# What Matters Most In Morphologically Segmented SMT Models?

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# Overview

- **Determine what steps and components of phrase-based SMT pipeline benefits the most from segmenting target language.**
- **Testing several scenarios by changing the desegmentation point in the pipeline on English-Arabic SMT system**
- **Phrases with flexible boundaries are a crucial property to a successful segmentation approach**
- **Show impact of unsegmented LMs on generation of morphologically complex words**

# Segmentation/Desegmentation

**Original Word**

وبلعبتها wblEbthA/*and with her game*

**Segmentation:** *t* **to** *p*

| w+/*and* | b+/*with* | lEbp/*game* | +hA/her |
|---|---|---|---|
| +و | +ب | لعبة | +ها |

**Desegmentation**

وبلعبتها wblEbthA

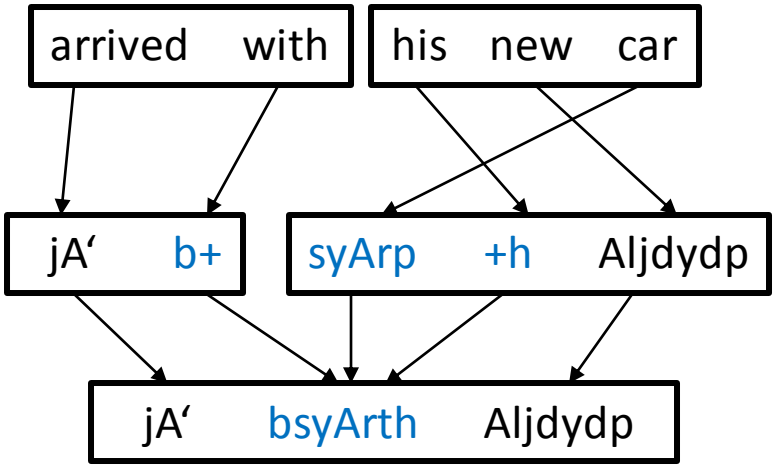
- **Morphological Segmentation** is the process of segmenting words into meaningful morphemes.
- **Desegmentation** is the process of converting segmented words into their original orthographically and morphologically correct surface form
- Segmented vs Unsegmented vs Desegmented

# Benefits and Complications of Segmentation

**English to Arabic (Morphologically Complex Language)**

## Benefits segmentation bring to SMT

- **Improves correspondence with morphologically simple languages**
- **Reduces data sparsity**
- **Increases expressive power by creating new lexical translations**




## Complications caused by segmentation

- **Account for less context compared to word based models**
- **Less efficient statistically**
- **Introducing errors due to reversing the segmentation process at the end of the pipeline**

# Measuring Segmentation Benefits

**Experimental study on English to Arabic**

- **Scenarios changing desegmentation point in pipeline :**
  - Before evaluation
  - Before decoding
  - Before phrase extraction
- **How these changes affect SMT component models:**
  - Alignment model, lexical weights, LM and
- **Introducing phrases with flexible boundaries**
  - suffix start: +h m$AryE fy "his projects in "
  - Prefix end: jA' b+ "arrived with"
  - Both: +hA AlAtHAd l+ "her union to"

# Techniques for Morphological Segmentation/Desegmentation

**Segmentation**

- **Penn Arabic Treebank Tokenization Scheme (El Kholy et al.[2012]) using MADA tool**

**Desegmentation**

- **Table+Rule based for Arabic (Badr et al [2008])**

| segmented | unsegmented | count |
|---|---|---|
| AbA' +km | AbAŷkm | 22 |
| AbA' +km | AbAWkm | 19 |
| DAŷqp +hm | DAŷqthm | 9 |
| kly +hA | klAhA | 5 |

# Unsegmented Baseline


- Suffers from data sparsity
- Poor correspondence
- All component models are based on words
- No desegmentation is required

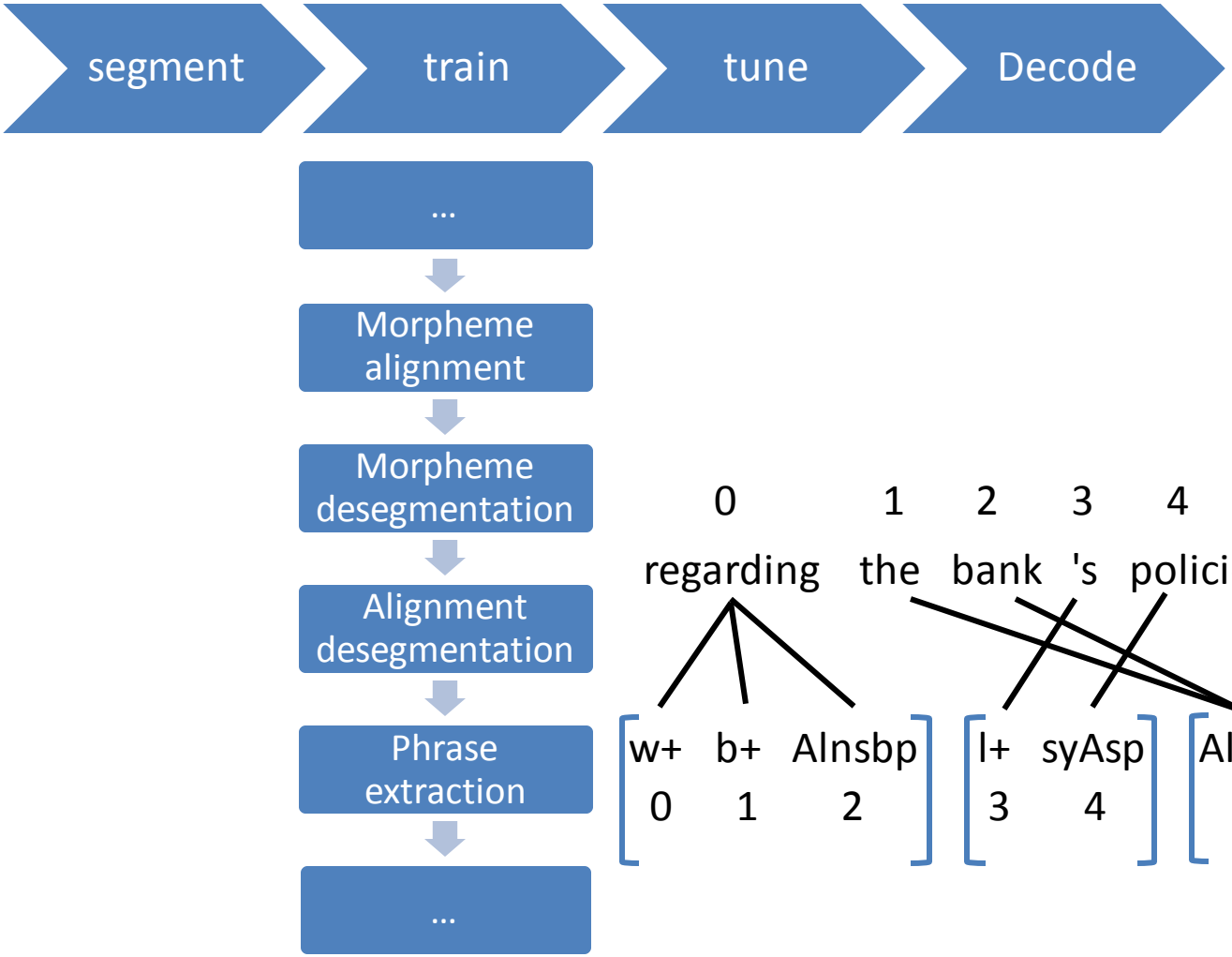
| SMT components | Scenario |
|---|---|
| *Desegment before* | **Never Segment** |
| *Alignment Model* | **Word** |
| *Lexical weights* | **Word** |
| *Language Model* | **Word** |
| *Tuning* | **Word** |
| *Flexible Boundaries?* | **No** |

