Effectiveness of Automatic Extraction of Bilingual Collocations Using Recursive Chain-link-type Learning

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Abstract

This paper describes a new method for automatic extraction of bilingual collocations from a parallel corpus. We use **R**ecursive **C**hain-link-type **L**earning (RCL), which is a learning algorithm, to extract bilingual collocations. In our method, new bilingual collocations are extracted efficiently from sentence pairs of source and target languages using only character strings of the bilingual collocations extracted previously. Therefore, a system using RCL can extract bilingual collocations with no need for analytical knowledge, even if the frequency of appearance is very low. Evaluation experiment results show that a system using RCL efficiently extracts bilingual collocations which correspond to English and Japanese word pairs. The recall of correct translation for unknown words in the commercial English-to-Japanese machine translation system was 72.4% when frequency of appearance of the correct translations is only one or two in a parallel corpus. This result shows that our method very efficiently extracts bilingual collocations.

1 Introduction

Statistic-based machine translation and example-based machine translation require effective utilization of a parallel corpus because comparison with a single-language corpus cannot yield a large parallel corpus. Therefore, effective extraction of translation knowledge from a small parallel corpus effectively is necessary.

This paper describes a new method for automatic extraction of bilingual collocations from a parallel corpus. Our method uses **R**recursive **C**hain-link-type **L**earning (RCL) (Echizen-ya et al., 2002) as a learning algorithm to extract bilingual collocations efficiently. In a system using RCL, various bilingual collocations are extracted efficiently using only character strings of bilingual collocations extracted previously. Therefore, a system using RCL requires no static analytical knowledge, in contrast with a rule-based approach (Kupiec, 1993; Kumano and Hirakawa, 1994; Smadja et al., 1996). Moreover, it does not need large amounts of frequency of appearance for bilingual collocations in parallel corpus, different from statistical approach (Brown, 1997; Haruno et al., 1996). In general, statistical approaches extract only bilingual collocations which the frequency of appearance is low in parallel corpus.

Evaluation experiment results demonstrate that this system using RCL extracted useful bilingual collocations. We obtained correct translation from extracted lexical collocations for unknown words in the English-to-Japanese machine translation system. The recall of correct translations for unknown words in the commercial English-to-Japanese machine translation system was 72.4% when the frequency of appearance of the correct translations was only one or two in the parallel corpus. These results confirmed that the system using RCL can extract bilingual collocations without requiring static linguistic knowledge, even in cases where frequency of appearance of bilingual collocations is very low.

2 Related Work

Numerous studies have proposed to extract bilingual collocations from a parallel corpus; many others have addressed extraction of collocation information for lexical ambiguity resolution(Yarowsky, 1995; Blum and Mitchell, 1998; Collins and Singer, 1999). Kupiec(Kupiec, 1993) proposes an algorithm for finding noun phrases from bilingual corpora. In this algorithm, noun phrase candidates are extracted from tagged and aligned parallel texts using a noun phrase recognizer. This algorithm requires a large number of parallel texts and NP recognizer for large-scale linguistic knowledge to obtain high accuracy. Kumano and Hirakawa(Kumano and Hirakawa, 1994) propose a method for finding compound nouns and unknown words from parallel texts. This method utilizes both statistical information and linguistic information to obtain corresponding words or phrases in parallel texts. This method also requires various static linguistic knowledge, e.g., a machine translation bilingual dictionary and NP recognizer. Smadja and McKeown(Smadja et al., 1996) propose a method to extract a wide range of collocations. This method first extracts English collocations using the Xtract system; it then seeks French collocations based on the Dice coefficient. The Xtract system uses parts-of-speech and a parser for English. However, in existing works that have been proposed on the premise of using some static linguistic knowledge, it is difficult to impart complete linguistic knowledge to the system ex ante. Therefore, the system is very ad hoc because developers must add new linguistic knowledge whenever the system faces linguistic phenomena that appear for the first time. Moreover, the system cannot extract bilingual collocations from a parallel corpus using the other language because it depends on a specific language.

On the other hand, Brown(Brown, 1997) proposes a method to create a Spanish-English dictionary from Spanish and English sentence pairs using co-occurrence information. Haruno et al.,(Haruno et al., 1996) propose a method to extract bilingual collocations by word-level sorting. This method first extracts useful word fragments (n-grams) by word-level sorting and then constructs bilingual collocations by combining the word fragments acquired. In general, the statistical approach requires large amounts of a parallel corpus to extract many bilingual collocations because it is difficult to extract bilingual collocations when the frequency of appearance for bilingual collocations is low. Experiments described in (Haruno et al., 1996), Haruno et al., considered only word fragments that appeared more than four times. This means that the system cannot extract bilingual collocations which appeared one time or two times.

