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Abstract

It is crucial for computers to detect metonymic expressions because sentences including them may have different meanings from literal ones. In previous studies, detecting metonymies has been done mainly by rule-based and statistical approaches. The problem of current metonymy detection is that using syntactic and semantic information may be not enough to detect metonymic expressions. In this study, we propose an approach for detecting them with associative information between words. We evaluated our method by comparing it with a baseline that uses syntactic and semantic information. As a result, our method showed significantly better accuracy (0.84) of judging words as metonymic or literal expressions than that of the baseline.

Keywords: Metonymy; Association Experiment; Associative Concept Dictionaries; Verbs; Nouns

Introduction

Metonymy is a figure of speech, where one item's name represents another which usually has a close relation with the first one. The metonymic relation, as shown in Table 1 (Lakoff & Johnson, 1980; Taniguchi, 2003; Yamanashi, 1988), has different patterns which are classified predominately into two types: spatial contiguity and temporal contiguity (Taniguchi, 2003). Below is a Japanese example for 'Container for Content':

kare-ga isshoubin-wo nomihoshita
(He drank up a 1.8-liter bottle.)

The Japanese sentence above means literally that he drank up the bottle. Of course, it does not mean that he drank or ate the bottle itself, but its content, usually Japanese sake. Japanese sake is generally in a large bottle made from glass, and called *bin* in Japanese. It has a capacity of 1.8 liters, *isshou*. Therefore, the above example sentence where *isshoubin* is a metonymic expression means that he drank up Japanese sake in a 1.8-liter bottle. Since a sentence including metonymy is grammatically correct on a literal level, it is difficult for computers to grasp its true meaning as humans do.

Table 1: Metonymic expressions with spatial contiguity and temporal contiguity.

Metonymic patterns -spatial contiguity-	Examples of sentences (metonymic reading)
Container for Content	*kare-ha glass-wo nonda* 'He drank the glass (liquid).'
Producer for Product	*kare-ha Mahler-wo kiita* 'He listened to Mahler (symphony).'
Controller for Controlled	*Nixon-ga Hanoi-wo bakugekishita* 'Nixon (government) bombed Hanoi.'
Object Used for User	*gakuseifuku-ga aruiteiru* 'The school uniform (student) is walking.'
Material for Product	*kare-ha caffeine-wo nonda* 'He drank caffeine (soft drink).'
Others	*riron-ga sore-wo jisshoushita* 'The theory (proposer) claimed that.'
Metonymic patterns -temporal contiguity-	**Examples of sentences (metonymic reading)**
Result for Cause	*kanojo-ga sekimensuru* 'She is blushing.'(She is ashamed)
Cause for Result	*kare-ga sakazuki-wo katamukeru* 'He is tipping the sake cup.' (He is drinking the Japanese sake)

In English metonymy detection, most previous studies have taken mainly rule-based and statistical approaches. The rule-based approach uses semantic networks and hand-crafted rules to detect metonymies (Bouaud, Bachimont, & Zweigenbaum, 1996; Fass, 1991; Iverson & Helmreich, 1992). The representative work of statistical approach used corpus-based metonymy resolution on location names (Markert & Nissim, 2003). Moreover, by using syntactic, semantic, encyclopedic, or collocation information as machine learning features, some conventional studies for detecting metonymic expressions were suggested (Markert & Nissim, 2007; Nastase & Stube, 2009). Their methods are effective, but they only dealt with metonymies on country names and companies. When considering the variety of metonymic patterns in Table 1, it is desirable to be able to detect various

Table 2: Semantic relations used in experiments.

Semantic relation	Content
Agent	Subject of an action
Object	Object of an action
Source	Source of an action
Goal	Goal or end of an action
Duration	Time or term of an action
Location	Location or space during an action
Tool	Tool or material of an action
Aspect	Aspect, degree or frequency of an action
Reason	Reason or cause of an action
Purpose	Purpose of an action

metonymies. In Japanese, although with small data sets, the manually constructed case frame dictionary and Goi-Taikei—A Japanese Lexicon (Ikehara et al., 1999), which consist of syntactic and semantic information, have been used for detecting various metonymies (Murata, Yamamoto, Kurohashi, Isahara, & Nagao, 2000; Suga & Ishizaki, 2006).