# One-best Desegmentation


- Alleviates data sparsity
- improves correspondence
- All component models are based on morphemes
- LM spans shorter context
- Desegmentation is required at the end of the pipeline

| SMT components | Scenario |
|---|---|
| *Desegment before* | **Evaluation** |
| *Alignment Model* | **Morph** |
| *Lexical weights* | **Morph** |
| *Language Model* | **Morph** |
| *Tuning* | **Morph** |
| *Flexible Boundaries?* | **Yes** |

# Alignment Desegmentation




| SMT components | Scenario |
|---|---|
| *Desegment before* | **Phrase extraction** |
| *Alignment Model* | **Morph** |
| *Lexical weights* | **Word** |
| *Language Model* | **Word** |
| *Tuning* | **Word** |
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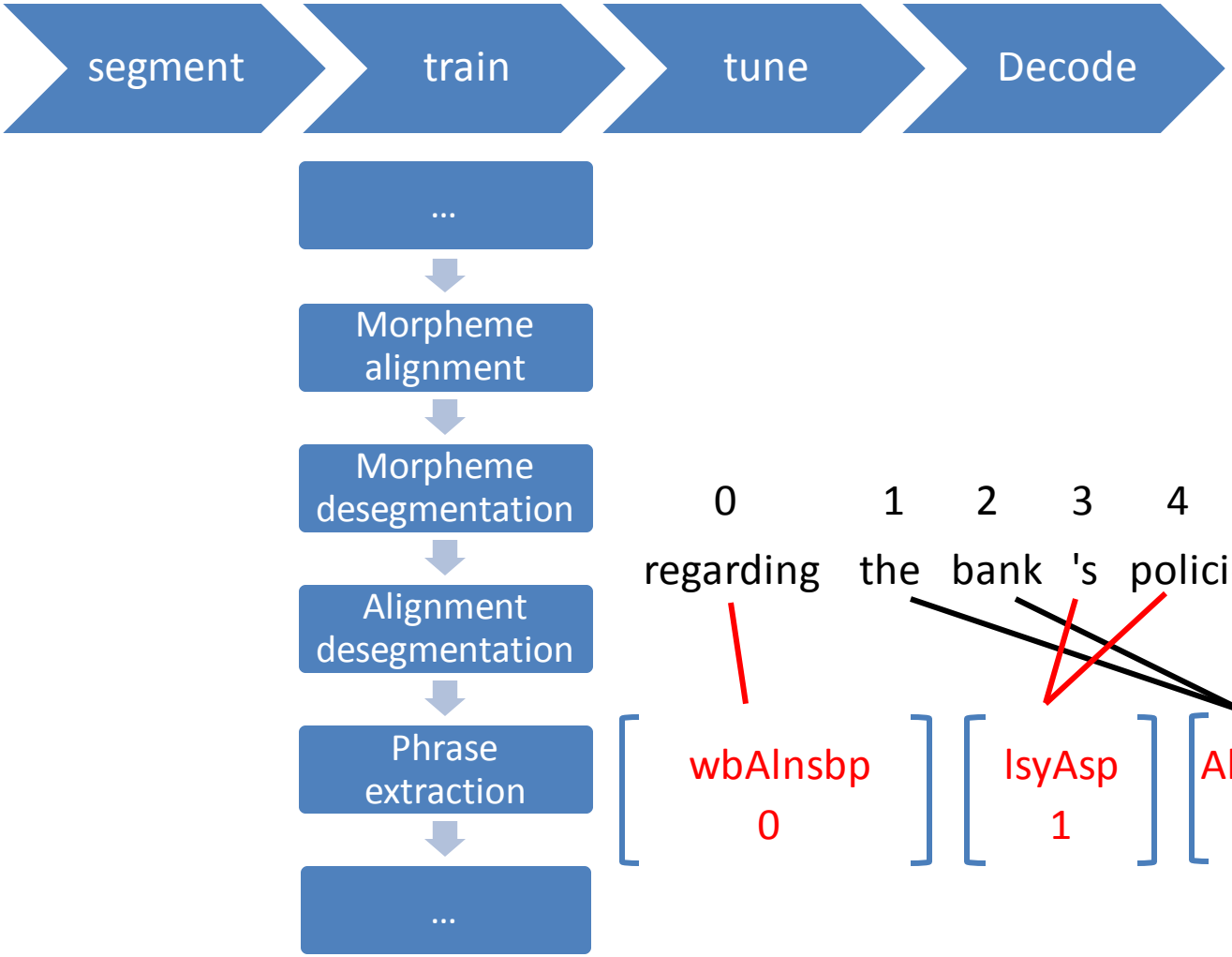
# Alignment Desegmentation




