PARAPHRASING ADAPTATION FOR WEB SEARCH RANKING

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MOTIVATION

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

?

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- 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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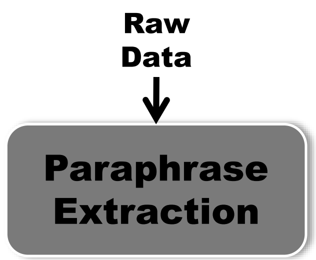
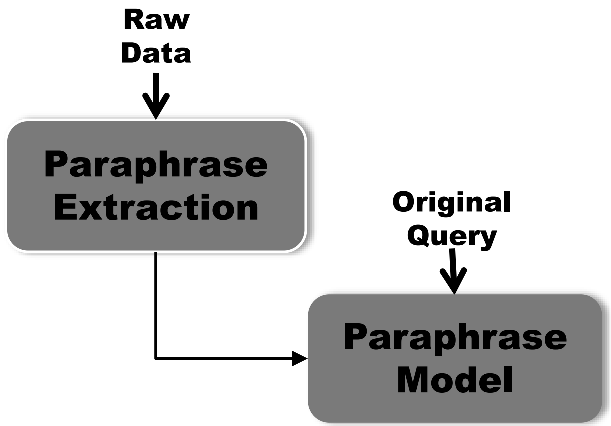


Paraphrase Extraction

- Extract paraphrase pairs from various data sources

Solution Overview



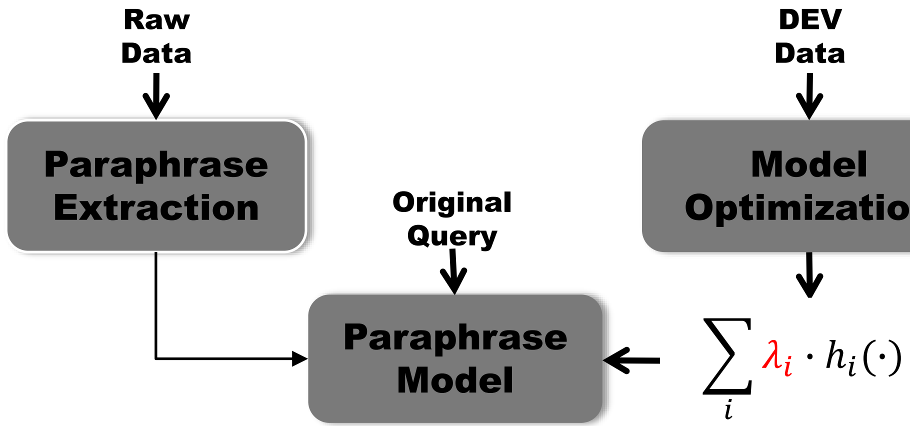
Paraphrase Extraction

- Extract paraphrase pairs from various data sources

Paraphrase Model

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

Solution Overview



Paraphrase Extraction

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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

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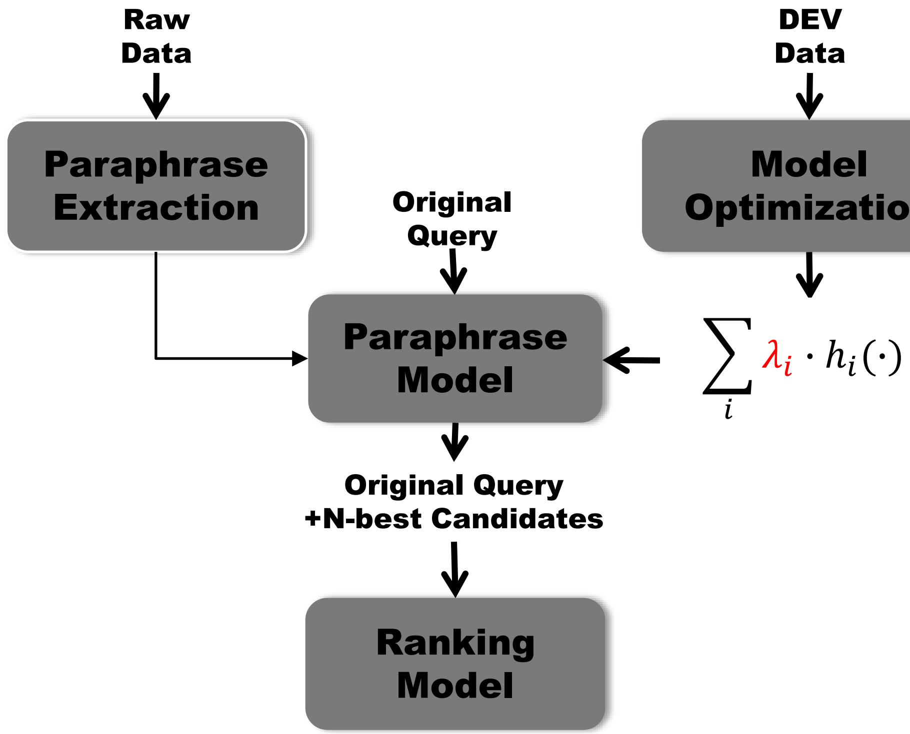

