Semantic Analysis of Japanese Noun Phrases : A New Approach to Dictionary-Based Understanding

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Abstract

This paper presents a new method of analyzing Japanese noun phrases of the form N_1 *no* N_2. The Japanese postposition *no* roughly corresponds to *of*, but it has much broader usage. The method exploits a definition of N_2 in a dictionary. For example, *rugby no coach* can be interpreted as *a person who teaches technique in rugby*. We illustrate the effectiveness of the method by the analysis of 300 test noun phrases.

1 Introduction

The semantic analysis of Japanese noun phrases of the form N_1 *no* N_2 is one of the difficult problems which cannot be solved by the current efforts of many researchers. Roughly speaking, Japanese noun phrase N_1 *no* N_2 corresponds to English noun phrase N_2 *of* N_1. However, the Japanese postposition *no* has much broader usage than *of* as follows:

watashi 'I' *no kuruma* 'car'	possession
tsukue 'desk' *no ashi* 'leg'	whole-part
gray no seihuku 'uniform'	modification
senmonka 'expert' *no chousa* 'study'	agent
rugby no coach	subject
yakyu 'baseball' *no senshu* 'player'	category
kaze 'cold' *no virus*	result
ryokou 'travel' *no jyunbi* 'preparation'	purpose
toranpu 'card' *no tejina* 'trick'	instrument
...	...

The conventional approach to this problem was to classify semantic relations, such as possession, whole-part, modification, and others. Then, classification rules were crafted by hand, or detected from relation-tagged examples by a machine learning technique (Shimazu et al., 1987; Sumita et al., 1990; Tomiura et al., 1995; Kurohashi et al., 1998).

The problem in such an approach is to set up the semantic relations. For example, the above examples and their classification came from the IPA nominal dictionary (Information-Technology Promotion Agency, Japan, 1996). Is it possible to find clear boundaries among subject, category, result, purpose, instrument, and others? No matter how fine-grained relations we set up, we always encounter phrases which are on the boundary or belong to two or more relations.

This paper proposes a completely different approach to the task, which exploits *semantic role information* of nouns in an ordinary dictionary.

2 Semantic Roles of Nouns

The meaning of a word can be recognized by the relationship with its semantic roles. In the case of verbs, the arguments of the predicates constitute the semantic roles, and a considerable number of studies have been made. For example, the case grammar theory is a semantic valence theory that describes the logical form of a sentence in terms of a predicate and a series of case-labeled arguments such as agent, object, location, source, goal (Fillmore, 1968). Furthermore, a wide-coverage dictionary describing semantic roles of verbs in machine readable form has been constructed by a great deal of labor (Ikehara et al., 1997).

Not only verbs, but also nouns can have semantic roles. For example, *coach* is a coach of *some sport*; *virus* is a virus causing *some disease*. Unlike the case of verbs, no semantic-

Table 1: Semantic relations in N_1 *no* N_2

Relation	Noun Phrase N_1 *no* N_2	Verb Phrase
Semantic-role	*rugby no coach*, *kaze* 'cold' *no virus*, *tsukue* 'desk' *no ashi* 'leg', *ryokou* 'travel' *no jyunbi* 'preparation'	*hon-wo* 'book-ACC' *yomu* 'read'
Agent Possession Belonging	*senmonka* 'expert' *no chousa* 'study' *watashi* 'I' *no kuruma* 'car' *gakkou* 'school' *no sensei* 'teacher'	*kare-ga* 'he-NOM' *yomu* 'read'
Time Place	*aki* 'autumn' *no hatake* 'field' *Kyoto no mise* 'store'	*3ji-ni* 'at 3 o'clock' *yomu* 'read' *heya-de* 'in room' *yomu* 'read'
Modification	*gray no seihuku* 'uniform' *huzoku* 'attached' *no neji* 'screw' *ki* 'wooden' *no hako* 'box'	*isoide* 'hurriedly' *yomu* 'read'
Complement	*kimono no jyosei* 'lady' *nobel-sho* 'Nobel prize' *no kisetsu* 'season'	

role dictionary for nouns has been constructed so far. However, in many cases, semantic roles of nouns are described in an ordinary dictionary for human being. For example, a Japanese dictionary for children, *Reikai Shougaku Kokugojiten* (abbreviated to RSK) (Tadika, 1997), gives the definition of the word *coach* and *virus* as follows[1]:

coach a person who teaches technique in some sport

virus a living thing even smaller than bacteria which causes infectious disease like influenza

If an NLP system can utilize these definitions as they are, we do not need to take the trouble in constructing a semantic-role dictionary for nouns in the special format for machine-use.

