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# Improvements in DP Beam Search for Phrase-based SMT

**Richard Zens and Hermann Ney**

**Human Language Technology and Pattern Recognition**
**Lehrstuhl für Informatik 6**
**Computer Science Department**
**RWTH Aachen University, Germany**

# Overview

1. Introduction & related work
2. Search for phrase-based MT
3. Experimental results
4. Summary & conclusions

# Contributions

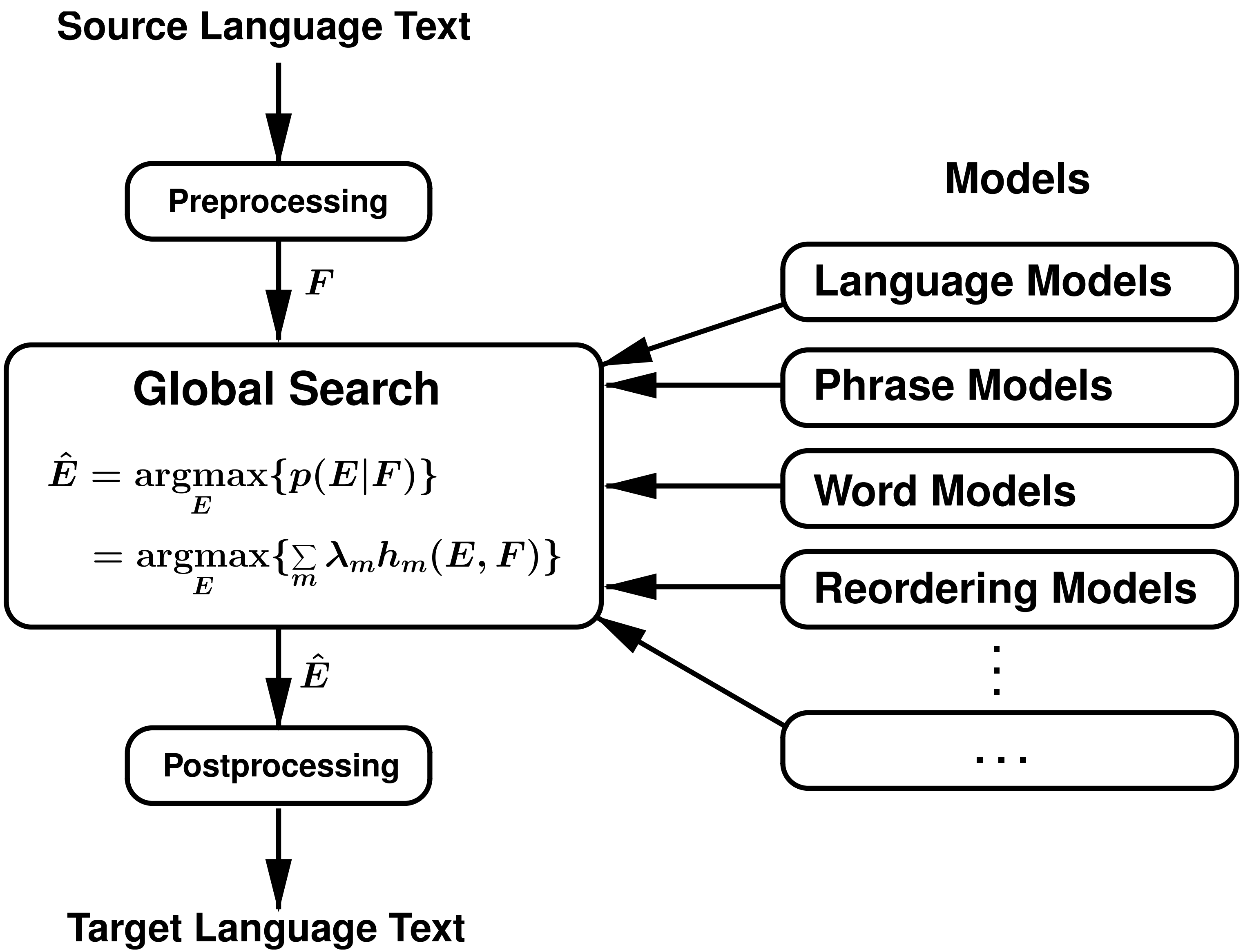
- clear & precise description of phrase-based search
- analysis of important aspects
  - rest score estimation
  - lexical vs. coverage hypotheses
  - beam search including cube pruning