Paraphrase Extraction

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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

Ranking Model

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

PARAPHRASE EXTRACTION

Monolingual-based

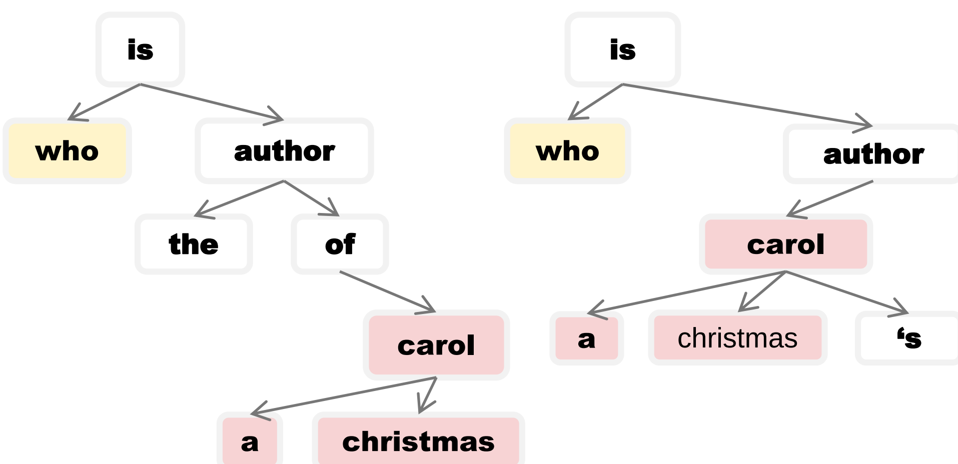
- **Hypothesis:**
  Words/Phrases that share the same context tend to have similar meanings

  (Lin and Pantel (2001))

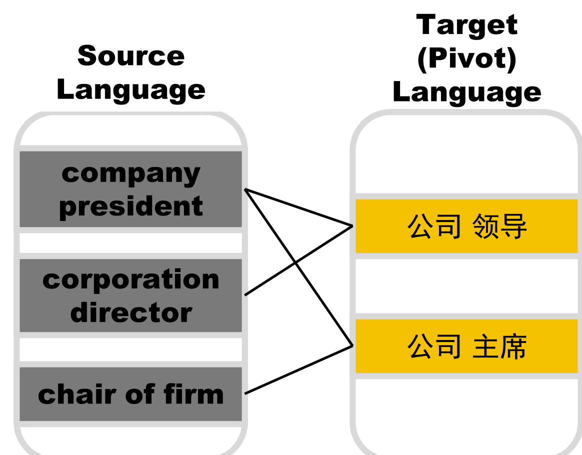
Bilingual-based

- **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

Candidate

$$\hat{Q} = \operatorname*{arg\,max}_{Q' \in \mathcal{H}(Q)} P(Q'|Q)$$

Original query

$$= \operatorname*{arg\,max}_{Q' \in \mathcal{H}(Q)} \sum_{m=1}^{M} \lambda_m h_m(Q, Q')$$

