Paraphrases and Applications

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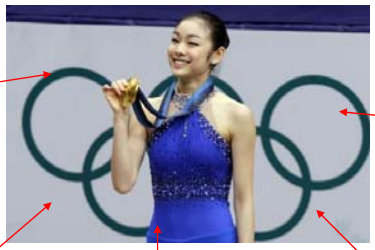
Outline

- **Part I**
  - **Introduction**
  - Paraphrase Identification
  - Paraphrase Extraction
- Part II
  - Paraphrase Generation
  - Applications of Paraphrases
  - Evaluation of Paraphrases
  - Conclusions and Future work

Definition

- Paraphrase
  - Noun
    - Alternative expressions of the same meaning
  - Verb
    - Generate paraphrases for the input expression
- "same meaning"?
  - Quite subjective
  - Different degrees of strictness
  - Depend on applications

Paraphrase (noun): Alternative expressions of the same meaning



Korean Kim Yuna won gold with a world-record score in women's figure skating at the Vancouver Olympics Thursday.

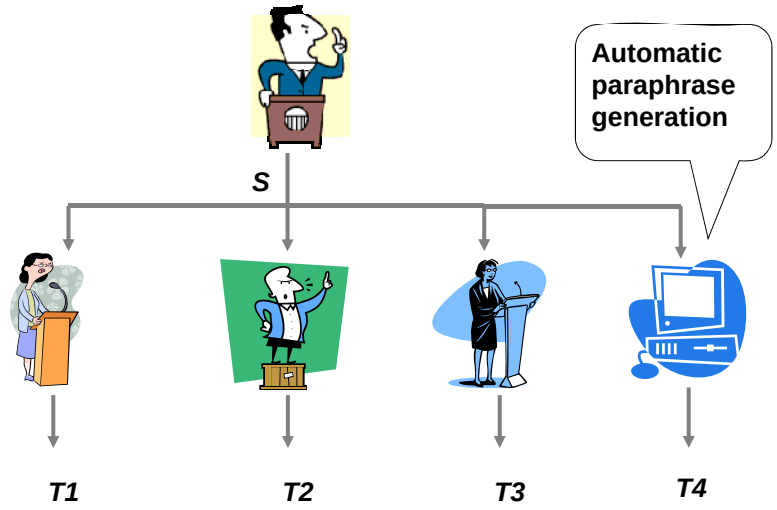
Korean figure skater Kim Yuna has won the gold medal of women's figure skating at the Winter Olympics in Vancouver

Kim Yu-Na (19) is a South Korean ice skater who took the gold medal at the Vancouver Olympics.

Yuna Kim of South Korea won the women's figure skating gold medal at the Vancouver Olympics in record fashion.

Kim Yuna, a South Korean figure skater has won the gold medal at the on-going Winter Olympics 2010.

Paraphrase (verb): Generate paraphrases for an input *S*.



Classification of Paraphrases

- According to granularity
  - —Surface paraphrases
    - Lexical level
    - Phrase level
    - Sentence level
    - Discourse level
  - —Structural paraphrases
    - Pattern level
    - Collocation level

Examples

- Lexical paraphrases (generally synonyms)
  - *solve* and *resolve*
- Paraphrase phrases
  - *look after* and *take care of*
- Paraphrase sentences
  - *The table was set up in the carriage shed.*
  - *The table was laid under the cart-shed.*
- Paraphrase patterns
  - *[X] considers [Y]*
  - *[X] takes [Y] into consideration*
- Paraphrase collocations
  - *(turn on, OBJ, light)*
  - *(switch on, OBJ, light)*

Classification of Paraphrases

- According to paraphrase style
  - Trivial change
  - Phrase replacement
  - Phrase reordering
  - Sentence split & merge
  - Complex paraphrases

Examples

- Trivial change
  - *all the members of* and *all members of*
- Phrase replacement
  - *He said there will be major cuts in the salaries of high-level civil servants.*
  - *He said there will be major cuts in the salaries of senior officials.*
- Phrase reordering
  - *Last night, I saw Tom in the shopping mall.*
  - *I saw Tom in the shopping mall last night.*
- Sentence split & merge
  - *He bought a computer, which is very expensive.*
  - *(1) He bought a computer. (2) The computer is very expensive.*
- Complex paraphrases
  - *He said there will be major cuts in the salaries of high-level civil servants.*
  - *He claimed to implement huge salary cut to senior civil servants.*

Applications of Paraphrases

- Machine Translation (MT)
  - Simplify input sentences
  - Alleviate data sparseness
  - Parameter tuning
  - Automatic evaluation
- Question Answering (QA)
  - Question reformulation
- Information Extraction (IE)
  - IE pattern expansion
- Information Retrieval (IR)
  - Query reformulation
- Summarization
  - Sentence clustering
  - Automatic evaluation
- Natural Language Generation (NLG)
  - Sentence rewriting
- Others
  - Changing writing style
  - Text simplification
  - Identifying plagiarism
  - Text steganography
  - ……

Research on Paraphrasing

- Paraphrase identification
  - Identify (sentential) paraphrases
- Paraphrase extraction
  - Extract paraphrase instances (different granularities)
- Paraphrase generation
  - Generate (sentential) paraphrases
- Paraphrase applications
  - Apply paraphrases in other areas

Textual Entailment – A Similar Direction

- Textual entailment:
  - A directional relation between two text fragments
    - ***T***: the entailing text
    - ***H***: the entailed hypothesis
  - ***T*** entails ***H*** if, typically, a human reading ***T*** would infer that ***H*** is most likely true.
  - Compare entailment with paraphrase
    - Paraphrase is bidirectional entailment

Text Entailment – A Similar Direction

- **R**ecognizing **T**extual **E**ntailment Track (RTE)
  - RTE-1 (2004) to RTE-5 (2009)
  - RTE-6 (2010) is in progress
- Example:
  - ***T*:** A shootout at the Guadalajara airport in May, 1993, killed Cardinal Juan Jesus Posadas Ocampo.
  - ***H*:** Juan Jesus Posadas Ocampo died in 1993.

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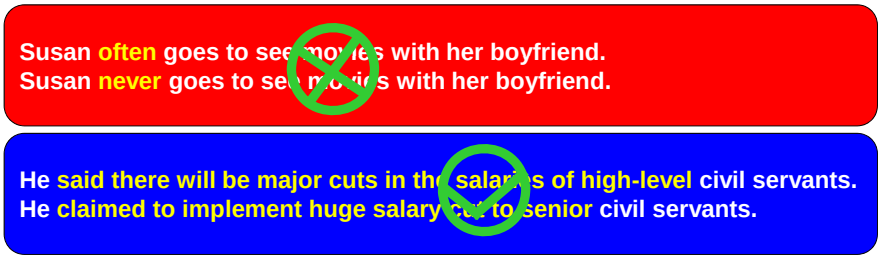
Paraphrase Identification

- Specially refers to sentential paraphrase identification
  - Given any pair of sentences, automatically identifies whether these two sentences are paraphrases
- Paraphrase identification is not trivial



Overview

- Classification based methods
  - Reviewed as a binary classification problem, i.e., input s_1 and s_2 to a classifier and output 0/1
  - Compute the similarities between s_1 and s_2 at different levels, which are then used as classification features
- Alignment based methods
  - Align s_1 and s_2 first, and score the sentence pair based on the alignment results
    - Alignment based on ITG
    - Alignment based on quasi-synchronous dependency grammars

Classification based Methods

- Brockett and Dolan, 2005
  - Features:
    - String similarity features
      - Sentence length, word overlap, edit distance, …
    - Morphological variants
      - Word pairs with the same stem
    - WordNet lexical mappings
      - Synonym pairs / word-hypernym pairs from WordNet
    - Word association pairs
      - Automatically learned synonym pairs
  - Classifier
    - SVM classifier

orbit | orbital

operation | procedure

vendors | suppliers

Classification based Methods (cont')

- Finch et al., 2005
  - Using MT evaluation techniques to compute sentence similarities, which are then used as classification features
    - WER, PER, BLEU, NIST
    - Feature vector *vec*(s_1, s_2)
      - *vec*1(s_1, s_2): s_1 as reference, s_2 as MT system output;
      - *vec*2(s_1, s_2): s_2 as reference, s_1 as MT system output;
      - *vec*(s_1, s_2): average of *vec*1(s_1, s_2) and *vec*2(s_1, s_2):
  - Classifier
    - SVM classifier

Classification based Methods (cont')

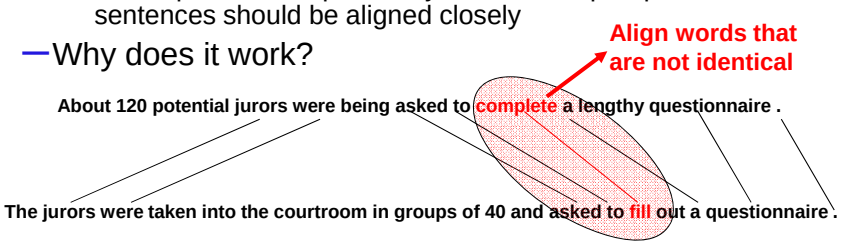
- Malakasiotis, 2009
  - Combining multiple classification features
    - String similarity (various levels)
      - Tokens, stems, POS tags, nouns only, verbs only, …
    - Different measures
      - Edit distance, Jaro-Winkler distance, Manhattan distance…
    - Synonym similarity
      - Treat synonyms in two sentences as identical words
    - Syntax similarity
      - Dependency parsing of two sentences and compute the overlap of dependencies
  - Classifier
    - Maximum Entropy classifier

Alignment based Methods

- Wu, 2005
  - Conduct alignment based on **I**nversion **T**ransduction **G**rammars (ITG)
    - Sensitive to the differences in sentence structures
    - Without using any thesaurus to deal with lexical variation
  - Performance is comparable to the classification based methods
  - Also performs well in recognizing textual entailment

Alignment based Methods (cont')

- Das and Smith, 2009
  - Conduct alignment based on **Q**uasi-Synchronous Dependency **G**rammar (QG)
    - Alignment between two dependency trees
    - Assumption: the dependency trees of two paraphrase sentences should be aligned closely
  - Why does it work?



  - Performs competitively with classification based methods

A Summary

- Classification based method is still the mainstream method, since:
  - Binary classification problem is well defined;
  - Classification algorithms and tools are readily available;
  - It can combine various features in a simple way;
  - It achieves state-of-the-art performance.

References

- Brockett and Dolan. 2005. Support Vector Machines for Paraphrase Identification and Corpus Construction.
- Finch et al. 2005. Using Machine Translation Evaluation Techniques to Determine Sentence-level Semantic Equivalence.
- Wu. 2005. Recognizing Paraphrases and Textual Entailment using Inversion Transduction Grammars.
- Malakasiotis. 2009. Paraphrase Recognition Using Machine Learning to Combine Similarity Measures.
- Das and Smith. 2009. Paraphrase Identification as Probabilistic Quasi-Synchronous Recognition.