3 Interpretation of N_1 *no* N_2 using a Dictionary

Semantic-role information of nouns in an ordinary dictionary can be utilized to solve the difficult problem in the semantic analysis of N_1 *no* N_2 phrases. In other words, we can say the problem disappears.

For example, *rugby no coach* can be interpreted by the definition of *coach* as follows: the dictionary describes that the noun *coach* has an semantic role of *sport*, and the phrase *rugby no coach* specifies that the *sport* is *rugby*. That is, the interpretation of the phrase can be regarded as matching *rugby* in the phrase to *some sport* in the *coach* definition. Furthermore, based on this interpretation, we can paraphrase *rugby no coach* into *a person who teaches technique in rugby*, by replacing *some sport* in the definition with *rugby*.

Kaze 'cold' *no virus* is also easily interpreted based on the definition of *virus*, linking *kaze* 'cold' to *infectious disease*.

Such a dictionary-based method can handle interpretation of most phrases where conventional classification-based analysis failed. As a result, we can arrange the diversity of N_1 *no* N_2 senses simply as in Table 1.

The *semantic-role* relation is a relation that N_1 fills in an semantic role of N_2. When N_2 is an action noun, an object-action relation is also regarded as a semantic-role relation.

On the other hand, in the *agent*, *possession* and *belonging* relations, N_1 and N_2 have a weaker relationship. In theory, any action can be done by anyone (my study, his reading, etc.);

[1]Although our method handles Japanese noun phrases by using Japanese definition sentences, in this paper we use their English translations for the explanation. In some sense, the essential point of our method is language-independent.

anything can be possessed by anyone (my pen, his feeling, etc.); and anyone can belong to any organization (I belong to a university, he belongs to any community, etc.).

The difference between the semantic-role relation and the agent, possession, belonging relations can correspond to the difference between the agent and the object of verbs. In general, the object has a stronger relationship with a verb than the agent, which leads several asymmetrical linguistic phenomena.

The *time* and *place* relations have much clearer correspondence to optional cases for verbs. A *modification* relation is also parallel to modifiers for verbs. If a phrase has a modification relation, it can be paraphrased into N_2 *is* N_1, like *gray no seihuku* 'uniform' is paraphrased into *seihuku* 'uniform' *is gray*.

The last relation, the *complement* relation is the most difficult to interpret. The relation between N_1 and N_2 does not come from N_1's semantic roles, or it is not so weak as the other relations. For example, *kimono no jyosei* 'lady' means a lady wearing a kimono, and *nobel-sho* 'Nobel prize' *no kisetsu* 'season' means a season when the Nobel prizes are awarded. Since automatic interpretation of the complement relation is much more difficult than that of other relations, it is beyond the scope of this paper.

4 Analysis Method

Once we can arrange the diversity of N_1 *no* N_2 senses as in Table 1, their analysis becomes very simple, consisting of the following two modules:

1. Dictionary-based analysis (abbreviated to DBA hereafter) for semantic-role relations.
2. Semantic feature-based analysis (abbreviated to SBA hereafter) for some semantic-role relations and all other relations.

After briefly introducing resources employed, we explain the algorithm of the two analyses.

4.1 Resources

4.1.1 RSK

RSK (Reikai Shougaku Kokugojiten), a Japanese dictionary for children, is used to find semantic roles of nouns in DBA. The reason why we use a dictionary for children is that, generally speaking, definition sentences of such a dictionary are described by basic words, which helps the system finding links between N_1 and a semantic role of a head word.