3 Overview of Our Method

Figure 1 shows a schema of the extraction process of English-Japanese collocations in our method.

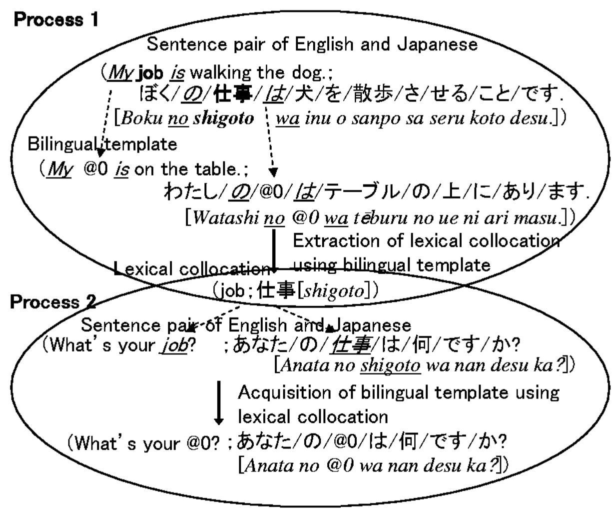

Figure 1: Schema in extraction process of English-Japanese collocations.

This is a system using RCL extracts two types of bilingual collocations. Figure 1 shows (job; 仕事 [*shigoto*][1]) is English-Japanese collocation

[1] Italics express the pronunciation in Japanese.

that can be registered in bilingual dictionary as lexical bilingual correspondence. Hereafter, we call this type of collocation **lexical collocation**. Bilingual collocation corresponds to fixed collocation described in (Haruno et al., 1996). In contrast, (What's your @0?; あなた/の/@0/は/何/です/か?[2][*Anata no @0 wa nan desu ka?*]) is English-Japanese collocation that is used as a template for extraction of lexical collocations. We call this type of collocation a **bilingual template**. The bilingual template corresponds to flexible collocation described in (Haruno et al., 1996). In this paper, a lexical collocation is a pair of source part and target part; a bilingual template is also a pair of source and target parts. In process 1 of Fig. 1, "My" and "is" adjoin the variable "@0" in the source part of the bilingual template; they are common parts with parts in the English sentence "My job is walking the dog." Moreover, "の [*no*]" and "は [*wa*]" adjoin the variable "@0" in the target part of the bilingual template; also, they are common parts with parts in the Japanese sentence "ぼく/の/仕事/は/犬/を/散歩/さ/せる/こと/です.[*Boku no shigoto wa inu o sanpo sa seru koto desu.*]". Therefore, the system acquires (job; 仕事 [*shigoto*]) as the lexical collocation by extracting "job" from the right of "My" to the left of "is" in the English sentence, and extracting "仕事 [*shigoto*]" from the right of "の [*no*]" to the left of "は [*wa*]" in the Japanese sentence.

Moreover, the system using RCL acquires bilingual templates using the extracted (job; 仕事 [*shigoto*]). In process 2 of Fig. 1, the source part "job" of lexical collocation (job; 仕事 [*shigoto*]) has the same character strings as the part in the English sentence "What's your job?"; also, the target part "仕事 [*shigoto*]" of the lexical collocation (job; 仕事 [*shigoto*]) has the same character strings as the part in the Japanese sentence "あなた/の/仕事/は/何/です/か?[*Anata no shigoto wa nan desu ka?*]". Therefore, the system acquires (What's your @0?; あなた/の/@0/は/何/です/か?[*Anata no @0 wa nan desu ka?*]) as the bilingual template by replacing "job" and "仕事 [*shigoto*]" with the variables "@0", with the sentence pair (What's your job?; あなた/の/仕事/は/何/です/か?[*Anata no shigoto wa nan desu ka?*]).