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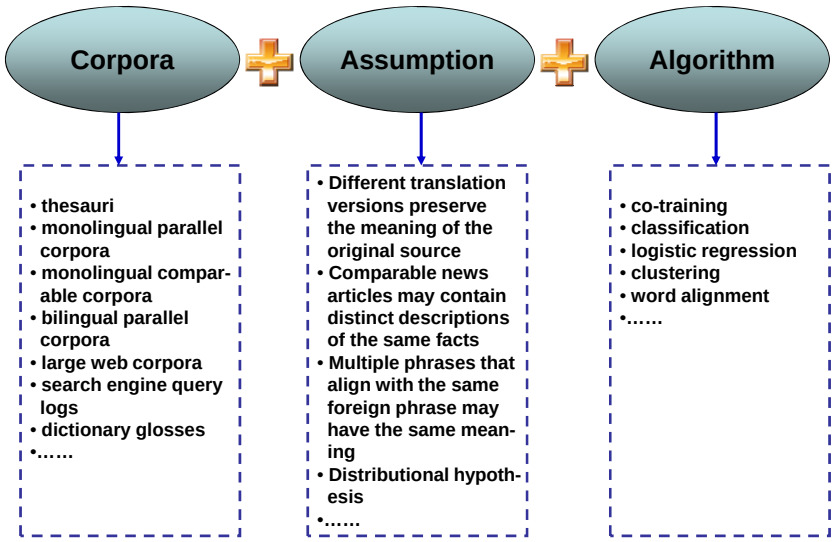
Three Elements for Paraphrase Extraction



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    - **From Thesauri**
    - From Monolingual Parallel Corpora
    - From Monolingual Comparable Corpora
    - From Bilingual Parallel Corpora
    - From Large Web Corpora
    - From Other Resources

Method Overview

- Extract words with specific semantic relations as paraphrases
  - Most common: synonyms
  - Other relations: hypernyms, hyponyms…
- Widely used thesauri
  - In English
    - WordNet
  - In other languages
    - E.g., HowNet, Tongyici Cilin in Chinese

Pros and Cons

- Pros
  - Existing resources
  - High quality
    - Thesauri are hand crafted
- Cons
  - Language limitation
    - Thesauri are not available in many languages
  - Difficult to update

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    - From Bilingual Parallel Corpora
    - From Large Web Corpora
    - From Other Resources

Method Overview

- Corpus
  - Multiple translations of the same foreign literary work
- Assumption
  - Different translation versions preserve the meaning of the original source, but may use different expressions

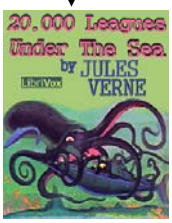
Example

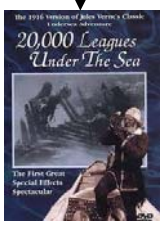
Vingt mille lieues sous les mers

(in French)

20000 Leagues Under the Sea

(different English translation versions)





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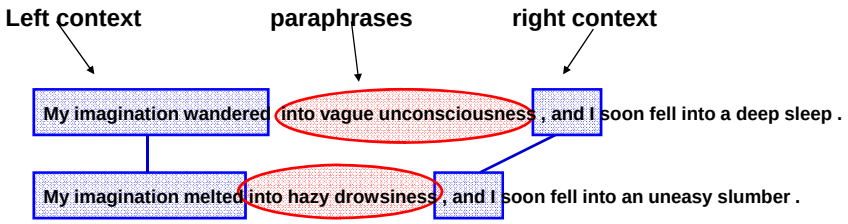
Sentence Alignment and Preprocessing

- Barzilay and McKeown, 2001
  - Collected 11 English translations for 5 foreign novels
    - E.g., *Madame Bovary*, *Fairy Tale*, *Twenty Thousand Leagues under the sea…*
  - Sentence alignment
    - A dynamic programming algorithm
    - Produced 44,562 pairs of parallel sentences
    - Precision is 94.5%
  - Other preprocessing
    - POS tagging and chunking
    - Phrases are the atomic units in paraphrase extraction

Paraphrase Phrase Extraction

- Barzilay and McKeown, 2001 (cont')
  - Extracting paraphrase phrases
    - Assumption: phrases in aligned sentences which appear in similar contexts are paraphrases
    - Method: co-training
      - Iteratively learn contexts and paraphrases



Pros and Cons

- Pros
  - Easy to align monolingual parallel sentences
- Cons
  - Domain limitation
    - Limited in literary works
  - Scale limitation
    - The size of the corpus is relatively small
  - Context dependence
    - E.g., "*John said*" and "*he said*"

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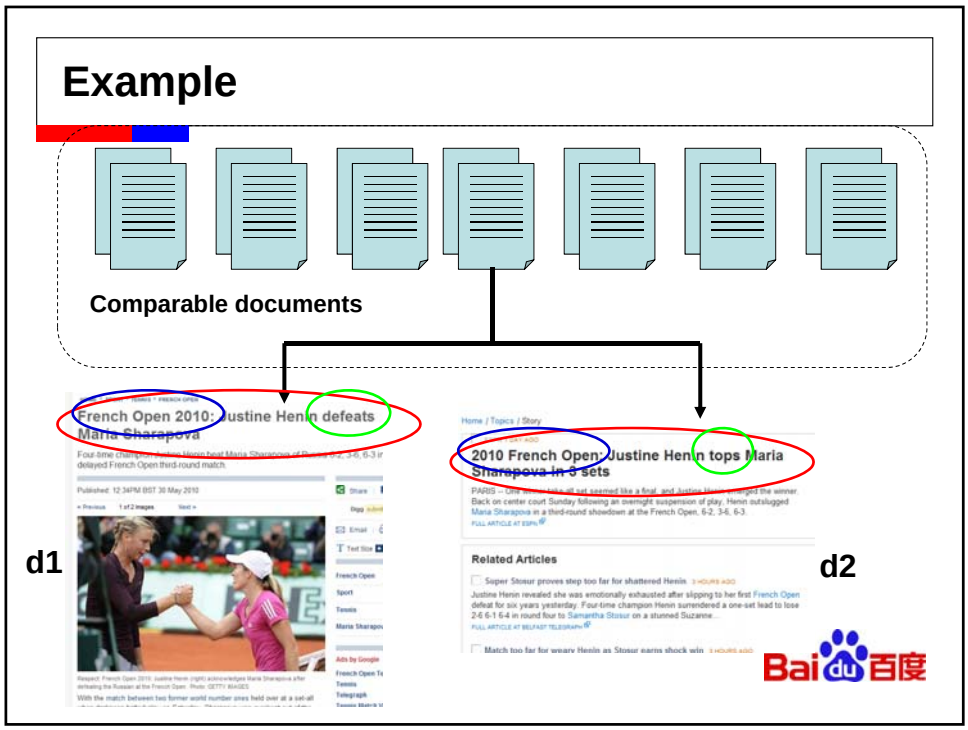
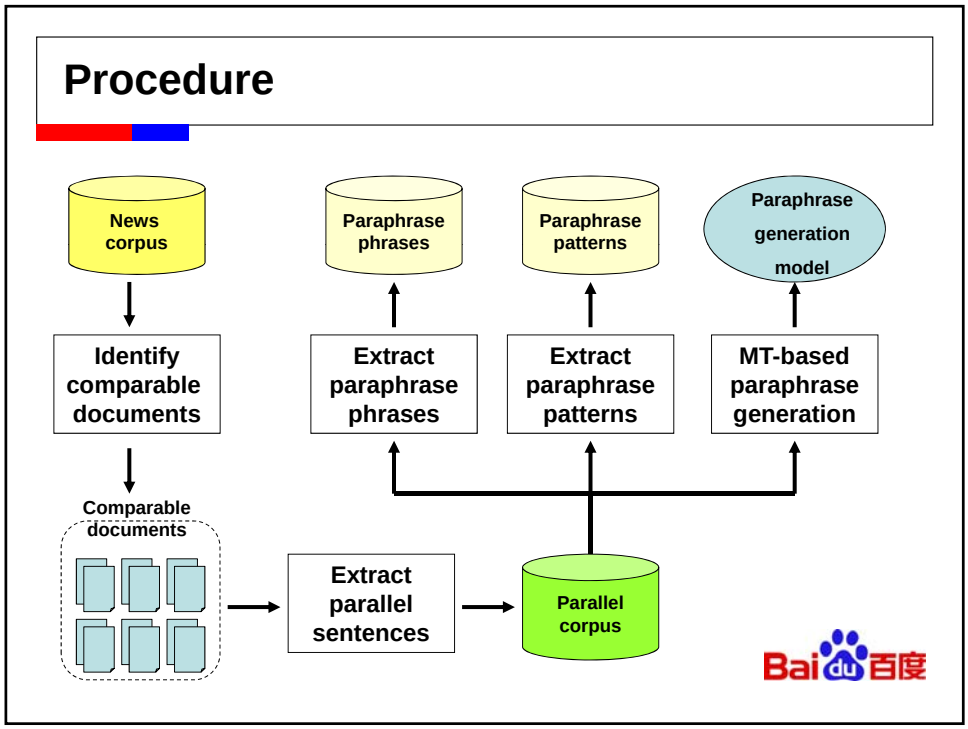
    - From Large Web Corpora
    - From Other Resources

Method Overview

- Corpus
  - News articles that report the same event within a brief period of time
    - Produced by different news agencies
- Assumption
  - Comparable news articles may contain distinct descriptions of the same facts


Example
Comparable documents
d1
d2
French Open 2010: Justine Henin defeats Maria Sharapova
2010 French Open: Justine Henin tops Maria Sharapova in 3 sets
Related Articles
Baidu 百度


Procedure
News corpus
Identify comparable documents
Comparable documents
Extract parallel sentences
Parallel corpus
Paraphrase phrases
Extract paraphrase phrases
Paraphrase patterns
Extract paraphrase patterns
Paraphrase generation model
MT-based paraphrase generation
Baidu 百度

Identify Comparable Documents

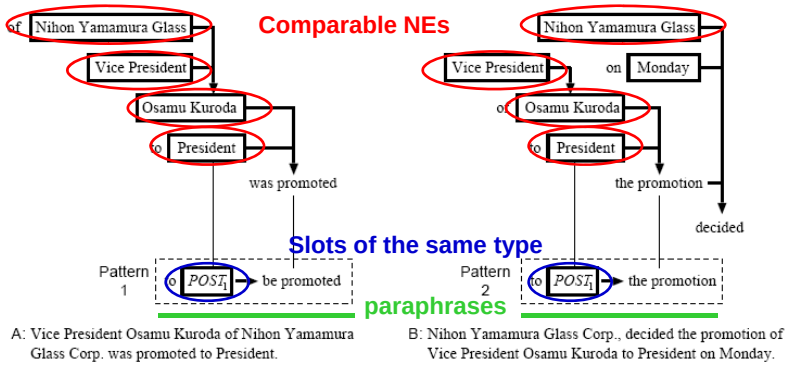
- Input
  - News articles from different news agencies
    - E.g., CNN, New York Times, Washington Post…
- Processing
  - Method-1: Retrieve documents on a given topic or event
    - Needs predefined topics or events
  - Method-2: Cluster documents
    - Content similarity; time interval
- Output
  - Corpus of comparable documents

Extract Parallel (Paraphrase) Sentences

- Input
  - Corpus of comparable documents
- Processing
  - Sentence clustering
    - Method-1: based on an assumption: first sentences of a news article usually summarize its content
    - Method-2: based on computing the content similarity
- Output
  - Corpus of parallel (paraphrase) sentences

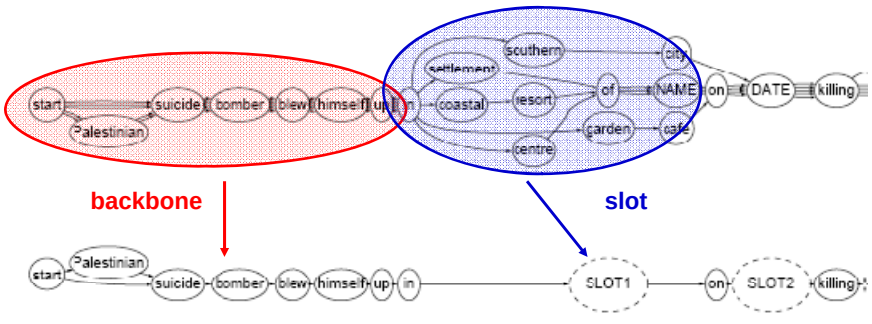
Extract Paraphrase Patterns

- Using NEs as anchors
  - Shinyama et al., 2002
  - Basic idea: paraphrase sentences should contain comparable NEs



Extract Paraphrase Patterns

- Multiple-sequence alignment
  - Barzilay and Lee, 2003



Pros and Cons

- Pros
  - Language-independent
    - Comparable news can be found in many languages
- Cons
  - Domain-dependent
    - Paraphrases are extracted from specific domains or topics
  - Sentence clustering
    - Either too strict or too loose

