Automatic Extraction of Word Sequence Correspondences in Parallel Corpora

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Abstract

This paper proposes a method of finding correspondences of arbitrary length word sequences in aligned parallel corpora of Japanese and English. Translation candidates of word sequences are evaluated by a similarity measure between the sequences defined by the co-occurrence frequency and independent frequency of the word sequences. The similarity measure is an extension of Dice coefficient. An iterative method with gradual threshold lowering is proposed for getting a high quality translation dictionary. The method is tested with parallel corpora of three distinct domains and achieved over 80% accuracy.

1 Introduction

A high quality translation dictionary is indispensable for machine translation systems with good performance, especially for domains of expertise. Such dictionaries are only effectively usable for their own domains, much human labour will be mitigated if such a dictionary is obtained in an automatic way from a set of translation examples.

This paper proposes a method to construct a translation dictionary that consists of not only word pairs but pairs of arbitrary length word sequences of the two languages. All of the pairs are extracted from a parallel corpus of a specific domain. The method is proposed and is evaluated with Japanese-English parallel corpora of three distinct domains.

Several attempts have been made for similar purposes, but with different settings. (see [Kupiec 93][Kumano & Hirakawa 94][Smadja 96])

Kupiec and Kumano & Hirakawa propose a method of obtaining translation patterns of noun compound from bilingual corpora. Kumano & Hirakawa stand on a different setting from the other works in that they assume ordinary bilingual dictionary and use non-parallel (non-aligned) corpora. Their target is to find correspondences not only of word level but of noun phrases and unknown words. However, the target noun phrases and unknown words are decided in the preprocessing stage.

Brown et al. use a probabilistic measure for estimating word similarity of two languages in their statistical approach of language translation [Brown 88]. In their work of aligning of parallel texts, Kay & Röscheisen used the Dice coefficient as the word similarity for insuring sentence level correspondence [Kay & Röscheisen 93].

Kitamura & Matsumoto use the same measure to calculate word similarity in their work of extraction of translation patterns. The similarity measure is used as the basis of their structural matching of parallel sentences so as to extract structural translation patterns. In texts of expertise a number of word sequence correspondences, not word-word correspondences, are abundant especially in the form of noun compounds or of fixed phrases, which are keys for better performance. Though the method proposed in this paper deals only with consecutive sequences of words and is intended to provide a better base for the structural matching that follows, the results themselves show very useful and informative translation patterns for the domain.

Our method extends the usage of the Dice coefficient in two ways: It deals not only with correspondence between the words but with correspondence between word-sequences, and it modifies the formula measure so that more plausible corresponding pairs are identified earlier.
2 Related Work and Some Results

Brown et. al., used mutual information to construct corresponding pairs of French and English words. A French word \( f \) is considered to be translated into English word \( e_j \) that gives the maximum mutual information:

\[
MI(e_j, f) = \log \frac{P(e_j | f)}{P(e_j)}
\]

Probabilities \( P(e_j | f) \) and \( P(e_j) \) are calculated from parallel corpus by counting the occurrences and co-occurrences of \( e_j \) and \( f \).

Kay & Röschisen used the following Dice coefficient for calculating the similarity between English word \( w_e \) and French word \( w_f \). In the formula, \( f(w_e) \), \( f(w_f) \) represent the numbers of occurrences of \( w_e \) and \( w_f \), and \( f(w_e, w_f) \) is the number of simultaneous occurrences of those words in corresponding sentences.

\[
sim(w_e, w_f) = \frac{2f(w_e, w_f)}{f(w_e) + f(w_f)}
\]

Kitamura & Matsumoto used the same formula for calculating word similarity from Japanese-English parallel corpora. A comparison between the above two method is done on a parallel corpus and the results are reported in [Ohmori 96]. They applied both approaches to a French-English corpus of about one thousand sentence pairs. The results are shown in Table 1 where the correctness is checked by human inspection. Since both methods show very inaccurate results for the words of one occurrence, only the words of two or more occurrences are selected for inspection. Table 1 shows the proportion that a French word is paired with the correct English words checked with the top, three and five highest candidates.

