Acquisition of Phrase–level Bilingual Correspondence using Dependency Structure

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Abstract

This paper describes a method to find phrase–level translation patterns from parallel corpora by applying dependency structure analysis. We use statistical dependency parsers to determine dependency relations between base phrases in a sentence. Our method is tested with a business expression corpus containing 10000 English–Japanese sentence pairs and achieved approximately 90 % accuracy in extracting bilingual correspondences. The result shows that the use of dependency relation helps to acquire interesting translation patterns.

1 Introduction

Since the advent of statistical methods in Machine Translation, the bilingual sentence alignment (Brown et al., 1991) or word alignment (Dagan et al., 1992) have been explored and achieved numerous success over the last decade. In contrast, fewer results are reported in phrase-level correspondence. As word sequences are not translated literally a word for a word, acquiring phrase–level correspondence still remains an important problem to be exploited.

This paper proposes a method to extract phrase–level correspondence from sentence–aligned parallel corpora using statistically probable *dependency relations*, i.e. head-modifier relations in a sentence.

The distinct characteristics of our approach is two-fold. First, our approach uses dependency relations rather than alignment, cognate and/or position heuristics previously applied (Melamed, 1995). Our approach is based on the assumption that the word ordering and positions may not necessarily coincide between the two languages, but the dependency structure between words will be preserved. We believe that dependency relations offer richer linguistic clues (syntactic information) and are effective for language pairs with different word ordering constraints.

Secondly, statistical dependency parsers are used to obtain candidate patterns. Previous methods mostly use rule-based parsers for preprocessing(Matsumoto et al., 1993), (Kitamura and Matsumoto, 1995). The progress in parsing technology are noteworthy, and in particular, various statistical dependency models have been proposed(Collins, 1997), , (Ratnaparkhi, 1997), (Charniak, 2000). It has an advantage over the rule-based counterpart in that it achieves wider coverage, does not need to care for consistency in rule writing, and is robust to domain changes. We conjecture that our approach improves coverage and robustness by use of statistical dependency parsers.

In this paper, we aim to investigate the efficacy of statistically probable dependency structure in finding phrase–level bilingual correspondence. Though our discussion will proceed for English–Japanese phrasal correspondence, the proposed approach is applicable to any pair of languages.

This paper is organised as follows: In the next section, we present the overview of our approach. In Sections 3 and 4, components are elaborated in detail. In Section 5, experiment and results are given. In Section 6, we compare our approach with related works, and finally our findings are concluded in Section 7.

2 Overview of Our Approach

Our approach presupposes a sentence-aligned parallel corpora. The task is divided into two steps: a monolingual step in which candidate patterns are generated by use of dependency relations, and a bilingual step in which these candidate patterns from each language are paired

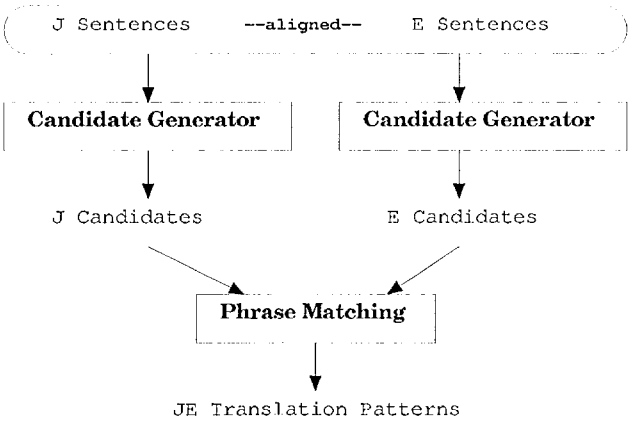


Figure 1: flow of our approach

with their translations. Figure1 shows the flow of our method.

Our primary aim is to investigate the effectiveness of dependency structures in the monolingual candidate generation step. For this reason, the bilingual step borrows the weighted Dice coefficient and greedy determination from (Kitamura and Matsumoto, 1996).

In the following sections, we explain each step in detail.

3 Dependency-Preserving Candidate Patterns

Dependency grammar or related paradigm (Hudson, 1984) focuses on individual words and their relationships. In this framework, every phrase is regarded as consisting of a governor and dependants, where dependants may be optionally classified further. The syntactically dominating word is selected as the governor, with modifiers and complements acting as dependants. Dependency structures are suitably depicted as a directed acyclic graph(DAG), where arrows direct from dependants to governors.

