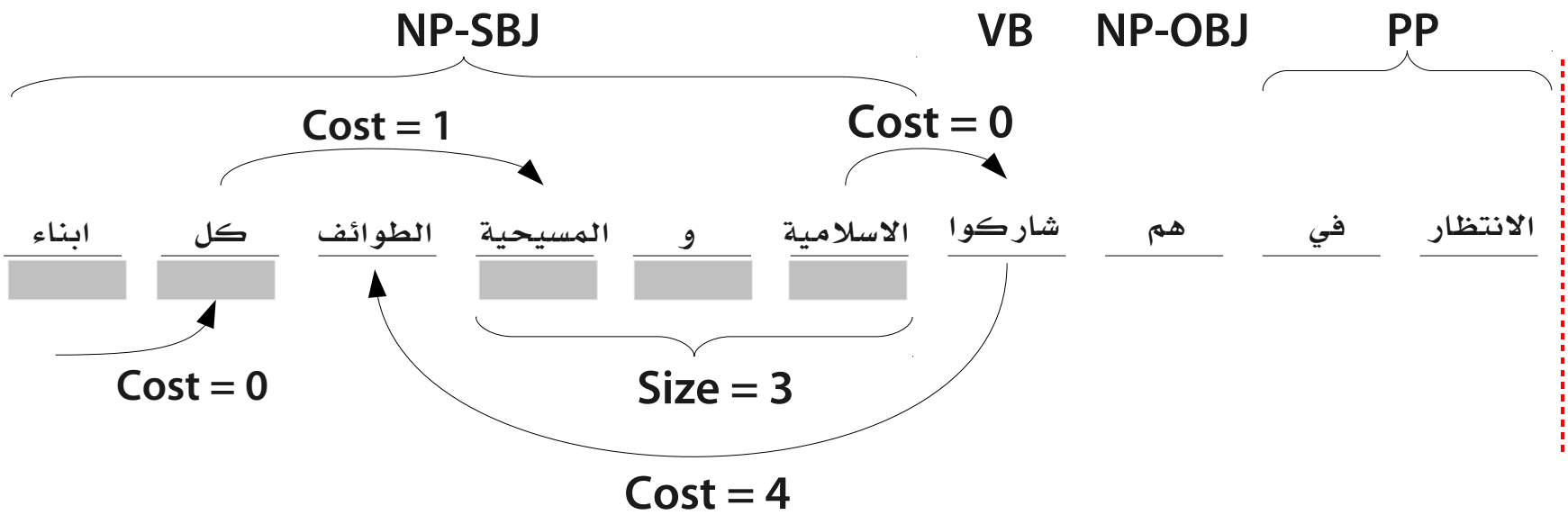

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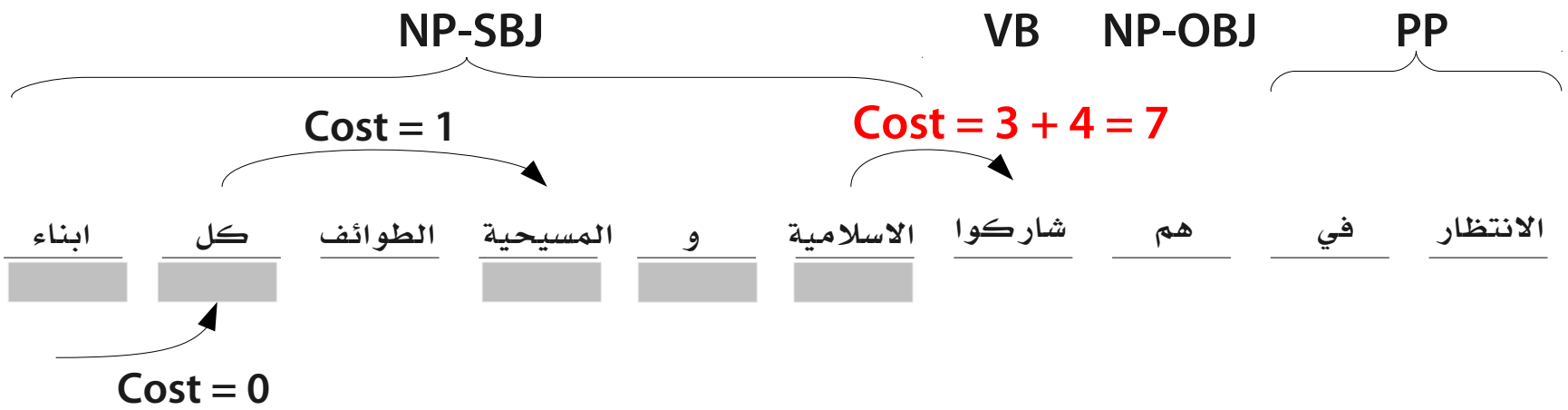