|            | Num. of words | 1st candidate | within best 3 | within best 5 |
|------------|---------------|---------------|---------------|---------------|
| Mutual Information | 697           | 43.6%         | 60.0%         | 65.4%         |
| Dice coefficient   | 574           | 46.2%         | 65.0%         | 66.5%         |

Table 1: Comparison of Mutual Information and Dice coefficient

The results show that though Dice coefficient gives a slightly better correctness both methods do not generate satisfactory translation pairs.

[Kupiec 93] and [Kumano & Hirakawa 94] broaden the target to correspondences between word sequences such as compound nouns. Kupiec uses NP recognizer for both English and French and proposed a method to calculate the probabilities of correspondences using an iterative algorithm like the EM algorithm. He reports that in one hundred highest ranking correspondences ninety of them were correct. Although the NP recognizers detect about 5000 distinct noun phrases in both languages, the correctness ratio of the total data is not reported.

Kumono & Hirakawa’s objective is to obtain English translation of Japanese compound nouns (noun sequences) and unknown words using a statistical method similar to Brown’s together with an ordinary Japanese-English dictionary. Japanese compound nouns and unknown words are detected by the morphological analysis stage and are determined before the later processes. Though they assume unaligned Japanese-English parallel corpora, alignment is performed beforehand. In an experiment with two thousand sentence pairs, 72.9% correctness is achieved by the best correspondences and 83.8% correctness by the top three candidates in the case of compound nouns. The correctness ratios for unknown words are 54.0% and 65.0% respectively.

Smadja proposes a method of finding translation patterns of continuous as well as discontinuous collocations between English and French [Smadja 96]. The method first extracts meaningful collocations in the source language(English) in advance by the XTRACT system. Then, aligned corpora are statistically analyzed for finding the corresponding collocation patterns in the target language(French). To avoid possible combinational explosion, some heuristics is introduced to filter implausible correspondences.

Getting translation pairs of complex expression is of great importance especially for technical domains where most domain specific terminologies appear as complex nouns. There are still a
number of other interesting and meaningful expression that should be translated in a specific way. We propose a method of finding corresponding translation pairs of arbitrary length word sequences appearing in parallel corpora and an algorithm that gradually produces "good" correspondences earlier so as to reduce noises when extracting less plausible correspondences.

3 Overview of the Method

Figure 1 shows the flow of the process to find the correspondences of Japanese and English word sequences. Both Japanese and English texts are analyzed morphologically.

We make use of two types of co-occurrences: Word co-occurrences within each language corpus and corresponding co-occurrences of those in the parallel corpus. In the current setting, all words and word sequences of two or more occurrences are taken into account. Since frequent co-occurrence suggests higher plausibility of correspondence, we set a similarity measure that takes co-occurrence frequencies into consideration. Deciding the similarity measure in this way reduces the computational overhead in the later processes. If every possible correspondence of word sequences is to be calculated, the combination is large. Since high similarity value is supported by high co-occurrence frequency, a gradual strategy can be taken by setting a threshold value for the similarity and by iteratively lowering it. Though our method does not assume any bilingual dictionary in advance, once words or word sequences are identified in an earlier stage, they are regarded as decisive entries of the translation dictionary. Such translation pairs are taken away from the co-occurrence data, then only the remaining word sequences need be taken into consideration in the subsequent iterative steps. Next section describes the details of the algorithm.

4 The Algorithm

The step numbering of the following procedure corresponds to the numbers appearing in Figure 1. In the current implementation, the Translation Dictionary is empty at the beginning. Steps 1 and 2 are performed on each language corpus separately.