We use a maximum likelihood model proposed in (Fujio and Matsumoto, 1998) where the dependency probability between segments are determined based on its co-occurrence and distance. It has constraints that (a) dependencies do not cross, (b) each segment has at least one governor[1]. Furthermore, the model has an option to allow multiple dependencies whose probabilities are above certain confidence. It is useful for cases where phrasal dependencies cannot be determined correctly using only syntactic information. It has an effect of improving recall by sacrificing precision and may contain more partially correct results useful for our candidate pattern generation.

We apply the following notions as units of segments: For English, (a) a preposition or conjunction is grouped into the succeeding baseNPs[2], (b) auxiliary verbs are grouped into the succeeding main verb. For Japanese, one (or a sequence of) content word(s) optionally followed by function words[3].

Having chunked into suitable segments, sentences are parsed to obtain dependency relations. We have setup the following three models:

1. **best–one model** : uses only the most likely (statistically best) dependency relations. At most one dependency is allowed for each segment.
2. **ambiguous model** : uses dependency relations above the certain confidence score 0.5[4]. Multiple dependencies may be considered for each segment.
3. **adjacent model** : uses only adjacency relations between segments. A segment is adjacent to the previous segment.

In the ambiguous model, we expect that more likely dependency relations will appear frequently given in a large corpus, thereby increasing the correlation score. Hence, ambiguity at parsing phase will hopefully resolved in the following bilingual pairing phase. As for the adjacent model, only chunking and its adjacency are used.

Finally, dependency relations between segments is used to generate candidate patterns.

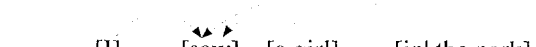
[1]except for the 'root' segment. For Japanese, the 'root' segment is the rightmost segment. For English, the segment that contains the main verb is regarded as the 'root' segment.

[2]a baseNP or 'minimal' NP is non-recursive NP, i.e. none of its child constituents are NPs.

[3]often referred as a *bunsetsu*.

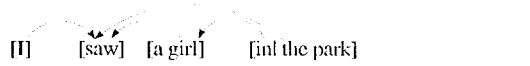
[4]statistically-not-the-best dependencies are also included if

$$\frac{\text{prob(kth} - \text{ranked dependency)}}{\text{prob((k} + 1)\text{th ranked dependency)}} \geq 0.5 \quad (1)$$



size 1) {I, saw, girl, park}
size 2) {I_saw, girl_saw, in-park_saw}
size 3) {I_girl_saw(T), I_in-park_saw(T)}

Figure 2: best–one model



size 1) {I, saw, girl, park}
size 2) {I_saw, girl_saw, in-park_saw, in-park_girl}
size 3) {I_girl_saw(T), I_in-park_saw(T), in-park_girl_saw(L)}

Figure 3: ambiguous model

In this paper, *dependency size* of a candidate pattern designates the number of segments connected through dependency relations. Figures 2, 3, and 4 illustrate examples of English candidate patterns of dependency size 1, 2 and 3 for the proposed dependency models.

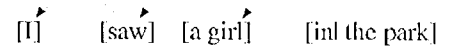
In a dependency-connected candidate pattern, function words of the governor segment is dropped. This is to cope with data sparseness in generated candidate patterns. Moreover, two types of DAGs can be generated from patterns of size 3, and we use DAG-type tags ('L' and 'T') to distinguish their types. We also note that candidate patterns do not necessarily follow the word ordering of original sentences.

The algorithm is as follows:

Input: a corpus, the minimum occurrence threshold in a corpus f_{min} and the dependency size d_w.

For each sentence in a corpus, process the following:

1. Part-of-Speech Tagging
2. Chunking: Rules are written as regular expressions defined over POS word sequences.
3. Dependency Analysis
4. Candidate Pattern Generation: Candidate patterns are generated and stored with their sentence ID. Dependency-connected patterns of less than or equal to the size d_w are extracted.



size 1) {I, saw, girl, park}
size 2) {saw_I, girl_saw, in-park_girl}
size 3) {girl_saw_I(L), in-park_girl_saw(L)}

Figure 4: adjacent model

Output: a hash-table that maps from candidate patterns appearing at least the minimum occurrence f_{min} to their sentence IDs found in the corpus.

4 Phrase-level Correspondence Acquisition

Pairing of candidate patterns is a combinatorial problem and we take the following tactics to reduce the search space. First, our algorithm works in a greedy manner. This means that a translation pair determined in the early stage of the algorithm will never be considered again.