Hypothesis space

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

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- **Word Addition**
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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

Traditional Features *(Koehn et al., 2003)*:

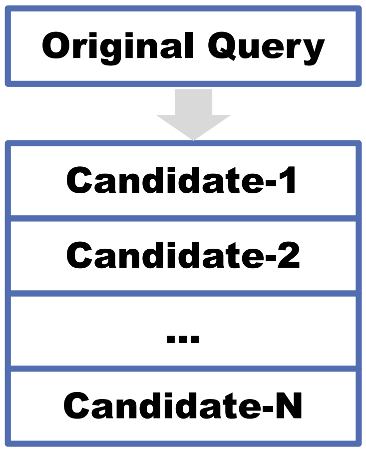
- **Translation Probability**
- **Lexical Weight**
- **Word Count**
- **Paraphrase Rule Count**
- **Language Model**

NDCG-BASED
PARAMETER OPTIMIZATION

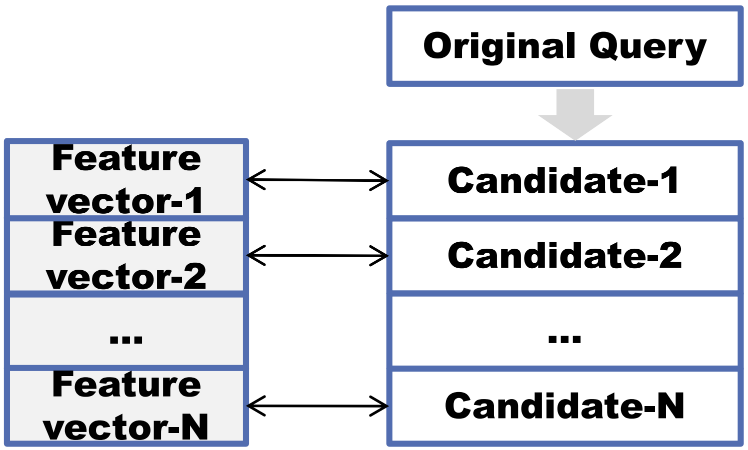
NDCG-BASED PARAMETER OPTIMIZATION