1. Japanese and English texts are analyzed morphologically and all content words (nouns, verbs, adjectives and adverbs) are identified.
2. All content words of two or more occurrences are extracted. Then, word sequences of length two that are headed by a previously extracted word are extracted, provided they appear at least twice in the corpus. In the same way, a word sequence of length i + 1 is taken into consideration only when its prefix of length i has been extracted and w appears at least twice in the corpus. This process is repeated until no new word sequences are obtained. The subsequent steps handle only those extracted word sequences. It would be natural to set a maximum length for the candidate word sequences, which we really have it be between 5 and 10 in the experiments.

3. A threshold for minimum frequency of occurrence \( f_{\text{min}} \) is decided, and the following process is repeated, every time decrementing the threshold by some extent.

4. For the word sequence occurring more than \( f_{\text{min}} \) times, the numbers of total occurrence and total bilingual co-occurrence are counted. This is done for all the pairs of such Japanese and English word sequences. It is not the case for a pair that already appeared in the Translation Dictionary.

5. For each pair of bilingual word sequences, the following similarity value \( (sim(w_J, w_E)) \) is calculated, where \( w_J \) and \( w_E \) are Japanese and English word sequences, and \( f_J, f_e \) and \( f_{je} \) are the total frequency of \( w_J \) in the Japanese corpus, that of \( w_E \) in the English corpus and the total co-occurrence frequency of \( w_J \) and \( w_E \) appearing in corresponding sentences.

\[
sim(w_J, w_E) = (\log_2 f_{je}) \frac{2f_{je}}{f_J + f_e}
\]

This formula is a modification of the Dice coefficient, weighting their similarity measure by logarithm of the pair's co-occurrence frequency. Only the pairs with their \( sim(w_J, w_E) \) value greater than \( \log_2 f_{\text{min}} \) are considered in this step. The fact that no word sequence occurring less than \( f_{\text{min}} \) times cannot yield greater similarity value than \( \log_2 f_{\text{min}} \) assures that all pairs of word sequences with the occurrence more than \( f_{\text{min}} \) times are surely taken into consideration.

6. The most plausible correspondences are then identified using the similarity values so calculated:

(a) For an English word sequence \( w_E \), let \( W_J = \{w_{J1}, w_{J2}, \ldots, w_{Jn}\} \) be the set of all Japanese word sequences such that \( \sim(w_{Ji}, w_E) \geq \log_2 f_{\text{min}} \). The set is called the candidate set for \( w_E \). For each Japanese word sequence \( w_J \) its candidate set is constructed in the same way.

(b) Of the candidate set \( W_J \) for \( w_E \), if the candidate with the highest similarity value \( (w_{Ji} = \arg \max_{w_j \in W_J} sim(w_{Ji}, w_E)) \) again selects \( w_E \) as the candidate with the highest similarity \( (w_E = \arg \max_{w_{E} \in W_E} sim(w_{Ji}, w_{Em})) \), where \( W_E \) is the candidate set for \( w_{Ji} \), the pair \( (w_{Ji}, w_E) \) is regarded as a translation pair.

7. The approved translation pairs are registered in the Translation Dictionary until no new pair is obtained, then the threshold value \( f_{\text{min}} \) is lowered, and the steps 4 through 6 are repeated until \( f_{\text{min}} \) reaches a predetermined value.

5 Experiments of Translation Pair Extraction

5.1 The settings

We used parallel corpora of three distinct domains: (1) a computer manual (9,792 sentence pairs), (2) a scientific journal (12,200 sentence pairs), and (3) business contract letters (10,016 sentence pairs). All the Japanese and English sentences are aligned and morphologically analyzed\(^1\).

The settings of the experiments are as follows: The maximum length of the extracted word sequences is set at 10. The initial value of \( f_{\text{min}} \) is set at the half of the highest number of occurrences of extracted word sequences and is lowered by dividing by two until it reaches to or under 10, then it is lowered by one in each iteration until 2.