  on a large data task

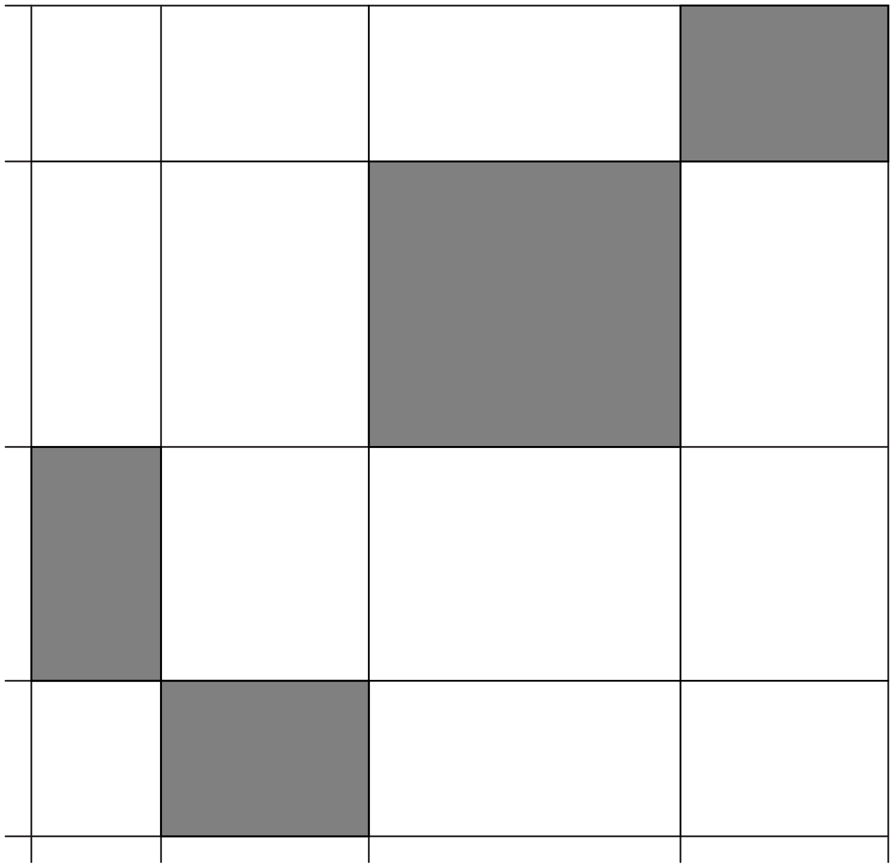
# Related Work

- based on
  - [Zens & Och$^{+}$ 02]: phrase-based model
  - [Och 02]: rest score estimation (for AT)
  - [Tillmann & Ney 03]: search for SWB models
- other related work:
  - Pharaoh [Koehn 03], Moses [Koehn & Hoang$^{+}$ 07]
  - many others, e.g. [Tillmann 06], [Moore & Quirk 07], ...

# System Architecture



# Search for Phrase-based SMT



interdependencies:

- find phrase boundaries
- reordering in target language
- find most ‘plausible’ sentence

constraints:

- no gaps
- no overlaps

# Search

- **goal:** $\underset{E}{\operatorname{argmax}} \left\{ \max_{S} \sum_{m=1}^{M} \lambda_m h_m(E, S; F) \right\}$

  **with target sentence $E$, segmentation $S$, source sentence $F$, models $h(\cdot)$, weights $\lambda$**

- **models:**
  - **within phrase models:**
    **phrase lexica, word lexica, word penalty, phrase penalty**
  - **$n$-gram backing-off language model**
  - **distortion penalty**