All definition sentences in RSK were analyzed by JUMAN, a Japanese morphological analyzer, and KNP, a Japanese syntactic and case analyzer (Kurohashi and Nagao, 1994; Kurohashi and Nagao, 1998). Then, a genus word for a head word, like *a person* for *coach* were detected in the definition sentences by simple rules: in a Japanese definition sentence, the last word is a genus word in almost all cases; if there is a noun coordination at the end, all of those nouns are regarded as genus words.

4.1.2 NTT Semantic Feature Dictionary

NTT Communication Science Laboratories (NTT CS Lab) constructed a semantic feature tree, whose 3,000 nodes are semantic features, and a nominal dictionary containing about 300,000 nouns, each of which is given one or more appropriate semantic features. Figure 1 shows the upper levels of the semantic feature tree.

SBA uses the dictionary to specify conditions of rules. DBA also uses the dictionary to calculate the similarity between two words. Suppose the word X and Y have a semantic feature S_X and S_Y, respectively, their depth is d_X and d_Y in the semantic tree, and the depth of their lowest (most specific) common node is d_C, the similarity between X and Y, $sim(X, Y)$, is calculated as follows:

$$sim(X, Y) = (d_C \times 2)/(d_X + d_Y).$$

If S_X and S_Y are the same, the similarity is 1.0, the maximum score based on this criteria.

4.1.3 NTT Verb Case Frame Dictionary

NTT CS Lab also constructed a case frame dictionary for 6,000 verbs, using the semantic features described above. For example, a case frame of the verb *kakou-suru* (process) is as follows:

N_1(AGENT)-*ga* N_2(CONCRETE)-*wo* *kakou-suru*

'N_1 process N_2'

where *ga* and *wo* are Japanese nominative and accusative case markers. The frame describes

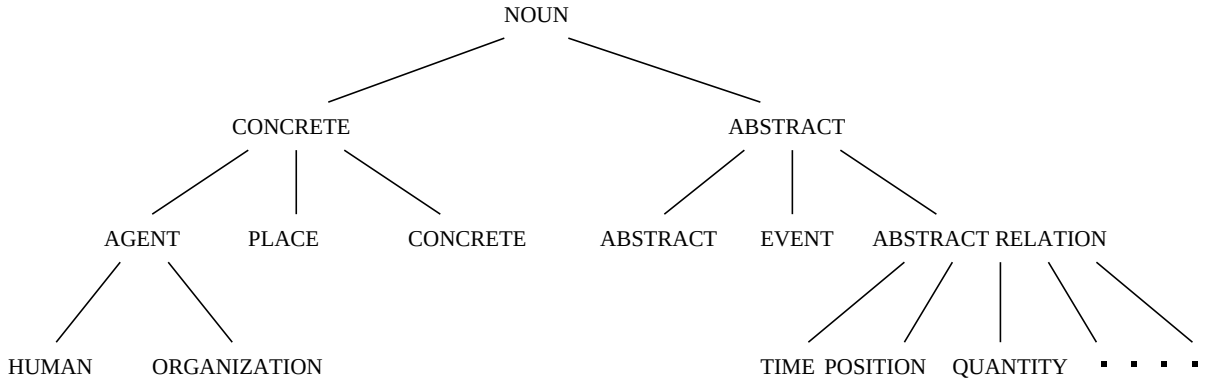

Figure 1: The upper levels of NTT Semantic Feature Dictionary.

that the verb *kakou-suru* takes two cases, nouns of AGENT semantic feature can fill the *ga*-case slot and nouns of CONCRETE semantic feature can fill the *wo*-case slot. KNP utilizes the case frame dictionary for the case analysis.

4.2 Algorithm

Given an input phrase N_1 *no* N_2, both DBA and SBA are applied to the input, and then the two analyses are integrated.

