Chinese Syntactic Reordering through Contrastive Analysis of Predicate-predicate Patterns in Chinese-to-Korean SMT

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Abstract

We propose a Chinese dependency tree reordering method for Chinese-to-Korean SMT systems through analyzing systematic differences between the Chinese and Korean languages. Translating predicate-predicate patterns in Chinese into Korean raises various issues such as long-distance reordering. This paper concentrates on syntactic reordering of predicate-predicate patterns in Chinese dependency trees through contrastively analyzing construction types in Chinese and their corresponding translations in Korean. We explore useful linguistic knowledge that assists effective syntactic reordering of Chinese dependency trees; we design two experiments with different kinds of linguistic knowledge combined with the phrase- and hierarchical phrase-based SMT systems, and assess the effectiveness of our proposed methods. The experiments achieved significant improvements by resolving the long-distance reordering problem.

1 Introduction

In the SMT community, word reordering has been treated as one of the most important tasks for resolving word-order differences when translating from a source language into a target one. Although many effective reordering methods have been proposed, long-distance reordering is still considered difficult. State-of-the-art SMT systems such as the phrase- and the hierarchical phrase-based SMTs, also are not free from this problem.

In this paper, we consider a specific structure, namely a predicate-predicate pattern which leads to a long-distance reordering problem when translating from Chinese into Korean. We define a predicate-predicate pattern as a pattern that consists of a pair of predicates in a dependency parse tree (D-tree) where a head predicate has another predicate as an immediate child. In Chinese, these patterns assume several different structures with little or no morphological differences, since Chinese is a morphologically poor language. We define long-distance reordering as the relocation of one predicate across another in predicate-predicate patterns in the D-tree. Without any linguistic clues from the surface forms, it is difficult to compile reordering rules for the predicate-predicate patterns. In this paper, we explore various linguistic knowledge for the purpose of effective long-distance reordering of Chinese D-trees.

As a preprocessing to a phrase-based SMT, a number of researchers have proposed syntactic reordering approaches to phrase structure parse trees (PS-trees) (Xia and McCord, 2004; Collins et al., 2005; Wang et al., 2007; Li et al., 2009) and D-trees (Chang et al., 2009; Xu et al., 2009; Hong et al., 2009). Previous work on deterministic syntactic reordering in a phrase-based SMT has been effective for language pairs that belong to different word-order typologies such as Chinese and Korean. This kind of reordering approach is very flexible to combine with various decoding models without adding computational complexity to the decoding phase.

Syntactic reordering methods for PS-trees and D-trees have their advantages and disadvantages due to the differences in their constituent and dependency structures. PS-trees contain hierarchy and precedence information of syntactic units (words or

Ch1.	张三(ZhangSan)/ 相信**(believe)**/ 李四(LiSi)/ 有**(have)**/ 才能(talent)/ 。	
En1.	ZhangSan **believes** *that(complementizer)* LiSi **has** the talent .	
Kr1.	ZhangSan은 LiSi가 재능(talent)이 있**(have)**다고*(conjunctive verb ending)* 믿**(believe)** 는다.	
Ch2.	张三(ZhangSan)/ 买**(buy)**/ 菜(vegetable)/ 做**(cook)**/ 饭(meal)/ 。	
En2.	ZhangSan **bought** vegetables *and(conjunction)* **cooked** a meal .	
Kr2.	ZhangSan은 채소(vegetable)를 사**(buy)**서*(conjunctive verb ending)* 밥(meal)을 지**(cook)**었다.	

Figure 1: Examples of predicate-predicate patterns extracted from the Penn Chinese Treebank 4.0.

phrases), and D-trees directly encode syntactic or semantic relations between words. Recent studies have shown that more flexible and high coverage reordering can be achieved with D-trees (Xu et al., 2009). Xu et al. (2009) described a set of manually constructed precedence rules using the dependency relations and showed great efficiencies in SMT systems targeting 5 subject-object-verb (SOV) languages including the Korean language.
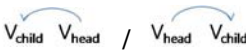
In our Chinese-to-Korean SMT, we adopt the principles of compiling reordering rules in a D-tree as Xu et al. (2009) proposed. Since Chinese is a morphologically poor language with insufficient linguistic clues, more careful concern is required when compiling syntactic reordering rules, especially for predicate-predicate patterns.