| SMT components | Scenario |
|---|---|
| *Desegment before* | **Phrase extraction** |
| *Alignment Model* | **Morph** |
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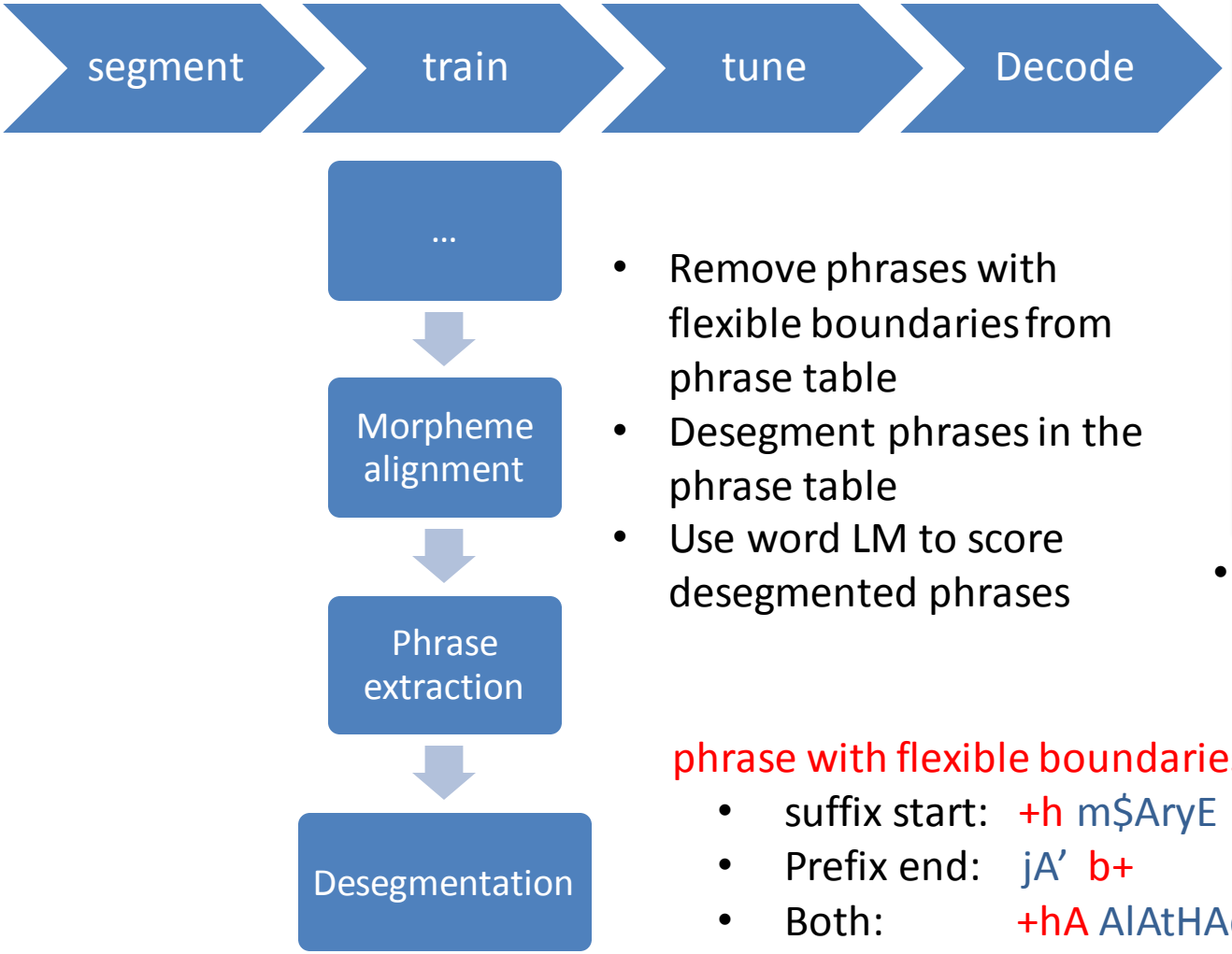
# Phrase Table Desegmentation




- Remove phrases with flexible boundaries from phrase table
- Desegment phrases in the phrase table
- Use word LM to score desegmented phrases

| SMT components | Scenario |
|---|---|
| *Desegment before* | **Decoding** |
| *Alignment Model* | **Morph** |
| *Lexical weights* | **Morph** |
| *Language Model* | **Word** |
| *Tuning* | **Word** |
| *Flexible Boundaries?* | **No** |

- Similar to Lyong et al. 2010

phrase with flexible boundaries

- suffix start: +h m$AryE fy "his projects in"
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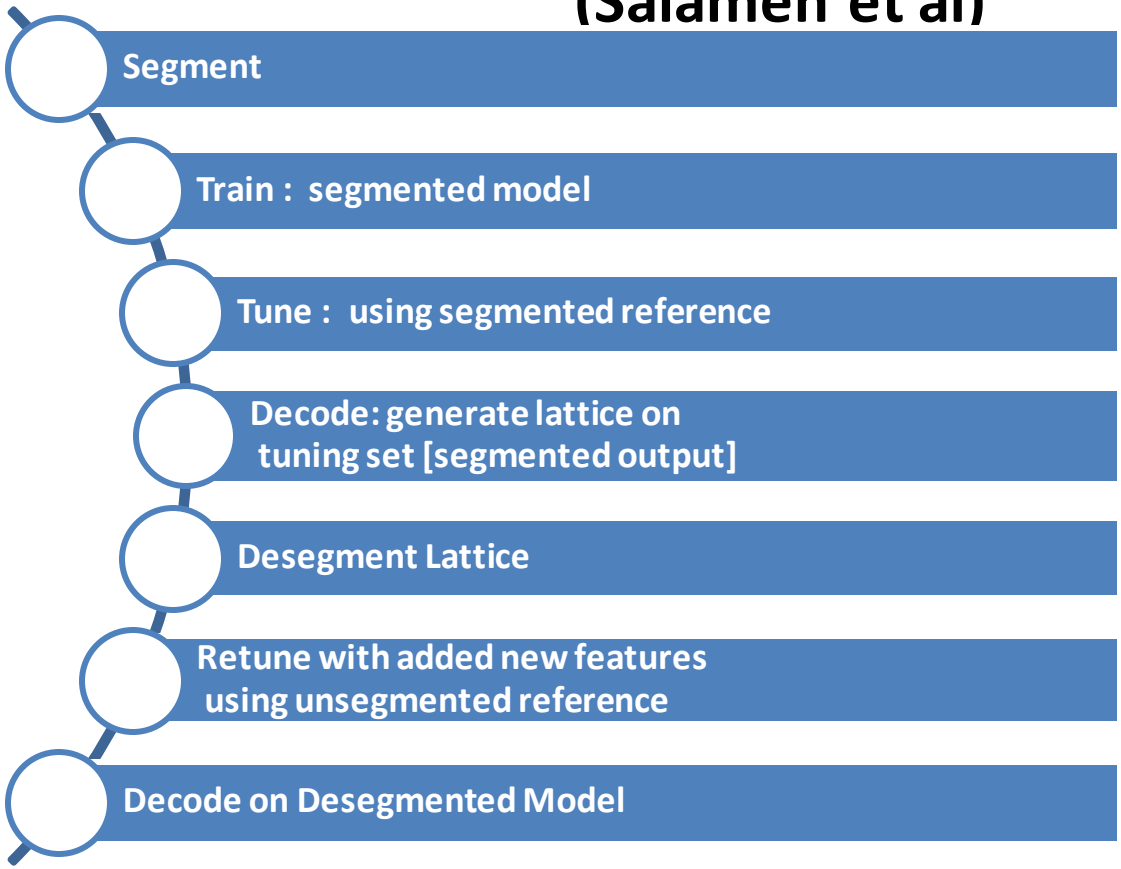
- Both: +hA AlAtHAd l+ "her union to"