Secondly, filtering process is incorporated. Figure 5 illustrates filtering for a sentence pair "I saw a girl in the park/私は公園の少女を見た". A set of candidate patterns derived from English is depicted on the left, while that from Japanese is depicted on the right. Once a pair "I_girl_saw(T)/私_少女を_見た (T)" is determied as a translation pair, then the algorithm assumes that "私_少女を_見た (T)" will not be paired with candidate patterns related to "I_girl_saw(T)" (cancelled by diagonal lines in Figure 5) for the sentence pair. The operation effectively discards the found pairs and causes recalculation of correlation scores in the proceeding iterations.

As mentioned in Section 2, our correlation score is calculated by the weighted Dice Coefficient defined as:

$$sim(p_e, p_j) = (log_2 f_{ej}) \frac{2f_{ej}}{f_e + f_j}$$

where f_j and f_e are the number of occurrences in Japanese and English corpora respectively and f_{ej} is the number of co-occurrences.

The algorithm is as follows:

Input: hash-tables of candidate patterns for each language, the initial threshold of frequency f_{curr} and the final threshold of frequency f_{min}.

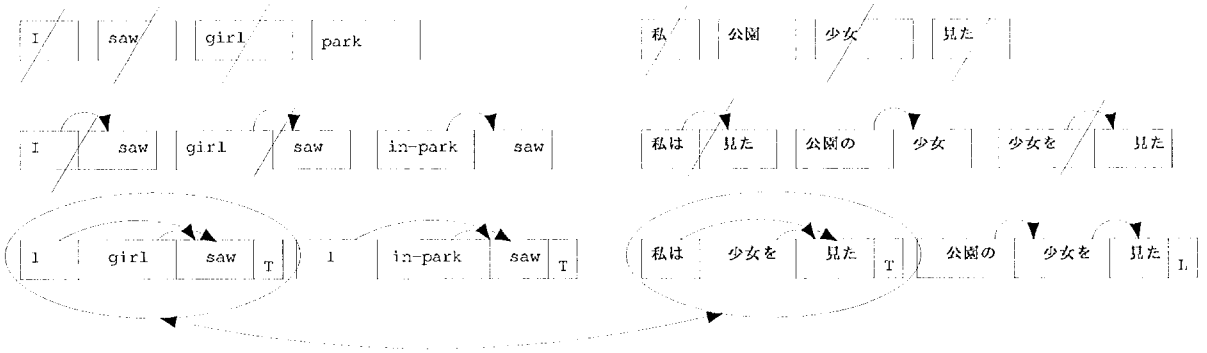


Figure 5: Filtering: word correspondence = (I, 私)(saw, 見た)(girl, 少女)(park, 公園)

Repeat the following until f_{curr} reaches f_{min}.

1. For each pair of English candidate p_e and Japanese candidate p_j appearing at least f_{curr} times, identify the most likely correspondences according to the correlation scores.
   - For an English pattern p_e, obtain the correspondence candidate set PJ = { $p_{j1}, p_{j2}, ..., p_{jn}$ } such that sim(p_e,p_{jk}) > $log_2 f_{min}$ for all k. Similarly, obtain the correspondence candidate set PE for an Japanese pattern p_j
   - Register (p_e,p_j) as a translation pair if p_j = argmax $p_{jk} \in$ PJ sim(p_e, p_{jk}) and p_e = argmax $p_{ek} \in$ PE sim(p_j, p_{ek}). The correlation score of (p_e,p_j) is the highest among PJ for p_e and PE for p_j.
2. Filter out the co-occurrence positions for p_e, p_j, and related candidate patterns.
3. Lower the threshold of frequency if no more pairs are found with f_{curr}.

5 Experiment and Result

5.1 Experimental Setting

We use a business expression corpus (Takubo and Hashimoto, 1995) containing 10000 sentences pairs which are pre-aligned.

NLP tools are summarised in Table 1.

Parameter setting are as follows: dependency size d_w is set to 3. Initially, f_{curr} and f_{min} are set to 100 and 2 respectively. As the algorithm proceeds, f_{curr} is adjusted to half of its previous value if it is greater than 10. Otherwise f_{curr} is decremented by 1. If the number of registered translation pairs is less than 10, then f_{curr} is lowered in the next iteration. All parameters are empirically chosen.

preprocessing	tool	
POS(E)	ChaSen2.0	96% precision
POS(J)	ChaSen2.0	97% precision
chunking(E)	SNPlex1.0	rule-based
chunking(J)	Unit	rule-based
dependency(E)	edep	trial system
dependency(J)	jdep	85–87 % precision

Table 1: NLP tools

5.2 Result

Our approach is evaluated by the metrics defined below:

$$precision = \frac{count(p_l)}{count(p_x)}$$

$$coverage = \frac{\sum_{p_l}(length(p_l) * cofreq(p_l))}{\sum_{p_l} occur(p_l)}$$

