

EFFECTIVENESS OF INFORMATION OBTAINED FROM MORPHOLOGICAL ANALYSIS IN PT-IL

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ABSTRACT

Translations of unknown words, such as technical terms, are one of problems in machine translation. To resolve the problem, we have proposed a method of prediction for target words using inductive learning. We call this method "a method of Prediction for Target words using Inductive Learning (PT-IL)." In our work, basic units for prediction are automatically extracted from two pairs of sequences of words in source and target languages. Moreover, our system generates target words for unknown words by combining these units. To acquire units, a experimental system built in our previous work used the only information of character strings. Our system in this current work uses the results of morphological analysis that give additional information about linguistic units and parts of speech. We have done evaluation experiments on unknown compound words. From the results of them, the rate of effectiveness was about 83.0%. The uses of additional information resulted in a dramatic improvement and we confirmed the effectiveness of our method.

KEYWORDS

natural language processing, machine translation, inductive learning, prediction, unknown word, target word.

1 INTRODUCTION

A bilingual dictionary is essential for a machine translation system. If words, that appear in texts, are not registered in the system's dictionary, the system cannot translate these unknown words. For the machine translation system, the large dictionary is needed; however, the cost of development and maintenance of the large dictionary is very high. It is one of problems in the construction of a machine translation system. Therefore, some methods for automatically generating a bilingual dictionary from a parallel corpus have been proposed [1, 2, 3, 4, 5]. In these studies, their systems mainly use some statistical information, such as co-occurrence frequencies of bilingual expressions, and the systems extract bilingual entries from parallel cor-

pora. Their results show that high precision can be achieved with a very large corpus. However, the problem addressed in this paper, i.e., translations of unknown words, cannot be resolved by only the additions of extracted entries. New words, for example technical terms and name entities, appear in texts and are not registered in a generated dictionary. Kumano and Hirakawa [6] and Ahrenberg et al. [7] proposed that their systems use linguistic information in addition to statistical information. However, the linguistic information has to be defined in terms of linguistic rules in advance. It is impossible to register all low-frequency expressions in a list of linguistic rules. Their paper [6] reported that the system could not achieve a high rate of effectiveness for unknown words.

On the other hand, a method [8] for translating words such as technical terms has been proposed. MBT3 [8] translates these words using many pairs of words in source and target languages. The system requires correspondences between elements in source and target languages. However, the cost of preparation for these correspondences is very high, and the correspondences have to be prepared in each domain of translation. Moreover, the system cannot translate words that include unknown elements.

In our method, the system can automatically acquire units for prediction of target words from learning data. The learning data are two pairs of words in source and target languages. Our system does not require a large amount of data for learning and there is no need to prepare correspondences between elements in source and target languages. Moreover, our system is adaptable to each domains of translation. In our previous research, the acquired pairs include effective and ineffective units for prediction of target words. One of reasons for these extractions of ineffective units is errors in dividing position when units are extracted from sources of units. In some languages, such as Japanese, sentences are non-segmented and it is difficult to be extracted effective units. Therefore, in this research, units for prediction are extracted using information obtained from results of morphological analysis in addition to character strings.

In this paper, we propose a method for the prediction of target words using inductive learning and consider the effectiveness of information obtained from results of morphological analysis. This current work has used the results of morphological analysis that give additional information about linguistic units and parts of speech. In section 2, the basic idea of our method is described. An overview of our system is presented in section 3. The procedure and results of evaluation experiments on our system are presented in section 4. Moreover, the effectiveness of inductive learning is discussed in section 5 and the effectiveness of using additional information is considered in section 6. Finally, conclusions are presented in section 7.