Extracted lexical collocations and bilingual templates are applied for other sentence pairs of English and Japanese to extract new ones. Therefore, lexical collocations and bilingual templates are extracted reciprocally as a linked chain. A characteristic of our method is that bilingual collocations are extracted efficiently using only character strings of sentence pairs of source language and target language. Therefore, a system using RCL can extract bilingual collocation with no analytical knowledge and even in cases where frequency of appearance is low, e.g., one or two. In Fig. 1, (job; 仕事 [*shigoto*]) could be extracted even though frequency of appearance is only one. These mean that our method is effective to solve of problems both rule-based and statistical approaches. Och and Ney(Och and Ney, 2002) propose a method that acquires the alignment templates based on maximum entropy models. In our method, various bilingual collocations are efficiently acquired using only character strings between each sentence pair and each previously-extracted bilingual collocation, different from their method based on statistical information. Therefore, a system using RCL is effective to acquire new bilingual collocations, even if cases where size of parallel corpus is small and frequency of appearance of the bilingual collocations is very low.

On the other hand, lexical collocations or bilingual templates that are used as starting points in the extraction process of new lexical collocations and new bilingual templates, like the bilingual template (My @0 is on the table?; わたし/の/@0/は/テーブル/の/上/に/あり/ます.[*Watashi no @0 wa tēburu no ue ni ari masu*]) in process 1 of Fig. 1, are extracted using **I**nductive **L**earning with **G**enetic **A**lgorithm (GA-IL)(Echizen-ya et al., 1996), which is a learning algorithm. The reason for using GA-IL is that our system can extract bilingual collocations using only a learning algorithm with no static linguistic knowledge. In this study, a system using RCL denotes a system that uses both RCL and GA-IL.

[2]"/" in Japanese sentences are inserted after each morpheme because Japanese is an agglutinative language. This process is performed automatically using the system based only on its learning method(Araki et al., 1995) without requiring any static linguistic knowledge.

4 Outline

Figure 2 shows the outline of a system using RCL to extract lexical collocations from sentence pairs of source and target languages. First, a user inputs a sentence pair. In the feedback process, the system evaluates extracted lexical collocations and extracted bilingual templates. In that case, the system determines whether lexical collocations and bilingual templates are correct or not using the given sentence pairs. This means that the user does not directly evaluate lexical collocations and bilingual templates. In the learning process, bilingual lexicons and bilingual templates are extracted automatically using two learning algorithms, i.e., RCL and GA-IL. In this paper, the system using RCL extracts English-Japanese lexical collocations.

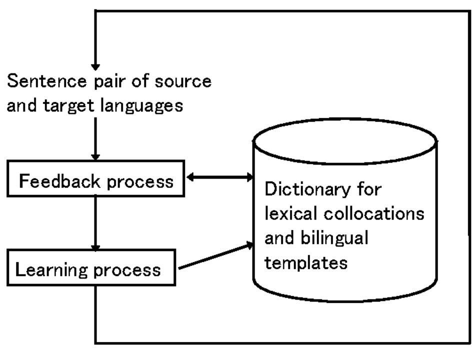

Figure 2: Process flow.

5 Process

5.1 Feedback Process

Erroneous bilingual collocations are also extracted in our method. To solve this problem, a system using RCL performs the feedback process for erroneous bilingual collocations. As a result, a system using RCL can evaluate automatically whether extracted bilingual collocations are correct or not. In this paper, correct bilingual collocation denotes the situation where source parts and target parts correspond to each other; erroneous bilingual collocations are cases where source parts and target parts do not correspond to each other. In the feedback process, first, the system generates sentence pairs in which source language sentences have the same character strings as source language sentences of the given sentence pairs, by combining bilingual templates with lexical collocations. Figure 3 shows an example of this process. In Fig. 3, (He is my friend.; 彼/は/わたし/の/友達/です.[*Kare wa watashi no tomodachi desu.*]) is generated. The system selects lexical collocations and bilingual templates from the dictionary. Selected lexical collocations and bilingual templates are ones in which source parts, except variables, have identical character strings as parts in English sentences of given sentence pairs. Three bilingual templates and one lexical collocation are selected in Fig. 3. Moreover, the system chooses (He is my @0.; 彼/は/わたし/の/@0/です.[*Kare wa watashi no @0 desu.*]) because the source part of this bilingual template is closest to the English sentence of given sentence pairs in three selected bilingual templates. As a result, the system can generate a sentence pair in which the English sentence has the same character strings as the English sentence of the given sentence pair. It does so by combining the chosen bilingual template (He is my @0.; 彼/は/わたし/の/@0/です.[*Kare wa watashi no @0 desu.*]) with lexical collocation (friend; 友だち [*tomodachi*]).