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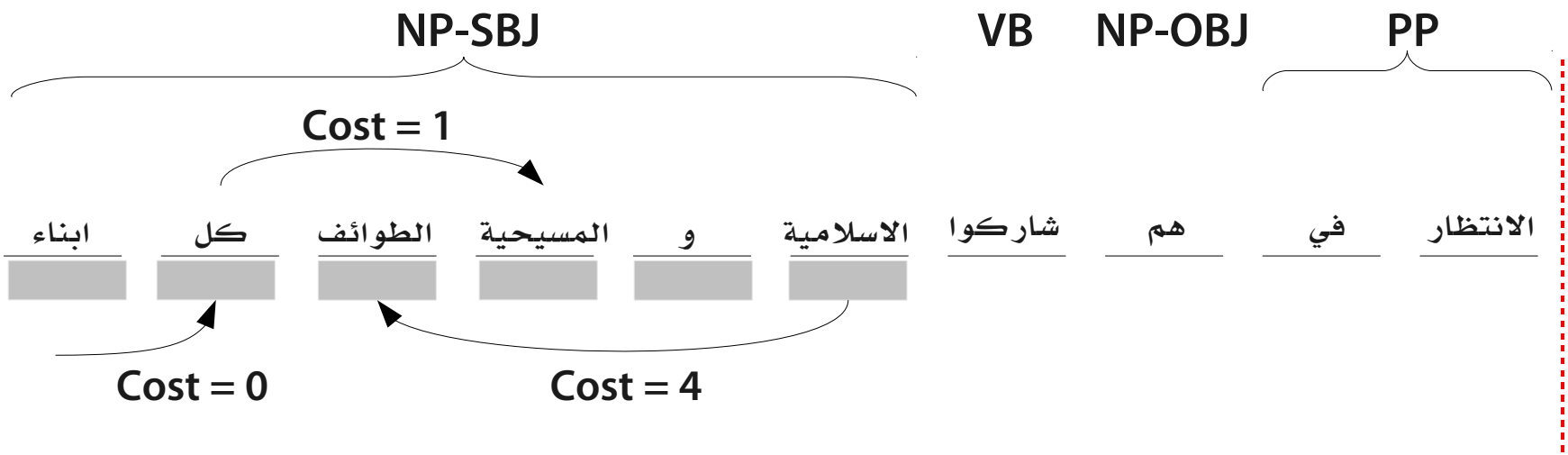

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Transition-based Discriminative Distortion Cost

Problem: Cost model still penalizes **all** reorderings

- Consider a verb-final language like Japanese
- Skipping over the entire verb complement is *good*
- Model should prefer particular reorderings

A **transition-based** discriminative distortion model

- Idea: compute cost of word-to-word transitions
- Source side features
- Discretized transition classes

Procedure

1. Classify discretized transitions with a log-linear model

$$p_\lambda\left(D_{j,j'} \mid \bar{\mathbf{s}}, j, j'\right) \propto \exp\left[\,\bar{\lambda} \cdot \bar{\mathbf{h}}\left(\bar{\mathbf{s}}, j, j', D_{j,j'}\right)\,\right]$$

2. Train with sorted word-to-word alignments
   - e.g. Arabic $\Longrightarrow$ Arabic$'$ (English word order)
3. Query model for transitions at each translation step

Features

This evaluation

- Words and POS tags
- Relative source sentence position (discretized)
- Source sentence length (discretized)

Future work

- POS tag chains (bigram, trigram, etc.)
- Agreement morphology
- Subject has been translated? (binary, global)

Further Motivation

Incremental processing like shift-reduce parsing

- Process source items in decoding order
- Classes are discrete jumps instead of "operations"
- Beam search via the decoder

Implementation: Constant-time During Decoding

Nine discrete distortion classes

- Same number of training examples per class

Separation into inbound/outbound models (Al-Onaizan and Papineni, 2006)

- Simplifies caching during decoding
- Future work: Combine into a single model

Model has four decoder features

- Inbound and outbound scores
- **Alignment penalty**
- **Future cost estimate**

Evaluation

MT system is Phrasal (Cer et al., 2010)