4.2.1 Dictionary-based Analysis

Dictionary based-Analysis (DBA) tries to find a correspondence between N_1 and a semantic role of N_2 by utilizing RSK, by the following process:

1. Look up N_2 in RSK and obtain the definition sentences of N_2.
2. For each word w in the definition sentences other than the genus words, do the following steps:
   - 2.1. When w is a noun which shows a semantic role explicitly, like *kotogara* 'thing', *monogoto* 'matter', *nanika* 'something', and N_1 does not have a semantic feature of HUMAN or TIME, give 0.9 to their correspondence[2].
   - 2.2. When w is other noun, calculate the similarity between N_1 and w by using NTT Semantic Feature Dictionary (as described in Section 4.1.2), and give the similarity score to their correspondence.
   - 2.3. When w is a verb, it has a vacant case slot, and the semantic constraint for the slot meets the semantic feature of N_1, give 0.5 to their correspondence.
3. If we could not find a correspondence with 0.6 or more score by the step 2, look up the genus word in the RSK, obtain definition sentences of it, and repeat the step 2 again. (The looking up of a genus word is done only once.)
4. Finally, if the best correspondence score is 0.5 or more, DBA outputs the best correspondence, which can be a semantic-role relation of the input; if not, DBA outputs nothing.

For example, the input *rugby no coach* is analyzed as follows (figures attached to words indicate the similarity scores; the underlined score is the best):

(1) *rugby no coach*

coach a person who teaches technique $_{0.21}$ in some $\underline{\text{sport}}_{1.0}$

Rugby, *technique* and *sport* have the semantic feature SPORT, METHOD and SPORT respectively in NTT Semantic Feature Dictionary. The lowest common node between SPORT and METHOD is ABSTRACT, and based on these semantic features, the similarity between *rugby* and *technique* is calculated as 0.21. On the other hand,

[2]For the present, parameters in the algorithm were given empirically, not optimized by a learning method.

the similarity between *rugby* and *sport* is calculated as 1.0, since they have the same semantic feature. The case analysis finds that all case slots of *teach* are filled in the definition sentence. As a result, DBA outputs the correspondence between *rugby* and *sport* as a possible semantic-role relation of the input.

On the other hand, *bunsho* 'writings' *no tatsujin* 'expert' is an example that N_1 corresponds to a vacant case slot of the predicate *outstanding*:

(2) *bunshou* 'writings' *no tatsujin* 'expert'

expert a person being outstanding (at $\underline{\phi_{0.50}}$)

Puroresu 'pro wrestling' *no chukei* 'relay' is an example that the looking up of a genus word *broadcast* leads to the correct analysis:

(3) *puroresu* 'pro wrestling' *no chukei* 'relay'

relay a relay broadcast

broadcast a radio$_{0.0}$ or television$_{0.0}$ presentation of news$_{0.48}$, $\underline{\text{entertainment}_{0.87}}$, music$_{0.80}$ and others

4.2.2 Semantic Feature-based Analysis

Since diverse relations in N_1 no N_2 are handled by DBA, the remaining relations can be detected by simple rules checking the semantic features of N_1 and/or N_2.

The following rules are applied one by one to the input phrase. Once the input phrase meets a condition, SBA outputs the relation in the rule, and the subsequent rules are not applied any more.

1. N_1:HUMAN, N_2:RELATIVE → semantic-role(relative)
   e.g. *kare* 'he' *no oba* 'aunt'
2. N_1:HUMAN, N_2:PERSONAL_RELATION → semantic-role(personal relation)
   e.g. *kare* 'he' *no tomodachi* 'friend'
3. N_1:HUMAN, N_2:HUMAN → modification(apposition)
   e.g. *gakusei* 'student' *no kare* 'he'
4. N_1:ORGANIZATION, N_2:HUMAN → belonging
   e.g. *gakkou* 'school' *no sensei* 'teacher'
5. N_1:AGENT, N_2:EVENT → agent
   e.g. *senmonka* 'expert' *no chousa* 'study'
6. N_1:MATERIAL, N_2:CONCRETE → modification(material)
   e.g. *ki* 'wood' *no hako* 'box'
7. N_1:TIME, N_2:∗ [3] → time
   e.g. *aki* 'autumn' *no hatake* 'field'
8. N_1:COLOR, QUANTITY, or FIGURE, N_2:∗ → modification
   e.g. *gray no seihuku* 'uniform'
9. N_1:∗, N_2:QUANTITY → semantic-role(attribute)
   e.g. *hei* 'wall' *no takasa* 'height'
10. N_1:∗, N_2:POSITION → semantic-role(position)
    e.g. *tsukue* 'desk' *no migi* 'right'
11. N_1:AGENT, N_2:∗ → possession
    e.g. *watashi* 'I' *no kuruma* 'car'
12. N_1:PLACE or POSITION, N_2:∗ → place
    e.g. *Kyoto no mise* 'store'