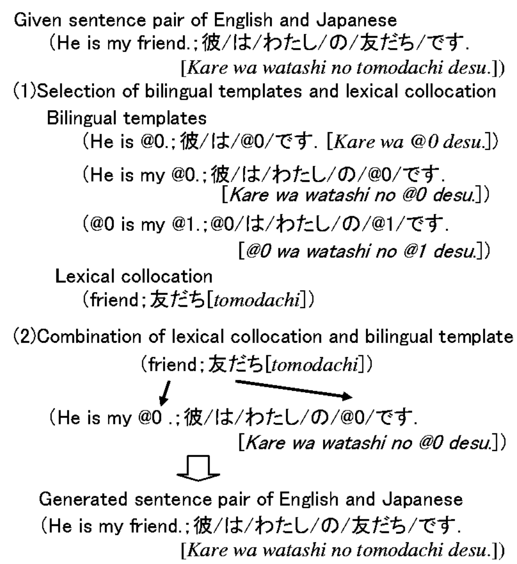

Figure 3: Example of generation of sentence pair.

Next, the system compares Japanese sentences of the generated sentence pairs with Japanese sentences of given sentence pairs. Lexical collocations and bilingual templates used to generate sentence pairs are decided as correct when Japanese sentences of generated sentence pairs have the same character strings as the Japanese sentences of given sentence pairs. As a result, the system adds one point to the correct frequency of the used lexical collocations and used bilingual templates. On the other hand, lexical collocations and bilingual templates used to generate sentence pairs are designated as erroneous when Japanese sentences of generated sentence pairs have different character strings from Japanese sentences of given sentence pairs. As a result, the system adds one point to the erroneous frequency of used lexical collocations and the used bilingual templates. In the case of Fig. 3, the system adds one point to the correct frequency of (He is my @0.; 彼/は/わたし/の/@0/です.[*Kare wa watashi no @0 desu.*]) and (friend; 友だち [*tomodachi*]) because the Japanese sentence of the generated sentence pair has the same character strings as the Japanese sentence of the given sentence pair. Using correct frequency and erroneous frequency, the system calculates **C**orrect **R**ate (CR) for used lexical collocations and used bilingual templates. CR is defined as follows:

$$\mathrm{CR}(\%) = \frac{\text{Correct frequency}}{\text{Correct frequency} + \text{Erroneous frequency}} \times 100$$

The system automatically evaluates lexical collocations and bilingual templates using CR. However, this evaluation method for lexical collocations and bilingual templates is insufficient because correct sentence pairs are sometimes generated by combining erroneous lexical collocations and erroneous bilingual templates. Consequently, the system adds one point to the correct frequency of the used erroneous lexical collocations and used erroneous bilingual templates. This indicates that an evaluation method based on the result of combinations of lexical collocations and bilingual templates is insufficient. Therefore, the system should focus on the process of combinations of lexical collocations and bilingual templates. From this point of view, we propose an evaluation method based on the process of combinations of lexical collocations and bilingual templates. We defer to another paper for detailed description of this evaluation method (Echizen-ya et al., 2000)

5.2 Learning Process

In a system using RCL, lexical collocations and bilingual templates are acquired reciprocally. We first describe the extraction process of lexical collocations using bilingual templates as in process 1 of Fig. 1. Details are as follows:

(1) The system selects sentence pairs of source and target languages that have the same parts as those parts that adjoin variables in bilingual templates.

(2) The system acquires lexical collocations by extracting parts that adjoin common parts, which are the same parts as those in bilingual templates, from sentence pairs of source language and target language. This means that parts extracted from sentence pairs of source and target languages correspond to variables in bilingual templates. In the extraction process, there are three patterns from the view of the position of variables and their adjoining words in bilingual templates:

Pattern 1: When common parts exist both on right and left sides of variables in source or target parts of bilingual templates, the system extracts parts between two common parts from source language sentences or target language sentences.

Pattern 2: When common parts exist only on the right side of variables in source parts or target parts of bilingual templates, the system extracts parts between words at the beginning and the words to the left of common parts in source language sentences or target language sentences.

Pattern 3: When common parts exist only on the left side of variables in source parts or target parts of bilingual templates, the system extracts parts between words to the right of common parts and words at the end in the source language sentences or target language sentences.

(3) The system yields CR that are identical to those bilingual templates used to extracted

lexical collocations. This means that lexical collocations extracted using bilingual templates that have high CR also have high CR.