In Section 2, we describe why it is difficult to reorder predicate-predicate patterns with comparison to other languages such as English and Korean. Section 3 analyzes the various structures of predicate-predicate patterns and deduces the structures that need reordering when translating. General reordering rules and specific reordering rules on predicate-predicate patterns will be given in Section 4. Finally, Section 5 shows the experimental results and discussion.

2 Reordering predicate-predicate patterns is difficult.

Translating predicate-predicate patterns from one language to another is problematic, especially from a morphologically poor language to a rich one. Chinese is a typical isolating language, and predicate-predicate patterns in Chinese may represent several structures (Table 1) with less (almost no) morphological differences than other languages such

Table 1: Types and structures of predicate-predicate patterns.

Type	Structure
Clausal subject construction	V_{child} V_{head}
Complex/Compound construction	V_{child} V_{head} / V_{head} V_{child}
Serial verb construction (SVC)	V_{head} V_{child}
Pivot construction	V_{head} N V_{child}
Clausal complement construction	V_{head} (N) V_{child}
Existential construction	VE_{head} V_{child}
Emphasis construction	VC_{head} V_{child}

as English and Korean.[1] Therefore, identifying the correct structure of a predicate-predicate pattern is a challenging task for Chinese dependency parsing. The patterns also frequently appear in Chinese sentences; on average, there are 1.78 predicate-predicate patterns per sentence in our training corpus.

In Figure 1, '相信(believe)' is a head predicate that dominates predicate '有(have)' in Ch1. and '买(buy)' dominates '做(cook)' in Ch2, but there is no contextual evidence to suggest these relations. In English, the complementizer 'that' and the conjunction 'and' signals clausal complement and coordinate constructions. In Korean, such structures are indicated by conjunctive verb-endings '고(ko)' and

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[1]For convenience and consistency, we describe the POS of predicate in the Penn Chinese Treebank style (Xue et al., 2000). V_{head} is either VV or VA. VV: common verb; VA: predicative adjective; VE: existential verb; VC: copula verb.
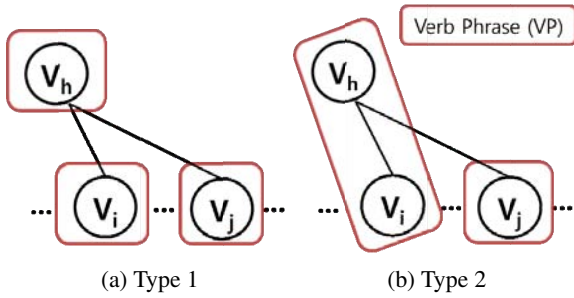
Figure 2: Two types of a head predicate according to the predicate's VP formation with the first predicate from its immediate right children.

'서(seo)'. In English and Korean, identifying particular structures of predicate-predicate patterns is relatively easy.

The predicate-predicate pattern in Ch1 needs reordering while the pattern in Ch2 does not, considering the order of predicates in the corresponding Korean sentences. In addition to identifying the structures of predicate-predicate patterns, further analysis on the characteristics of translation from the constructions will help us infer more effective syntactic reordering rules.

3 Predicate-predicate patterns of Chinese

In this section, we analyze the types of predicate-predicate patterns to deduce the structures that need to be reordered when translating.

A predicate-predicate pattern where the immediate child is located to the left of the head predicate forms either a clausal subject construction or a complex construction. These constructions seldom require long distance reordering in Chinese-to-Korean MT, so we do not treat the issue in this paper.

A head predicate V_h may have several predicates as immediate right children such as V_i and V_j (Figure 2). A head predicate is categorized into two types; if the predicate forms a base verb phrase (VP) without its child predicates, the predicate falls into Type 1, and if the predicate constructs a base VP with the first predicate from its right children, the predicate is categorized as Type 2.

Construction types listed in Table 1 fall into one of the following types; a compound construction and SVC correspond to Type 1, and pivot,

clausal complement, existential, and emphasis constructions correspond to Type 2. The constructions which correspond to Type 2 are strong candidates for reordering. If reordered, we relocate the head predicate V_h right after the first right-child predicate V_i, since the head predicate only dominates the first right-child predicate. '相信(believe)' in Figure 1 belongs to Type 2, and '买(buy)' Type 1.