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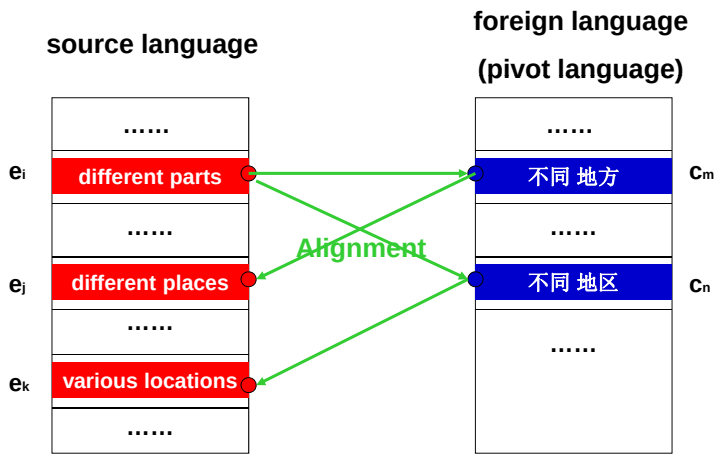
    - **From Bilingual Parallel Corpora**
    - From Large Web Corpora
    - From Other Resources

Method Overview

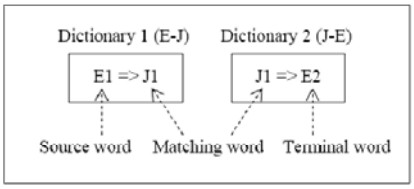
- Corpus
  - A parallel corpus of the source language and a foreign language
- Assumption
  - Multiple phrases that align with the same foreign phrase may have the same meaning
- The method is also termed as "***pivot approach***"

Example



A Simple Version

- Takao et al., 2002
  - Basic idea:
    - Generating lexical paraphrases using 2-way dictionaries
    - English word e_1 can be translated to a Japanese word *j* with an E-J dic. D_1, and then *j* can be translated back to an English word e_2 with a J-E dictionary D_2. e_1 and e_2 are extracted as paraphrases



Extracting Paraphrase Phrases

- Bannard and Callison-Burch, 2005
  - Word alignment and phrase extraction
  - Basic assumption:
    - If two English phrases e_1 and e_2 can be aligned with the same foreign phrase *f*, e_1 and e_2 are likely to be paraphrases.
  - Paraphrase probability:

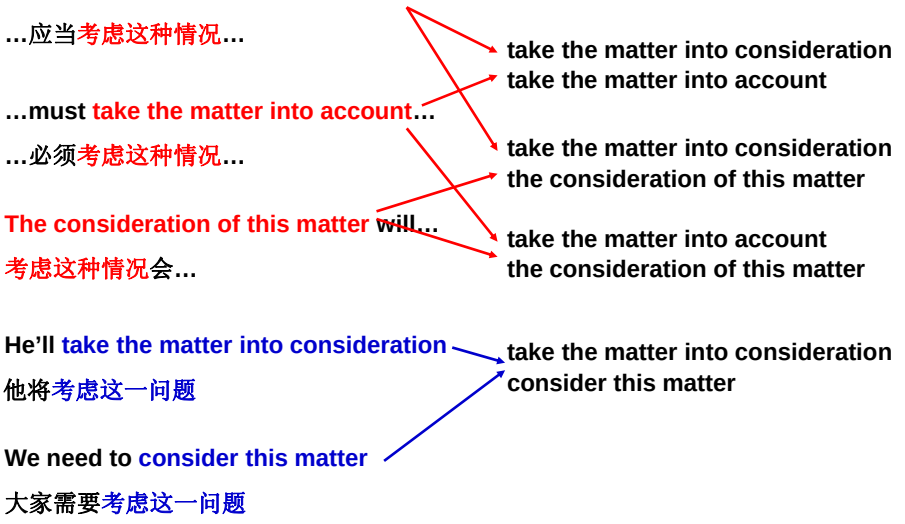
$$\hat{e}_2 = \arg\max_{e_2 \neq e_1} p(e_2 \mid e_1)$$

$$= \arg\max_{e_2 \neq e_1} \sum_f p(f \mid e_1)\, p(e_2 \mid f)$$

Pivot in a foreign language

Translation probability

Bannard & Callison-Burch (2005) 's results:



Add Syntactic Constraints

- Callison-Burch, 2008
  - Basic idea:
    - Two paraphrase phrases should have the same syntactic type.
  - Paraphrase probability:

$$\hat{e}_2 = \arg\max_{e_2: e_2 \neq e_1 \wedge s(e_2)=s(e_1)} p(e_2 \mid e_1, s(e_1))$$

given the syntactic type

$$= \arg\max_{e_2: e_2 \neq e_1 \wedge s(e_2)=s(e_1)} \sum_f p(f \mid e_1, s(e_1)) p(e_2 \mid f, s(e_1))$$

  - Syntactic constraints are also used when substituting paraphrases in sentences

Callison-Burch (2008) 's results:

…should take the matter into consideration…

…应当考虑这种情况…

…must take the matter into account…

…必须考虑这种情况…

The consideration of this matter will…

考虑这种情况会…

He'll take the matter into consideration

他将考虑这一问题

We need to consider this matter

大家需要考虑这一问题

take the matter into consideration

take the matter into account

take the matter into consideration

the consideration of this matter

take the matter into account

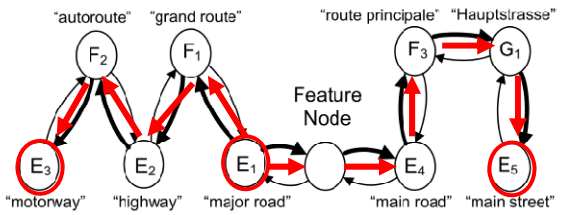
the consideration of this matter

take the matter into consideration

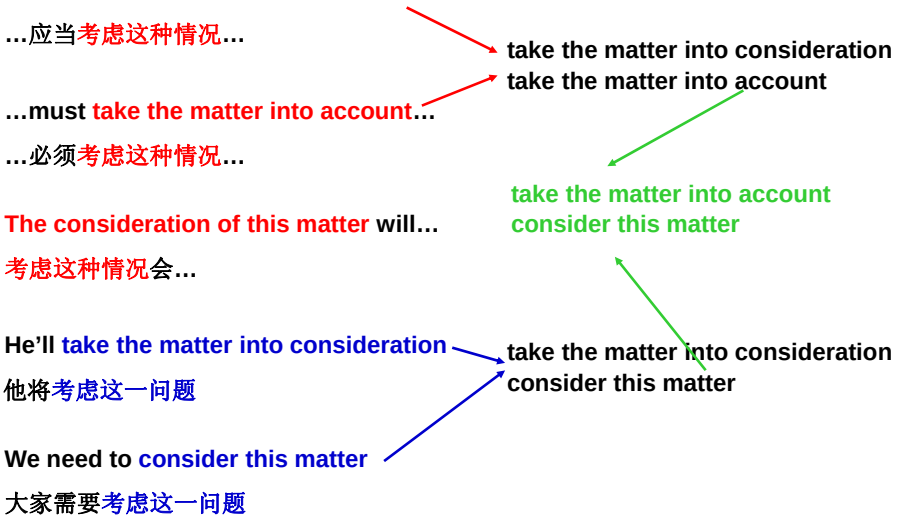
consider this matter

Learning Paraphrases from Graphs

- Kok and Brockett, 2010
  - Basic idea:
    - Convert aligned phrases into a graph, extract paraphrases based on random walks and hitting times



Kok and Brockett (2010) 's results:



Extracting Paraphrase Patterns

- Zhao et al., 2008
  - Basic idea:
    - Generate paraphrase patterns that include part-of-speech slots.
  - Paraphrase probability:

$$score(e_2 \mid e_1) = \sum_c \exp[\sum_{i=1}^{N} \lambda_i h_i(e_1, e_2, c)]$$

$$h_1(e_1, e_2, c) = score_{MLE}(c \mid e_1)$$
$$h_2(e_1, e_2, c) = score_{MLE}(e_2 \mid c)$$

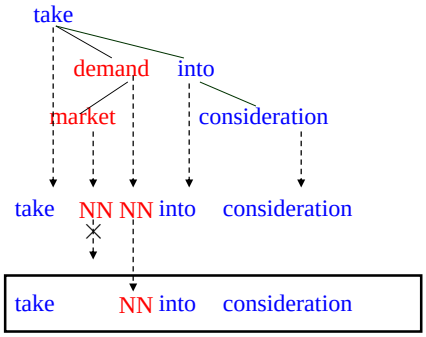
Based on maximum likelihood estimation

$$h_3(e_1, e_2, c) = score_{LW}(c \mid e_1)$$
$$h_4(e_1, e_2, c) = score_{LW}(e_2 \mid c)$$

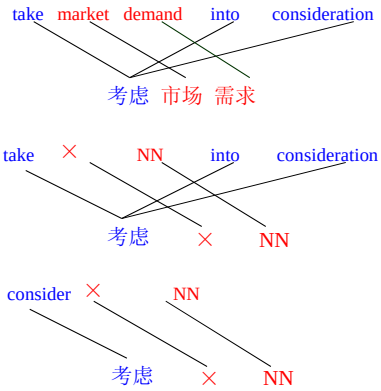
Based on lexical weighting

Example

Inducing English patterns



Inducing Chinese patterns



Extract paraphrase patterns

take NN into consideration & consider NN

Zhao et al (2008) 's results:

…should take the matter into consideration…

…应当考虑这种情况…

…must take the matter into account…

…必须考虑这种情况…

The consideration of this matter will…

考虑这种情况会…

He'll take the matter into consideration

他将考虑这一问题

We need to consider this matter

大家需要考虑这一问题

take [NN] into consideration
take [NN] into account

take [NN] into consideration
the consideration of [NN]

take [NN] into account
the consideration of [NN]

take [NN] into consideration
consider [NN]

Pros and Cons

- Pros
  - The method proves effective, hence it's widely used
    - High precision
    - Large scale
- Cons
  - Language limitation
    - Cannot work where the large-scale bilingual parallel corpora are not available

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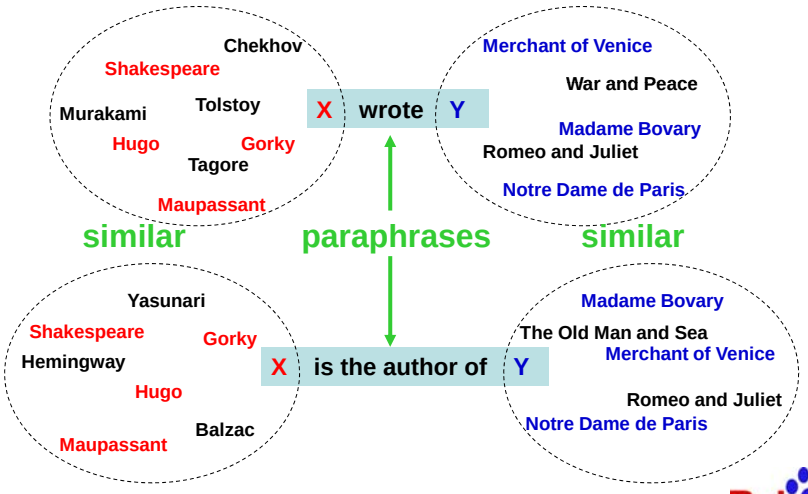
    - From Bilingual Parallel Corpora
    - **From Large Web Corpora**
    - From Other Resources

Method Overview

- Corpus
  - Large corpus of web documents
  - Or directly based on web mining
- Assumption
  - Distributional hypothesis
    - If two words / phrases / patterns often occur in similar contexts, their meanings tend to be similar

Example



Extracting Lexical Paraphrases (Word Clustering)