# Lattice Desegmentation (Salameh et al)




| SMT components | Scenario |
|---|---|
| *Desegment before* | **Evaluation** |
| *Alignment Model* | **Morph** |
| *Lexical weights* | **Morph** |
| *Language Model* | **Morph+ Word** |
| *Tuning* | **Morph then Word** |
| *Flexible Boundaries?* | **Yes** |

Benefits:

- gain access to a compact desegmented view of a large portion of the translation search space.
- Use features that reflect the desegmented target language
- Annotate with Unsegmented LM + Discontiguity features

# Segmented LM scoring in Desegmented Models

- **Add additional LM feature that scores segmented form to :**
  - **Phrase table Desegmentation**
  - **Alignment Desegmentation**

*All our problems* *and conflicts*

[kl m$AklnA] [ wxlAfAtna ]

[kl m$akl +nA] [ w+ xlAfAt +nA ]

# Data

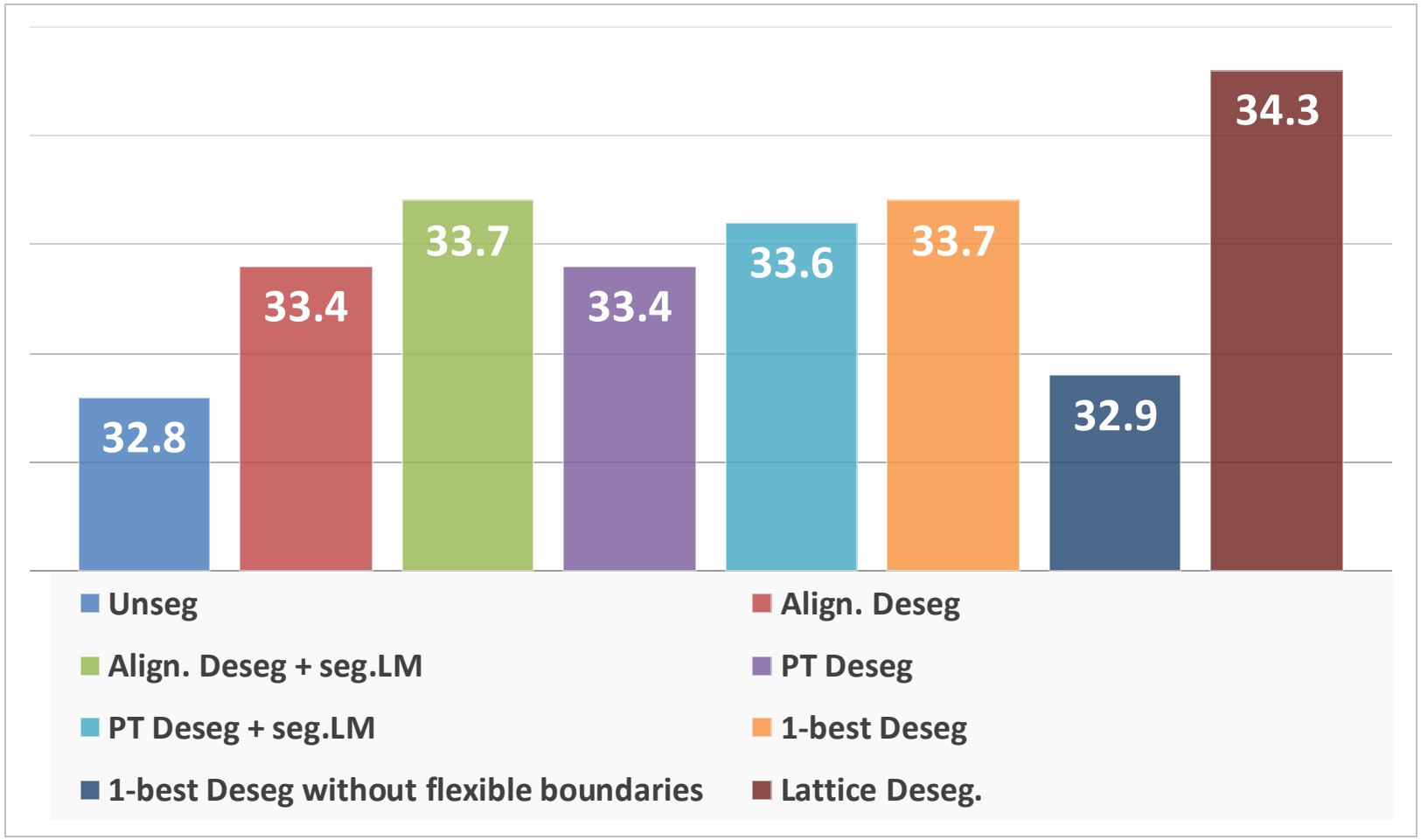
## English-Arabic Data

- **Train on NIST 2012 training set, excluding the UN data (1.49M sentence pairs)**
- **Tune on NIST 2004 (1353 pairs)**
  **Test on NIST 2005 (1056 pairs)**
- **Tune on NIST 2006 (1664 pairs)**
  **Test on NIST 2008 (1360 pairs)**
  **Test on NIST 2009 (1313 pairs)**