The Type 1 constructions do not require reordering of its predicates. SVC in Chinese is where two or more predicates are juxtaposed sharing a subject. Dominantly, the predicates in the SVC and compound construction are translated into Korean in sequential order.

For the four constructions of Type 2, the head predicate V_h takes the child predicate V_i as its sentential argument. However, in some cases V_i remains in its original position when translating.

In the pivot construction (V_{head} + N + V_{child}), N functions as the object of V_{head} as well as the subject of V_{child}. This kind of head verbs is described as the object control verb in the Penn Chinese Treebank. We do not reorder pivot constructions when the lexical meaning of the head verb is command; this construction is usually translated non-literarily and improving translation results of such constructions requires more than syntactic reordering. Only object control verbs with other lexical meanings are reordered.

The head predicate in the clausal complement construction (V_{head} + N + V_{child}) takes up to two objects. If N exists, it functions as a direct object. V_{child} functions as a sentential object. The objects have a strong tendency to be translated at the pre-verbal position in Korean sentences. The Penn Chinese Treebank describes verbs belonging to this construction as psychological verbs, subject control verbs, and other verbs such as '告诉(tell) and 通知(announce)'.

In existential and emphasis constructions, VE and VC have functional roles as well as lexical meanings. To translate these structures adequately, a linguistic process more complex than syntactic reordering is necessary.

In conclusion, predicate-predicate patterns form clausal complement constructions and some of the pivot constructions require a long-distance reordering of verbs when translated into Korean.

Ch3. Syn.	他(he)	不能(cannot)	去(go)	北京(Beijing)	了(Aspect particle)
	subj	mmod	Root	dobj	asp
	L_Children		Predicate	*R_Children*	

Re.	他(he)	北京(Beijing)	不能(cannot)	去(go)	了(Aspect particle)
	L_Other	*L_FromRight*	*L_Modal*	Predicate	*R_Modal*

Figure 3: An example of reordered Chinese sentence after applying the general reordering method. Ch3.: a Chinese sentence; Syn.: dependency structure; Re.: reordered Chinese sentence;

4 Chinese syntactic reordering on predicate-predicate patterns

4.1 General syntactic reordering

We compile a set of general Chinese syntactic reordering rules under the same principles proposed by Li et al. (2009) and Xu et al. (2009). The two work describe syntactic reordering of PS-trees and D-trees respectively, and translation directions are both from SVO to SOV languages. Despite the differences in parse structures, their main principles of syntactic reordering are similar.

Li et al. (2009) move modality-bearing words near their verbal heads. They argue that Chinese expresses the modality information using discontinuous morphemes scattered throughout a sentence; while the modality of Korean is expressed intensively by verb endings. Since Korean is a verb-final language, all the other elements should take the pre-verbal positions in Korean sentences. Xu et al. (2009) use verb precedence rules to organize a verb group and move it to the end of the sentence. Although they did not use the term 'modality-bearing word', the elements which they grouped are closely related to 'modality-bearing words' such as phrasal verb particle, auxiliary verb, passive auxiliary verb, and negation.

We also apply reordering rules to prepositions in Chinese, which originate from verbs and preserve the characteristics of verbs. Objects of the prepositions are positioned as a right child, and it will move to the left side for reordering.

We will describe the principle of the general syntactic reordering rules as follows in which the head word is a predicate. Here is an example shown in Figure 3. Every predicate in a Chinese D-tree consists of left children (*L_Children*) and right children (*R_Children*). From the left children, the modality-bearing words (*L_Modal*) are relocated near the predicate, and the other elements (*L_Other*) remain on the left side of the predicate.

For the right children, the process is slightly different. Modality-bearing words (*R_Modal*) are relocated near the predicate, as *L_Modal*. However, as Korean is a verb-final language, most right children will be moved to the left side of the predicate (*L_FromRight*). A right child belonging to *R_Remnant* always forms predicate-predicate patterns with the head predicate if the right child is a predicate. The movement of child nodes in this case will be carefully controlled using the reordering rules of predicate-predicate patterns which we proposed in Section 4.2. In other words, in general reordering rules, all of the child nodes of predicate-predicate patterns remain in *R_Remnant* due to the lack of linguistic knowledge.