# Search Space

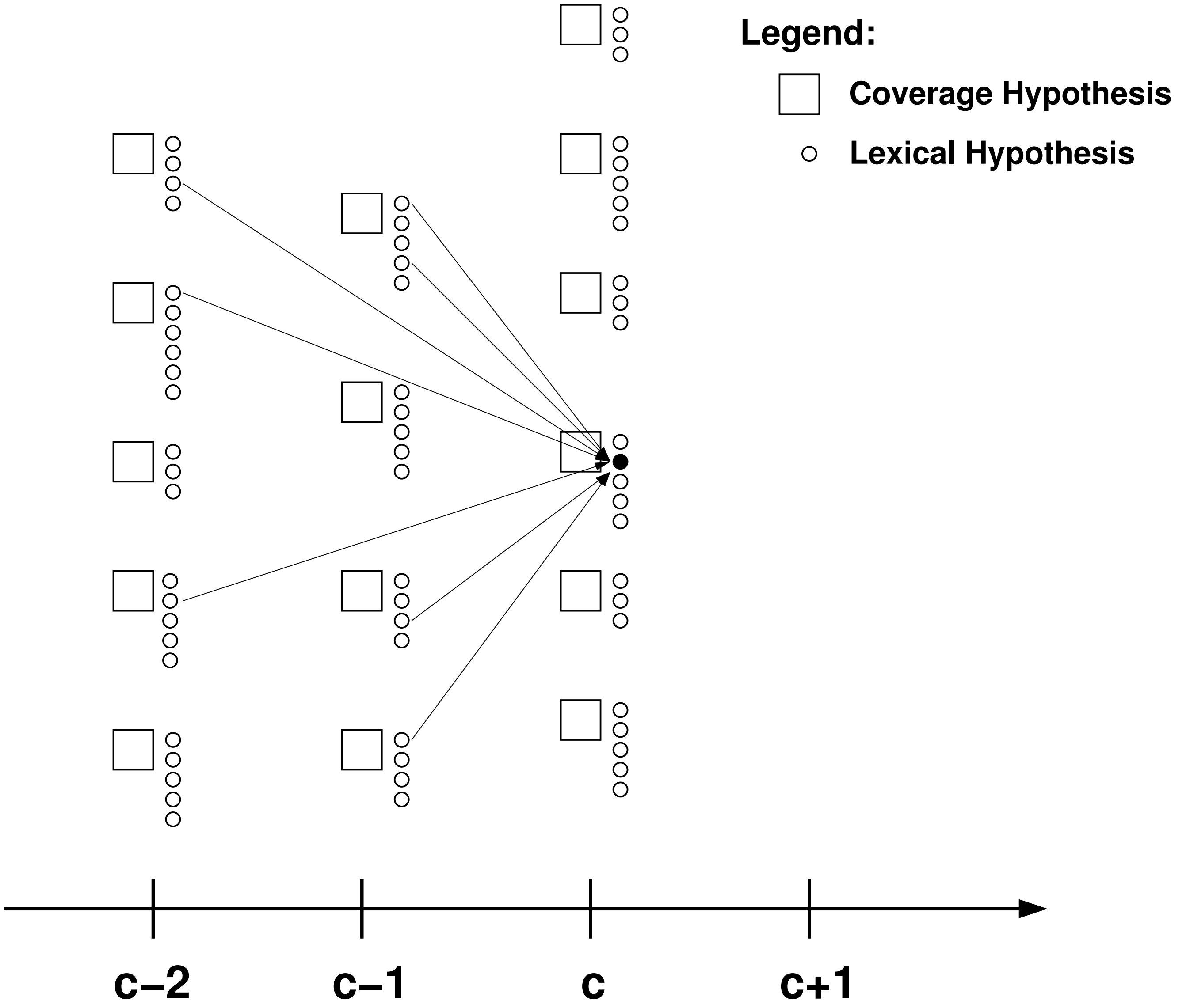
- source sentence $F = f_1, ..., f_J$
- states $(C, \tilde{e}, j)$
  - coverage $C \subseteq \{1, ..., J\}$: translated input positions
  - LM history $\tilde{e}$ to predict the next target word
  - source position $j$ for the distortion model
- edges $(\tilde{e}, j, j')$
  - generate target phrase $\tilde{e}$
  - which covers the source sentence words $f_j, ..., f_{j'}$
- expanding $(C, \tilde{e}, j)$ with $(\tilde{e}', j'', j')$ results in state

$$(C \cup \{j'', \ldots, j'\}, \tilde{e} \oplus \tilde{e}', j')$$

# Lexical vs. Coverage Hypotheses

- **(partial) hypothesis: path to state** $(C, \tilde{e}, j)$
- **for each cardinality** $c = |C|$**:**
  **we have a list of *coverage* hypotheses** $C$
- **for each coverage** $C$**:**
  **we have a list of *lexical* hypotheses** $(\tilde{e}, j)$
- **beam search: limit the list sizes**