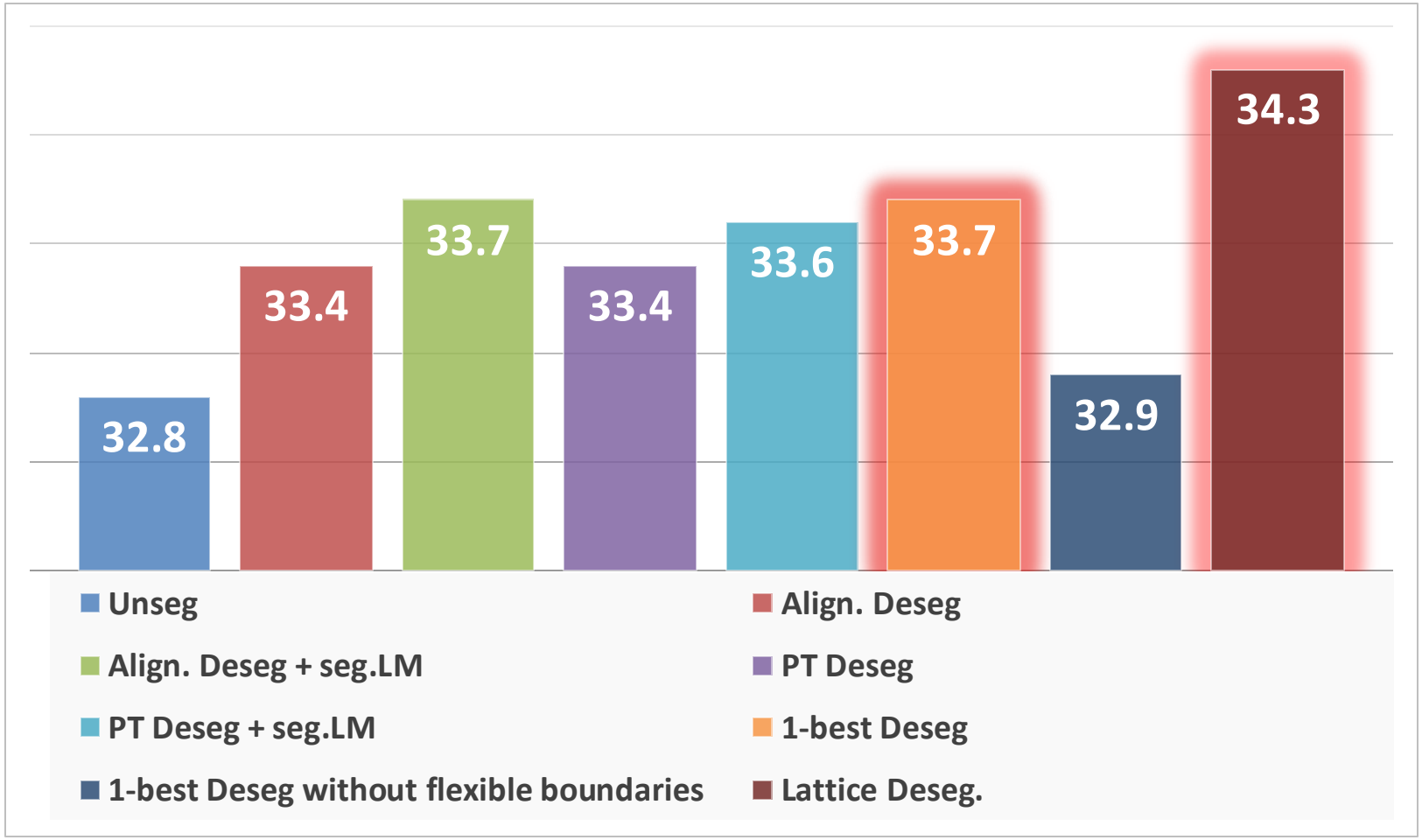
# System

- Train a 5-gram Language Model on target side using SRILM
- Align parallel data with GIZA++
- Decode using Moses
- Tune the decoder's log-linear model with MERT
- Reranking Lattice desegmented model is tuned using a batch variant of hope-fear MIRA
- Evaluate the system using BLEU