Precision measures the correctness of extracted translation pairs, while coverage measures the proportion of correct translation pairs in the parallel corpora. Let X be a pattern. $count(X)$ gives the number of X returned, $occur(X)$ gives the number of occurrences of X in each corpus, $length(X)$ gives the dependency size of X and $cofreq(X)$ gives the number of co-occurrences in the parallel corpora.. p_x means extracted patterns, and of which correct patterns are designated as p_l. p_l means the candidate patterns generated from each side of parallel corpora. Coverage is calculated for English

th	correct	extracted	c / e	precision
25	6	6	100.00	100.00
12	7	7	100.00	95.00
10	6	7	85.71	95.83
9	4	4	100.00	92.30
8	13	13	100.00	97.29
7	10	13	76.92	92.00
6	19	20	95.00	92.85
5	29	29	100.00	94.94
4	67	72	93.05	94.15
3	150	164	91.46	92.83
2	414	461	89.80	91.08
(*2	264	474	55.69	77.93)
total	**725**	**796**	—	**91.08**
(*total	989	1269	—	77.93)

Table 2: Precision: best–one model

th	correct	extracted	c / e	precision
25	6	6	100.00	100.00
12	7	7	100.00	100.00
10	6	7	85.71	95.00
9	4	4	100.00	95.83
8	13	13	100.00	97.29
7	11	13	84.61	94.00
6	18	19	94.73	94.20
5	29	29	100.00	95.91
4	68	73	93.15	94.73
3	118	126	93.65	94.27
2	432	468	91.50	93.07
(*2	256	759	33.72	63.51)
total	**712**	**765**	—	**93.07**
(*total	968	1524	—	63.51)

Table 3: Precision: ambiguous model

and Japanese separately and then thier mean is taken.

Precision for each model is summarised in Tables 2, 3, and 4, while coverage is shown in Table 5. To examine the characteristics of each model, we expand correspondence candidate sets PE and PJ so that patterns[5] with the correlation score $\geq log_2\ 2\ (\geq 1)$ are also considered. These are marked by asterisks "*" in Tables.

Random samples of correct and near–correct translation pairs are shown in Table 6, Table 7 respectively. Extracted translation pairs are matched against the original corpora to restore their word ordering. This restoration is done manually this time, but can be automated with little modification in our algorithm.

[5]i.e. patterns where $f_{ej} = f_e = f_j = f_{min} = 2$

th	correct	extracted	c / e	precision
25	6	6	100.00	100.00
12	7	7	100.00	100.00
10	6	7	85.71	95.00
9	4	4	100.00	95.83
8	13	13	100.00	97.29
7	10	13	84.61	92.00
6	18	19	94.73	92.75
5	29	29	100.00	94.89
4	68	73	93.15	94.15
3	114	126	93.65	92.59
2	419	484	86.57	88.86
(*2	280	496	56.45	76.27)
total	**694**	**781**	—	**88.86**
(*total	974	1277	—	76.27)

Table 4: Precision: adjacent model

model	English	Japanese	coverage
best–one	18.16 %	18.43 %	18.29 %
best–one*	19.12 %	19.59 %	19.13 %
ambiguous	18.63 %	18.82 %	18.72 %
ambiguous*	19.57 %	19.95 %	19.76 %
adjacent	17.74 %	18.03 %	17.88 %
adjacent*	18.69 %	19.20 %	18.94 %

Table 5: Coverage

5.3 Discussion

As we see from Table 2 and 3, the best–one model achieves better precision than the adjacent model. Upon inspecting the results, nearly the same translation patterns are extracted for higher thresholds. This is because our dependency parsers use the distance feature in determining dependency. Consequently, nearer segments are likely to be dependency-related. Experiment data shows that the exact overlaps are found in 9348 out of 14705 (63.55%) candidate patterns for English and 6625 out of 11566 (57.27%) for Japanese.

However, the difference appears when the threshold reaches 3 and patterns such as " not hesitate to contact/遠慮なくご連絡" which is not found in the adjacent model are extracted. Moreover, the best–one model is better in terms of coverage. These results support that the dependency relations appear useful clues than just being linearly ordered.