\(^1\) Japanese and English morphological analyzers of Machine Translation System PENSÉE were used. PENSÉE is a trademark of Osaka Gas corporation, OGIS-RI, and Oki Electric Industry Co.,Ltd.
|            | single word          | word seq.          |
|------------|----------------------|--------------------|
|            | total                | occurrence > 2    |
|            | Eng. | Jap. | Eng. | Jap. | Eng. | Jap. |
| Business   | 2,300 | 3,739 | 2,218 | 3,568 | 73,026 | 72,574 |
| Science    | 7,254 | 9,415 | 6,764 | 8,856 | 16,555 | 24,998 |
| Manual     | 3,701 | 4,926 | 3,478 | 4,799 | 32,049 | 38,796 |

Table 2: Numbers of extracted words and word sequences

| threshold | Num. of pairs | correct | near miss | incorrect | correctness (+near) % | accumulative correctness % |
|-----------|---------------|---------|-----------|-----------|------------------------|---------------------------|
| 1151      | 2             | 2       | 0         | 0         | 100(100)               | 100(100)                  |
| 575       | 3             | 3       | 0         | 0         | 100(100)               | 100(100)                  |
| 287       | 4             | 4       | 0         | 0         | 100(100)               | 100(100)                  |
| 143       | 12            | 12      | 0         | 0         | 100(100)               | 100(100)                  |
| 71        | 19            | 18      | 1         | 0         | 94.7(100)              | 97.5(100)                 |
| 35        | 48            | 48      | 0         | 0         | 100(100)               | 98.9(100)                 |
| 17        | 103           | 101     | 2         | 0         | 98.1(100)              | 99.0(100)                 |
| 10        | 164           | 155     | 8         | 1         | 94.5(99.4)             | 96.6(99.7)                |
| 9         | 53            | 51      | 2         | 0         | 96.2(100)              | 96.6(99.8)                |
| 8         | 67            | 63      | 4         | 0         | 94.0(100)              | 96.2(99.8)                |
| 7         | 82            | 75      | 6         | 1         | 91.5(98.8)             | 95.5(99.6)                |
| 6         | 134           | 114     | 20        | 0         | 85.1(100)              | 93.5(99.7)                |
| 5         | 163           | 145     | 15        | 3         | 89.0(98.2)             | 92.6(99.4)                |
| 4         | 318           | 257     | 50        | 11        | 80.8(96.5)             | 89.4(98.6)                |
| 3         | 755           | 502     | 195       | 59        | 66.5(92.2)             | 80.4(96.1)                |
| total     | 1,927         | 1,550   | 302       | 75        | 80.5(96.1)             | --                        |

Table 3: Results of Business Letter

Table 2 summarizes the numbers of word sequences extracted by Step 2. For each corpus the table shows the numbers of distinct content words, those of two or more occurrences, and the numbers of word sequences of two or more occurrences.

5.2 The results

Tables 3, 4 and 5 show the statistics obtained from the experiments. The columns specify the numbers of approved translation pairs. The correctness of the translation pairs are checked by a human inspector. A "near miss" means that the pair is not perfectly correct but some parts of the pair constitute the correct translation.

It is noticeable that the pairs with high frequencies give very accurate translation in the cases of the computer manual and the business letters, whereas the scientific journal does not necessarily give high accuracy to highly frequent pairs. The reason is that the former two corpora are really in a homogeneous domain, while the corpus of scientific journal is a complex of distinct scientific fields. The former two corpora reveal a worse performance with the pairs with low frequency threshold. This is because those corpora frequently contain a number of lengthy fixed expression or particular collocations. One such example is that "p type (silicon)" frequently collocates with "n type (silicon)," making the correspondence uncertain.

The science journal shows a stable accuracy of translation pair extraction. The accuracy exceeds 90% in most of the stages. The reason would be that scientific papers do not repeat fixed expression and the terminologies are used not in a fixed way.