# Search Illustration



# Algorithm Details

- DP beam search
  - generate hypotheses with increasing cardinality by expanding hypotheses with lower cardinality
  - recombine hypotheses with same state
  - expand only promising hypotheses
- share computations between expansions,
  e.g. check for overlap, rest score computation, ...
- early pruning
  stop expansion as soon as possible
- expand most promising candidates first

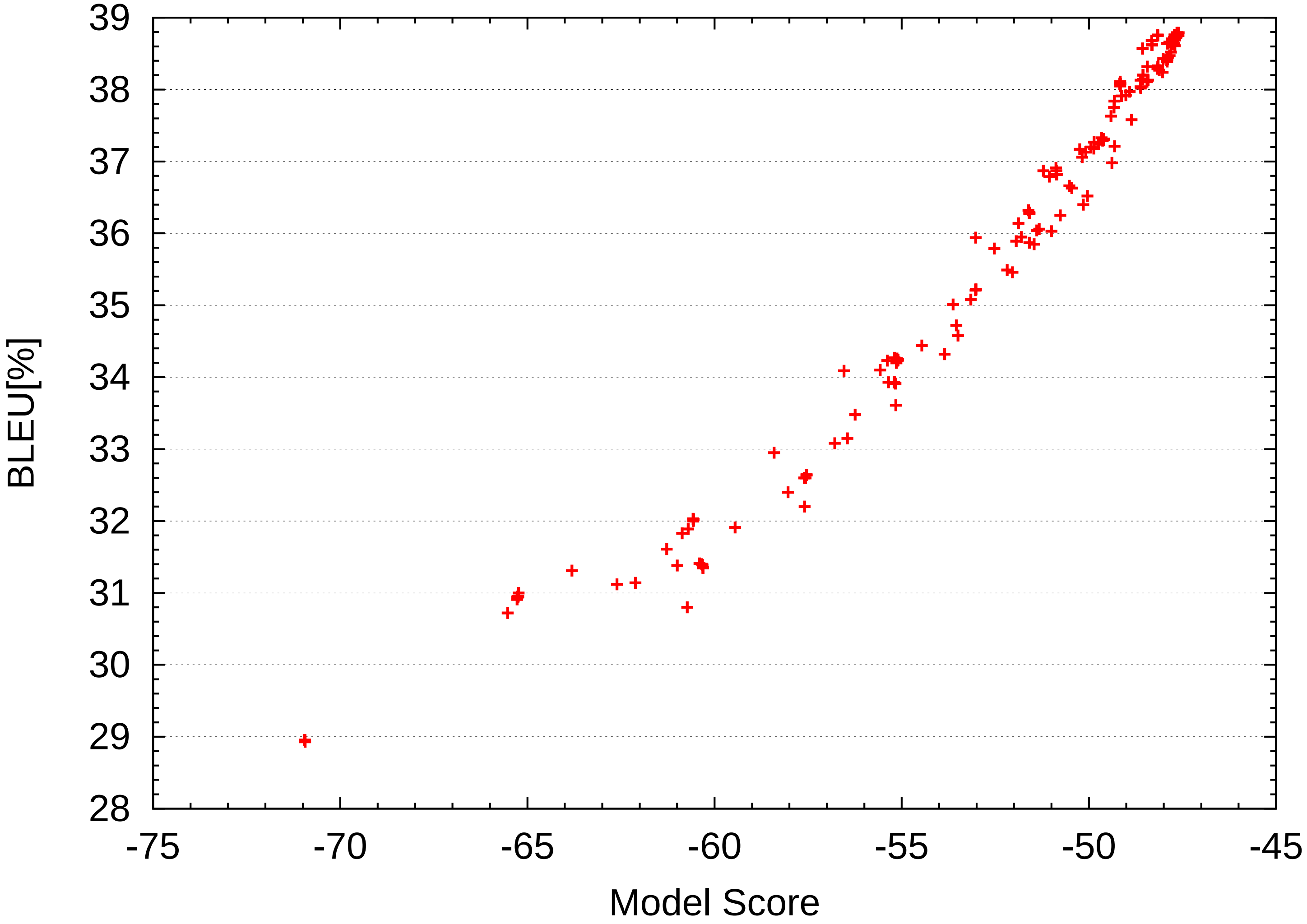
# Rest Score Estimation

- estimated score of hypothesis completion (inspired by A*)
- previous work:
  - [Och 02, Och & Ney 04]
    TM & LM per source position, distortion
  - [Koehn 03]
    TM & LM per source sequence, no distortion
- here: comparison of
  - computation per position and per sequence
  - models: TM only; TM & LM; TM, LM & distortion

# Experimental Results

- NIST Chinese-English large data task
- TM:
  training data: 8 M sentence pairs, 250 M words
  phrase-based, word-based lexica, word / phrase penalty
- LM:
  4-gram, trained on 650 M words, SRILM [Stolcke 02]
- reordering:
  distortion penalty, reordering window: 10
  lexicalized reordering model [Zens & Ney 06]
- evaluation:
  case-insensitive Bleu score (mt-eval) on NIST 2002 test set