After applying the reordering rules, such as in Algorithm 1, each predicate will have newly constructed children such as, *L_Other*, *L_FromRight*, *L_Modal*, *R_Modal*, and *R_Remnant*, in which the children reserve the relative orders of the original sentence.[2]

4.2 Syntactic reordering of predicate-predicate patterns

In this section, we present the syntactic reordering methods for predicate-predicate patterns. As pointed out in Section 3, a very specific type of predicate-predicate pattern needs our attention for long-distance reordering: a head predicate of Type

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[2]Following are a set of dependency relations defined in Stanford Chinese typed dependency parser. mmod: modal verb modifier; neg: negative modifier; pass: passive marker; asp: aspect marker; rcomp: resultative complement; comod: coordinated verb compound modifier; ccomp: clausal complement; punct: punctuation.

Algorithm 1 General syntactic reordering rules

Input: *L_Children*, *R_Children* of a Predicate P
Output: *L_Other*, *L_FromRight*, *L_Modal*, *R_Modal*, *R_Remnant*

    for node N in *L_Children* **do**
      if dep. relation of N $\in$ {mmod, neg, pass} **then**
        L_Modal $\Leftarrow$ *L_Modal* + {N}
      else
        L_Other $\Leftarrow$ *L_Other* + {N}
      end if
    end for
    for node N in *R_Children* **do**
      if dep. relation of N $\in$ {comod, asp, neg, rcomp} **then**
        R_Modal $\Leftarrow$ *R_Modal* + {N}
      else if dep. relation of N $\in$ {ccomp, punct} **then**
        R_Remnant $\Leftarrow$ *R_Remnant* + {N}
      else
        L_FromRight $\Leftarrow$ *L_FromRight* + {N}
      end if
    end for

Table 2: Features for the SVM binary classifier.

Feature	Description
	Surface form of V_h
Lexical	V_h is a pivot construction verb with the lexical meaning of command
	V_h is a verb that can take a clausal complement
	V_h has a direct object
Syntactic	V_i has a "," or ":" punctuation as left sibling
	V_i has a nominal subject

Table 3: Accuracy of the SVM classifiers for predicate-predicate pattern reordering.

Feature	Accuracy (%)
All features	93.3
w/o lexical feature	77.1
w/o syntactic features	90.7

2 corresponding to a clausal complement and some pivot constructions. These patterns need be discovered.

We adopt a binary classifier using SVMlight[3] for robust classification. The task is simplified as determining whether a reordering is necessary or not, given a head predicate (V_h) of VV or VA and its first right-child predicate (V_i) in *R_Remnant*.

The features used by the classifier are described in Table 2. Two kinds of features are used: lexical and syntactic information from D-trees.

We collect positive instances from the Penn Chinese Treebank 4.0. Positive instances are either 1) a head predicate V_h (VV or VA) with its sentential argument V_i corresponding to IP-OBJ[4], or 2) a head predicate V_h (VV or VA) without a lexical meaning of command, and has a sentential argument V_i corresponding to IP.

PKU dictionary is a dictionary of "the Grammatical Knowledge-base of Contemporary Chinese" from Peking University which contains about 80,000 entries. It was developed for the purpose of Chinese language processing with various information including morphology, syntax and semantics. We refer to the PKU dictionary to collect the pivot construction verbs with the lexical meaning of command. It also provides a list of verbs that can take a clausal complement.

From 18,487 valid instances extracted from the Penn Chinese Treebank, the number of positive instances is 5,544. The accuracy of the SVM classifier is measured using 10-fold cross validation (Table 3). It reveals that the lexical information of head predicate is the most important feature.

For comparison purposes, we estimate the classification accuracy of heuristic rules which only uses the PKU dictionary information. If V_h has the property of taking a clausal complement, reordering is performed. Its performance is 87.2%, 6.1% lower than the SVM classifier.

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[3]http://svmlight.joachims.org, version 6.02.
[4]The Penn Chinese Treebank is annotated with the functional tags of phrase such as IP-OBJ. IP-OBJ is an IP (simple clause headed by INFL.) that acts as a sentential object in the sentences.