Table 6 summarizes the combination of the length of English and Japanese word sequences. The fraction in each entry shows the number of correct pairs over the number of extracted pairs. This table indicates that translation pairs of lengthy or unbalanced sequences are safely regarded
| threshold | Num. of pairs | correct | near miss | incorrect | correctness (+near) % | accumulative correctness % |
|-----------|---------------|---------|-----------|-----------|------------------------|---------------------------|
| 68        | 1             | 1       | 0         | 0         | 100(100)               | 100(100)                  |
| 34        | 21            | 19      | 1         | 1         | 90.5(95.2)             | 90.9(95.5)                |
| 17        | 69            | 64      | 5         | 0         | 92.3(100)              | 92.3(98.9)                |
| 10        | 142           | 133     | 8         | 1         | 93.7(99.3)             | 93.6(99.1)                |
| 9         | 52            | 49      | 3         | 1         | 94.2(98.1)             | 93.3(97.9)                |
| 8         | 69            | 69      | 0         | 0         | 100(100)               | 94.6(99.2)                |
| 7         | 66            | 63      | 2         | 1         | 95.5(98.5)             | 94.7(99.0)                |
| 6         | 105           | 99      | 6         | 0         | 94.3(100)              | 94.7(99.2)                |
| 5         | 168           | 155     | 12        | 1         | 92.3(98.8)             | 94.1(99.1)                |
| 4         | 292           | 283     | 25        | 4         | 90.1(98.6)             | 92.9(99.0)                |
| 3         | 536           | 494     | 34        | 8         | 92.2(97.2)             | 92.6(98.4)                |
| 2         | 1,307(500)    | (445)   | (46)      | (9)       | 89.0(97.4)             | 91.7(98.1)                |
| total     | 2,828(2,021)  | (1,854) | (129)     | (38)      | 91.7(98.1)             |                           |

Table 4: Results of Science Journal

| threshold | Num. of pairs | correct | near miss | incorrect | correctness (+near) % | accumulative correctness % |
|-----------|---------------|---------|-----------|-----------|------------------------|---------------------------|
| 209       | 1             | 1       | 0         | 0         | 100(100)               | 100(100)                  |
| 104       | 4             | 4       | 0         | 0         | 100(100)               | 100(100)                  |
| 52        | 19            | 19      | 0         | 0         | 100(100)               | 100(100)                  |
| 26        | 55            | 54      | 0         | 1         | 98.1(98.1)             | 98.7(98.7)                |
| 13        | 145           | 140     | 5         | 0         | 96.6(100)              | 97.3(99.6)                |
| 10        | 81            | 76      | 5         | 0         | 93.8(100)              | 96.4(99.7)                |
| 9         | 58            | 55      | 2         | 1         | 94.8(98.3)             | 96.1(99.4)                |
| 8         | 75            | 68      | 5         | 2         | 90.7(93.6)             | 95.2(99.1)                |
| 7         | 106           | 99      | 7         | 0         | 93.4(100)              | 94.9(99.3)                |
| 6         | 126           | 118     | 7         | 1         | 93.7(99.2)             | 94.6(99.3)                |
| 5         | 214           | 198     | 13        | 3         | 92.5(98.6)             | 94.1(99.1)                |
| 4         | 367           | 330     | 26        | 11        | 89.9(97.0)             | 92.9(98.5)                |
| 3         | 629           | 519     | 97        | 13        | 82.5(97.9)             | 89.4(98.3)                |
| 2         | 1,401(500)    | (395)   | (87)      | (18)      | 79.0(96.4)             | 87.2(97.9)                |
| total     | 3,281(2,380)  | (2,076) | (254)     | (50)      | 87.2(97.9)             |                           |