Comparing the best–one model with the ambiguous model, the ambiguous model achieves a higher precision except for *2. This indicates

English	Japanese	score
thank+you	ありがとう	4.7037
consultations+include	協議_に_は+含める	2.3219
apply+for_the_position	職_に+応募_いたす	2.2157
thank+you+in_advance	前もって+お願い+申し上げる	1.6000
not+hesitate+to_contact	遠慮なく+ご連絡	1.6000
be+enclosed+a_copy	1_部_同封_いたす	1.0566
be_writing+to_let+know	書状_をもって+お知らせ_いたす	1.0566
applications+include	用途_に_は+ある	1.0000
upcoming_borard+of_director_s´_meeting	次回_の+取締役_会	1.0000
will_have+to_cancel	中止_せ_ざる_を+得_なく+なる	1.0000
have+high_hope	大いに+期待_する	1.0000
business+is_expanded	商売_は+発展_する	1.0000
we+have_learned+from_your_fax	貴_ファックス_で+知る	1.0000
leaving+in+about_ten_days	約_10_日_後+出発	1.0000
get+you+in_close_business_relationship	緊密_な+取引_関係_を+築く	1.0000
we+are_inquiring+regarding	に関し+お尋ね_いたす	1.0000
pay+special_attention	特別_の+注意_を+払う	1.0000

Table 6: random samples of correct translation patterns in best-one model. "+" indicates a segment-separator and "_" indicates a morpheme-separator.

English	Japanese
(have_been_pleased)+to_serve+as_thier_main_banker	主力_銀行_と+なる
[be_held]+at_hotel_new_ohtani	ホテル_ニューオータニ_で+開催_する
assets_position+(in_good_shape)	資産_状態
(have_been_placed)+into_our_file	私ども_の+ファイル
(put)+one_month_limit	1_ケ月_の+期限
[passed]+on_past_tuesday	火曜日_に+亡くなら_れる

Table 7: randam samples of near-correct translation patterns where score is 1.000. Segments to be deleted to become correct patterns are embraced by "()". Segments to be added are embraced by "[]"

that the accuracy of dependency parsers currently achieves are insufficient, and therefore, better to expand the possibilities of candidate patterns by allowing redundant dependency relations. As the dependency parsers improve, the best-one model will outperform the ambiguous model. However, as the result of *2 shows, candidates from redundant dependency relations are mostly extracted at the low threshold. The overall trend reveals that redundant relations act as noise at low thresholds, but help to scale up the the correlation score at higher thresholds.

As shown in Table 6, a domain-specific disambiguation sample ("Thank you/ありがとう" vs. "Thank you in advance/前もってお願い申し上げます") is found. As for long-distance dependency-related translation patterns, "は"-case (nominative) and verb patterns (consultations include/協議には含める) are extracted[6]. Other types of long-distance translation patterns such as "で"-case (accusative) and verb patterns (be held at X/Xで開催する) are not extracted even candidate patterns from each corpus are generated.

Generally speaking, acquiring long-distance translation patterns is a hard problem. We still require further investigation examining under what circumstance the dependency relations are really effective. So far, we use relatively "clean" business expression corpora which is a collection of standard usage. However, in the real world setting, more repetitions and variations will be observed. Adjuncts can be placed in less constrained way and the adjacent model cannot deal with if they are apart. In such cases, availablilty of robust dependency parsers become essential, dependency relations plays a key role in finding the long-distance translation patterns.

[6]A typical Japanese sentence follows S-O-V structure, while the English counterpart follows S-V-O structure.

6 Related Works

Smadja et al.(1996) finds rigid and flexible collocations. They first identify candidate collocations in English, and subsequently, find the corresponding French collocations by gradually expanding the candidate word sequences. Kitamura et al.(1996) enumerates word sequences of arbitrary length (n-gram of content words) that appear more than the minimum threshold from English and Japanese and attempts to find the correspondence based on the prepared candidate lists.

Difference from Smadja et al.(1996) is that our method is bi-directional and difference from Kitamura et al. (1996) is that we use dependency relations which leads to "structured" phrasal correspondence as opposed to "flat" adjacent correspondence.

On the other hand, Matsumoto et al.(1993), Kitamura et al.(1995) and Meyers et al.(1996) use dependency structure for structural matching of sentences to acquire translation rules. Their methods employ grammar-based parsers and only work for declarative sentences. Their objectives are complete matching of dependency trees of two languages.

Instead, our method uses statistical dependency parsers and are not restricted to simple sentences for input. Furthermore, we are concerned with partial matching of dependency trees so that the overall robustness and coverage will be improved.

7 Conclusion

In this paper, we propose a method to find phrase–level bilingual correspondence using dependency structure from parallel corpora. We have conducted a preliminary experiment with 10000 business sentence pairs of English and Japanese and achieved approximately 90% precision.

Though a fuller investigation still requires, our finding shows that the dependency relations serve as useful linguistic clues in the task of phrase-level bilingual correspondence acquisition.

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