2 UNITS FOR PREDICTION

2.1 BASIC IDEA OF PREDICTION

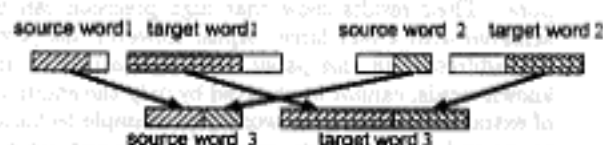


Figure 1: Basic idea for prediction of target word

We consider units for prediction as pairs of parts that construct source and target words, and target words can be generated by combining these units. In our basic idea, if parts of words have appeared previously as parts of similar words, then they can be translated similarly. Figure 1 shows this idea. In this figure, source word 3 is constructed from parts of source words 1 and 2, and target word 3 is constructed from parts of target words 1 and 2. Source word 3 and target word 3 are generated from a pair of these parts. This idea for the combination of parts is based on "the compositionality principle" [8, 9]. We consider that target words can be generated by combining the units for prediction, and we call such a unit "a Pair of Pieces of Words (PPW)."

In our method, these units are acquired and the target words are generated by the units using inductive learning. Inductive learning includes a process by which rules are acquired from examples and a process by which certainties of these rules are decided. Araki et al. [10] developed a system for Kana-Kanji translation and reported that their system achieved a high rate of effectiveness. Their system could adapt to some processing domains with a small amount of learning data. Sasacka et al. [11] proposed a method for prediction of target words using inductive learning, and they confirmed the effectiveness of their method.

In the previous method, units for prediction are extracted using inductive learning and this process is based on information obtained from character strings. The research aims to acquire basic units that include both linguistic and non-linguistic units. Linguistic

units are regarded as morpheme, and non-linguistic units include character strings that are shorter than morpheme and character strings that are longer than morpheme. We consider that effective units for prediction need to include character strings that cannot be regarded as linguistic units such as morpheme.

2.2 EXTRACTION OF UNITS FOR PREDICTION USING INFORMATION OBTAINED FROM CHARACTER STRINGS

In this section, we show examples of PPWs that are extracted from learning data in uses of character strings. Our system extracts both common and different parts in source and target languages. Figure 2 shows some examples of PPWs. In English, "electro" is a common part and "chemistry" and "lytic" are different parts. The *italic character strings* express Japanese phonograms. In Japanese, "電気 (denki)" is a common part and "化学 (hagaku)" and "分解の (bunkai no)" are different parts.

However, there are many difficulties of extraction in uses of the only information obtained from results of morphological analysis, for example extraction of PPW 1 and 3. The reason is that pairs of units are hard to be registered in general bilingual dictionary and morphological rules. In a bilingual dictionary that has 50,000 headwords, PPW 1 and 3 are not registered. We consider that they can be effective units for prediction process.

Source pair 1	(electrochemistry,	電気化学)
		(denki hagaku)
Source pair 2	(electrolytic,	電気分解の)
		(denki bunkai no)
		↓
PPW1	(electro@1,	電気@1)
		(denki)
PPW2	(chemistry,	化学)
		(hagaku)
PPW3	(lytic,	分解の)
		(bunkai no)

Figure 2: Examples of PPWs extracted by using information obtained from character strings

In a PPW, the mark "@1" means a variable. The positions of variables are equal to the positions of different parts in the learning sources. The system substitutes a unit for the variable and generates a new character string.

2.3 EXTRACTION OF UNITS FOR PREDICTION USING INFORMATION OBTAINED FROM MORPHOLOGICAL ANALYSIS

In English, character strings can be divided into linguistic units by spaces or hyphens, and the divided units are words or affixes. On the other hand, in Japanese, character strings are non-segmented. In this work, our

system extracts PPWs from learning data in use of results of morphological analysis. A process of extraction uses two types of information obtained from morphological analysis. One of them is sequences of linguistic units and the other is sequences of parts of speech.