Original Query

NDCG-BASED PARAMETER OPTIMIZATION



NDCG-BASED PARAMETER OPTIMIZATION



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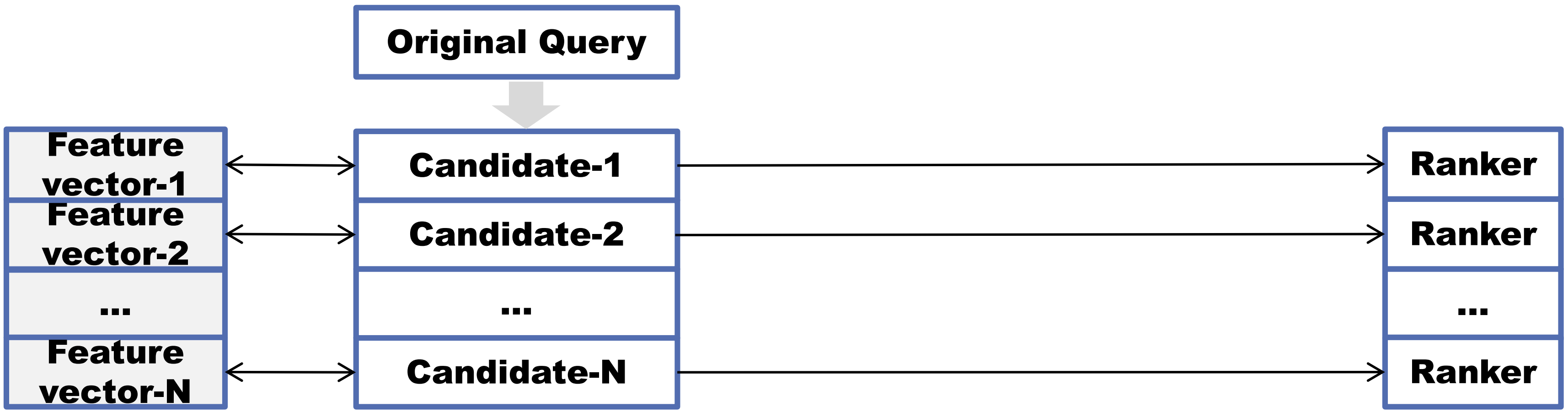
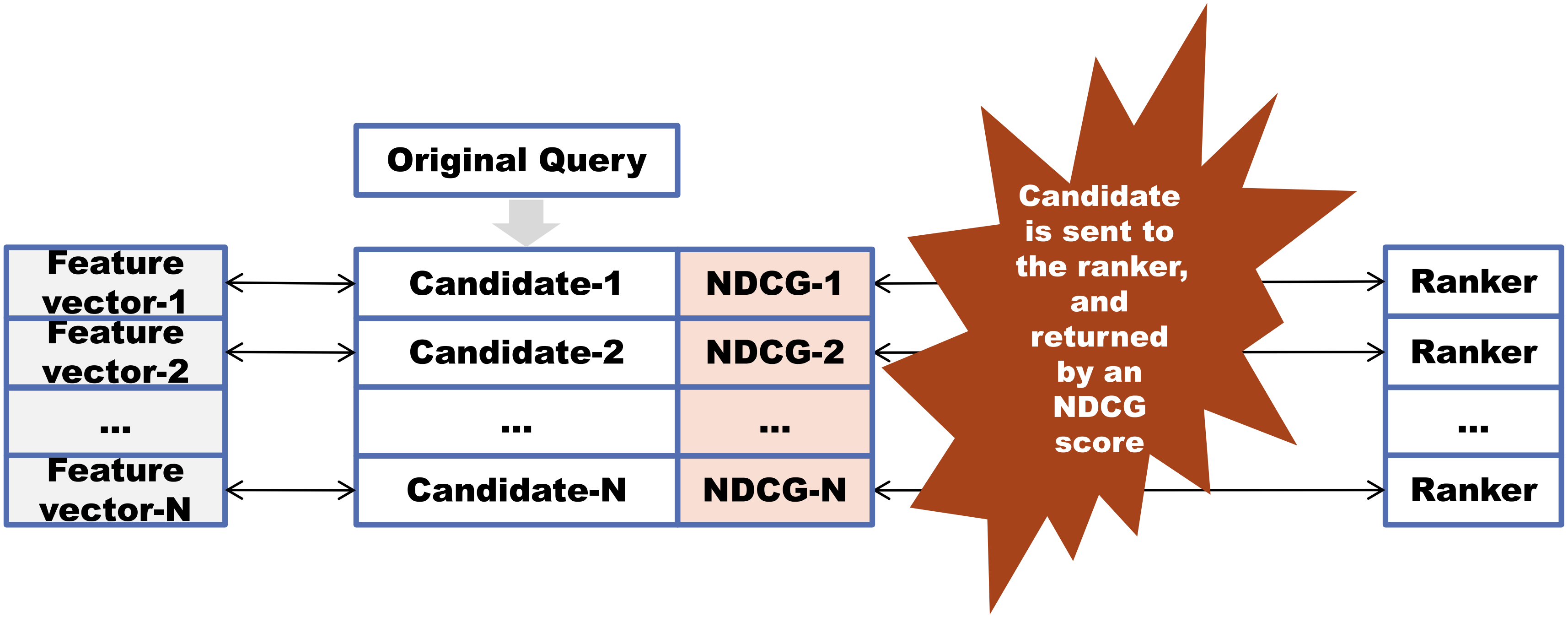
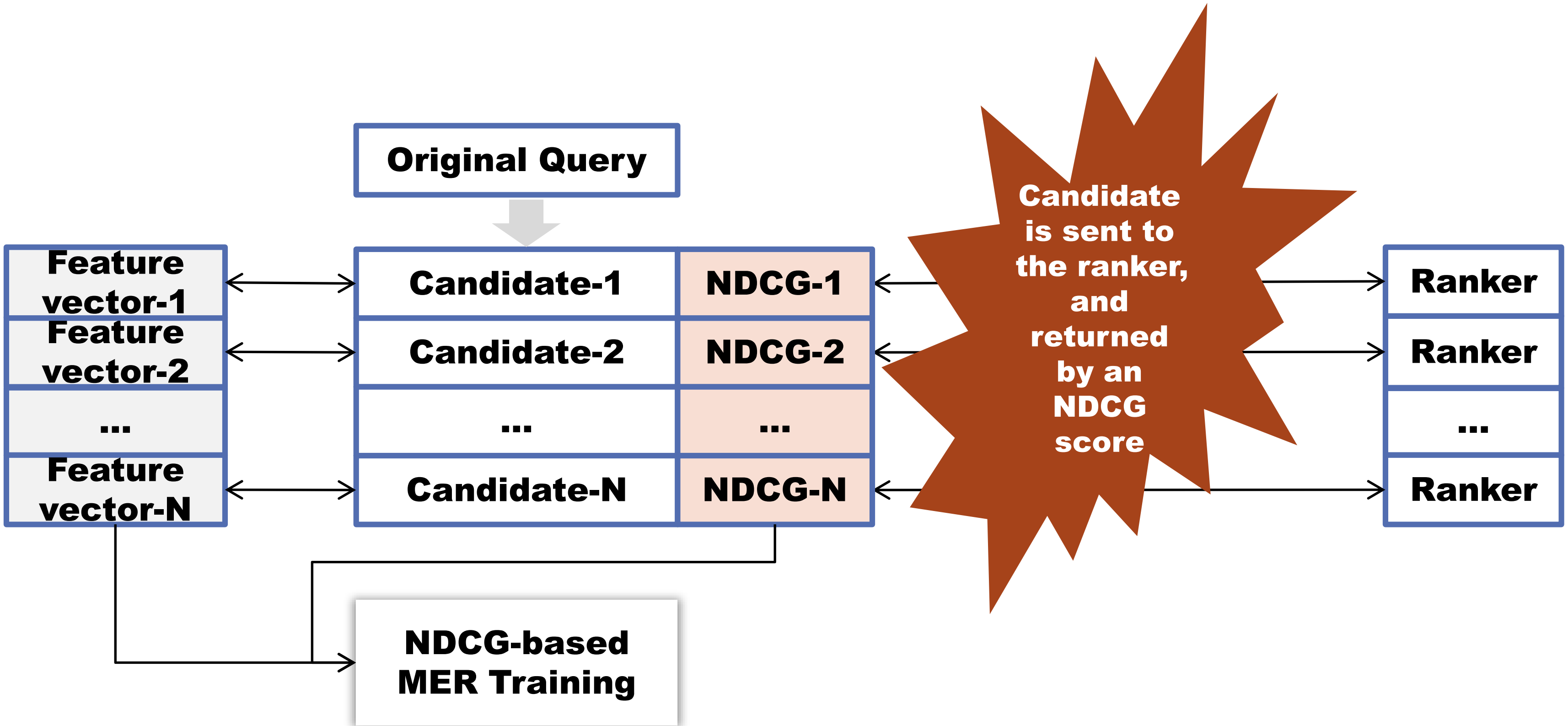