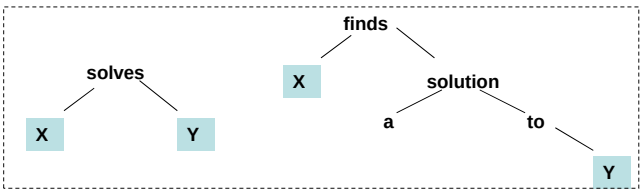
- Lin, 1998
  - Basic idea
    - Measure words' similarity based on the distributional pattern of words
  - Corpus
    - A (dependency) parsed corpus
  - Word similarity

Mutual information

$$sim(w_1, w_2) = \frac{\sum_{(r,w) \in T_r(w_1) \cap T_r(w_2)} (I(w_1, r, w) + I(w_2, r, w))}{\sum_{(r,w) \in T_r(w_1)} I(w_1, r, w) + \sum_{(r,w) \in T_r(w_2)} I(w_2, r, w)}$$

Extracting Syntactic Paraphrase Patterns

- Lin and Pantel, 2001
  - Basic idea: extended distributional hypothesis
  - Corpus: a large corpus of parsed monolingual sentences
  - pattern pairs



  - Pattern similarity

$$sim(p_1, p_2) = \sqrt{sim(SlotX_1, SlotX_2) \times sim(SlotY_1, SlotY_2)}$$

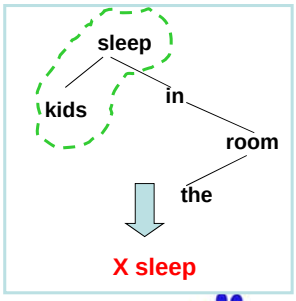
Similarity of the slot fillers

Extracting Surface Paraphrases

- Bhagat and Ravichandran, 2008
  - Basic idea is the same as the above work
  - Corpus:
    - a large corpus of monolingual sentences without parsing
      - 150GB, 25 billion words
  - Surface paraphrases
    - Pairs of n-grams
      - E.g., "*X acquired Y*" and "*X completed the acquisition of Y*"
  - Techniques
    - Apply locality sensitive hashing (LSH) to speed up the computation

Learning Unary Paraphrase Patterns

- Szpector and Dagan, 2008
  - Binary paraphrase patterns (most of the previous work)
    - Each pattern has two slots at both ends
      - E.g., "*X solves Y*" and "*X found a solution to Y*"
  - Unary paraphrase patterns
    - Each pattern has a single slot
      - E.g., "*X take a nap*" and "*X sleep*"
  - Method
    - The same with the above works
      - Based on distributional hypothesis



Extracting Paraphrases based on Web Mining

- Ravichandran and Hovy, 2002
  - Basic idea
    - Learn paraphrase patterns with search engines
  - Corpus
    - The whole internet
  - Method
    - Extract paraphrase patterns for each type, e.g., "*BIRTHDAY*"
    - Provide hand-crafted seeds, e.g., "*Mozart, 1756*"
    - Retrieve sentences containing the seeds from the web with a search engine
    - Extract patterns, e.g.,
      - *born in <ANSWER> , <NAME>*
      - *<NAME> was born on <ANSWER> ,*
      - *……*

Pros and Cons

- Pros
  - Language independent
- Cons
  - For methods based on large web corpora
    - Computation complexity is high
      - Needs to process an extremely large corpus
      - Needs to compute pairwise similarity for all candidates
  - For methods based on web mining
    - Extract paraphrase patterns type by type
    - Needs to prepare seeds beforehand

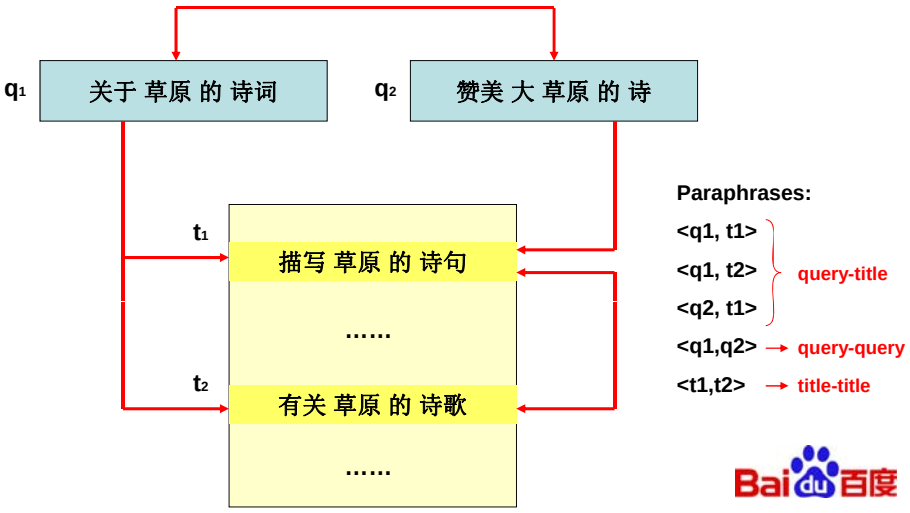
Outline

- **Part I**
  - Introduction
  - Paraphrase Identification
  - **Paraphrase Extraction**
    - From Thesauri
    - From Monolingual Parallel Corpora
    - From Monolingual Comparable Corpora
    - From Bilingual Parallel Corpora
    - From Large Web Corpora
    - **From Other Resources**

Paraphrasing with Search Engine Query Logs

- Zhao et al., 2010
  - Corpus
    - Query logs (queries and titles) of a search engine
  - Assumption
    - If a query q hits a title t, then q and t are likely to be paraphrases
    - If queries q_1 and q_2 hit the same title t, then q_1 and q_2 are likely to be paraphrases
    - If a query q hits titles t_1 and t_2, then t_1 and t_2 are likely to be paraphrases

Example



Method

- Step-1: extracting <*q*, *t*> paraphrases
  - Extracting candidate <*q*, *t*> pairs from query logs
  - Paraphrase validation based on binary classification
    - Combining multiple features
- Step-2: extracting <*q*, *q*> paraphrases
  - Extracting candidate <*q*, *q*> from <*q*, *t*> paraphrases
  - Paraphrase validation based on binary classification
- Step-3: extracting <*t*, *t*> paraphrases
  - Extracting candidate <*t*, *t*> from <*q*, *t*> paraphrases
  - Paraphrase validation based on binary classification

Pros and Cons

- Pros
  - No scale limitation
    - Query logs keep growing
    - A large volume of paraphrases can be extracted
  - Query logs reflect web users' real needs
- Cons
  - Query logs data are only available in IR companies
  - User queries are noisy
    - Spelling mistakes, grammatical errors…

Extracting Paraphrases from Dictionary Glosses

- Corpus
  - Glosses of dictionaries
- Assumption
  - A word and its definition (gloss) in the dictionary have the same meaning

Example (Encarta Dictionary)

Method

- Prune and reformulate the definitions
  - For a verb *v*, extracts the head of the definition (*h*) and *h*'s adverb modifier *m* as *v*'s paraphrase
    - Kaji et al., 2002
  - Rule based method for extracting the appropriate part from the definition
    - Higashinaka and Nagao, 2002
    - E.g., *w* should not be in *def*; ignore contents in parentheses in *def*; avoid double negation…

Pros and Cons

- Pros
  - Explain unfamiliar words with simpler definitions
- Cons
  - Transformation of *person*, *number*, *tense*

E.g., **president** → **head of company**

presidents

heads of company

head of companies

heads of companies

References

- From monolingual parallel corpora
  - Barzilay and McKeown. 2001. Extracting Paraphrases from a Parallel Corpus.
- From monolingual comparable corpora
  - Yusuke Shinyama, Satoshi Sekine, Kiyoshi Sudo. 2002. Automatic Paraphrase Acquisition from News Articles.
  - Regina Barzilay and Lillian Lee. 2003. Learning to Paraphrase: An Unsupervised Approach Using Multiple-Sequence Alignment.
  - Bill Dolan, Chris Quirk, and Chris Brockett. 2004. Unsupervised Construction of Large Paraphrase Corpora: Exploiting Massively Parallel News Sources.

References (cont')

- From bilingual parallel corpora
  - Takao et al. 2002. Comparing and Extracting Paraphrasing Words with 2-Way Bilingual Dictionaries.
  - Bannard and Callison-Burch. 2005. Paraphrasing with Bilingual Parallel Corpora.
  - Callison-Burch. 2008. Syntactic Constraints on Paraphrases Extracted from Parallel Corpora.
  - Kok and Brockett. 2010. Hitting the Right Paraphrases in Good Time.
  - Zhao et al. 2008. Pivot Approach for Extracting Paraphrase Patterns from bilingual corpora.

References (cont')

- From large web corpora
  - Lin. 1998. Automatic Retrieval and Clustering of Similar Words.
  - Lin and Pantel. 2001. Discovery of Inference Rules for Question Answering.
  - Bhagat and Ravichandran. 2008. Large Scale Acquisition of Paraphrases for Learning Surface Patterns.
  - Szpector and Dagan. 2008. Learning Entailment Rules for Unary Templates.
  - Ravichandran and Hovy. 2002. Learning Surface Text Patterns for a Question Answering System.

References (cont')

- From other resources
  - Zhao et al. 2010. Paraphrasing with Search Engine Query Logs.
  - Kaji et al. 2002. Verb Paraphrase based on Case Frame Alignment.
  - Higashinaka and Nagao. 2002. Interactive Paraphrasing Based on Linguistic Annotation.

Coffee Break!

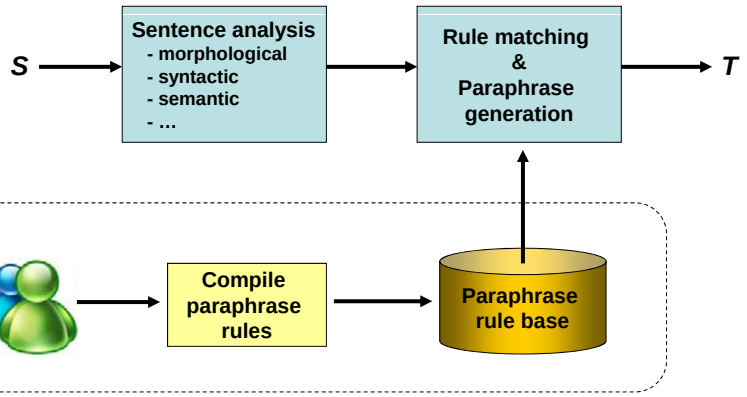
Outline

- **Part 2**
  - **Paraphrase Generation**
    - **Rule based Method**
    - Thesaurus based Method
    - NLG based Method
    - MT based Method
    - Pivot based Method
  - Applications of Paraphrases
  - Evaluation of Paraphrases
  - Conclusions and Future work

Rule based Method

- Two types:
  - Based on hand-crafted rules
    - Widely used in early studies of paraphrase generation
    - McKeown, 1979; Zong et al., 2001; Tetsuro et al., 2001; Zhang and Yamamoto, 2002……
  - Based on automatically extracted rules
    - Extract paraphrase patterns from corpora
    - Barzilay and Lee, 2003, Zhao et al., 2009……

Based on Hand-crafted Rules



Based on Hand-crafted Rules

- Examples of paraphrase rules
  - Change the positions of adverbials
    - *He booked a single room in Beijing **yesterday**. =>*
      - ***Yesterday**, he booked a single room in Beijing.*
  - Split a compound sentence into a group of simple sentences
    - *He booked a single room in Beijing yesterday =>*
      - *He booked a single room in Beijing.*
      - *He booked a single room yesterday.*
      - *He booked a room.*
  - Rewrite a sentence using hand-crafted patterns
    - ***Can** I have a cup of tea? =>*
      - ***May** I have a cup of tea?*
      - ***I would like** a cup of tea, please.*
      - ***Give me** a cup of tea.*

Based on Automatically Extracted Rules

- Studies on paraphrase patterns extraction has been introduced above
- Some of them have tried to apply the extracted paraphrase patterns in paraphrase generation
  - Complex paraphrase patterns
    - Barzilay and Lee, 2003
    - E.g.,

  - Short and simple paraphrase patterns
    - Zhao et al., 2009
    - E.g., *consider [NN]* and *take [NN] into consideration*

Pros and Cons

- Methods based on hand-crafted rules
  - Pros
    - Can design paraphrase rules for specific applications and requirements
  - Cons
    - It is time-consuming to construct paraphrase rules
    - Problem of rules conflict
    - Coverage of paraphrase rules is limited
- Methods based on automatically extracted rules
  - Pros
    - Can generate paraphrases with structural changes
  - Cons
    - Coverage of paraphrase rules is limited

References

- McKeown. 1979. Paraphrasing Using Given and New Information in a Question-Answer System.
- Zong et al. 2001. Approach to Spoken Chinese Paraphrasing Based on Feature Extraction.
- Tetsuro et al.. 2001. KURA: A Transfer-Based Lexico-Structural Paraphrasing Engine.
- Zhang and Yamamoto. 2002. Paraphrasing of Chinese Utterances.
- Barzilay and Lee. 2003. Learning to Paraphrase - An Unsupervised Approach Using Multiple-Sequence Alignment.
- Zhao et al. 2009. Application-driven Statistic Paraphrase Generation.