The rules 1, 2, 9 and 10 are for certain semantic-role relation. We use these rules because these relations can be analyzed more accurately by using explicit semantic features, rather than based on a dictionary.

4.2.3 Integration of Two Analyses

Usually, either DBA or SBA outputs some relation. In rare cases, neither analysis outputs any relation, which means analysis failure. When both DBA and SBA output some relations, the results are integrated as follows (basically, if the output of the one analysis is more reliable, the output of the other analysis is discarded):

If a semantic-role relation is detected by SBA, discard the output from DBA.

Else if the correspondence of 0.95 or more score is detected by DBA, discard the output from SBA.

Else if some relation is detected by SBA, discard the output from DBA if the correspondence score is 0.8 or less.

In the case of the following example, *rojin* 'old person' *no shozo* 'portrait', both analyses were accepted by the above criteria.

[3] '∗' meets any noun.

Table 2: Experimental results of N_1 *no* N_2 analysis.

Relation (R)	Correct	R is correct, but the detected correspondence was incorrect	R was detected, but incorrect	R was not detected, though R is possibly correct
Semantic-role (DBA)	137	19	21	19
Semantic-role (SBA)	15	—	2	0
Agent	10	—	1	2
Possession	32	—	7	0
Belonging	12	—	1	2
Time	20	—	1	0
Place	23	—	7	2
Modification	20	—	3	21

(4) *rojin* 'old person' *no shozo* 'portrait'

DBA :

portrait a painting$_{0.17}$ or photograph$_{0.17}$ of a face$_{0.18}$ or figure$_{0.0}$ of real person$_{0.84}$

SBA : N_1:AGENT, N_2:$*$ $\rightarrow$ possession

DBA interpreted the phrase as a portrait on which an old person was painted; SBA detected the possession relation which means an old person possesses a portrait. One of these interpretations would be preferred depending on context, but this is a perfect analysis expected for N_1 *no* N_2 analysis.

5 Experiment and Discussion

5.1 Experimental Evaluation

We have collected 300 test N_1 *no* N_2 phrases from EDR dictionary (Japan Electronic Dictionary Research Institute Ltd., 1995), IPA dictionary (Information-Technology Promotion Agency, Japan, 1996), and literatures on N_1 *no* N_2 phrases, paying attention so that they had enough diversity in their relations. Then, we analyzed the test phrases by our system, and checked the analysis results by hand.

Table 2 shows the reasonably good result both of DBA and SBA. The precision of DBA, the ratio of correct analyses to detected analyses, was 77% (=137/(137+19+21)); the recall of DBA, the ratio of correct analyses to potential semantic-role relations, was 78% (=137/(137+19+19)). The result of SBA is also good, excepting modification relation.

Some phrases were given two or more relations. On average, 1.1 relations were given to one phrase. The ratio that at least one correct relation was detected was 81% (=242/300); the ratio that all possibly correct relations were detected and no incorrect relation was detected was 73% (=219/300).

5.2 Discussion of Correct Analysis

The success ratio above was reasonably good, but we would like to emphasize many interesting and promising examples in the analysis results.

(5) *mado* 'window' *no curtain* 'curtain'

curtain a hanging cloth that can be drawn to cover a window$_{1.0}$ in a room$_{0.83}$, to divide a room$_{0.83}$, etc.