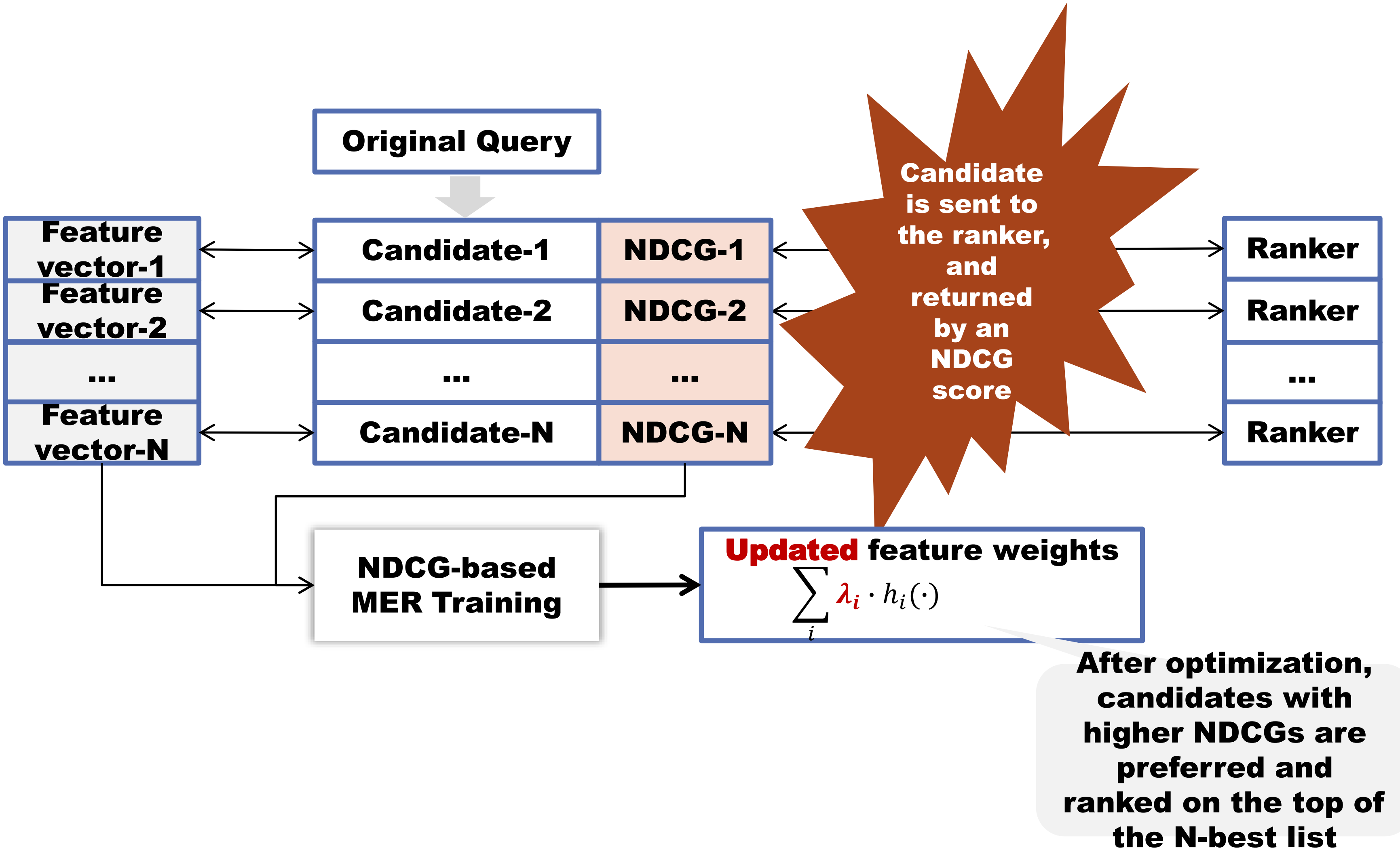
NDCG-BASED PARAMETER OPTIMIZATION



NDCG-BASED PARAMETER OPTIMIZATION



NDCG-BASED PARAMETER OPTIMIZATION



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

Labeled documents for original query

Ranking model

Best paraphrase candidate

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

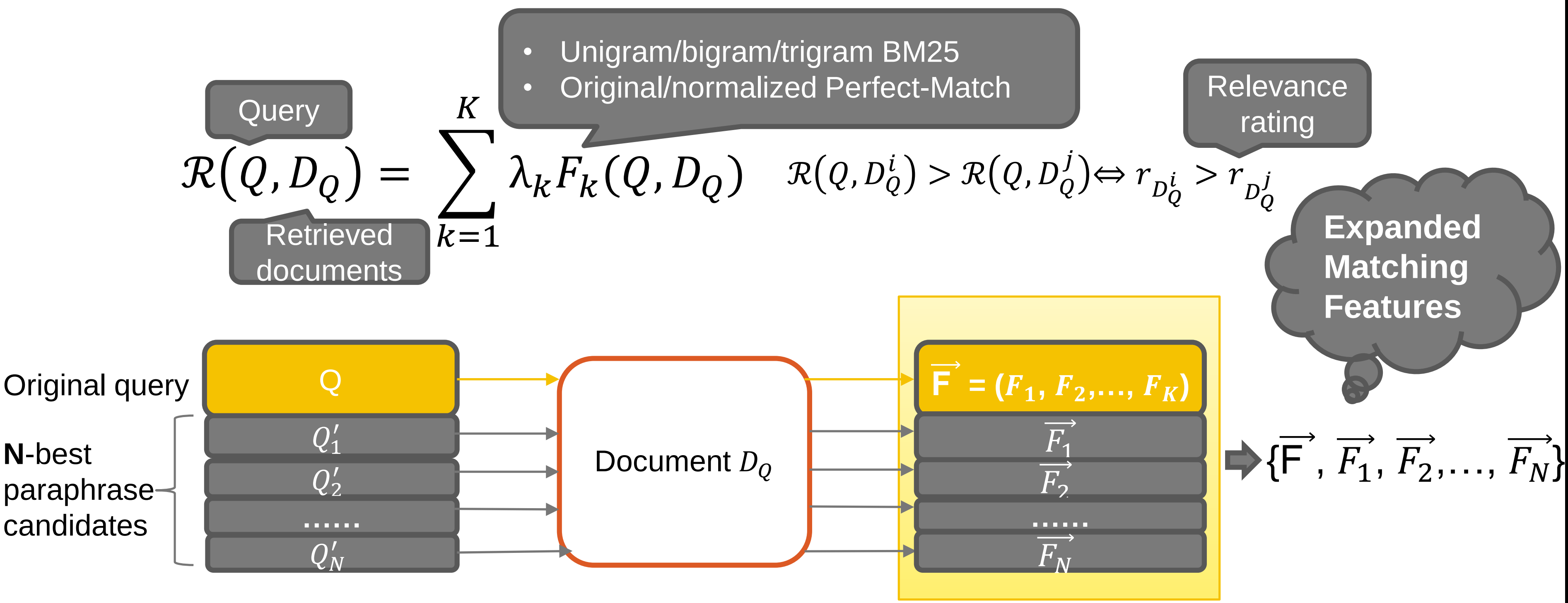
NDCG score

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

ENHANCED RANKING MODEL

Ranking model

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



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

Bing's query log	# of queries
Development	1,419
Test	1,419

SYSTEMS

Paraphrasing

Denotation	Features	Optimization Metric
BL-Para (baseline)	Traditional features	BLEU
BL-Para+SF	Traditional features + Search-oriented features	BLEU
BL-Para+SF+Opt	Traditional features + Search-oriented features	NDCG

Ranking Model

Denotion	Features
BL-Rank (baseline: Liu et al., 2007)	Query-documents matching features (unigram/bigram/trigram BM25 and original/normalized Perfect-Match)
BL-Rank+Para (Enhanced ranking model)	Query+Paraphrase-documents matching features

***The ranking model is learned based on SVMrank toolkit (Joachims, 2006) with default parameter setting.**

IMPACTS OF SEARCH-ORIENTED FEATURES

Test Set		
	BL-Para	BL-Para+SF
Original Query	**Cand@1**	**Cand@1**
27.28%	26.44%	26.53%

Top-1 Paraphrase Candidate

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

IMPACTS OF OPTIMIZATION ALGORITHM

Test Set		
	BL-Para+SF	**BL-Para+SF+Opt**
Original Query	**Cand@1**	**Cand@1**
27.28%	26.53%	27.06%**(+0.53%)**

Top-1 Paraphrase Candidate

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*

IMPACTS OF ENHANCED RANKING MODEL

Ranking model baseline (Liu et al., 2007)

Dev Set		
	NDCG@1	**NDCG@5**
BL-Rank	25.31%	33.76%
BL-Rank+Para	28.59%**(+3.28%)**	34.25%**(+0.49%)**

Enhanced ranking model

Test set		
	NDCG@1	**NDCG@5**
BL-Rank	27.28%	34.79%
BL-Rank+Para	28.42%**(+1.14%)**	35.68%**(+0.89%)**

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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