Outline

- **Part 2**
  - **Paraphrase Generation**
    - Rule based Method
    - **Thesaurus based Method**
    - NLG based Method
    - MT based Method
    - Pivot based Method
  - Applications of Paraphrases
  - Evaluation of Paraphrases
  - Conclusions and Future work

Thesaurus based Method

- Also known as lexical substitution
  - Substitute words in a sentence with their synonyms that fit in the given context
  - SemEval-2007: English lexical substitution task
  - SemEval-2010: Cross-lingual lexical substitution
  - Example:
    - *There will be major cuts in the salaries of high-level civil servants.*
    - *There will be major cuts in the wages of high-level civil servants.*

Thesaurus based Method

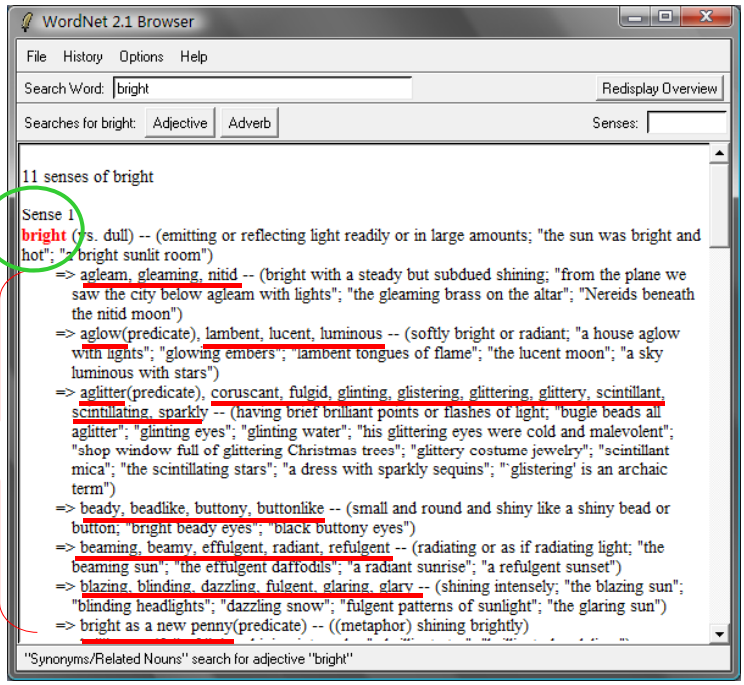
- Include two stages
  - **Stage-1:** extract candidate substitutes from predefined inventories.
    - E.g., WordNet
  - **Stage-2:** find substitutes that fit in the given context
    - Using language model or web data (e.g., Google 5-gram) for evaluating the fitness in the context
    - Disambiguation may also be useful

Stage-1: Candidate Extraction

- Various thesauri have been tried
  - WordNet:
    - the most commonly used
  - Others:
    - Encarta, Roget, Oxford American Writer's Thesaurus…
- Extracting different information as candidates
  - Synsets (all synsets vs. best synset)
  - Hypernyms, similar-to, also-see…
  - Words in glosses

Example:

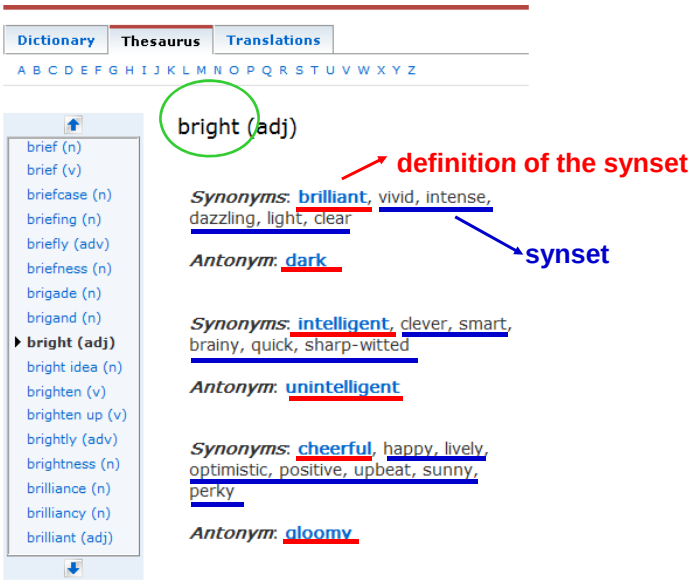
WordNet



different synsets

Example:

Encarta



Stage-2: Substitute Selection

- Rank the candidates and select the one fits best in the given context
- Context constraints
  - Semantic constraints
    - Select substitutes with the correct meaning wrt the given context
  - Syntactic constraints
    - The sentence generated after substitution should keep grammatical

SubFinder: A Lexical Substitution System

- SubFinder
  - University of North Texas
  - Performs well in SemEval-2007 English lexical substitution task
- Candidate extraction
  - WordNet
  - Encarta
  - Others
    - Prove to be useless

SubFinder: A Lexical Substitution System

- Substitute selection (5 ranking methods R1~R5)
  - Language model
    - Google 1T 5-gram (R1)
    - Query search engine (R2)
  - Latent semantic analysis (LSA) (R3)
    - Rank a candidate by its relatedness to the context sentence
  - Word sense disambiguation (WSD) (R4)
    - Disambiguate the target word and select the synset of the right sense
  - Pivot approach (R5)
    - Check whether a candidate substitute can be generated via a 2-way translation

SubFinder: A Lexical Substitution System

- Combine R1~R5:
  - Voting mechanism

$$score(c_i) = \sum_{m \in rankings} \lambda_m \frac{1}{r_{c_i}^m}$$

Ranks according to R1-R5

  - Contribution of each ranking method is not analyzed☹

Pros and Cons

- Pros
  - Based on existing inventories
- Cons
  - Cannot generate structural paraphrases
  - Language limitation
- Question
  - *How to merge different thesauri?*
    - Thesauri have different forms of synset clustering

References

- McCarthy and Navigli. 2007. SemEval-2007 Task 10: English Lexical Substitution Task.
- Hassan et al. 2007. UNT: SubFinder: Combining Knowledge Sources for Automatic Lexical Substitution.
- Yuret. 2007. KU: Word Sense Disambiguation by Substitution.
- Giuliano et al. 2007. FBK-irst: Lexical Substitution Task Exploiting Domain and Syntagmatic Coherence.
- Martinez et al. 2007. MELB-MKB: Lexical Substitution System based on Relatives in Context.
- Kauchak and Barzilay. 2006. Paraphrasing for Automatic Evaluation.

Outline

- **Part 2**
  - **Paraphrase Generation**
    - Rule based Method
    - Thesaurus based Method
    - **NLG based Method**
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    - Pivot based Method
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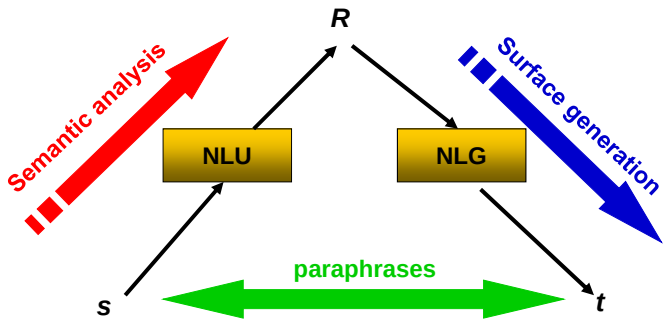
  - Conclusions and Future work

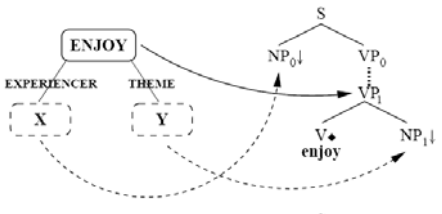
Overview

- Two steps
  - (1) analysis and (2) generation



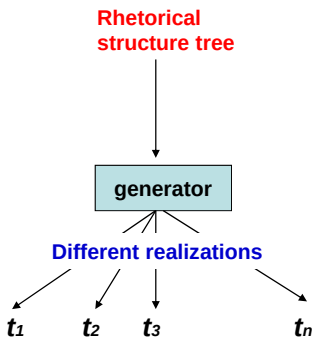
NLG based Methods

- Kozlowski et al., 2003
  - Generate single-sentence paraphrases
  - Input: predicate/argument structure
    - Not natural language sentences☹
  - Based on lexico-grammatical resources
    - Map elementary semantic structures with syntactic realization



NLG based Methods (cont')

- Power and Scott, 2005
  - Concerning *larger-scale* paraphrases
    - Paraphrases of multiple sentences or even the whole text
    - Paraphrases vary not only at lexical and syntactic levels, but also in document structure and layout
  - Problem:
    - The input is not natural language texts☹



NLG based Methods (cont')

- Power and Scott, 2005 (cont')
  - Example:

Rhetorical structure tree

reason
NUCLEUS: recommend(doctors, elixir)
SATELLITE: conjunction
1: quick-results(elixir)
2: few-side-effects(elixir)

solution1

Doctors recommend Elixir since it gives quick results and it has few side effects.

solution2

(1) Elixir gives quick results.
(2) Elixir has few side effects.
(3) Therefore, it is recommended by doctors.

NLG based Methods (cont')

- Fujita et al., 2005
  - Paraphrase *light-verb constructions* (LVC) in sentences
    - LVC: consists of a light-verb that syntactically governs a deverbal noun
  - Semantic representation
    - LCS: Lexical Conceptual Structure
  - Procedure
    - Semantic analysis
    - Semantic transformation
    - Surface generation

Pros and Cons

- Pros
  - It simulates human being's behavior when generating paraphrases:
    - Step-1: understand the meaning of a sentence
    - Step-2: generate a new sentence expressing the meaning
- Cons
  - Both deep analysis of sentences and NLG are difficult to realize

References

- Kozlowski et al. 2003. Generation of single-sentence paraphrases from predicate/argument structure using lexico-grammatical resources.
- Power and Scott. 2005. Automatic generation of large-scale paraphrases.
- Fujita et al. 2005. Exploiting Lexical Conceptual Structure for Paraphrase Generation.