Table 5: Results of Computer Manual

| Business Letters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|------------------|---|---|---|---|---|---|---|---|---|----|
| Letters          | 823/843 | 45/58 | 0/6 | 0/1 | 0 | 0 | 0 | 0 | 0 | 0 |
| of Jap. Seq.     | 32/45 | 401/450 | 17/55 | 1/23 | 0/5 | 0/4 | 0/1 | 0 | 0/1 | 0 |
| Length           | 79/122 | 72/90 | 7/23 | 0/8 | 0/4 | 0 | 0 | 0 | 0 | 0 |
| of Eng. Seq.     | 6/21 | 29/45 | 15/23 | 0/5 | 1/2 | 0 | 0 | 0 | 0/1 | 0/1 |
| Seq.             | 3/10 | 2/13 | 7/14 | 3/10 | 2/3 | 0 | 0/1 | 0/1 | 0/1 | 0/1 |
| total            | 0 | 0/1 | 0/2 | 0 | 0/1 | 0 | 0/1 | 0/1 | 0 | 0/1 |

Table 6: Length Combination of Word Sequences and their Accuracy (Business Letter)
| Japanese | English | Similarity |
|----------|---------|------------|
| 独占実施権 | exclusive license | 4.95 |
| 紛争( )論争(又は)意見 | dispute( ) controversy (or) difference (which may) arise | 4.34 |
| 営業秘密 | trade secret | 3.72 |
| 契約(の)発効日 | effective date (of this) agreement | 3.12 |
| 営業時間 | business hour | 2.92 |
| 特許実用新案商標意匠著作権 | utility model( ) trademark( ) design (or) copyright | 2.81 |
| 確認(付)取消不能信用状 | irrevocable confirm(ed) letter (of) credit | 2.81 |
| 技術製造ノウハウ | technique manufacture know-how | 2.62 |
| 特許( )ノウハウ(又は)技術情報 | patent(s)( ) know-how (or) technical information | 1.06 |
| 出血熱ウイルス | hemorrhage fever virus | 3.19 |
| アクリル酸メチル | methyl acrylate | 3.17 |
| ロスアラモス国立研究所 | Los Alamos national laboratory | 2 |
| n型シリコーン | n type | 1.78 |
| * n型シリコーン | p type | 1.78 |
| カリフォルニア大学デービス校 | university (of) California (at) Davis | 1.58 |
| ワイヤレスネットワーク | wireless network | 1.19 |
| 光ファイバーネットワーク | fiber(-)optic network | 1.19 |
| 出血熱 | hemorrhage fever | 1.14 |
| インターネット | internet | 5.25 |
| インターネットアドレス | internet address | 2.83 |
| 倍精度浮動小数点 | double precision float point | 1.79 |
| インターネットプロトコルIP | internet protocol IP | 1.78 |
| インターネットプロトコル | internet protocol | 1.66 |
| * ホストテーブル | DoD internet | 1.6 |
| ネームトゥアドレスマッピング | name (to) address map (ping) | 1.58 |
| インターネットサービス | internet service | 1.45 |

△ indicates "near miss" and * indicates "incorrect".

Table 7: Samples of Corresponding Word Sequences

as incorrect correspondences.

Tables 7 and 8 list samples of translation pairs extracted from the experiments. Table 7 lists some of typical word sequence pairs. Many of Japanese translation of English technical terms are automatically detected. Table 8 lists the top 30 pairs from the experiment on the business contract letters.

The method is capable of getting interesting translation patterns. For example, "営業秘密" and "営業時間" are found to correspond to "trade secret" and "business hour" respectively. Note that Japanese word "営業" is translated into different English words according to their occurrences with distinct word.