# Results on MT05

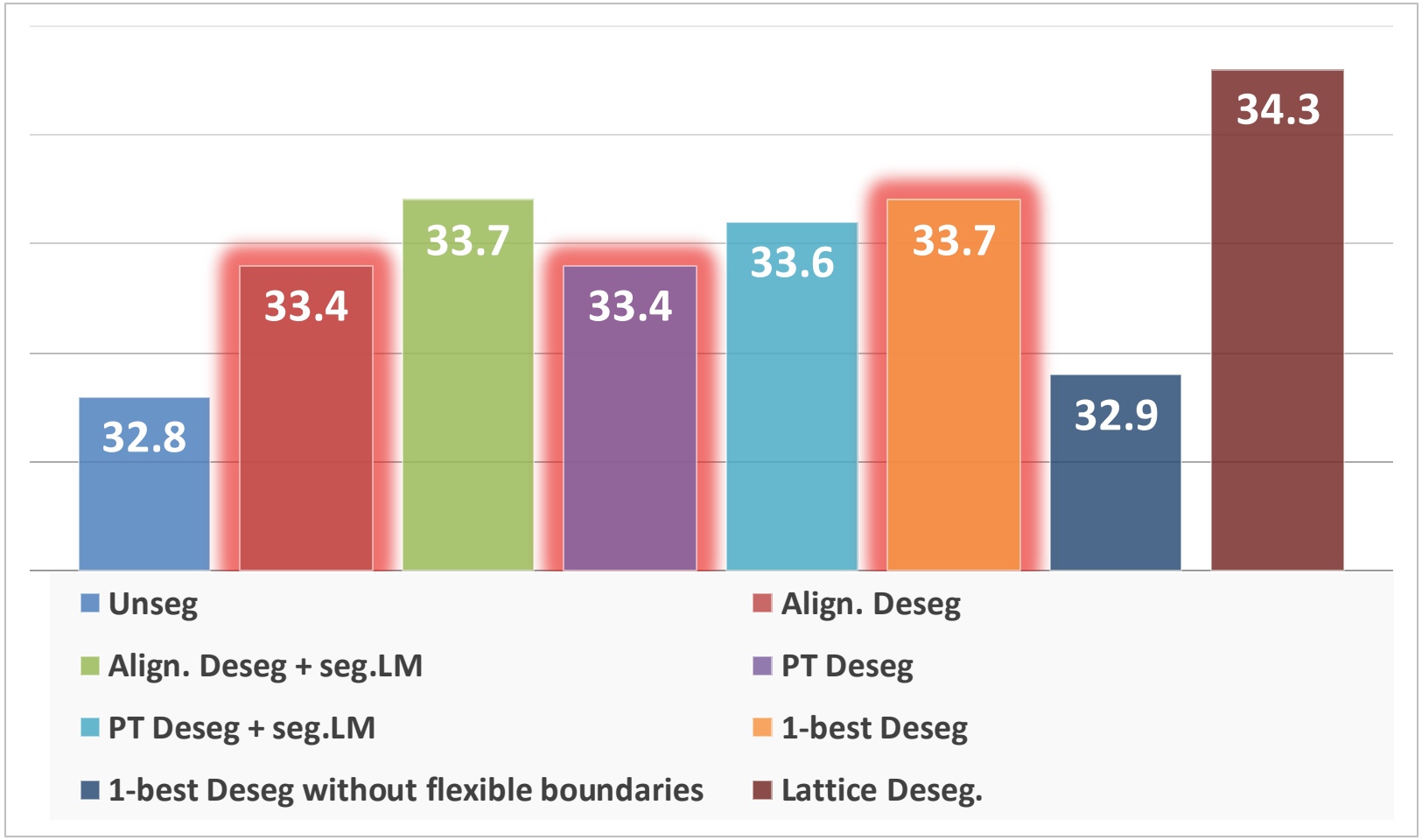


# Results on MT05




**Decoder Integration:** lattice desegmentation and 1-best are only systems without access to unsegmented information in the decoder

# Results on MT05




**Flexible Boundaries:** PT Deseg and Align Deseg. lack flexible phrase boundaries with respect to 1-best Deseg

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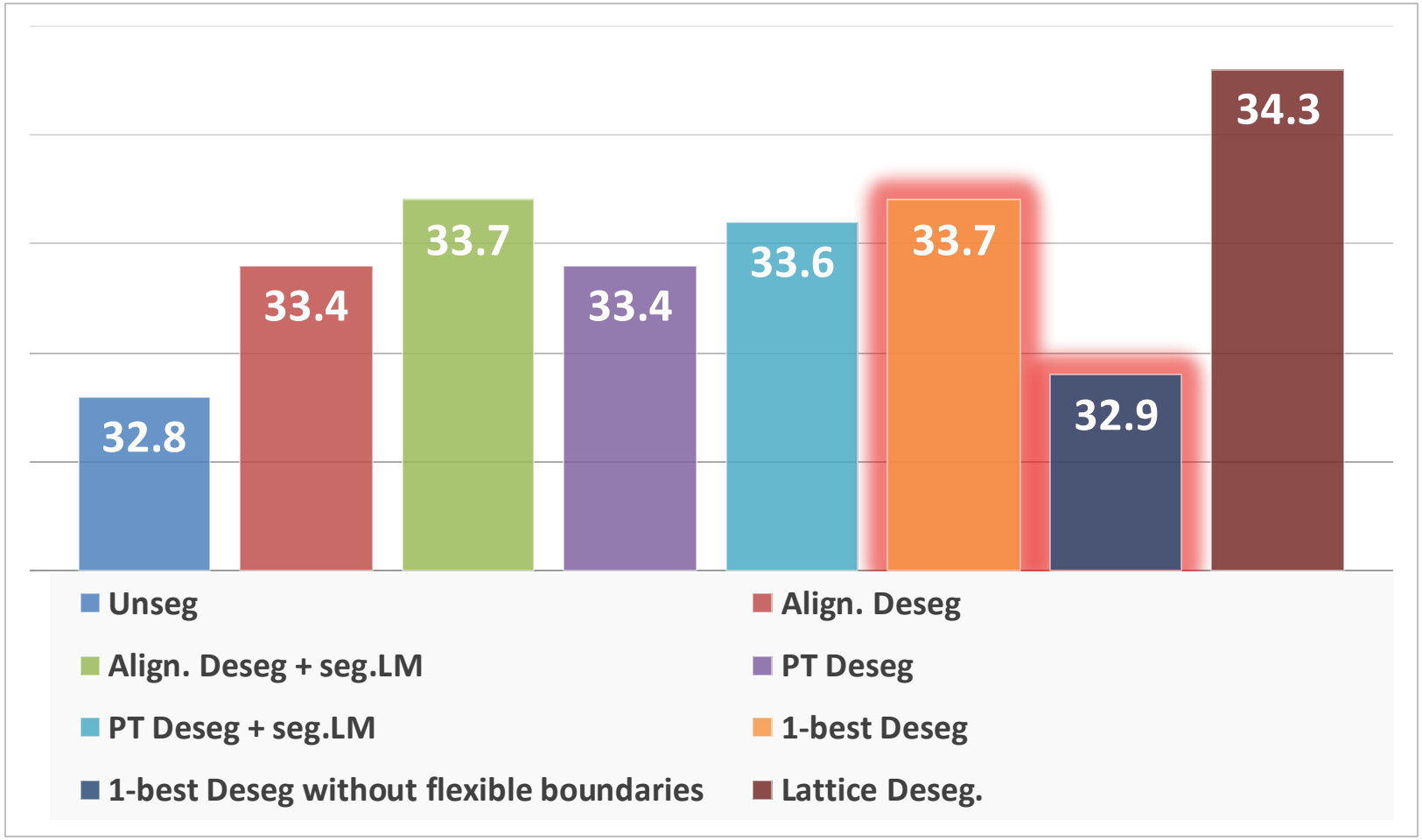