Outline

- **Part 2**
  - **Paraphrase Generation**
    - Rule based Method
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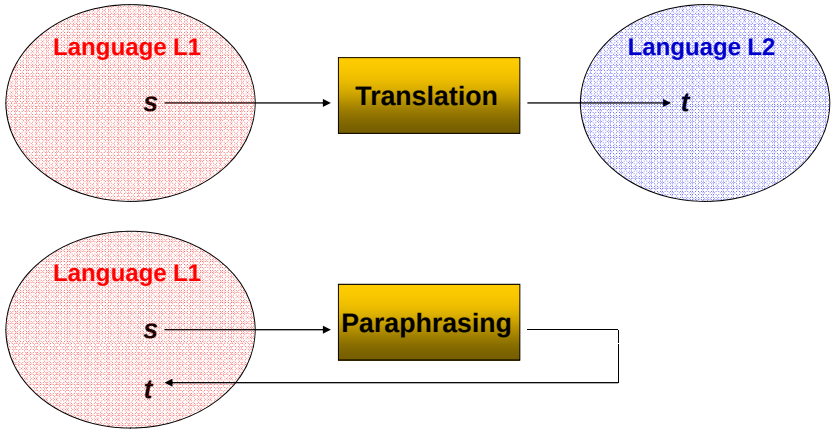
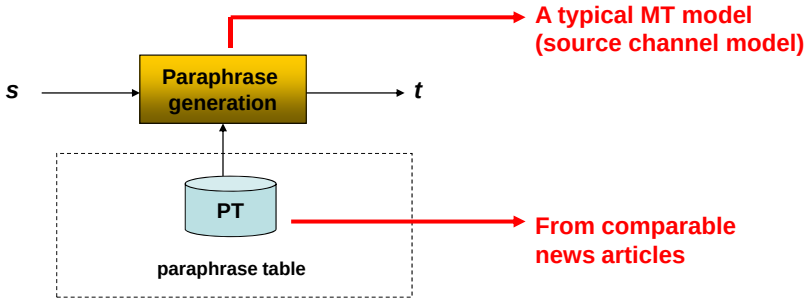
Machine Translation *vs*. Paraphrase Generation



For both machine translation and paraphrase generation:
(1) *t* should preserve the meaning of *s*
(2) *t* should be a fluent sentence

Paraphrase Generation as Machine Translation

- Quirk et al., 2004
  - First recast paraphrase generation as a monolingual machine translation task



Paraphrase Generation as Machine Translation (cont')

- Model
  - Source channel model

$$t^* = \arg\max_t p(t \mid s)$$
$$= \arg\max_t p(s \mid t)\, p(t)$$

$p(t)$: Language model

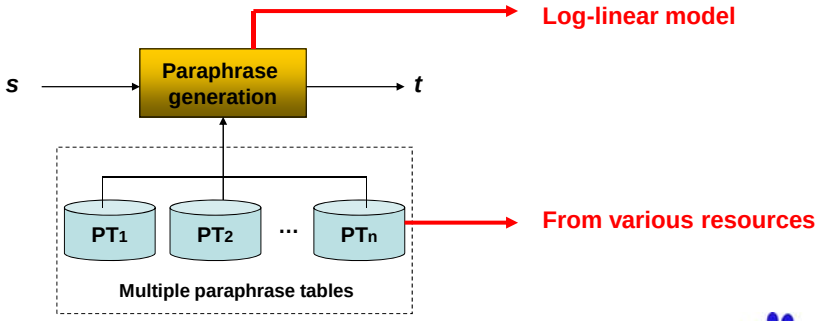
$p(s \mid t)$: "Translation" model (based on a phrasal paraphrase table)

Paraphrase Generation as Machine Translation (cont')

- Paraphrase table
  - Monolingual parallel sentences
    - Extracted from comparable news articles
    - 139K pairs
  - Word alignment & phrase pair extraction
    - With Giza++
- Limitation
  - Lack of monolingual parallel corpora to train the paraphrase table!!!

Paraphrase Generation as Machine Translation (cont')

- Zhao et al., 2008
  - Combine multiple resources to train the paraphrase table



Paraphrase Generation as Machine Translation (cont')

- Model
  - Log-linear model

$$t^* = \arg\max_t \{ \sum_{i=1}^{N} \lambda_{TM\_i} h_{TM\_i}(t,s) + \lambda_{LM} h_{LM}(t,s) \}$$

N paraphrase tables, each feature corresponds to a paraphrase table

Language model

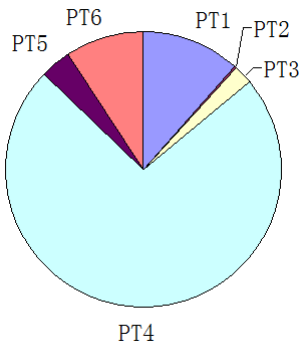
$$h_{TM\_i}(t,s) = \log \prod_{k=1}^{K_i} score_i(t_k, s_k)$$

Paraphrase Generation as Machine Translation (cont')

- Paraphrase tables
  - **PT1**: from word clusters (Lin, 1998)
  - **PT2**: from monolingual parallel corpora
  - **PT3**: from monolingual comparable corpora
  - **PT4**: from bilingual parallel corpora
  - **PT5**: from Encarta dictionary glosses
  - **PT6**: from clusters of similar user queries

Proves most useful!

- Volumes of the PTs:



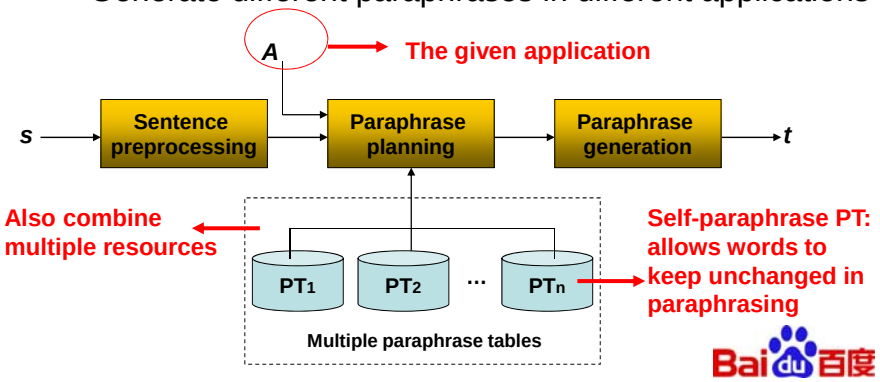
Paraphrase Generation *vs.* Machine Translation

- Differences between machine translation and paraphrase generation (Zhao et al., 2009):

Machine Translation (MT)	Paraphrase Generation (PG)
MT has a unique purpose	PG has distinct purposes in different applications
In MT, all words in a sentence should be translated	In PG, not all words need to be paraphrased
In MT, the bilingual parallel data are easy to collect	In PG, multiple resources need to be combined
In MT, automatic evaluation metrics (e.g., BLEU) are available	In PG, automatic evaluation metrics are not available

Application-driven Statistical Paraphrase Generation

- Zhao et al., 2009
  - Propose a statistical model for paraphrase generation
  - Generate different paraphrases in different applications

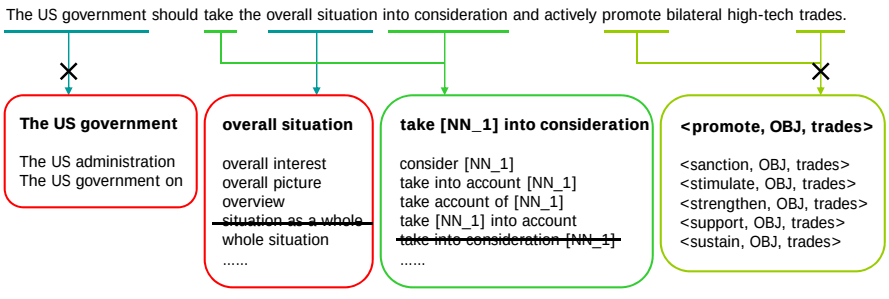


Application-driven Statistical Paraphrase Generation (cont')

- Paraphrase planning
  - When an application *A* is given, only the paraphrase pairs that can achieve *A* are kept

Example:

Paraphrase application: sentence compression



Application-driven Statistical Paraphrase Generation (cont')

- Model:
  - Log-linear model

$$p(\mathbf{t}\mid\mathbf{s}) = \sum_{k=1}^{K}(\lambda_k \sum_{k_i}\log\phi_k(\bar{s}_{k_i},\bar{t}_{k_i})) \longrightarrow \text{Paraphrase model}$$

$$+\lambda_{lm}\sum_{j=1}^{J}\log p(t_j \mid t_{j-2}t_{j-1}) \longrightarrow \text{Language model}$$

$$+\lambda_{um}\sum_{i=1}^{I}\mu(\bar{s}_i,\bar{t}_i) \longrightarrow \text{Usability model (defined for each application)}$$

References

- Lin. 1998. Automatic Retrieval and Clustering of Similar Words.
- Quirk et al. 2004. Monolingual Machine Translation for Paraphrase Generation.
- Finch et al. 2004. Paraphrasing as Machine Translation.
- Zhao et al. 2008. Combining Multiple Resources to Improve SMT-based Paraphrasing Model.
- Zhao et al. 2009. Application-driven Statistical Paraphrase Generation.

Outline

- **Part 2**
  - **Paraphrase Generation**
    - Rule based Method
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    - **Pivot based Method**
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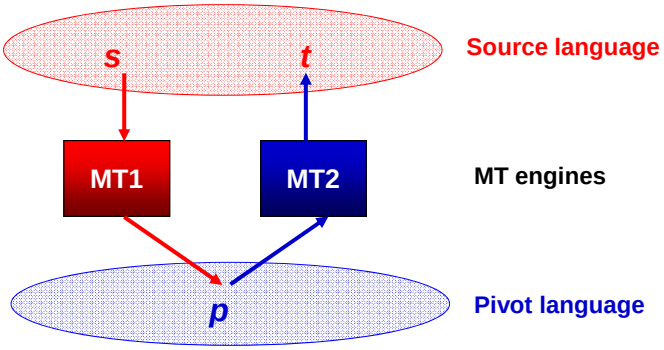
  - Conclusions and Future work

Overview

- Basic idea
  - We can generate a paraphrase ***t*** for a sentence ***s*** by translating ***s*** into a foreign language, and then translating it back into the source language.



Overview (cont')

- Example:

- Single-pivot
  - Using a single pivot language
- Multi-pivot
  - Using multiple pivot languages

Pivot based Methods

- Duboue and Chu-Carroll, 2006
  - Applied in QA systems
    - Paraphrase the input questions so as to improve the coverage in answer extraction
  - Pivot languages
    - 11
  - MT engines
    - 2: Babelfish (**B**) and Google MT (**G**)
    - 4 combinations: B+B, B+G, G+G, G+B

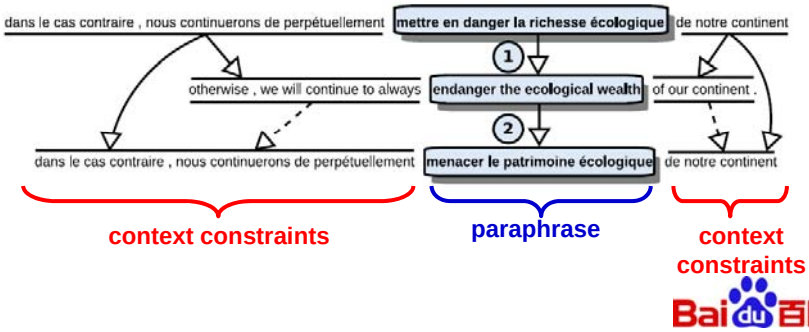
Pivot based Methods (cont')

- Duboue and Chu-Carroll, 2006 (cont')
  - Given a list of automatically generated paraphrases, we need to select a ***best*** one.
    - For QA, we need to select the paraphrase that can find the answer more easily than the original question.