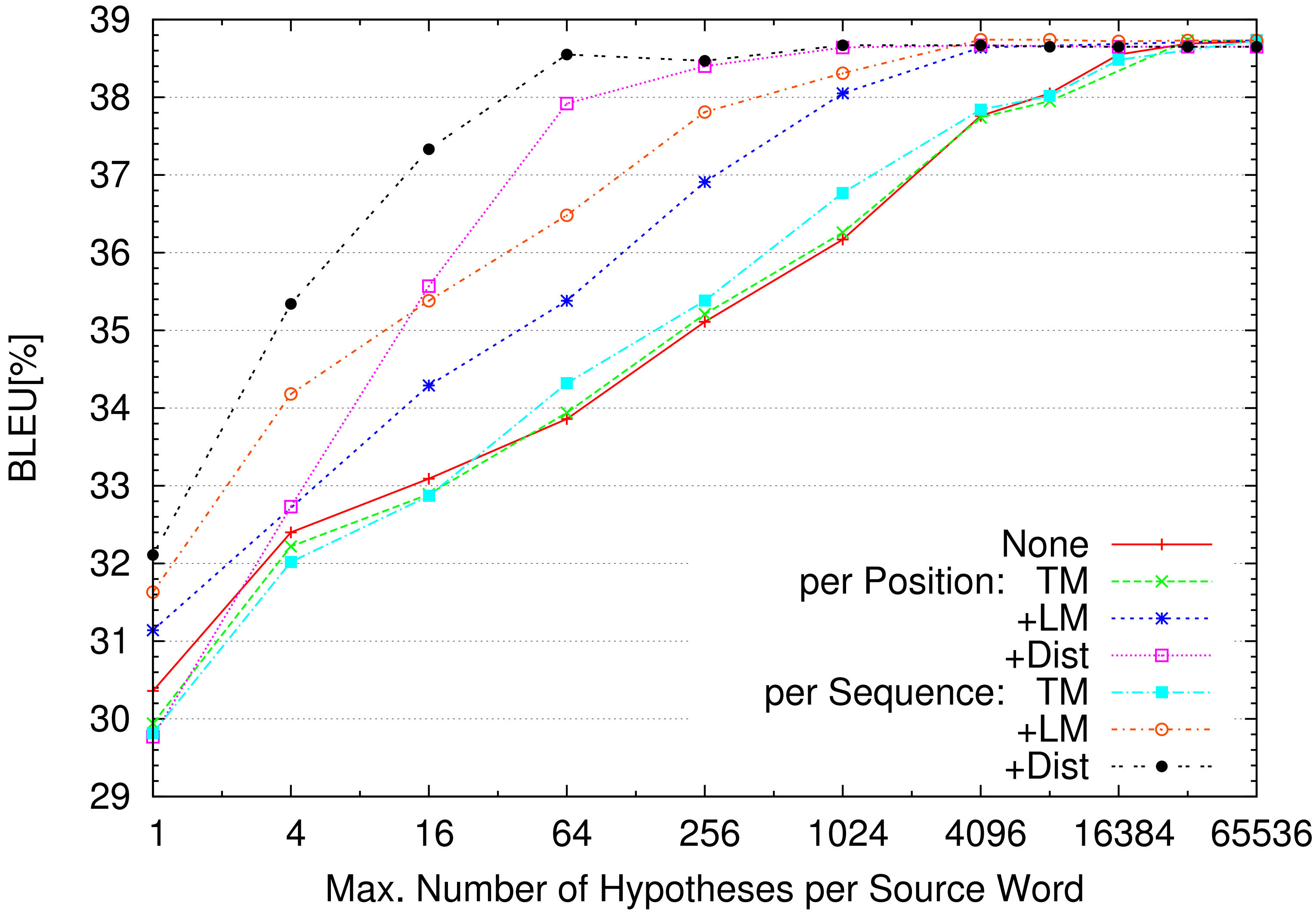
# Effect of Search Errors



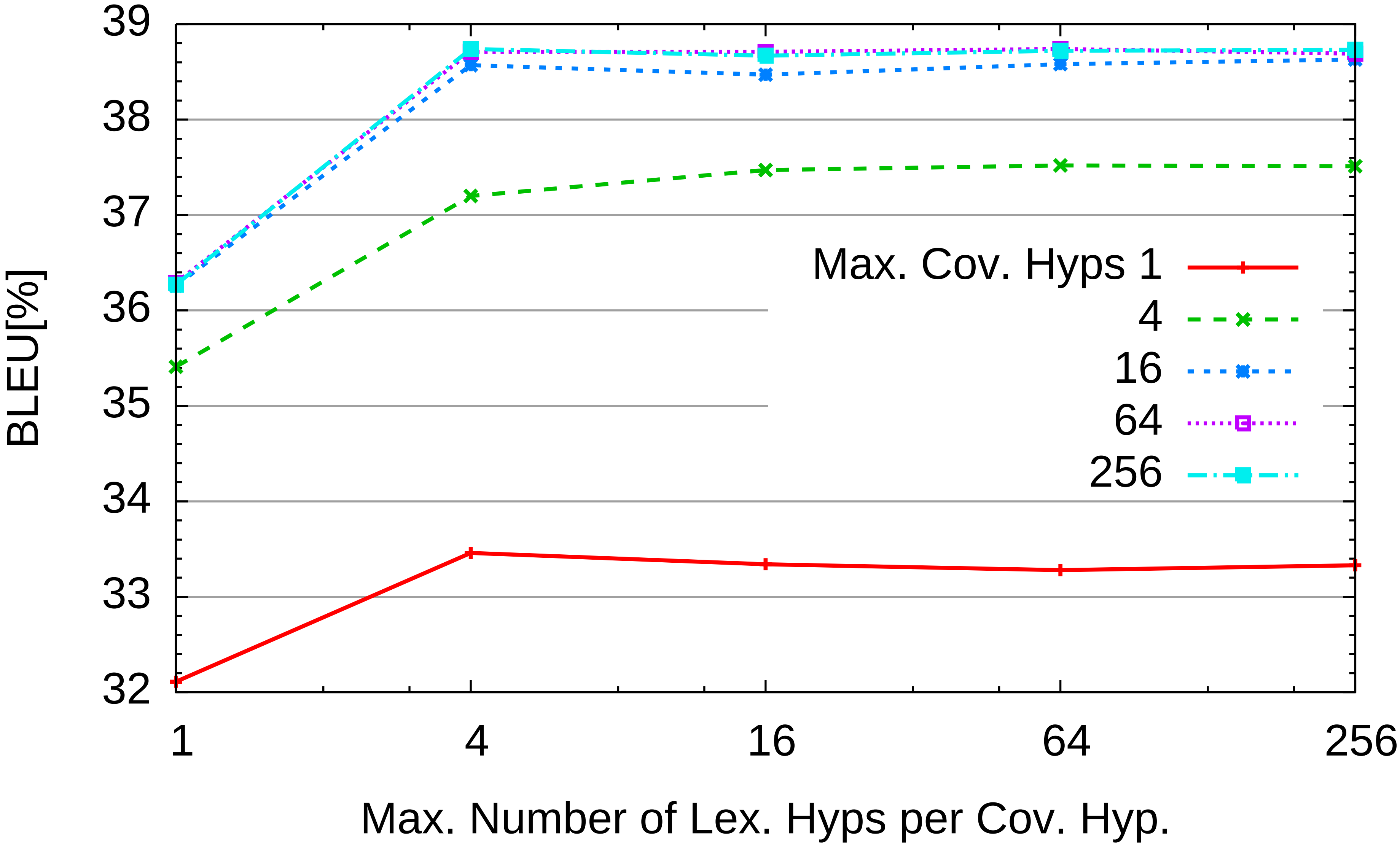

**Translate test set with various pruning parameters settings.**

**Model score averaged over whole test set (878 sentences).**

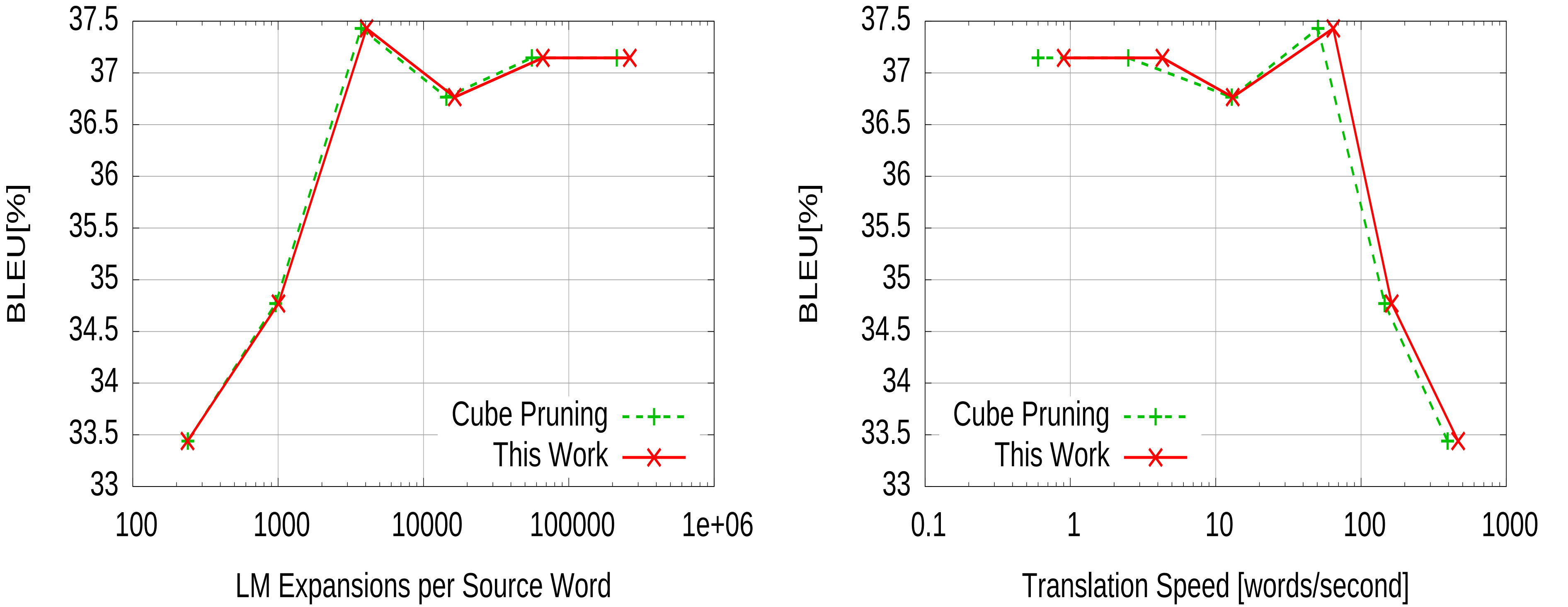