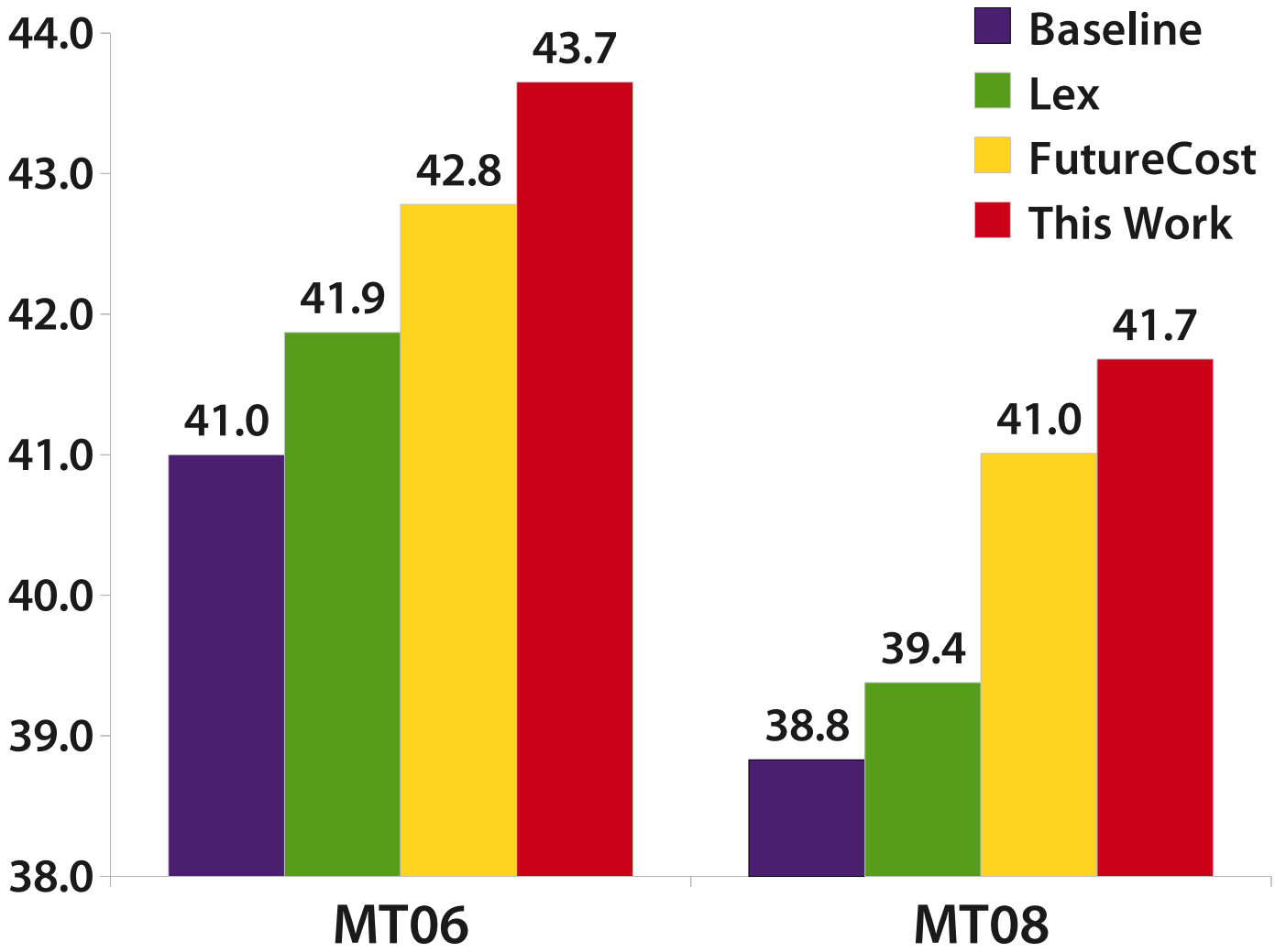
- Baseline: Moses feature set
- Lexicalized reordering model of Galley and Manning (2008)