Features for paraphrase selection (in a classification framework)	
SUM IDF	The sum of the IDF scores for all terms in the original question and the paraphrase. (prefer paraphrases with more informative terms)
Lengths	Number of query terms for each of the paraphrase and the original question. (prefer shorter paraphrases)
Cosine Distance	The distance between the vectors of both questions, IDF-weighted. (filter paraphrases that diverge too much from the original)
Answer Types	Whether answer types, as predicted by the question analyzer, are the same or overlap. (the answer type should be the same)

Pivot based Methods (cont')

- Max, 2009
  - Paraphrasing sub-sentential fragments
    - Allows the exploitation of context during both source-pivot translation and pivot-source back-translation

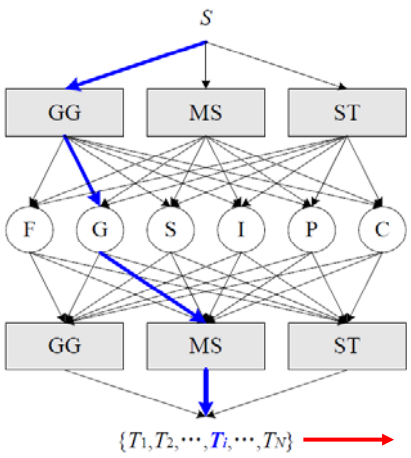


Pivot based Methods (cont')

- Max, 2009 (cont')
  - Application
    - Text revision
  - Pivot language
    - English
      - Paraphrases are acquired for French sub-sentences
  - MT engine
    - Source context aware SMT (Stroppa et al., 2007)

Pivot based Methods (cont')

- Zhao et al., 2010



3 MT engines: (1) Google translator (GG), (2) Microsoft translator (MS), (3) Systran translator (ST)

6 pivot languages: (1) French (F), (2) German (G), (3) Spanish (S), (4) Italian (I), (5) Portuguese (P), (6) Chinese (C)

54 combinations

Pivot based Methods (cont')

- Zhao et al., 2010 (cont')
  - Produce a high-quality paraphrase using the list of candidates

Source	he said there will be major cuts in the salaries of high-level civil servants
(GG, G, MS)	he said there **are significant** cuts in the salaries of high-level **officials**
(GG, F, GG)	he said there will be **significant** cuts in the salaries of **top civil level**
(GG, P, GG)	he said there will be **big** cuts in salaries of **high-level civil**
(MS, C, MS)	he said **that** there will be **a major senior civil service pay cut**
(MS, S, GG)	he said there will be **significant** cuts in the salaries of **senior officials**
(MS, F, ST)	he said there will be **great** cuts in the **wages** of the **high level civils servant**
(ST, G, GG)	he said **that** there **are** major cuts in the salaries of **senior government officials**
……	……

Good paraphrases **Bad paraphrases**

Pivot based Methods (cont')

- Zhao et al., 2010 (cont')
  - Two techniques for producing high-quality paraphrases using the candidates
    - Selection-based technique
      - Select a best paraphrase from the 54 candidates based on Minimum Bayes Risk (MBR)
    - Decoding-based technique
      - Train a MT model using the 54 candidates, and generates a new paraphrase with it

References

- Duboue and Chu-Carroll. 2006. Answering the Question You Wish They Had Asked: The Impact of Paraphrasing for Question Answering.
- Stroppa et al. 2007. Exploiting Source Similarity for SMT using Context-informed Features.
- Max. 2009. Sub-sentential Paraphrasing by Contextual Pivot Translation.
- Zhao et al. 2010. Leveraging Multiple MT Engines for Paraphrase Generation.

Outline

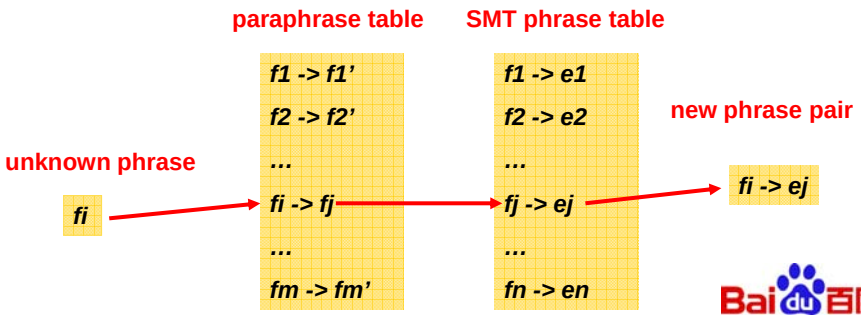
- **Part 2**
  - Paraphrase Generation
  - **Applications of Paraphrases**
    - **Paraphrasing for MT**
    - Other Applications
  - Evaluation of Paraphrases
  - Conclusions and Future work

Paraphrasing for MT

- Applications:
  - Translate unknown terms (phrases)
  - Expand training data
  - Rewrite input sentences
  - Improve automatic evaluation
  - Tune parameters

Translate Unknown Terms (Phrases)

- Basic idea:
  - In SMT, when encountering an unknown source term (phrase), we can substitute a paraphrase for it and then proceed using the translation of that paraphrase



Translate Unknown Terms (Phrases) (cont')

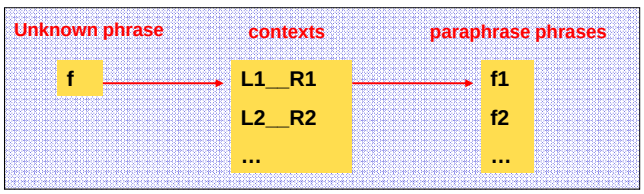
- Callison-Burch et al., 2006
  - Paraphrases are extracted from bilingual parallel corpora using the pivot approach
  - New phrase pairs generated through paraphrasing are incorporated into the phrase table
    - The paraphrase probability is added as a new feature function:

paraphrase probability ← $p(f_2 \mid f_1)$

$$h(e, f_1) = \begin{cases} p(f_2 \mid f_1) & \text{If phrase table entry } (e, f_1) \text{ is generated from } (e, f_2) \\ 1 & \text{Otherwise} \end{cases}$$

Translate Unknown Terms (Phrases) (cont')

- Marton et al., 2009
  - Paraphrases are extracted from monolingual corpora, based on distributional hypothesis



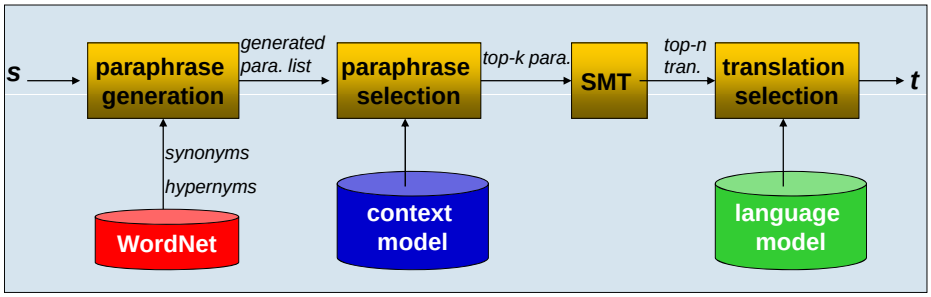
  - Combine the new phrase pairs in the phrase table

Context similarity ← $psim(DP_{f_1}, DP_{f_2})$

$$h(e, f_1) = \begin{cases} psim(DP_{f_1}, DP_{f_2}) & \text{If phrase table entry } (e, f_1) \text{ is generated from } (e, f_2) \\ 1 & \text{Otherwise} \end{cases}$$

Translate Unknown Terms (Phrases) (cont')

- Mirkin et al., 2009
  - Use not only paraphrases but also entailment rules
    - From WordNet
      - Paraphrases: *synonyms* in WordNet
      - Entailment rules: *hypernyms* in WordNet



Translate Unknown Terms (Phrases) (cont')

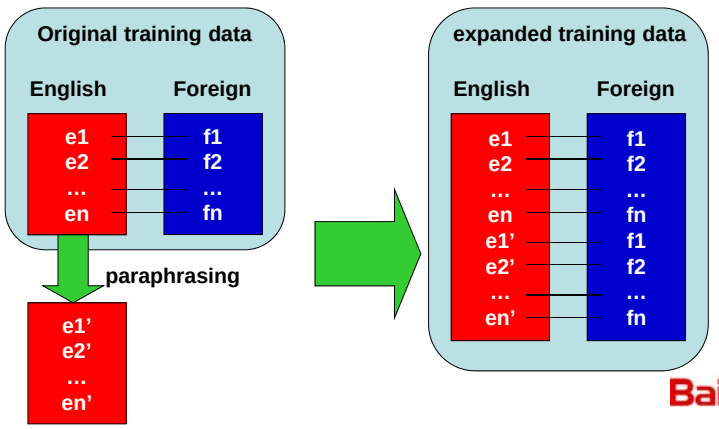
- Onishi et al., 2010
  - Using paraphrase lattices for SMT
    - **Step-1:** Paraphrase the input sentence, and generate a paraphrase lattice
      - Paraphrases are extracted from bilingual parallel corpora based on the pivot approach
    - **Step-2:** Give the paraphrase lattice as the input to the lattice decoder

Translate Unknown Terms (Phrases) (cont')

- Effectiveness
  - When the training data of SMT is small
    - Effective☺
      - Problem of unknown terms is more serious when the training data is small
  - When the training data of SMT is large
    - Ineffective☹
      - Unknown terms can be covered by adding more training data

Expand Training Data

- Enlarge training data via paraphrasing the source-side sentences in the parallel corpus



Rewrite Input Sentences

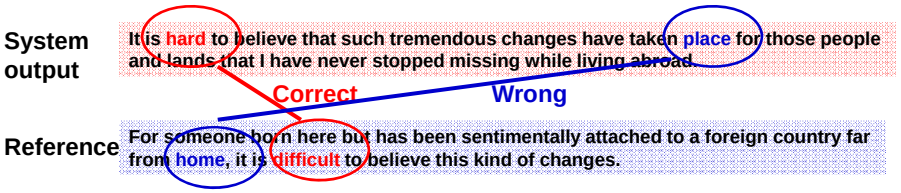
- Paraphrase the sentence to be translated, so as to make it more translatable
  - Yamamoto, 2002; Zhang and Yamamoto, 2002
    - Rule-based Paraphraser for simplifying the source sentences
  - Shimohata et al., 2004
    - Shorten long sentences and sentences with redundant information in a speech translation system

Improve Automatic Evaluation

- Automatic evaluation of MT
  - Based on counting the overlaps between the references and machine outputs
    - E.g., BLEU, NIST…
  - Only computing the surface similarity is limited
    - A meaning may be expressed in a way that is not included in the references
  - Human references are expensive to produce
  - Solution: paraphrase the references so as to include as many correct expressions as possible!

Improve Automatic Evaluation (cont')

- Kauchak and Barzilay, 2006
  - Find a paraphrase of the reference that is closer in wording to the system output
    - Extract candidates from WordNet synonyms



  - Filter the invalid substitution given the context
    - Binary classification
      - Features: context n-grams and local collocations

Improve Automatic Evaluation (cont')

- Zhou et al., 2006
  - ParaEval: Compute the similarity of reference and system output using paraphrases
    - Paraphrases are learned from bilingual parallel corpora with a pivot approach
  - Two-tier matching strategy for SMT evaluation
    - First tier: paraphrase match
    - Second tier: unigram match for words not matched by paraphrases

Tune Parameters

- Madnani et al. 2007
  - Similar to the studies using paraphrases to improve automatic evaluation of MT
  - Parameter tuning in SMT also needs references
    - Parameter estimation of SMT:
      - optimize BLEU on a development set
  - Expand the references automatically via paraphrasing
    - Paraphrase generation
      - Paraphrase resources are acquired based on a pivot approach
      - Recast paraphrase generation as a monolingual MT problem and decode with a typical SMT decoder

References

- Translate unknown terms (phrases)
  - Callison-Burch et al. 2006. Improved Statistical Machine Translation Using Paraphrases.
  - Marton et al. 2009. Improved Statistical Machine Translation Using Monolingually-Derived Paraphrases.
  - Mirkin et al. 2009. Source-Language Entailment Modeling for Translating Unknown Terms.
  - Onishi et al. 2010. Paraphrase Lattice for Statistical Machine Translation.
- Expand training data
  - Nakov. 2008. Improved Statistical Machine Translation Using Monolingual Paraphrases.
  - Bond et al. 2008. Improving Statistical Machine Translation by Paraphrasing the Training Data.