5 Experiment

5.1 Experimental setting

Our baseline system is the state-of-the-art phrase- and hierarchical phrase-based SMT system built in Moses (Chiang, 2005; Koehn et al., 2007) with 5-gram SRI language modeling (Stolcke, 2002) tuned with Minimum Error Rate Training (MERT) (Och, 2003). We adopt NIST (Doddington, 2002) and BLEU (Papineni et al., 2001) as our evaluation metrics. A significance test is also conducted using a paired bootstrap resampling method[5] (Koehn, 2004).

We use the Stanford Chinese typed dependency parser (Levy and Manning, 2003; Chang et al., 2009) to parse Chinese sentences. Chinese sentences in training and test corpora are first parsed into dependency trees and are applied to a series of syntactic reordering rules recursively from the root to the bottom. Korean sentences are segmented into morphemes using an in-house morphological analyzer[6].

We designed two experiments with different types of knowledge: the first is to assess the effectiveness of the heuristic classifier with verb lists from the PKU dictionary, and the second with the SVM classifier that shows the highest performances in the classification.

5.2 Corpus profile

We used the same corpus introduced in (Li et al., 2009), namely Dong-A newspaper corpus. It is a non-literally translated Korean-to-Chinese corpus. The training corpus has 98,671 sentence pairs, and the development and test corpora each have 500 sentence pairs. The original training corpus size is 99,226 sentence pairs. However, we only use 98,671 pairs because of the parsing errors of Stanford Chinese typed dependency parser. The corpus profile is displayed in Table 5.

5.3 Result and discussion

The experimental results show that the proposed methods improve the baseline of phrase- and hierarchical phrase-based Chinese-to-Korean SMT effectively (Table 4). All the performances using the hi-

Table 5: Corpus profile of Dong-A newspaper.

		Chinese	Korean
Training	# words	2,673,422	3,120,466
	Sen. length	27.09	31.62
Development	# words	14,452	16,738
	Sen. length	28.90	33.48
Test	# words	14,619	16,925
	Sen. length	29.24	33.85

erarchical phrase-based SMT (Hiero) is much better than the phrase-based SMT with lexicalized reordering. Our proposed method using the SVM classifier indicates significant improvements, and the gain is smaller in the Hiero than in the phrase-based SMT. Since the domains of the training corpora for the SVM classifier and the SMT system are vastly different, we consider that the SVM classifier is very robust even in an out-of-domain text.

Hiero has stronger reordering power than the phrase-based SMT with lexicalized reordering, it still cannot overcome the long-distance reordering problem. The translated results (Figure 4) show the effectiveness of our proposed method for resolving the long-distance reordering problem. In the given Chinese sentence, '表示(announce)' and '提供(supply)' consist a predicate-predicate pattern where '表示(announce)' dominates '提供(supply)'. In other words, '表示(announce)' belongs to Type 2 described in Section 3. The baseline of phrase-based system even cannot translate both of the predicates into Korean. The baseline of hierarchical phrase-based system only translated '提供(supply)'. Both of the general reordering methods translated the predicate '提供(supply)' however not the main predicate. Our proposed method translated both predicate correctly. Though '提供(supply)' is translated as '공급(supply)' in the reference sentence, in Korean '제공(supply)' and '공급(supply)' are synonyms and they mean the same thing.

6 Conclusion

We have presented an effective Chinese syntactic reordering method for the phrase- and hierarchical phrase-based Chinese-to-Korean SMT with an emphasis on predicate-predicate patterns through contrastive analysis of the source and the target languages. We examined the predicate-predicate pat-

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[5]http://www.nlp.mibel.cs.tsukuba.ac.jp/bleu_kit/

[6]http://kle.postech.ac.kr:8000/demos/KOMA_KTAG/koma_and_tagger.html

Table 4: BLEU scores under different experimental settings. † mark shows significant improvement over the general syntactic reordering method with the confidence level over 95%, and †† with the confidence level over 99%.