The problem of current metonymy detection is that using syntactic and semantic information may not be enough to detect metonymic expressions because in our daily conversations and readings we understand metonymic expressions in sentences by using associative relations between words unconsciously. As Yamanashi described (Yamanashi, 1987, 1988), metonymic relations relate to psychological association; we consider that computers also need associative information to improve the accuracy of metonymy detection.

By using our associative concept dictionaries for verbs and nouns (hereinafter referred to as Verb-ACD and Noun-ACD, respectively) (Okamoto & Ishizaki, 2001; Teraoka, Okamoto, & Ishizaki, 2010), our previous study proposed an approach to metonymy detection with associative information and showed its effectiveness (Teraoka, Okamoto, & Ishizaki, 2011). In this study, we focus on detecting only metonymic expressions of the spatial contiguity type as our first step, and enhance our approach by using decision tree learning.

ACD Construction

In this section, we describe the Verb-ACD and the Noun-ACD that we use to extract associative information for detecting metonymic expressions.

Verb-ACD

The Verb-ACD (Teraoka et al., 2010) consists of the following three elements: stimulus words, associated words from the stimulus words with semantic relations, and word distances among them. The stimulus words are basic verbs with semantic relations that corresponded to deep cases. We quantify word distance between the stimulus word and the associated one.

Association Experiments To collect associative information on verbs, we conducted large-scale association experiments on the web. The stimulus words were verbs from Japanese elementary school textbooks, and we prioritized 200 of them that were entry words in a basic Japanese dictionary (Morita, 1989). We prepared ten semantic relations shown in Table 2: Agent, Object, Source, Goal, Duration, Location, Tool, Aspect, Reason, and Purpose. The experiment participants were requested to give associated words of the stimulus words with these semantic relations.

Quantification of Word Distances We used the linear programming method to calculate distances between stimulus words and associated ones. As shown in Eq. (1), the distance $D(x,y)$ between the stimulus word x and the associated word y is expressed with the following formulae:

$$D(x,y) = \frac{7}{10} IF(x,y) + \frac{1}{3} S(x,y) \qquad (1)$$

$$\textit{where}\;\; IF(x,y) = \frac{N}{n(x,y)+\delta}, \qquad (2)$$

$$\delta = \frac{N}{10} - 1 (N \geq 10), \qquad (3)$$

$$S(x,y) = \frac{1}{n(x,y)} \sum_{i=1}^{n(x,y)} s_i(x,y). \qquad (4)$$

The distance consists of the inverse of frequency of an associated word $IF(x,y)$ in Eq. (2) and the average of the associated word order $S(x,y)$ in Eq. (4). Each coefficient was obtained by using the Simplex Method. Let N denote the number of participants in the experiments, and $n(x,y)$ denote the number of participants who responded with the associated word y to the stimulus word x. Let δ in Eq. (3) denote a factor which limits $IF(x,y)$ to a certain numerical level when N increases. Let $s(x,y)$ denote the associated word's order of each participant.

Each semantic relation of two words is expressed by each distance where the smaller the distance is, the closer two words are. For example, when a stimulus verb is the Japanese word, *aruku* 'walk' and the semantic relation is Source, one of the associated words is *ie* 'home' of which the distance is 1.38. Meanwhile, the distance between walk and *kaisha* 'office' is 9.92. The relation of these distances thus expresses a degree of association from the verb with the semantic relation.

Currently, there are 345 stimulus verbs in the Verb-ACD and the number of all participants is approximately 1,300. The participants were undergraduates and graduate students of Keio University. Each stimulus verb was presented to 40 participants. There were approximately 135,000 associated words. When all overlapping words were eliminated, there were 30,000 associated words.

