PARAPHRASING ADAPTATION FOR WEB SEARCH RANKING

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Mismatch between queries and documents is a key issue for the web search task

- Caused by expressing the same meaning in different natural language ways
  - E.g.
    - X is the author of Y
    - Y was written by X

Who is the author of Gone with the Wind?

Paraphrases

Gone with the Wind was written by whom?

Search Engine
Mismatch between queries and documents is a key issue for the web search task

- Caused by expressing the same meaning in different natural language ways
  - E.g.
    - X is the author of Y
    - Y was written by X

Paraphrasing engine produces alternative expressions to convey the same meaning of the input text

- Improve paraphrasing from different perspectives
  - E.g.
    - Paraphrase extraction
    - Paraphrase generation
    - Model optimization
MOTIVATION (CONT.)

Q1: Could paraphrasing engine alleviate the mismatches of query and its relevant documents?

Q2: How to adapt the paraphrasing engine for web search ranking task specifically?
Solution Overview
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Paraphrase Extraction
- Extract paraphrase pairs from various data sources

Raw Data

Paraphrase Extraction
Solution Overview

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Paraphrase Model
- A search-oriented model generates candidates for each original query

Raw Data

Paraphrase Extraction

Original Query

Paraphrase Model
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Paraphrase Model
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Parameter Optimization
- Optimize the weights of the features used in paraphrasing model on development data

\[ \sum_i \lambda_i \cdot h_i(\cdot) \]
Solution Overview

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- Extract paraphrase pairs from various data sources

Paraphrase Model
- A search-oriented model generates candidates for each original query

Parameter Optimization
- Optimize the weights of the features used in paraphrasing model on development data

Ranking Model
- An enhanced ranking model by using augmented features computed on paraphrases of original queries

Raw Data
  ↓
Paraphrase Extraction
  ↓
Original Query
  ↓
Paraphrase Model
  ↓
Original Query + N-best Candidates
  ↓
Ranking Model
  ↓
DEV Data
  ↓
Model Optimization
  ↓
\[ \sum_{i} \lambda_i \cdot h_i(\cdot) \]
PARAPHRASE EXTRACTION

Monolingual-based

- **Hypothesis:** Words/Phrases that share the same context tend to have similar meanings
  
  *(Lin and Pantel (2001))*

Bilingual-based

- **Hypothesis:** Phrases that align with identical pivot phrases tend to have similar meanings
  
  *(Bannard and Callison-Burch (2005))*

#1 is the author of #2
#1 is #2 ‘s author
SEARCH-ORIENTED PARAPHRASING MODEL

\[ \hat{Q} = \arg \max_{Q' \in \mathcal{H}(Q)} P(Q'|Q) \]

\[ = \arg \max_{Q' \in \mathcal{H}(Q)} \sum_{m=1}^{M} \lambda_m h_m(Q, Q') \]
SEARCH-ORIENTED PARAPHRASING MODEL

Search-Oriented Features:

- Word Addition
- Word Deletion
- Word Overlap
- Word Alteration
- Word Reordering
- Length Difference
- Edit Distance

Candidate

\[ \hat{Q} = \arg \max_{Q' \in \mathcal{H}(Q)} P(Q'|Q) \]

Original query

\[ = \arg \max_{Q' \in \mathcal{H}(Q)} \sum_{m=1}^{M} \lambda_m h_m(Q, Q') \]

Hypothesis space

found a company

start a business
SEARCH-ORIENTED PARAPHRASING MODEL

Search-Oriented Features:
- Word Addition
- Word Deletion
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- Word Reordering
- Length Difference
- Edit Distance

Traditional Features (Koehn et al., 2003):
- Translation Probability
- Lexical Weight
- Word Count
- Paraphrase Rule Count
- Language Model

\[ \hat{Q} = \arg \max_{Q' \in \mathcal{H}(Q)} P(Q' | Q) \]
\[ = \arg \max_{Q' \in \mathcal{H}(Q)} \sum_{m=1}^{M} \lambda_m h_m(Q, Q') \]
NDCG-BASED PARAMETER OPTIMIZATION
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Original Query

Candidate-1

Candidate-2

...

Candidate-N
NDCG-BASED PARAMETER OPTIMIZATION

Original Query

Feature vector-1
Feature vector-2
...
Feature vector-N

Candidate-1
Candidate-2
...
Candidate-N
NDCG-BASED PARAMETER OPTIMIZATION

Original Query

Feature vector-1
Feature vector-2
...
Feature vector-N

Candidate-1
Candidate-2
...
Candidate-N

Ranker
Ranker
...
Ranker
NDCG-BASED PARAMETER OPTIMIZATION

** Candidate is sent to the ranker, and returned by an NDCG score **
NDCG-BASED PARAMETER OPTIMIZATION

Candidate is sent to the ranker, and returned by an NDCG score

Original Query

Feature vector-1
Feature vector-2
...
Feature vector-N

Candidate-1 NDCG-1
Candidate-2 NDCG-2
...
Candidate-N NDCG-N

NDCG-based MER Training

Ranker
Ranker
...
Ranker
NDCG-BASED PARAMETER OPTIMIZATION

Candidate is sent to the ranker, and returned by an NDCG score

After optimization, candidates with higher NDCGs are preferred and ranked on the top of the N-best list
NDCG-BASED PARAMETER OPTIMIZATION (CONT.)