Method	Lexicalized reordering		Hiero	
	NIST	BLEU (gain)	NIST	BLEU (gain)
Baseline	5.8428	22.19	6.1020	23.77
General syntactic reordering	6.0288	23.84	6.1207	24.59
Method 1: PKU dictionary	6.1348	24.26 (+0.42)†	6.1622	25.05 (+0.46)
Method 2: SVM Classifier	6.1242	24.73 (+0.89)††	6.2258	25.28 (+0.69)†

Ch4:	三星/ 电子 (Samsung Electronics)/ 11/ 日/ 表示 **(announce)**/ , 对/ " 诺贝尔 博物馆(Nobel Museum) "/ 提供(supply)/ 薄膜/ 晶体/ 液晶/ 显示器/ (TFT-LCD)/ 之后/ , 将/ 对/ 4 月(April)/ 完工(complete)/ 的/ 该(this)/ 馆(museum)/ 继续(continuously)/ **提供(supply)**/ DVDP/ 设备(equipment)/ 。/

	phrase-based SMT with lexicalized reordering
B:	삼성전자 는 11 일 노벨상 박물관 를 제공 하 는 필름 晶体 액정표시장치 (TFT - LCD) 에 잇 어 4 월 완공 되 ㄴ 이 과 DVDP 계속 하 였 다 .
G:	삼성전자 는 11 일 노벨 박물관 초 박막 트랜지스터 액정표시장치 (TFT - LCD) 晶体 을 제공 하 ㄴ 뒤 4 월 에 완공 되 ㄴ 이 과 DVDP 장비 를 **제공(supply)** 하 고 있 다 .
P:	삼성전자 는 11 일 노벨 박물관 晶体 초 박막 트랜지스터 액정표시장치 (TFT - LCD) 이 제공 하 ㄴ 뒤 4 월 에 완공 되 ㄴ 이 성균관 DVDP 장비 를 **제공(supply)** 하 였 다 고 **밝히(announce)** 었 다 .

	hierarchical phrase-based SMT
B:	삼성전자 는 11 일 노벨 박물관 에 대하 ㄴ 필름 晶体 액정표시장치 (TFT - LCD) 에 잇 어 4 월 완공 되 ㄴ 이 제공 과 계속 DVDP 장비 를 **제공(supply)** 하 고 있 다 .
G:	삼성전자 는 11 일 노벨 박물관 을 필름 晶体 액정표시장치 (TFT - LCD) 을 제공 하 ㄴ 뒤 4 월 에 완공 되 ㄴ 이 과 DVDP 장비 를 **제공(supply)** 하 기 로 하 였 다 .
P:	삼성전자 는 11 일 노벨 박물관 을 필름 晶体 액정표시장치 (TFT - LCD) 을 제공 하 ㄴ 뒤 4 월 에 완공 되 ㄴ 이 성균관 DVDP 장비 를 **제공(supply)** 하 였 다 고 **밝히(announce)** 었 다 .
Ref:	삼성전자 (Samsung Electronics) 는 스웨덴(Sweden) 노벨상(Nobel Prize) 재단(Foundation) 이 올해(this year) 4 월(April) 완공(complete) 을 목표(purpose) 로 짓(build) 고 있 는 노벨 박물관 (Nobel Museum) 에 초 박막 트랜지스터 액정표시장치 (TFTLCD) 모니터(Monitor) 에 잇 어 DVDP 도 **공급(supply)** 하 게 되 었 다 고 11 일 **밝히(announce)** 었 다 .

Figure 4: Translated results of Baseline (B), General reordering method(G), and Proposed method (P) with phrase- and hierarchical phrase-based SMT systems.

terns relating to long-distance reordering, and inspected which specific constructions contribute to better translation through syntactic reordering. Useful linguistic knowledge is explored to detect the constructions which need to be reordered. Different experimental settings with different kinds of knowledge were proposed and tested for effectiveness.

Acknowledgments

References

Pi-Chuan Chang, Huihsin Tseng, Dan Jurafsky, and Christopher D. Manning. 2009. Discriminative reordering with Chinese grammatical relations features. In *Proceedings of the Third Workshop on Syntax and Structure in Statistical Translation (SSST-3) at NAACL HLT 2009*, pages 51–59, Boulder, Colorado, June. Association for Computational Linguistics.

David Chiang. 2005. A hierarchical phrase-based model for statistical machine translation. In *Proceedings of the 43rd Annual Meeting of the Association for Computational Linguistics (ACL'05)*, pages 263–270, Ann Arbor, Michigan, June. Association for Computational Linguistics.