Noun-ACD

The Noun-ACD consists also of stimulus words, i.e., nouns, associated words with semantic relations, and word distances among these words (Okamoto & Ishizaki, 2001). Table 3 shows the semantic relations and examples when the stimulus word is a Japanese word *jisho* 'dictionary'. Currently, the number of the stimulus words in the Noun-ACD is 1,100 and

Table 3: Examples of associated words in the Noun-ACD when the stimulus word is 'dictionary'.

Semantic relation	Examples of associated words
Hypernym	*shuppanbutsu* 'Publication', *hon* 'Book'
Hyponym	*waeijisho* 'Japanese-English dictionary'
Part / Material	*midashigo* 'Entry word'
Attribute	*muzukashii* 'Difficult', *yasashii* 'Easy'
Synonym	*jiten* 'Encyclopedia'
Action	*yomu* 'Read', *shiraberu* 'Investigate'
Situation	*toshokan* 'Library', *honya* 'Book store'

the number of participants is 50. The total number of associated words is approximately 280,000. When all of overlapping words are eliminated, the number of associated words is about 64,000.

Proposed Method for Detecting Metonymies

To detect metonymic expressions in sentences, we use associative information between words in the Verb-ACD and the Noun-ACD. Our proposed method extracts attribute values of input sentences and detects metonymic expressions with decision tree learning. We first describe our basic idea, and then, the attributes of decision tree learning.

Basic Idea for Metonymy Detection

Semantic relations between metonymic expressions and their predicates seem to be more unnatural than that of literal expressions and their predicates. Hence, it is natural for humans to associate more literal expressions from predicates than metonymic ones. Our basic idea therefore is that the degree of word distances in the Verb-ACD and the Noun-ACD can express the measures of judging expressions as 'Metonymic' or 'Literal'.

A method based on the basic idea is detecting metonymic expressions with associative information by using relations of two paths of synset nodes in the Japanese WordNet (Isahara, Bond, Uchimoto, Utiyama, & Kanzaki, 2008). One is the path from synsets of associated words to their hypernym synsets. The other is from synsets of each word in a sentence to their hypernym synsets. If there is a shared synset node between these two paths, the word in the sentence is regarded as a literal expression. On the other hand, it is possible to be a metonymic expression if there is no shared synset. Our system outline consists of four steps:

1. **Morphological and Syntactic Analyses.** The system analyzes an input sentence morphologically and syntactically by using MeCab and CaboCha, respectively.

2. **Extraction of Associative Information.** From the results of morphological and syntactic analyses, the system extracts a predicate in the sentence and its modification relations. When the predicate is a verb or a verbal noun followed by *suru*, e.g., *taiho-suru* 'arrest (verb)' where *suru* added to *taiho* 'arrest (noun)', the shortest and the second-shortest associated words from a pair of the predicate verb and a particle corresponding to the semantic relation in Table 2 are extracted from the Verb-ACD. If the sentence has more than one particle, the system extracts associated words from each noun with the particle. If the predicate is anything except a verb, two stimulus words of the noun as an associated word with the semantic relation Attribute in Table 3 are extracted from the Noun-ACD. In the same manner as the case with the predicate verb, these word distances are the shortest and the second-shortest ones between the predicate, i.e., the associated and the stimulus word.

3. **Extraction of Noun Information.** The system extracts synsets and hypernym synsets of all nouns in the sentence from the Japanese WordNet. These hypernym synsets are all synsets which the system obtains from nouns in the sentence to each third upper level for the synset hierarchy. If there are proper nouns in the sentence, it extracts each synset of properties which are from the result of the morphological analysis because the Japanese WordNet does not have enough synsets of proper nouns. For example, if one of the proper nouns in the sentence in Table 1 is *hanoi* 'Hanoi', the system extracts sysnsets and hypernym synsets of *chiiki* 'LOCATION' which is a property from the result of morphological analysis.