Minimum error rate training (MERT) (Och, 2003)

- To find the optimal feature weight vector that minimizes the error criterion $Err$ according to the NDCG scores of top-1 paraphrase candidates

$$\hat{\lambda}_1^M = \arg\min_{\lambda_1^M} \sum_{i=1}^{S} Err(D_i^{Label}, \hat{Q}_i; \lambda_1^M, R)$$

$$Err(D_i^{Label}, \hat{Q}_i; \lambda_1^M, R) = 1 - N(D_i^{Label}, \hat{Q}_i, R)$$
ENHANCED RANKING MODEL

Ranking model

- The paraphrase candidates act as hidden variables and expanded matching features between queries and documents

\[ R(Q, D_Q) = \sum_{k=1}^{K} \lambda_k F_k(Q, D_Q) \]

\[ R(Q, D_Q^i) > R(Q, D_Q^j) \iff r_{D_Q^i} > r_{D_Q^j} \]

- Unigram/bigram/trigram BM25
- Original/normalized Perfect-Match

Original query

Q

N-best paraphrase candidates

Q_1
Q_2
......
Q_N

Retrieved documents

Query

Document D_Q

Expanded Matching Features

\[ \overline{F} = (F_1, F_2, \ldots, F_K) \]

\[ \{\overline{F}, \overline{F}_1, \overline{F}_2, \ldots, \overline{F}_N\} \]
EXPERIMENTS: DATASETS

Paraphrase Extraction

- Training data
  - Bilingual corpus (NIST 2008 constrained track): 5.1M sentence pairs
  - Monolingual corpus (Bing’s query log): 16.7M queries
  - Human annotated data (WordNet dictionary): 0.3M synonym pairs
- # of paraphrase pairs: 58M

Evaluation Set

<table>
<thead>
<tr>
<th>Bing’s query log</th>
<th># of queries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td>1,419</td>
</tr>
<tr>
<td>Test</td>
<td>1,419</td>
</tr>
</tbody>
</table>
**SYSTEMS**

### Paraphrasing

<table>
<thead>
<tr>
<th>Denotation</th>
<th>Features</th>
<th>Optimization Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL-Para (baseline)</td>
<td>Traditional features</td>
<td>BLEU</td>
</tr>
<tr>
<td>BL-Para+SF</td>
<td>Traditional features + Search-oriented features</td>
<td>BLEU</td>
</tr>
<tr>
<td>BL-Para+SF+Opt</td>
<td>Traditional features + Search-oriented features</td>
<td>NDCG</td>
</tr>
</tbody>
</table>

### Ranking Model

<table>
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<tr>
<th>Denotation</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL-Rank (baseline: Liu et al., 2007)</td>
<td>Query-documents matching features (unigram/bigram/trigram BM25 and original/normalized Perfect-Match)</td>
</tr>
<tr>
<td>BL-Rank+Para (Enhanced ranking model)</td>
<td>Query+Paraphrase-documents matching features</td>
</tr>
</tbody>
</table>

*The ranking model is learned based on SVMrank toolkit (Joachims, 2006) with default parameter setting.*
## IMPACTS OF SEARCH-ORIENTED FEATURES

<table>
<thead>
<tr>
<th>Test Set</th>
<th>BL-Para</th>
<th>BL-Para+SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Query</td>
<td>Cand@1</td>
<td>Cand@1</td>
</tr>
<tr>
<td>27.28%</td>
<td>26.44%</td>
<td>26.53%</td>
</tr>
</tbody>
</table>

**BL-Para:**
Paraphrase Baseline with **Features:** Traditional features

**Optimization Metric:** BLEU

**BL-Para+SF:**
Paraphrase Baseline with **Features:** Traditional features + Search-oriented features

**Optimization Metric:** BLEU

Top-1 Paraphrase Candidate
## IMPACTS OF OPTIMIZATION ALGORITHM

<table>
<thead>
<tr>
<th>Test Set</th>
<th>BL-Para+SF</th>
<th>BL-Para+SF+Opt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Query</td>
<td>Cand@1</td>
<td>Cand@1</td>
</tr>
<tr>
<td>27.28%</td>
<td>26.53%</td>
<td>27.06% (+0.53%)</td>
</tr>
</tbody>
</table>

**BL-Para+SF:**
- Paraphrase Baseline with Features: Traditional features + Search-oriented features
- Optimization Metric: **BLEU**

**BL-Para+SF+Opt:**
- Paraphrase Baseline with Features: Traditional features + Search-oriented features
- Optimization Metric: **NDCG**

*Top-1 Paraphrase Candidate*
# IMPACTS OF ENHANCED RANKING MODEL

<table>
<thead>
<tr>
<th></th>
<th>Dev Set</th>
<th>Test set</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NDCG@1</td>
<td>NDCG@5</td>
</tr>
<tr>
<td>BL-Rank</td>
<td>25.31%</td>
<td>33.76%</td>
</tr>
<tr>
<td>BL-Rank+Para</td>
<td>28.59% (+3.28%)</td>
<td>34.25% (+0.49%)</td>
</tr>
</tbody>
</table>

BL-Rank: **Query-documents** matching features (unigram/bigram/trigram BM25 and original/normalized Perfect-Match)

BL-Rank+Para: **Query+Top 1 Paraphrase-documents** matching features (unigram/bigram/trigram BM25 and original/normalized Perfect-Match)
CONCLUSION

We present an in-depth study on adapting paraphrasing for web search

- Paraphrasing model with search-oriented features
- NDCG-based optimization method

Future directions:

- Compare and combine paraphrasing with other query reformulation techniques to further improve the search quality
  - E.g., pseudo-relevance feedback, and conditional random field-based approach
THANK YOU!

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