Source 1	(electron gas,	電子気体)
Linguistic units	electron gas	(denshi kitas)
Source 2	(electron gun,	電子銃)
Linguistic units	electron gun	(denshi ju)
	↓	
PPW 1	(electron @1,	電子@1)
PPW 2	(gas,	気体)
PPW 3	(gun,	銃)

Figure 3: Examples of PPWs extracted by using information obtained from linguistic units

Figure 3 shows some examples of PPWs that are extracted by linguistic units. In this process, our system extracts a common part and different parts according to sequences of linguistic units. In English, "electron" is a common part and "gas" and "gun" are different parts. In Japanese, "電子 (denshi)" is a common part and "気体 (kitas)" and "銃 (ju)" are different parts. In a case of extraction in the only uses of character strings, the extracted PPWs can be (electron @1, 電子@1 (denshi)), (as, 気体 (kitas)) and (un, 銃 (ju)). They do not have effective correspondence between source and target languages and are not effective units in prediction.

Figure 4 shows some examples of PPWs, that are extracted by using parts of speech. In this process, our system extracts a common part and different parts according to sequences of parts of speech. In English, "NN" (which means "noun") is common and "electron" becomes a common part. "Secondary" and "trapped" become different parts. In Japanese, "名詞:一般" is common and "電子 (denshi)" becomes a common part. "二次 (ni ji)" and "捕獲 (hosoku)" become different parts according to character strings. In this example, "二 (ni)" and "次 (ji)" are separated by using information obtained from parts of speech. However, in our method, they are regarded as one unit. The reason for this is that they are extracted as one different part from learning data.

3 EXPERIMENTAL SYSTEM

Figure 5 shows the outline of our experimental system. This system uses two dictionaries: a PPW dictionary and an English-Japanese dictionary. The system executes three processes: a prediction process, learning process, and feedback process. If erroneous results are

Source 1	(secondary electron,	二次電子)
Linguistic units	secondary electron	(ni ji denshi)
Parts of speech	JJ,NN	名詞-数, 名詞-接尾
	(Adjective, Noun)	-助数詞, 名詞-一般
Source 2	(trapped electron,	捕獲電子)
Linguistic units	trapped electron	(hosoku denshi)
Parts of speech	VB,NN	動詞 電子
	(Verb-past-participle, Noun)	(hosoku denshi)
		名詞-サ変, 名詞-一般
		(Noun-saben, Noun)
	↓	
PPW 1	(@1 electron,	@1 電子)
PPW 2	(secondary,	二次)
PPW 3	(trapped,	捕獲)

Figure 4: Examples of PPWs extracted by using information obtained from sequences of parts of speech

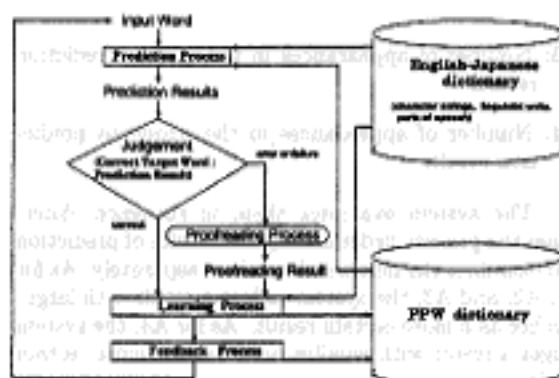


Figure 5: Experimental system

generated, the results have to be proofread by the user. In this study, our system was used to translate English into Japanese.

When the user gives the system an English word, the system first attempts to translate the word using PPWs in the PPW dictionary. If the system cannot generate the target word, it will attempt to acquire new PPWs from selected learning data in the bilingual dictionary. The process of selection of these learning data has described elsewhere [11]. The system then tries to generate the target word using the newly acquired PPWs. If the system generates one result or some results, it decides the priority order for them with the numerical values of the PPWs used. The numerical values to which the system refers to are as follows:

- A1: Number of appearances in the experimental data
- A2: Number of appearances in the prediction results