References (cont')

- Rewrite input sentences
  - Yamamoto. 2002. Machine Translation by Interaction between Paraphraser and Transfer.
  - Zhang and Yamamoto. 2002. Paraphrasing of Chinese Utterances.
  - Shimohata et al. 2004. Building a Paraphrase Corpus for Speech Translation.
- Improve automatic evaluation
  - Kauchak and Barzilay. 2006. Paraphrasing for Automatic Evaluation.
  - Zhou et al. 2006. Re-evaluating Machine Translation Results with Paraphrase Support.
- Tune parameters
  - Madnani et al. 2007. Using Paraphrases for Parameter Tuning in Statistical Machine Translation.

Outline

- **Part 2**
  - Paraphrase Generation
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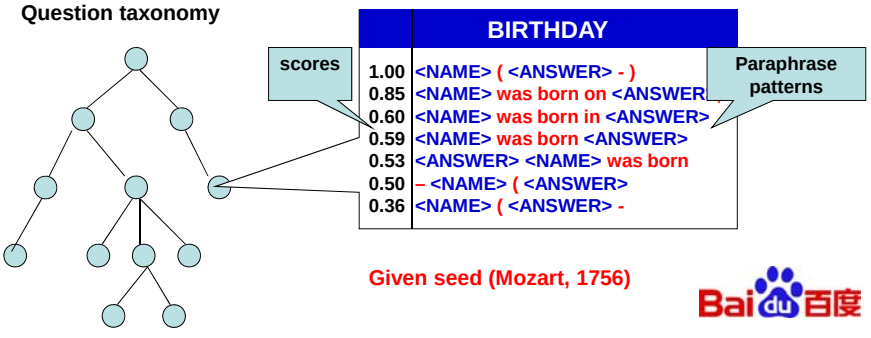
    - Paraphrasing for MT
    - **Other Applications**
  - Evaluation of Paraphrases
  - Conclusions and Future work

Paraphrasing for QA

- Goal:
  - Alleviate the problem of *word mismatch* between questions and answers
- Two directions:
  - Paraphrase questions
    - Rewrite a question into a group of paraphrases, so as to improve the coverage in answer extraction
  - Paraphrase answer extraction patterns
    - Generate answer extraction patterns as many as possible

Paraphrasing for QA

- Ravichandran and Hovy, 2002.
  - Mining paraphrase patterns from the web
    - Using hand-crafted seeds (e.g., (*Mozart, 1756*) for BIRTHDAY)
    - Mining patterns containing the seeds



Paraphrasing for Summarization

- Improve automatic evaluation of summaries
  - Zhou et al., 2006
  - Similar to the automatic evaluation of MT
    - Measure the similarity between references and system outputs using paraphrase match as well as exact match
- Improve sentence clustering
  - Barzilay et al., 1999
  - Considering paraphrase match when Computing sentence similarity

Other Applications

- Paraphrasing for NLG
  - Text revision and transformation
    - Dras, 1997
      - Text transformation in order to meet external constraints, such as length and readability
- Paraphrasing for IR
  - Query rewriting
    - Zukerman and Raskutti. 2002.
      - Paraphrase user queries with WordNet synonyms

Other Applications (cont')

- Writing style transformation
  - Kaji et al., 2004
    - Paraphrasing predicates from written language to spoken language
- Text simplification
  - Carroll et al. 1999
    - Simplifying texts for language-impaired readers or non-native speakers
- Identify plagiarism
  - Uzuner et al. 2005
    - Using paraphrases to better identify plagiarism

References

- Paraphrasing for QA
  - Ravichandran and Hovy. 2002. Learning Surface Text Patterns for a Question Answering System.
  - Duboue and Chu-Carroll. 2006. Answering the Question You Wish They Had Asked: The Impact of Paraphrasing for Question Answering.
- Paraphrasing for summarization
  - Barzilay et al. 1999. Information Fusion in the Context of Multi-Document Summarization.
  - Zhou et al. 2006. ParaEval: Using Paraphrases to Evaluate Summaries Automatically.
- Paraphrasing for NLG
  - Dras. 1997. Reluctant Paraphrase: Textual Restructuring under an Optimisation Model.

References (cont')

- Paraphrasing for IR
  - Zukerman and Raskutti. 2002. Lexical Query Paraphrasing for Document Retrieval.
- Writing style transformation
  - Kaji et al. 2004. Paraphrasing Predicates from Written Language to Spoken Language Using the Web.
- Text simplification
  - Carroll et al. 1999. Simplifying Text for Language-Impaired Readers.
- Identify plagiarism
  - Uzuner et al. 2005. Using Syntactic Information to Identify Plagiarism.

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Evaluation of Paraphrases

- No widely accepted evaluation criteria☹
  - **Problem-1:** Researchers define various evaluation methods in their studies
    - Difficult to make a direct comparison among different works
  - **Problem-2:** Human evaluation is commonly used
    - Human evaluation is rather subjective
    - Difficult to replicate

Evaluation of Paraphrase Identification

- Human evaluation
- Automatic evaluation
  - Brockett and Dolan, 2005
  - **A**lignment **E**rror **R**ate (AER)
    - AER is indicative of how far the corpus is from providing a solution under a standard SMT tool

$$AER = \frac{|A \cap P| + |A \cap S|}{|A + S|}$$

Automatic alignment

POSSIBLE + SURE alignment in the gold standard

SURE alignment in the gold standard

Evaluation of Lexical Substitution

- Automatic evaluation
  - McCarthy and Navigli, 2007
  - Construction of gold standard data
    - Five annotators, who are native speakers
    - For each test word, each annotator provides up to three substitutes
  - Evaluation:
    - Precision and Recall

Evaluation of Paraphrase Phrases

- Human evaluation
  - Ask judges:
    - Whether paraphrases were approximately conceptual equivalent
    - Whether the paraphrases were roughly interchangeable given the genre
    - Whether the substitutions preserved the meaning and remained grammatical
    - ……
  - The criteria above are vaguely defined and not easy to reproduce

Evaluation of Paraphrase Phrases (cont')

- Automatic evaluation
  - Callison-Burch et al., 2008
  - Data:
    - Parallel sentences, in which paraphrases are annotated through manual alignment (gold standard)
  - Two fashions of evaluation
    - Calculate how well an automatic paraphrasing technique can ***align*** the paraphrases in a sentence pair
    - Calculate the ***lower-bound precision*** and ***relative recall*** of a paraphrasing technique (which extracts paraphrases from other resources)

Evaluation of Paraphrase Phrases (cont')

- Alignment precision and recall
- Lower-bound precision and relative recall

Manual alignment

System alignment

Paraphrase acquired with a method *MET*

Paraphrase in the gold standard set

$$Align_{Precision} = \frac{\sum_{<e_1,e_2>\in C} |PP(e_1,e_2,S) \cap PP(e_1,e_2,M)|}{\sum_{<e_1,e_2>\in C} |PP(e_1,e_2,S)|}$$

$$LB-Precision = \sum_{<s,G>\in C} \sum_{p\in s} \frac{|para_{MET}(p,s) \cap para_{REF}(p_1,s,G)|}{|para_{MET}(p,s)|}$$

$$Align_{Recall} = \frac{\sum_{<e_1,e_2>\in C} |PP(e_1,e_2,S) \cap PP(e_1,e_2,M)|}{\sum_{<e_1,e_2>\in C} |PP(e_1,e_2,M)|}$$

$$Rel-Recall = \sum_{<s,G>\in C} \sum_{p\in s} \frac{|para_{MET}(p,s) \cap para_{REF}(p_1,s,G)|}{|para_{REF}(p_1,s,G)|}$$

Evaluation of Paraphrase Patterns

- Human evaluation
  - Paraphrase patterns cannot be evaluated without context information
    - E.g., *X acquire Y, X buy Y*
      - Correct or not? It depends on what fill in slots *X* and *Y*
    - Common view:
      - A pair of paraphrase patterns is considered correct if the judge could think of contexts under which it holds
    - Problem:
      - Different judges may think of totally distinct contexts, thus the agreement among the judges could be low

Evaluation of Paraphrase Patterns (cont')

- Szpektor et al., 2007
  - Evaluate paraphrase patterns (and entailment rules) with instances rather than directly evaluate patterns
    - Judges are presented not only with a pair of patterns, but also a sample of sentences that match its left-hand side
    - Judges assess whether two patterns are paraphrases under each specific example
    - A pair of paraphrase patterns is considered as correct only when the percentage of correct examples is high enough

Evaluation of Paraphrase Generation

- Human evaluation
  - —Similar to human evaluation of SMT
  - —Criteria (Zhao et al., 2009, 2010)
    - **Adequacy**: If the meaning of the source sentence is preserved in the paraphrase?
    - **Fluency**: if the generated paraphrase is well-formed?
    - **Usability** (Zhao et al., 2009): If the paraphrase meets the requirement of the given application?
    - **Paraphrase rate** (Zhao et al., 2009): How different the paraphrase is from the source sentence?

Evaluation of Paraphrase Generation (cont')

- Three scales for adequacy, fluency, and usability (Zhao et al., 2009)

Adequacy	**1**	The meaning is evidently changed.
	2	The meaning is generally preserved.
	3	The meaning is completely preserved.
Fluency	**1**	The paraphrase t is incomprehensible.
	2	t is comprehensible.
	3	t is a flawless sentence.
Usability	**1**	t is opposite to the application purpose.
	2	t does not achieve the application.
	3	t achieves the application.

- Five scales for adequacy and fluency (Zhao et al., 2010)

Evaluation of Paraphrase Generation (cont')

- Paraphrase rate (Zhao et al., 2010):
  - PR-1: based on word overlap rate

$$PR1(T) = 1 - \frac{OL(S,T)}{L(S)}$$

Word overlap rate

Number of words in the source sen.

  - PR-2: based on edit distance

$$PR2(T) = \frac{ED(S,T)}{L(S)}$$

Edit distance

Evaluation of Paraphrase Generation (cont')

- Two questions:
  - **Q1:** Why not adopt automatic MT methods here, e.g., BLEU, NIST, TER…?
    - **Reason-1:** It is much more difficult to construct human references in paraphrase generation than MT
    - **Reason-2:** Paraphrases that change less will get larger scores in criteria like BLEU
  - **Q2:** How to combine the evaluation of *paraphrase quality* and *paraphrase rate*?
    - They seem to be incompatible

Evaluation within Applications

- Evaluate the role of a paraphrasing module within a certain application system
  - E.g., in MT, examine whether a paraphrasing module helps to alleviate the unknown term problem
  - E.g., in QA, whether paraphrasing the answer patterns can improve the coverage of answer extraction
- Problems:
  - Whether the result can hold for a different application?
  - How to evaluate the role of the paraphrase module independently (not influenced by other modules)?

References

- Brockett and Dolan. 2005. Support Vector Machines for Paraphrase Identification.
- Szpektor et al. 2007. Instance-based Evaluation of Entailment Rule Acquisition.
- McCarthy and Navigli. 2007. SemEval-2007 Task 10: English Lexical Substitution Task.
- Callison-Burch et al. 2008. ParaMetric: An Automatic Evaluation Metric for Paraphrasing.
- Zhao et al. 2009. Application-driven Statistical Paraphrase Generation.
- Zhao et al. 2010. Leveraging Multiple MT Engines for Paraphrase Generation.

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Conclusions and Future Work

- Conclusions
  - Paraphrasing is important in various research areas
  - Many different kinds of corpora and data resources have been investigated for paraphrase extraction
  - Paraphrase generation is a task similar to MT, but not the same
  - Paraphrase evaluation is problematic. Automatic evaluation methods are in need

Conclusions and Future Work (cont')

- Future work
  - Paraphrase extraction
    - Improve the quality of the extracted paraphrases
  - Paraphrase generation
    - Application-driven paraphrase generation
  - Paraphrase application
    - Apply paraphrasing techniques in commercial NLP systems, rather than merely in labs
  - Paraphrase evaluation
    - Come up with evaluation methods that can be widely accepted

Thanks!

QA