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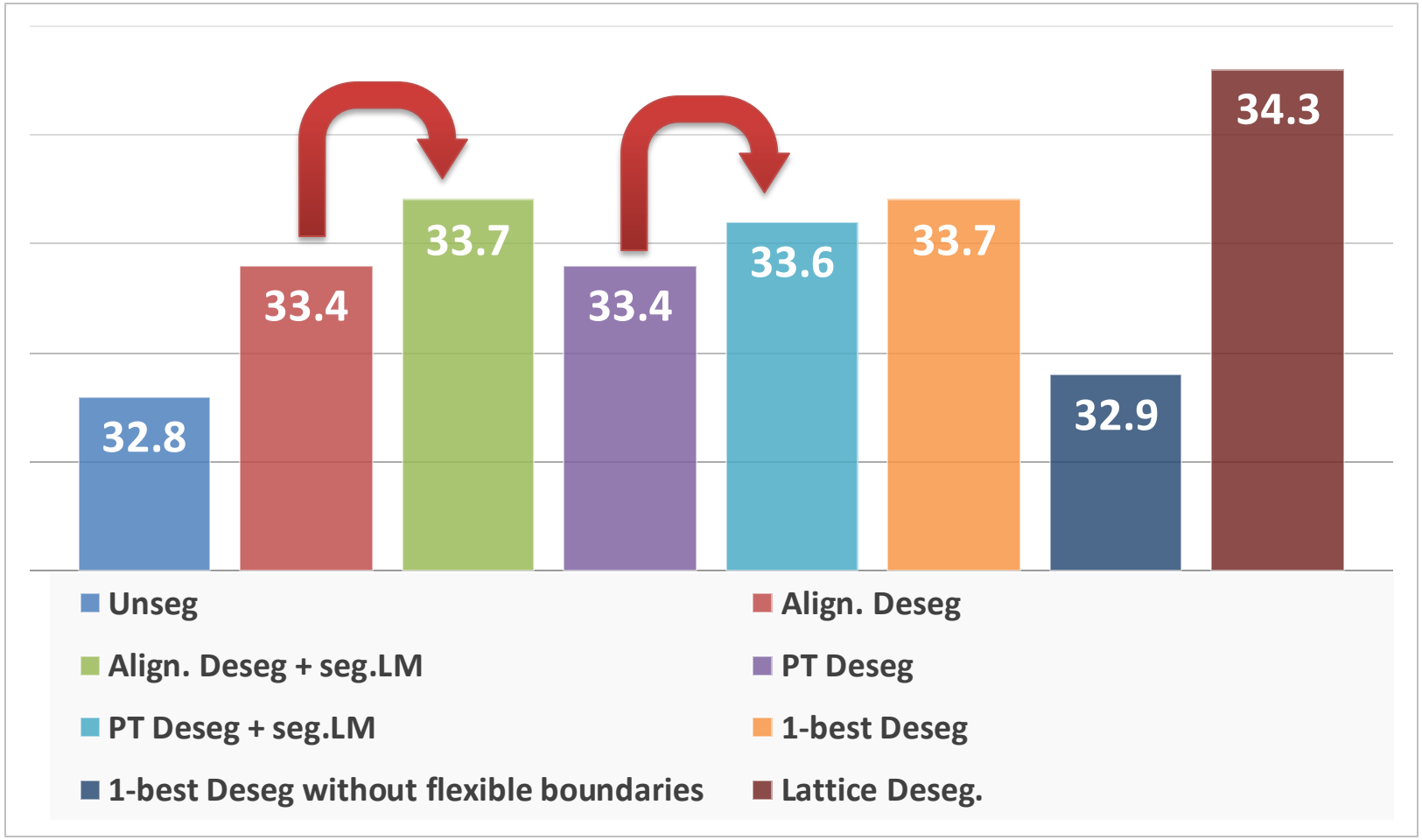
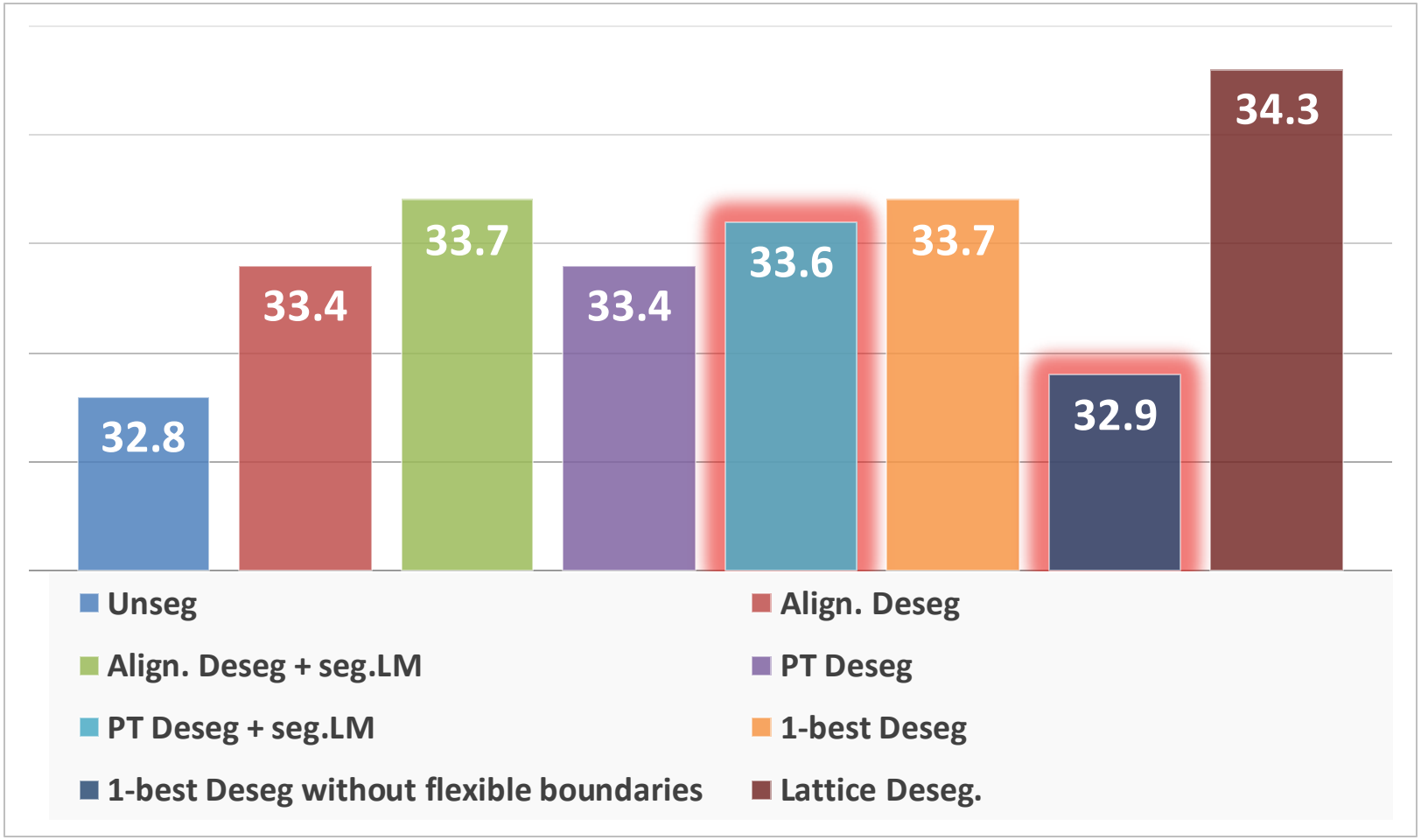