Table 1: Succeeded and failed results

succeeded	rate[%]	failed	rate[%]	total
59	59.0	41	41.0	100

Table 2: Correct, effective and erroneous results

correct	rate[%]	effective	rate[%]	erroneous	rate[%]	succeeded
19	32.2	30	50.8	10	17.0	59

Table 3: Succeeded and failed results

	succeeded	rate[%]	failed	rate[%]	total
with PPW dic.	59	59.0	41	41.0	100
without PPW dic.	34	34.0	66	66.0	100

Table 4: Correct, effective and erroneous results

	correct	rate[%]	effective	rate[%]	erroneous	rate[%]	succeeded
with PPW dic.	19	32.2	30	50.8	10	17.0	59
without PPW dic.	8	23.5	18	52.9	8	23.5	34

Table 5: Numbers of improvement in experimental results

without PPW dic.	with PPW dic.	Numbers
erroneous results	→ correct results	1
effective results	→ correct results	1
failed results	→ correct or effective results	22

A3: Number of appearances in the correct prediction results

A4: Number of appearances in the erroneous prediction results

The system evaluates them in sequence, determines the priority order among the results of prediction and examines the numerical numbers separately. As for A1, A2, and A3, the system judges a result with larger number as a more certain result. As for A4, the system judges a result with smaller number as a more certain result.

In the process of learning, the system extracts PPWs and adds them to the PPW dictionary. The process of extraction using each type of information is executed separately.

Finally, the system performs a feedback process. In this process, numerical values of A1 and A2 increase by 1. If the system can predict the correct result, a numerical value of A3 increases by 1. In other cases, a numerical value of A4 increases by 1. This process aims to improve the capability of the process of prediction.

4 EVALUATION EXPERIMENT

4.1 PROCEDURE

We performed an evaluation experiment using our system. We call this experiment the first experiment. This section describes the procedure of this experiment. One hundred English compound words were used in the experiment. They included the names of research groups, fields of research, and so on. The English-Japanese dictionary used in our system was "gene" [12]. We

also referred to the document of words in English and Japanese [13] and extracted some PPWs that were affixes and their target words. The total number of units in the initial dictionary was 102,507. We used two tools for morphological analysis in this experiment. The tool for English is "Brill Tagger" [14] and the tool for Japanese is "Chasen" [15].

The results of prediction were classified into two groups: one group of results that can be generated by this system and another group of results that cannot be generated. The results in the first group are termed succeeded results, and the results in the second group are termed failed results. Moreover, the succeeded results were divided into three groups. In the first group, the results were equal to the target words that fitted in the context of the field and were ranked within the 10th place among the succeeded results in the prediction. The results in this group were called correct results. The results in the second group were target words that were not completely equal to the correct results, but that could be regarded as target words. The results in the second group were called effective results. The other group contained succeeded results that did not meet the criteria for the first and second group. These results were called erroneous results.

4.2 RESULTS

Table 1 shows the numbers and rates of succeeded and failed results, and Table 2 shows the numbers and rates of correct, effective and erroneous results.

The rate of correct and effective results in succeeded results is 83.0% and we confirmed the effectiveness of our method.

Table 6: Succeeded and failed results

	succeeded	rate%	failed	rate%	total
(1)	59	59.0	41	41.0	100
(2)	52	52.0	48	48.0	100
(3)	46	46.0	54	54.0	100
(4)	35	35.0	65	65.0	100
(5)	57	57.0	43	43.0	100
(6)	54	54.0	46	46.0	100
(7)	47	47.0	53	53.0	100

Table 7: Correct, effective and erroneous results

	correct	rate%	effective	rate%	erroneous	rate%	produced
(1)	19	32.2	30	50.8	10	17.0	59
(2)	15	28.8	23	44.2	14	27.0	52
(3)	15	32.6	19	41.3	12	26.1	46
(4)	1	2.9	4	11.4	30	85.7	35
(5)	19	33.3	24	42.1	14	24.6	57
(6)	16	29.6	22	40.7	16	29.6	54
(7)	16	34.0	20	42.6	11	23.4	47