Moreover, we describe the extraction process of bilingual templates using lexical collocations as in process 2 of Fig. 1. Details are as follows:

(1) The system selects lexical collocations in which source parts have identical character strings to those parts in source language sentences, and in which target parts have the same character strings as parts in the target language sentences.

(2) The system acquires bilingual templates by replacing common parts that are identical to lexical collocations with variables.

(3) The system yields CR that are identical to those lexical collocations used to acquired bilingual templates. This means that those bilingual templates acquired using lexical collocations that have high CR also have high CR.

On the other hand, GA-IL described in Section 3 is utilized for extracting bilingual lexicons and bilingual templates that are used as starting points in RCL. Using GA-IL, a system using RCL can extract lexical collocations using only a learning algorithm from sentence pairs. In GA-IL, similar sentence pairs are generated automatically by applying a crossover process of genetic algorithm. In that case, crossover positions are common parts between two sentence pairs. Moreover, using Inductive Learning, from generated sentence pairs and the given sentence pairs, a system acquires lexical collocations by extracting different parts between two sentence pairs; it acquires bilingual templates by replacing different parts with variables.

Figure 4 shows an example of the extraction process of bilingual collocations in GA-IL. In (1) of Fig. 4, "likes" is the crossover position in the English sentences and "は"[*wa*] is the crossover position in the Japanese sentences. Therefore, one-point crossover is performed by using these crossover positions. By this process, two sentence pairs are automatically generated. Moreover, by using Inductive Learning, from the generated sentence pairs and the given sentence pairs, the system acquires lexical collocations by extracting different parts between two sentence pairs, and it acquires bilingual templates by replacing the different parts with variables.

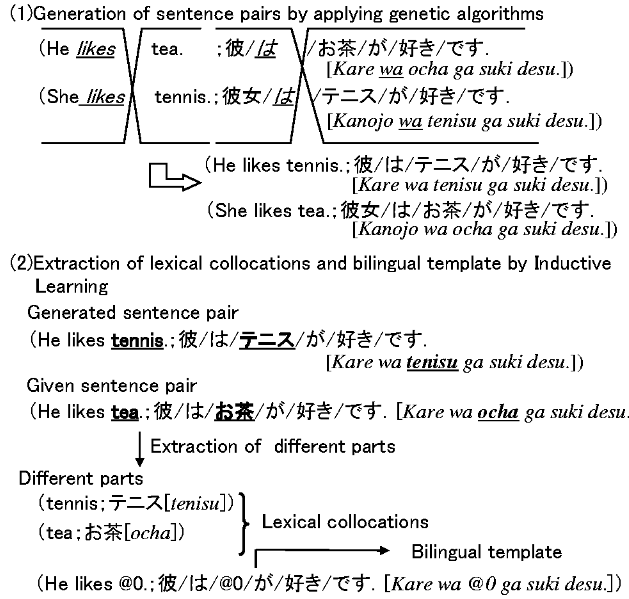

Figure 4: Example of extraction process of bilingual collocations in GA-IL.

6 Experiments

6.1 Experimental Procedure

To evaluate a system using RCL, 2,856 English and Japanese sentence pairs were used as experimental data. These sentence pairs were taken from textbooks for first(Nihon Kyozai(1), 2001) and second(Nihon Kyozai(2), 2001; Hoyu Shuppan, 2001; Bunri, 2001; Sinko Shuppan, 2001) grade junior high school students. The total number of characters of the 2,856 bilingual sentences is 142,592. The average number of words in English sentences in the 2,856 sentence pairs is 6.0. All sentence pairs are processed by the system based on the outline described in Section 4 and the process described in Section 5. The dictionary is initially empty.

Moreover, we gave English sentences of 2,856 sentence pairs used as evaluation data to the commercial English-to-Japanese machine translation system. As a result, 37 unknown words were included in Japanese translation results generated by the commercial machine translation system. In that case, their unknown words appear as alphabets in Japanese translation results because the commercial machine translation system cannot translate them at all.

6.2 Evaluation Standards

This study investigated the recall of correct translation for unknown words in the commercial English-to-Japanese machine translation system. Extracted lexical collocations are ranked when several different translations are obtained for the same unknown words. In that case, lexical collocations are sorted so that lexical collocations which have the highest CR described in Section 5.1 are ranked at the top. Among ranked lexical collocations, three bilingual lexicons ranked from No. 1 to No. 3 are evaluated by the user.