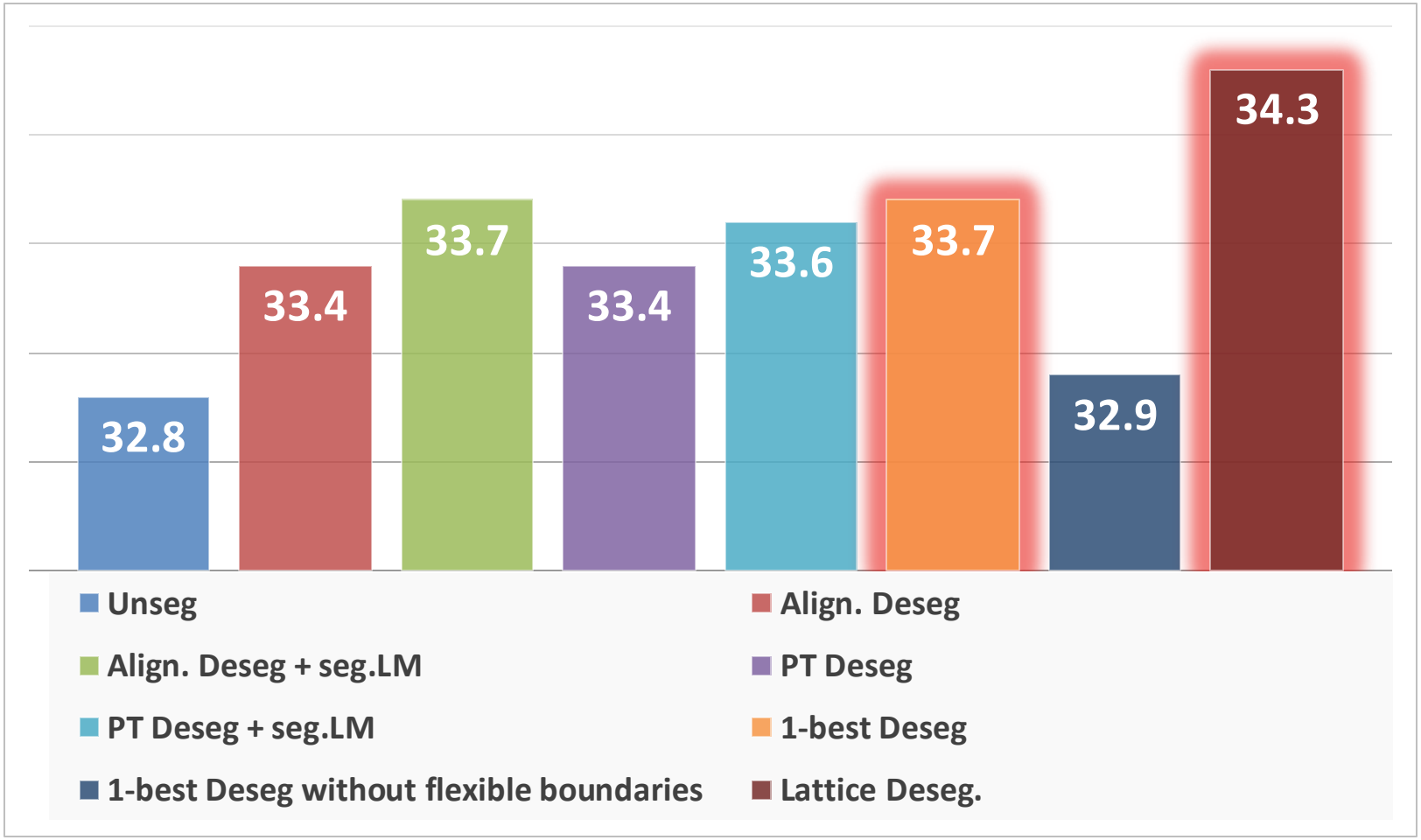

**Language Models:** Align Deseg and Phrase Table Deseg show consistent but small, improvements from addition of a segmented LM.

# Results on MT05




**Language Models:** Phrase Table Deseg with segmented LM and 1-best Deseg. without flexible boundaries have exactly same output space.

# Results on MT05




**Language Models:** main difference between 1-best Deseg. and Lattice Deseg. Is the unsegmented LM and discontiguity features.

# Analysis

1. **Flexible boundaries**
   - **Constitute 12% of phrases in final output of 1-best-deseg**
   - **Novel words: 3% of the desegmented types**
     - Randomly selected 40 out of each set:
       - 64/120 violates morphological rules
     - 37/115 novel words from the reference could be constructed from morphemes
2. **Impact of *ngram* order for segmented LM**
   - **No improvement seen over 5-gram LM with 6, 7 and 8-grams**
3. **Overall affix usage**

# Overall affix usage

| Model | mt05 | mt08 | mt09 |
|---|---|---|---|
| Reference | 15.9 | 18.1 | 18.9 |
| Unsegmented | 12.0 | 12.2 | 12.6 |
| Alignment Deseg. | 11.6 | 11.0 | 11.8 |
| with Segmented LM | 11.7 | 11.2 | 12.0 |
| Phrase Table Deseg. | 11.3 | 10.1 | 11.2 |
| with Segmented LM | 11.6 | 10.5 | 11.4 |
| 1-best Deseg. | 16.1 | 18.2 | 19.2 |
| without flexible boundaries | 14.2 | 14.7 | 15.4 |
| Lattice Deseg. | 10.0 | 11.5 | 12.2 |

**Percentage of words in SMT output that have non-identity morphological segmentation**

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**Percentage of words in SMT output that have non-identity morphological segmentation**

# Conclusion

- **Presented experimental study on translation into segmented language by creating models that apply desegmentation at different points.**
- ***Flexible boundaries* are the most important factor in improving translation in segmented models**
- **Although unsegmented LMs improve BLEU score, they hinder generation of morphologically complex words**

# Thank You