NIST MT09 Ar-En constrained track training data

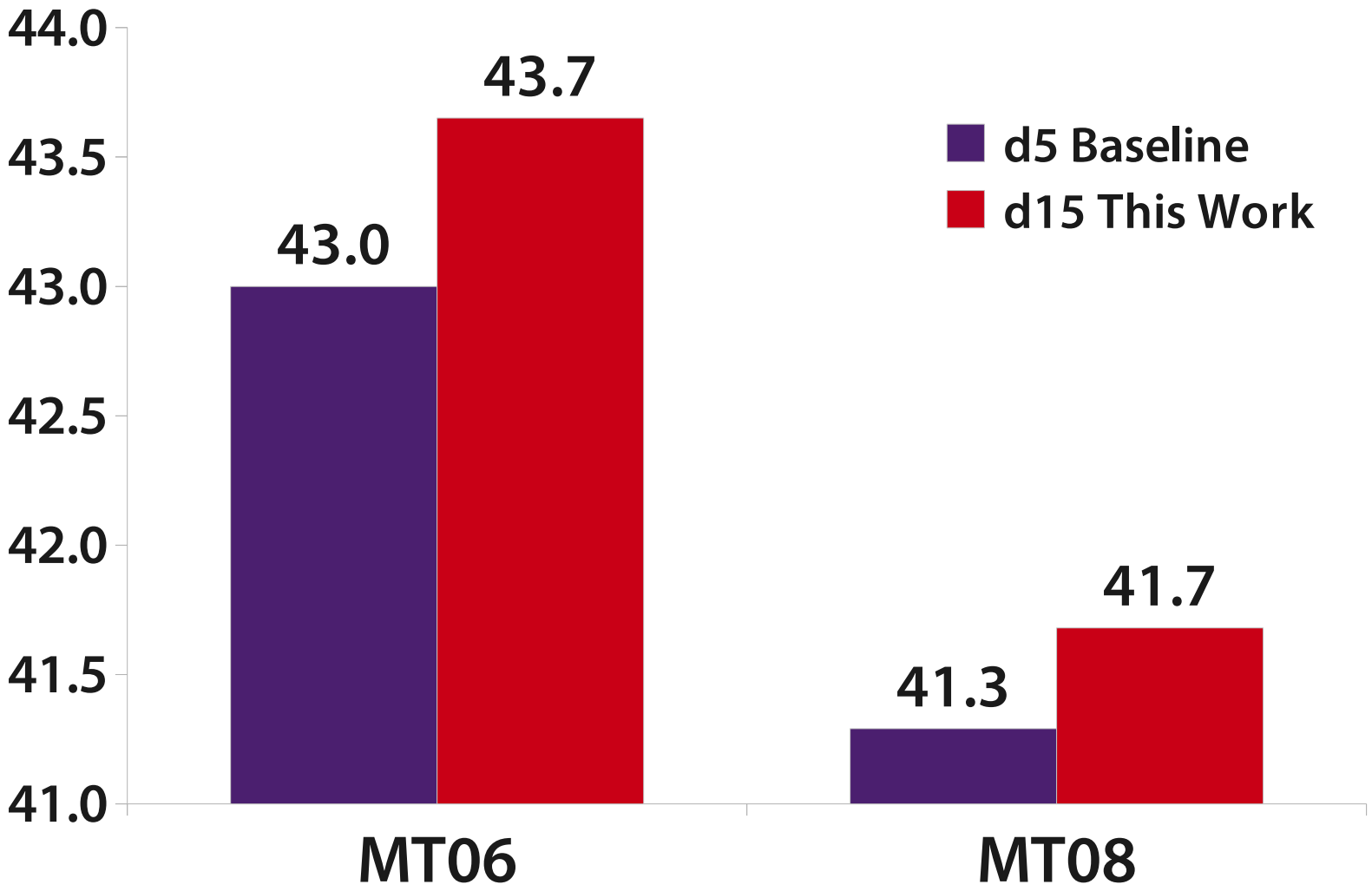
- Removed UN and comparable data
  - Same baseline, faster experiments
- 6.20M English and 5.73M Arabic tokens

Evaluated BLEU-4 on MT03/05/06/08 at dlimit = 15

High Distortion Limit (15)



Improvement Over the Low Distortion Limit Baseline



Conclusion

Contributions of this work

- Fixed search errors caused by linear distortion
- Added a distortion model with linguistic features
- Modest improvement over Moses at a high distortion limit

Software:

Phrasal	http://nlp.stanford.edu/phrasal/
Arabic NLP tools	http://nlp.stanford.edu/projects/arabic.shtml

Thank You!

Thanks to Daniel Cer and Claude Reichard.

Distortion Cost Curve for the adjective *American*