4.3 CONSIDERATION

4.3.1 CONSIDERATION FOR CORRECT AND EFFECTIVE RESULTS

An unknown compound word
"system control laboratory"

PPW 1	(system,	システム)
		(shisutemu)
PPW 2	(① control,	① 制御)
		(seigyō)
PPW 3	(① laboratory,	① 研究室)
		(kenkyū shitsu)
	↓	
Results	「システム 制御 研究室」	
	(shisutemu seigyō kenkyū shitsu)	

Figure 6: An example of a correct result

Source 1	(advanced control,	先行制御)
		(senkō seigyō)
Linguistic unit	advanced control,	先行 制御
		(senkō seigyō)
Source 2	(automatic exposure	自動飛行制御)
	control,	(jūdō hīkō seigyō)
Linguistic unit	automatic exposure	自動 飛行
	control,	制御
		(jūdō hīkō
		seigyō)
	↓	
PPW 1	(① control,	① 制御)
		(seigyō)
PPW 2	(advanced,	先行)
		(senkō)
PPW 3	(automatic exposure,	自動飛行)
		(jūdō hīkō)

Figure 7: An extraction of PPWs

Source 1	(applied electric power laboratory,	電力応用研究室)
		(denryoku ōyō kenkyū shitsu)
Linguistic unit	applied electric power laboratory,	電力 応用 研究 室
		(denryoku ōyō kenkyū shitsu)
Source 2	(airborne laser laboratory,	機上レーザー研究室)
		(kijō rēzā kenkyū shitsu)
Linguistic unit	airborne laser laboratory,	機上 レーザー 研究 室
		(kijō rēzā kenkyū shitsu)
	↓	
PPW1	(① laboratory,	① 研究室)
		(kenkyū shitsu)
PPW2	(applied electric power,	電力応用)
		(denryoku ōyō)
PPW3	(airborne laser,	機上レーザー)
		(kijō rēzā)

Figure 8: Extraction of PPWs

Figure 6 shows an example of a correct result. PPW 1 is registered in the English-Japanese dictionary. PPW 2 is extracted by information obtained from linguistic units. Source pairs are "advanced control, 先行制御 (先行 || 制御) (senkō seigyō)" and "automatic exposure control, 自動飛行制御 (自動 || 飛行 || 制御) (jūdō hīkō seigyō)". Figure 7 shows a process of extraction of PPW2. PPW 2 is a common pair of parts in source and target words. Moreover, PPW 3 is extracted using information obtained from linguistic units. Source pairs are "applied electric power laboratory, 電力応用研究室 (電力 || 応用 || 研究 || 室) (denryoku ōyō kenkyū shitsu)" and "airborne laser laboratory, 機上レーザー研究室 (機上 || レーザー || 研究 || 室) (kijō rēzā kenkyū shitsu)". Figure 8 shows a process of extraction of PPW3. PPW 3 is also a common pair of parts in source and target words.

4.3.2 CONSIDERATION FOR ERRONEOUS RESULTS

In this section, we discuss reasons for the erroneous results of prediction. One of reasons for erroneous results is errors of ranking results of prediction. In these erroneous results, there were effective PPWs for the processes in PPW dictionary. Our experimental system could generate a result that was equal to the target word, however, the system could not rank the result within the 10th place. To decide a priority order among results of prediction, the system evaluates some numerical values that are described in section 3. Small numbers of uses of PPWs resulted in these erroneous results. In a prediction of word "optical engineering laboratory", our system can generate a result that is equal to the target word. However, the rank of it is the 13th place and the result was judged as a erroneous result. We consider that more sources of learning and using them can improve the performance.