Table 9 shows the recall ratio based on the results of the experiments. The figures show the numbers of words that are included at least one extracted translation pairs. The recall rates are shown in parentheses, which indicates how much proportion of the words with two or more occurrences in the corpora are finally participated in at least one translation pair. The major reason that the recall is not sufficiently high is that we decided to use a rather severe condition on selecting a translation pairs in Step 6 in the algorithm. The condition may be loosen to get better recall ratio though we may lose high precision. We have not yet tested our method with other conditions.
| Freq.Stage 1151 | Japanese | English | Similarity | Pair.Freq. | Jap.Freq. | Eng.Freq. |
|----------------|----------|---------|------------|------------|-----------|-----------|
| 会社           | company  | 10.73   | 3952       | 4081       | 4720      |
| ライセンシー     | licensee | 10.47   | 2436       | 2521       | 2715      |
| Freq.Stage 575 |          |         |            |            |           |           |
| 販売店         | distributor | 9.55   | 1471       | 1562       | 1679      |
| 契約品         | product  | 9.26    | 2511       | 2996       | 3127      |
| 売り手         | seller   | 9.24    | 999        | 1039       | 1116      |
| Freq.Stage 287 |          |         |            |            |           |           |
| 買い手         | buyer    | 8.92    | 940        | 970        | 1112      |
| 当事者         | party    | 8.84    | 1276       | 1394       | 1584      |
| 書面           | writing  | 8.39    | 754        | 860        | 858       |
| 條            | article  | 8.34    | 778        | 837        | 955       |
| Freq.Stage 143 |          |         |            |            |           |           |
| b             | b        | 8.07    | 332        | 345        | 344       |
| a             | a        | 8.01    | 324        | 335        | 340       |
| 與 ABC         | ABC      | 7.99    | 354        | 362        | 388       |
| 情報           | information | 7.87  | 489        | 549        | 561       |
| X Y Z          | XYZ      | 7.77    | 327        | 333        | 370       |
| 特許           | patent   | 7.65    | 455        | 545        | 505       |
| 技術           | technical | 7.64    | 520        | 558        | 670       |
| 権利           | right    | 7.60    | 664        | 869        | 769       |
| 商標           | trademark | 7.50   | 369        | 401        | 438       |
| c             | c        | 7.41    | 218        | 231        | 226       |
| 地域           | territory | 7.26  | 668        | 693        | 1033      |
| 必要           | necessary | 7.26   | 332        | 356        | 410       |
| Freq.Stage 71  |          |         |            |            |           |           |
| 技術 情報      | technical information | 7.08 | 214        | 227        | 241       |
| 受託           | consignee | 6.99  | 225        | 244        | 259       |
| ロイヤルティ    | royalty  | 6.84    | 295        | 377        | 331       |
| 契約 以下       | hereinafter | 6.82  | 198        | 223        | 220       |
| d             | d        | 6.76    | 126        | 130        | 130       |
| 販売           | sale     | 6.75    | 626        | 804        | 920       |
| 獨占           | exclusive | 6.74   | 235        | 278        | 271       |
| 製造           | manufacture | 6.72  | 578        | 930        | 648       |
| 義務           | obligation | 6.59  | 228        | 255        | 287       |

△ indicates "near miss".

Table 8: Sample of Top Correspondences (Business Letter(Best 30))

| Corpus     | English (recall) | Japanese (recall) |
|------------|-----------------|------------------|
| Business   | 867 (39.1%)     | 1,005 (28.2%)    |
| Science    | 2,240 (33.1%)   | 2,359 (26.6%)    |
| Manual     | 1,922 (55.3%)   | 2,224 (46.3%)    |

Table 9: Numbers of words identified
6 Conclusion

A method for obtaining translation dictionary from parallel corpora was proposed, in which not only word-word correspondences but arbitrary length word sequence correspondences are extracted. This work is originally motivated for the purpose of improving the performance of our translation pattern extraction from parallel corpora [Kitamura & Matsumoto 95], in which translation patterns are extracted by syntactically analyzing both Japanese and English sentences and by structurally matching them. Some discrepancy is caused by poor quality of translation dictionary. This is why we tried to pursue a way to obtain better translation dictionary from parallel corpora. We believe that the proposed method gives results of good performance compared with previous related work. The translation pairs obtained through our method are directly usable as the base resource for MT systems based on translation memory [Lehmann 95].

We hope to acquire better translation patterns by combining the current results with our work of structural matching for finding out fine grained correspondence.

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