6.3 Experimental Results and Discussion

The system using RCL acquired 28 correct translations for the 37 unknown words. Therefore, the recall of correct translations for unknown words is 75.7%. Moreover, the number of the unknown words for which the frequency of appearance is one or two is 29 among 37 unknown words. The system using RCL acquired 21 correct translations for 29 unknown words for which the frequency of appearance of the correct translations is one or two. Therefore, the recall of correct translations for unknown words for which the frequency of appearance of the correct translations is one or two is 72.4%. This result demonstrates that the system using RCL is effective to efficiently extract lexical collocations for which the frequency of appearance is very low. Table 1 shows examples of acquired correct translations for unknown words.

The system using RCL acquires not only correct lexical collocations and correct bilingual templates, but also erroneous lexical collocations and erroneous bilingual templates. As mentioned in Section 5.1, erroneous lexical collocations and erroneous bilingual templates indicate that source parts and target parts do not correspond to each other. We investigated precision of extracted lexical collocations and acquired bilingual templates. Consequently, we confirmed that precision of extracted lexical collocations was 47.3%. This precision is insufficient. Extraction of erroneous lexical collocations is, in most cases, caused by structural differences between bilingual templates and sentence pairs. For example, from the bilingual template (He is @0.; 彼/は/@0/です.[*Kare wa @0 desu.*]), which is the affirmative sentence and sentence pairs (Who is this boy?; この/少年/は/誰/です/か?[*Kono shōnen wa dare desu ka?*]) which are interrogative sentences, (this boy; だれ [*dare*]) is extracted as the erroneous lexical collocation because "this boy" corresponds to the variable"@0" by collocations between "is @0" in the source part of the bilingual template and "is this boy" in the English sentence, and "だれ [*dare*]" corresponds to the variable "@0" by collocations between "は/@0/です[*wa @0 desu*]" in the target part of the bilingual template and "は/だれ/です[*wa dare desu*]" in the Japanese sentence. However, this extracted lexical collocation (this boy; だれ [*dare*]) is the erroneous lexical collocation because "this boy" in English means "この/少年 [*kono shōnen*]" in Japanese, not "だれ [*dare*]". On the other hand, precision of the acquired bilingual templates was 54.6%. This precision is also insufficient. However, in the feedback process described in Section 5.1, a system using RCL can evaluate these lexical collocations as erroneous lexical collocations. The rate that the system could decide as erroneous lexical collocations for extracted erroneous lexical collocations was 69.2%. In that case, erroneous lexical collocations mean extracted lexical collocations whose CR is under 50.0%.

Table 1: Examples of acquired correct translations for unknown words.

English	Japanese
Rika	りか [*rika*]
りか means a Japanese name.	
Shinkansen	新幹線 [*shinkansen*]
新幹線 means a transportation like train.	
Lake Biwa	琵琶湖 [*biwa ko*]
琵琶湖 means a famous lake in Japan.	
Ishikari River	石狩川 [*ishikari gawa*]
石狩川 means a famous river in Japan.	
Mt. Asama	浅間山 [*asama yama*]
浅間山 means a famous mountain in Japan.	

7 Conclusion

This paper proposed a new method to extract bilingual collocations from a parallel corpus. In our system, various bilingual collocations are extracted efficiently using RCL, which is based only on character strings of bilingual collocations extracted previously. Consequently, this system using RCL can solve problems of a rule-based approach because it automatically extracts bilingual collocations from only the given sentence pairs of source language and target language. Moreover, a system using RCL can solve problems of statistical approaches because it does not require large amounts of frequency of appearance for bilingual collocations in a parallel corpus. In general, statistical approaches cannot extract bilingual collocations which the frequency of appearance is less than 2 times in parallel corpus. In a system using RCL, evaluation experiment results show that the recall of correct translations for unknown words in the commercial English-to-Japanese machine translation system was 75.7%. The recall of correct translations for unknown words which the frequency of appearance of the correct translations is one or two was 72.4%. Therefore, we confirmed that our system very efficiently extracts bilingual collocations.

In the future, we will continue evaluation experiments using practical data. We will confirm that a system using RCL can acquire lexical collocations from sentence pairs using other languages. This means that a system using RCL is a learning algorithm that does not depend on specific language. Moreover, we will apply RCL to other natural language processing systems, e.g., a dialog system, to confirm RCL effectiveness.

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