4. **Confirmation of Shared Synset.** By comparing synsets and hypernym synsets of the associated words with those of nouns or the properties of proper nouns in the sentence, the system confirms whether a shared synset node is between both paths of synset nodes. If there are one or more shared synsets, the system judges the noun as 'Literal'. On the other hand, if there is no shared synset, the system judges it as 'Metonymic'.

The system thus decides on the correct category, 'Metonymic' or 'Literal', of every noun in input sentences and can detect metonymies with associative information.

Metonymy Detection using Decision Tree Learning

We prepared attributes shown in Table 4 for the decision tree learning. These attributes are all factors obtained in the basic idea.

Semantic_relation represents semantic relations corresponding to particles with nouns in sentences. In addition, one of its values 'Noun' was used when the predicate was not a verb. *Distance_1st_ candidate* and *Distance_2nd_candidate* were the shortest word distance and the second one between the predicate and the associated word, respectively. *Number_A_synset* and *Num_A_hypernym* were the number of synsets of the associated words and the sum of hypernym synsets from the synsets for three upper levels, respectively. *Num_N_synset* and *Num_N_hypernym* were also the number of synsets of nouns in the sentence and the sum of hypernym synsets for three upper levels. *Num_HN_synset* and *Num_HN_hypernym* were the number of synsets of the noun's hypernyms and the sum of hypernym synsets of the

Table 4: Attributes and values with decision tree learning.

Attribute	Description	Value
Semantic_relation	Semantic relations corresponding to particles with nouns in a sentence	Agent, Object, Source, Goal, Location, Tool, Noun
Distance_1st_candidate	The shortest word distance between the predicate and associated words	Continuous
Distance_2nd_candidate	The second shortest word distance between the predicate and associated words	Continuous
Number_A_synset	The number of synsets of associated words	Continuous
Number_A_hypernym	The sum of hypernym synsets from the associated words for three upper levels	Continuous
Number_N_synset	The number of synsets of nouns in a sentence	Continuous
Number_N_hypernym	The sum of hypernym synsets from the nouns for three upper levels	Continuous
Number_HN_synset	The number of synsets of hypernyms of nouns in a sentence	Continuous
Number_HN_hypernym	The sum of hypernym synsets of hypernyms of the nouns in a sentence	Continuous
Match_node	The degree of linked nodes from each synset of the associated words and the nouns in a sentence to a shared synset	None, Near, Middle-Near, Middle, Middle-Far, Far

hypernyms for two upper levels to equalize hypernym levels from initial synsets as above, i.e., three upper levels. Let *Match_node* denote the degree of linked synset nodes from each synset of the associated words and the nouns in the sentence to the shared synset. By using the sum number of linked nodes, this degree was separated to the following six levels: 'None', 'Near', 'Middle-Near', 'Middle', 'Middle-Far', and 'Far'. 'None' means that there was no shared synset, i.e., the noun was judged as 'Metonymic'. 'Near' means that either of the synset of the associated word or that of the noun in the sentence was just the shared synset at least, i.e., the sum of linked nodes was 0 or 1. 'Middle-Near' means that the average of each node was 1, i.e., the sum of linked nodes was 2. 'Middle' means that the sum of linked nodes was 3. 'Middle-Far' means that the average of each node was between 2 and 3. 'Far' means that the average of each node was more than 3, i.e., the sum of linked node was more than 6.

Experiment

To evaluate our method, we prepared a baseline system where the Goi-Taikei—A Japanese Lexicon (Ikehara et al., 1999) was used to automatically detect metonymies. We prepared test sentences with literal and metonymic expressions and evaluated our method by comparing its recall, precision, and F-measure rates with those of the baseline. In this section, we describe the baseline, test sentences, and the evaluation results.