(6) *osetsuma* 'living room' *no curtain* 'curtain'

curtain a hanging cloth that can be drawn to cover a window$_{0.82}$ in a room$_{1.0}$, to divide a room$_{1.0}$, etc.

(7) *oya* 'parent' *no isan* 'legacy'

lagacy property left on the death of the owner$_{0.84}$

Mado 'window' *no curtain* must embarrass conventional classification-based methods; it might be place, whole-part, purpose, or some other relation like being close. However, DBA can clearly explain the relation. *Osetuma* 'living room' *no curtain* is another interestingly analyzed phrase. DBA not only interprets it in a simple sense, but also provides us with more interesting information that a curtain might be being used for partition in the living room.

The analysis result of *oya* 'parent' *no isan* 'legacy' is also interesting. Again, not only the correct analysis, but also additional information was given by DBA. That is, the analysis result tells us that the parent died. Such information would facilitate intelligent peformance in a dialogue system analyzing:

User : I bought a brand-new car by the legacy from my parent.

System : Oh, when did your parent die? I didn't know that.

By examining these analysis results, we can conclude that the dictionary-based understanding approach can provide us with much richer information than the conventional classification-based approaches.

5.3 Discussion of Incorrect Analysis

It is possible to classify some of the causes of incorrect analyses arising from our method.

One problem is that a definition sentence does not always describe well the semantic roles as follows:

(8) *shiire* 'stocking' *no saikaku* 'resoucefulness'
resoucefulness the ability to use one's head$_{0.18}$ cleverly

Saikaku 'resourcefulness' can be the ability for some task, but the definition says nothing about that. On the other hand, the definition of *sainou* 'talent' is clearer about the semantic role as shown below. Concequently, *shiire* 'stocking' *no sainou* 'talent' can be interpretted correctly by DBA.

(9) *shiire* 'stocking' *no sainou* 'talent'
talent power and skill, esp. to do something$_{0.90}$

This represents an elementary problem of our method. Out of 175 phrases which should be interpreted as semantic-role relation based on the dictionary, 13 were not analyzed correctly because of this type of problem.

However, such a problem can be solved by revising the definition sentences, of course in natural language. This is a humanly reasonable task, very different from the conventional approach where the classification should be reconsidered, or the classification rules should be modified.

Another problem is that sometimes the similarity calculated by NTT semantic feature dictionary is not high enough to correspond as follows:

(10) *ume* 'ume flowers' *no meisho* 'famous place'
famous place a place being famous for scenery$_{0.20}$, etc.

In some cases the structure of NTT semantic feature dictionary is questionable; in some cases a definition sentence is too rigid; in other cases an input phrase is a bit metaphorical.

As for SBA, most relations can be detected well by simple rules. However, it is not possible to detect a modification relation accurately only by using NTT semantic feature dictionary, because modifier and non-modifier nouns are often mixed in the same semantic feature category. Other proper resource should be incorporated; one possibility is to use the dictionary definition of N_1.

6 Related Work

From the view point of semantic roles of nouns, there have been several related research conducts: the mental space theory is discussing the functional behavior of nouns (Fauconnier, 1985); the generative lexicon theory accounts for the problem of creative word senses based on the qualia structure of a word (Pustejovsky, 1995); Dahl et al. (1987) and Macleod et al. (1997) discussed the treatment of nominalizations. Compared with these studies, the point of this paper is that an ordinary dictionary can be a useful resource of semantic roles of nouns.

Our approach using an ordinary dictionary is similar to the approach used to creat MindNet (Richardson et al., 1998). However, the semanitc analysis of noun phrases is a much more specialized and suitable application of utilizing dictionary entries.

7 Conclusion

The paper proposed a method of analyzing Japanese N_1 *no* N_2 phrases based on a dictionary, interpreting obscure phrases very clearly.

The method can be applied to the analysis of compound nouns, like *baseball player*. Roughly speaking, the semantic diversity in compound nouns is a subset of that in N_1 *no* N_2 phrases. Furthermore, the method must be applicable to

the analysis of English noun phrases. The translated explanation in the paper naturally indicates the possibility.

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