Another reason for erroneous results is the uses of PPWs that have ineffective correspondence between source and target languages. In these cases of predictions, there were not effective PPWs in PPW dictionary. An example of the erroneous results of a word "physio engineering" is "まあ 理 工 学 (maā ri kōgaku)" and the target word is "生理工学 (seiri kōgaku)". The erroneous results are generated by using (physi①, ① 理 (ri)), (o, まあ (maā)) and (① engineering, ① 工 学 (kōgaku)). To decrease the numbers of uses of these ineffective PPWs, we consider that our system needs constraints, such as combination rules for PPWs. Moreover our system using inductive learning needs a new process that can acquire more number of effective PPWs from these small number of sources of learning.

5 EVALUATION FOR INDUCTIVE LEARNING

5.1 PROCEDURE

To consider the effectiveness of PPWs acquired by inductive learning, we developed an experimental system that did not have PPW dictionary and performed another experiment on this system. We call this experiment the second experiment. The procedure and data were the same as that used in the first experiment, that are described in subsection 4.1.

5.2 RESULTS AND CONSIDERATION

Table 3 and Table 4 show numbers and rates in the experiments. From the results, numbers of correct and effective results increase by the use of PPW dictionary. Table 5 shows the improvement of experimental results.

On the other side, the number of results of becoming worse is 3. One of reasons is errors of ranking among produced results. The number of acquired PPWs is 804 and they include effective PPWs for prediction. However, some of them do not use the process of prediction. Therefore, the small number of uses of these PPWs resulted in the erroneous results. Another

reason is uses of PPWs that have ineffective correspondences between pairs of character strings in source and target languages. To improve these erroneous results, we consider that our system needs constraints that are described in subsection 4.3.2.

6 EVALUATION FOR USES OF ADDITIONAL INFORMATION

6.1 PROCEDURE

We performed experiments under seven different conditions of extraction of PPWs. We call this experiment the third experiment. The purpose of the third experiment is that we discuss the performance of each additional information. The information sources for the extraction of PPWs are as follows:

- (1) Character strings, linguistic units and parts of speech (= the first experiment)
- (2) Character strings (= the previous work [1])
- (3) Linguistic units
- (4) Parts of speech
- (5) Character strings and linguistic units
- (6) Character strings and parts of speech
- (7) Linguistic units and parts of speech

The procedure and data are the same as that used in the first experiment, that are described in subsection 4.1.

6.2 RESULTS AND CONSIDERATION

Table 6 shows numbers and rates of succeeded and failed results, and Table 7 shows numbers and rates of correct, effective and erroneous results.

The uses of information (7), that are linguistic units and parts of speech, resulted in the highest rate of correct results, 34.0%. However, numbers of produced and correct results were much less than the case of using the information (1), that are shown in Table 7. A comparison of them shows that the system based on our method could perform most effectively by using information obtained from character strings, linguistic units and parts of speech.

Table 7 indicates that the smallest number of correct and effective results in uses of condition (4), that is, in the only uses of parts of speech. The reason of this is that, in Japanese target words, the similarity of sequences of parts of speech are very high. The most of appearing sequences is "Noun Noun." In our method, the system has extracted a common and different parts from learning data. Therefore, the system could hardly extract any units for prediction and the number of acquired PPWs was very small.

7 CONCLUSIONS

This paper has proposed the method of prediction of target words using inductive learning. In this study, we have done three experiments. In the first experiment, our system have tried to translate one hundred unknown words in English into their target words in Japanese. The rate of correct and effective results is about 83.0%. Moreover, to consider the effectiveness of PPWs acquired by inductive learning, we have done the second experiment on the another system that did not have PPW dictionary. The total number of differences between them is 24. At last, to compare the performance of each added information, we have done the third experiment. We could see that the system in uses of character strings, linguistic units and parts of speech has performed the most effectively. From these results, we have confirmed the effectiveness of our method.

In the near future, we try to develop more practical system using inductive learning in natural language processing. Therefore, we are going to consider a method that integrate rules prepared in advanced with rules acquired by inductive learning.

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