Baseline System

The baseline system consisted of syntactic structures and noun properties in the Goi-Taikei, which was used for detecting metonymies (Murata et al., 2000). It first selects a syntactic type of the predicate using its syntactic information in the Goi-Taikei after morphological and syntactic analyses of an input sentence. It employs the highest priority order of syntactic information in each predicate verb because this order indicates an order of preference in the Goi-taikei. The preference order was defined in order to translate from Japanese to English or from English to Japanese (Shirai, Ooyama, Ikehara, Miyazaki, & Yokoo, 1998). The syntactic information on each verb is a set of syntactic type and noun properties, and expresses that each verb has nouns with a part of speech. The baseline system then obtains nouns in the syntactic information and their properties. These noun properties consist of some nouns and are expressed by the hypernyms and hyponyms in the noun semantic hierarchy. Finally, the system judges the word as 'Metonymic' if each word in the sentence does not belong to the noun's hyponyms in the hierarchy.

Test Sentences

We prepared 90 test sentences which consisted of 45 ones with metonymic expressions and 45 ones with literal expressions. As shown in Table 5, most of the former sentences were extracted from the previous studies (Murata et al., 2000; Yamanashi, 1988). The latter were extracted from newspaper corpora of the Mainichi Newspaper ('93–'95 and '03–'04) and included words used in the metonymic sentences. In 90 test sentences, there were 113 nouns which both our method and the baseline judged as 'Metonymic' or 'Literal'.

Results and Discussion

To judge each noun as 'Metonymic' or 'Literal', we extracted attributes from 90 test sentences and constructed 113 cases. We trained 112 cases, tested the other case with the training data, and repeated this procedure in a round-robin fashion. By running 113 folds, each case was judged as 'Metonymic' and 'Literal'. From Table 6, we can see that our method judged correctly 95 cases and the baseline system did 81 cases correctly. Our method showed higher accuracy (0.84) than that of the baseline. There was significant difference ($p < 0.05$) between them. Here, the statistical difference was determined by McNemar's test. The evaluation measurements

Table 5: Examples of test sentences (in Japanese).

Metonymic sentence (English translation)	Literal sentence (English translation)
isshoubin-wo nonda	*isshoubin-wo saidan-ni oita*
(Someone drank the issho-bottle.)	(He places the issho-bottle on the altar.)
kasetsu-ga genri-wo setsumei-suru	*kankeisha-ga setsumei-shita*
(The hypothesis explains the elements.)	(People involved explained that.)
shirobai-ga ihansha-wo taiho-shita	*keisatsukan-ga hanzaisha-wo taiho-shita*
(The police motorcycle arrested the criminals.)	(The police man arrested the criminals.)
shikisha-ha sono-clarinet-wo waratta	*jibun-wo waratta*
(The conductor laughed at the clarinet.)	(Someone laughed about oneself.)
kao-wo soru	*hige-wo soru*
(Someone shaves own face.)	(Someone shaves a beard.)
atama-wo karu	*tanbo-de ine-wo karu*
(Someone clips own head.)	(Someone mows rice plants in the paddies.)

Table 6: Accuracy in judging whether metonymic expressions or literal meanings. Asterisk indicates statistical significance over baseline. (* $p < 0.05$)

	Baseline	Proposed method
Accuracy	0.72 (81/113)	0.84 (95/113)*

Table 7: Precision, recall, and F-measure rates in detecting metonymic expressions.

	Baseline	Proposed method
Precision	0.63 (31/49)	0.85 (33/39)
Recall	0.69 (31/45)	0.73 (33/45)
F-measure	0.66	0.79

were recall, precision, and F-measure calculated by using the numbers of correct detections above. Our method expressed higher recall (0.73), precision (0.85), and F-measure (0.79) than those of the baseline system as shown in Table 7.