# Rest Score Estimation



# Lexical vs. Coverage Hypotheses



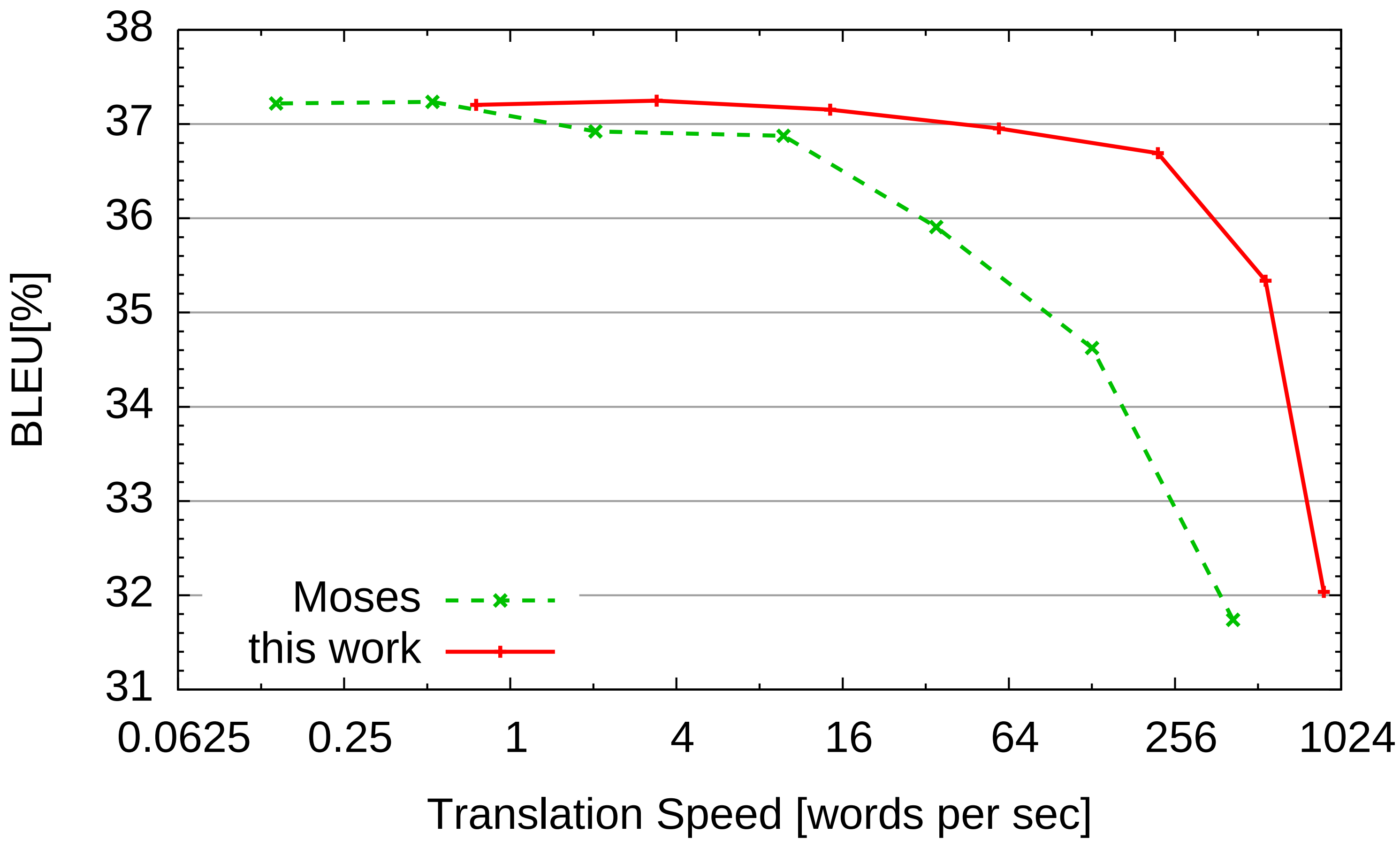
# Effect of Cube Pruning




**Numbers averaged over whole test set; vary beam sizes.**

**Lexicalized reordering not used, just distortion penalty.**

# Comparison with Moses




**Same TM, LM, etc.; vary beam setting**

**Lexicalized reordering not used, just distortion penalty.**

# Summary & Conclusions

- Summary
  - detailed problem description
  - efficient solution
  - in-depth analysis
- Conclusions
  - search important for good translation quality
  - rest score estimation allows for small beam sizes
  - distinction lexical vs. coverage hypothesis important
  - additional cube pruning not necessary
  - significantly faster than Moses

**THANK YOU FOR YOUR ATTENTION!**

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