Michael Collins, Philipp Koehn, and Ivona Kucerova. 2005. Clause restructuring for statistical machine translation. In *Proceedings of the 43rd Annual Meeting of the Association for Computational Linguistics (ACL'05)*, pages 531–540, Ann Arbor, Michigan, June. Association for Computational Linguistics.

George Doddington. 2002. Automatic evaluation of machine translation quality using n-gram co-occurrence statistics. In *Proceedings of the second international conference on Human Language Technology Research*, pages 138–145, San Francisco, CA, USA. Morgan Kaufmann Publishers Inc.

Gumwon Hong, Seung-Wook Lee, and Hae-Chang Rim. 2009. Bridging morpho-syntactic gap between source and target sentences for english-korean statistical machine translation. In *Proceedings of the ACL-IJCNLP 2009 Conference Short Papers*, pages 233–236, Suntec, Singapore, August. Association for Computational Linguistics.

Philipp Koehn, Hieu Hoang, Alexandra Birch, Chris Callison-Burch, Marcello Federico, Nicola Bertoldi, Brooke Cowan, Wade Shen, Christine Moran, Richard Zens, Chris Dyer, Ondrej Bojar, Alexandra Constantin, and Evan Herbst. 2007. Moses: Open source toolkit for statistical machine translation. In *Proceedings of the 45th Annual Meeting of the Association for Computational Linguistics Companion Volume Proceedings of the Demo and Poster Sessions*, pages 177–180, Prague, Czech Republic, June. Association for Computational Linguistics.

Philipp Koehn. 2004. Statistical significance tests for machine translation evaluation. In Dekang Lin and Dekai Wu, editors, *Proceedings of EMNLP 2004*, pages 388–395, Barcelona, Spain, July. Association for Computational Linguistics.

Roger Levy and Christopher D. Manning. 2003. Is it harder to parse chinese, or the chinese treebank? In *Proceedings of the 41st Annual Meeting of the Association for Computational Linguistics*, pages 439–446, Sapporo, Japan, July. Association for Computational Linguistics.

Jin-Ji Li, Jungi Kim, Dong-Il Kim, and Jong-Hyeok Lee. 2009. Chinese syntactic reordering for adequate generation of Korean verbal phrases in Chinese-to-Korean SMT. In *Proceedings of the Fourth Workshop on Statistical Machine Translation*, pages 190–196, Athens, Greece, March. Association for Computational Linguistics.

Franz Josef Och. 2003. Minimum error rate training in statistical machine translation. In *Proceedings of the 41st Annual Meeting of the Association for Computational Linguistics*, pages 160–167, Sapporo, Japan, July. Association for Computational Linguistics.

Kishore Papineni, Salim Roukos, Todd Ward, and Wei-Jing Zhu. 2001. Bleu: a method for automatic evaluation of machine translation. Technical report, Research report RC22176, IBM.

Andreas Stolcke. 2002. Srilm—an extensible language modeling toolkit. In *In Proceedings of the 7th International Conference on Spoken Language Processing (ICSLP 2002*, pages 901–904.

Chao Wang, Michael Collins, and Philipp Koehn. 2007. Chinese syntactic reordering for statistical machine translation. In *Proceedings of the 2007 Joint Conference on Empirical Methods in Natural Language Processing and Computational Natural Language Learning (EMNLP-CoNLL)*, pages 737–745, Prague, Czech Republic, June. Association for Computational Linguistics.

Fei Xia and Michael McCord. 2004. Improving a statistical mt system with automatically learned rewrite patterns. In *Proceedings of Coling 2004*, pages 508–514, Geneva, Switzerland, Aug 23–Aug 27. COLING.

Peng Xu, Jaeho Kang, Michael Ringgaard, and Franz Och. 2009. Using a dependency parser to improve smt for subject-object-verb languages. In *Proceedings of Human Language Technologies: The 2009 Annual Conference of the North American Chapter of the Association for Computational Linguistics*, pages 245–253, Boulder, Colorado, June. Association for Computational Linguistics.

Nianwen Xue, Fei Xia, Shizhe Huang, and Anthony Kroch Kroch. 2000. The bracketing guidelines for the penn chinese treebank (3.0). Technical report, IRCS Technical Report, University of Pennsylvania.