The two main reasons for our method's superiority are as follows. First, there were differences between our method and the baseline in the way that knowledge was used. As described previously, the baseline used the highest priority order of syntactic information in each predicate. The priority order in the Goi-Taikei was defined as preference to translate, so it seemed to express the order of frequency of its usage (Shirai et al., 1998). From these, the baseline system used the highest frequency of syntactical information of the predicates. On the other hand, information on the predicates which our method used was short word distances between them and their associated words in the Verb-ACD and the Noun-ACD. From the results, it seemed to be more suitable to use the associative information of predicates. The second reason is that separating stages of *Match_node* was a good way to detect metonymies. Here, to investigate the detail of our method, we show the result of the decision tree learning in training 113 cases in Figure 1. As shown in the figure, *Match_node* in 'None' or 'Far' was judged as 'Metonymic' and that in 'Near' or 'Middle' was done as 'Literal'. As mentioned previously, 'Far' means that the average of each node is more than 3. There

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Match_node in {None,Far}: Metonymic (32/5)
Match_node in {Near,Middle}: Literal (43/6)
Match_node = Middle-Near:
:...Distance_2nd_candidate <= 2.74: Metonymic (3)
:   Distance_2nd_candidate > 2.74: Literal (8)
Match_node = Middle-Far:
:...Number_S_hypernym <= 19: Literal (22/4)
    Number_S_hypernym > 19: Metonymic (5)
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Figure 1: Result of decision tree learning in 113 cases.

are more synsets of abstract nouns in higher levels hence it is natural to be judged as 'Metonymic' in 'Far' where the matching synset is at higher levels in the mean. On the other hand, it is also natural to be judged as 'Literal' in 'Near' or 'Middle'. From these, the sum of both the synset node from associated words and that from nouns indicates the measures of detecting metonymies.

Given an example of the results, when an input Japanese sentence was *shikisha-ha sono-clarinet-wo waratta* 'The conductor laughed at the clarinet.' in Table 5, our method judged 'clarinet' as 'Metonymic' while the baseline could not. In the Verb-ACD, the associated words whose distances were especially short were *hito* 'human' and *telebi-bangumi* 'TV program'. Therefore, it extracted these associated words, their synsets, and hypernym synsets from Japanese WordNet. It then compared them with 'clarinet' and its synset expressed by music instruments. Since the extracted words and their synsets did not match 'clarinet' and or its synset, the expression was judged as 'Metonymic'. Meanwhile, the baseline extracted syntactic information of the following predicate verb 'laugh' from the Goi-Taikei: "N1 laughs at N2" where noun properties of "N1" and "N2" were *hito* 'human' and *asterisk* 'all properties', respectively. The property of 'clarinet' was *gakki* 'instrument' and belonged to "N2" whose property was *asterisk* 'all properties'. As a result, the baseline system judged 'clarinet' as 'Literal'. In general, we usually understand the meaning 'The conductor laughed at the clarinet player' when we read the sentence. Of course, it is not wrong syntactically that the conductor laughed at the instrument of clarinet, but it is unnatural in daily conversations. Our method was closer to our associations in daily conversations and more appropriate to detect metonymies than the baseline. We therefore conclude that using associative information can improve computer's ability to detect metonymies as humans do.

However, our method incorrectly judged some literal expressions as 'Metonymic'. The reason was that some associated words in the Verb-ACD and those in their synsets in the Japanese WordNet were metonymies. Our method incorrectly judged some metonymic expressions as 'Literal ' because the variety of associated words with the short word distances was sometimes too restricted. This small variety within the group of associated words could have led to a smaller range in the search space of the Japanese WordNet, leading to the tendency to detect too many metonymies.

Summary and Future Work

We used the Verb-ACD and the Japanese WordNet to detect metonymic expressions in sentences with associative information. We found that our method has a higher accuracy of judging 'Metonymic' or 'Literal', recall, precision, and F-measure of detecting metonymies than those of the baseline that only uses syntactic and semantic information.

Future work includes detecting metonymies for the temporal contiguity and constructing a system for interpreting metonymic expressions. We would like to integrate them into our current detection method to improve our analysis of metonymy.

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