

# Anaphora Resolution of Japanese Zero Pronouns with Deictic Reference

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## Abstract

This paper proposes a method to resolve the reference of deictic Japanese zero pronouns which can be implemented in a practical machine translation system. This method focuses on semantic and pragmatic constraints such as semantic constraints on cases, modal expressions, verbal semantic attributes and conjunctions to determine the deictic reference of Japanese zero pronouns. This method is highly effective because the volume of knowledge that must be prepared beforehand is not very large and its precision of resolution is good. This method was implemented in the Japanese-to-English machine translation system, ALT-J/E. According to a window test for 175 zero pronouns with deictic referent in a sentence set for the evaluation of Japanese-to-English machine translation systems, all of zero pronouns could be resolved consistently and correctly.

## 1 Introduction

In all natural language, elements that can be easily deduced by the reader are frequently omitted from expressions in texts (Kuno, 1978). This phenomenon causes considerable problems in natural language processing systems. For example in a machine translation system, the system needs to recognize that elements which are not present in the source language, may become mandatory elements in the target language. In particular, the subject and object are often omitted in Japanese; whereas they are often mandatory in English. Thus, in Japanese-to-English machine translation systems, it is necessary to identify case elements omitted from the original Japanese (these are referred to as “zero pronouns”) for their translation into English expressions.

Several methods have been proposed with regard to this problem (Kameyama, 1986) (Walker et al., 1990) (Yoshimoto, 1988) (Dousaka, 1994).

When considering the application of these methods to a practical machine translation system for which the translation target area can not be limited, it is not possible to apply them directly, both because their precision of resolution is low as they only use limited information, and because the volume of knowledge that must be prepared beforehand is so large.

The zero pronouns that must be resolved by a machine translation system can be classified into 3 types; (a) zero pronouns with antecedents within the same sentence (intrasentential), (b) zero pronouns with antecedents elsewhere in the text (intersentential) and (c) zero pronouns with deictic reference (extrasentential). Regarding type (b), Nakaiwa and Ikehara (1992) proposed a method to determine the intersentential antecedents using verbal semantic attributes. The rules used in this method are independent of the field of the source text. Therefore, anaphora resolution may be conducted with a relatively small volume of knowledge, making the proposed method very suitable for machine translation systems. Furthermore, for type (a), Nakaiwa and Ikehara(1995) proposed a method to determine the intrasentential antecedents of Japanese zero pronouns using semantic constraints such as verbal semantic attributes and pragmatic constraints such as types of conjunctions and modal expressions.

In this paper, we propose a widely applicable method to determine the deictic referents of Japanese zero pronouns (type (c)) using not only semantic constraints to the cases but also further semantic constraints such as verbal semantic attributes and pragmatic constraints such as modal expressions and types of conjunctions.

## 2 Appearance of Zero Pronouns in Japanese Texts

In order to understand the distribution of zero pronouns with antecedents that do not appear in the text, in this section, we examine which zero pronouns must be resolved and where their antecedents appear, using a test set designed to evaluate the performance of Japanese-to-English ma-

chine translation systems (Ikehara et al., 1994). The results of the examination of zero pronouns and their referential elements in the functional test sentence set (3718 sentences) are shown in Table 1. There were a total of 512 zero pronouns in 463 sentences. The location of referential elements can be divided into 2 kinds: those expressed in the same sentence, and those not expressed in the same sentence. The latter were further classified into 6 kinds.

- The zero pronoun is not translated because the passive voice is used.
- The referent is the writer or speaker, *I* or a group, *we*.
- The referent is the reader or hearer, *you*.
- The referent is human but it is not known who the human is.
- The zero pronoun should be translated as it.
- The referent is another specific element.

According to this study of the functional test sentence set, in 373 out of 512 instances (73%) the antecedent was not expressed in the sentence. Zero pronouns could be left unexpressed by converting the translation to the passive voice in 173 instances (34%). The other zero pronouns, 200 instances (39%), referred to antecedents that did not appear in the sentence. In 69 out of the 200 instances (13%) zero pronouns were the subject of the sentence and referred to the writer or speaker *I* or a group *we*. Further examination revealed that only in these 69 instances did the verb that governed them express some modality such as *-shitai* ‘- want to -’ or *-shiyoubi* ‘Let us -’ or the verbs were *omou* ‘think’ and other such words indicating ‘THINKING ACTION’. Furthermore, zero pronouns that were the subjects and that referred to the reader or hearer *you*, amounted to 28 out of the 200 instances (5%). In these 28 instances, the verbs that governed these zero pronouns expressed the modalities of *-subekida* ‘should’ or *-sitchanaranai* ‘must not’. Similarly, modalities and verb types can be used to identify *it* or the ‘unknown human’. This type of zero pronoun can be resolved by deducing their referents using modality or categorized verbal semantic attributes.

### 3 Deictic Resolution of Japanese Zero Pronouns

Based on the results shown in section 2, we propose a method to resolve Japanese zero pronouns whose antecedents do not appear in the texts.

#### 3.1 Deictic Resolution using Semantic Constraints on Cases

To resolve Japanese zero pronouns whose antecedents do not appear within the texts, it is possible to use the semantic constraints on verbs’ case

Table 1: Distribution of zero pronouns and their referential elements

Loc. of zero pron.	Loc. of ‘referential elements’						Total		
	Intra-sentential	Deictic							
		Psvce	I we	you	hu-man	it		mi-sc	
<i>ha</i>	1	5	0	0	0	2	0	8	
<i>ga</i>	128	166	69	28	25	50	3	469	
<i>o</i>	8	0	0	0	0	11	0	19	
<i>ni</i>	1	2	2	5	0	0	2	12	
misc	1	0	1	1	0	1	0	4	
Total	139	373							512

elements to deduce likely referents. The semantic information used to estimate supplementing elements is similar to the constraints on cases used for selecting the transfer patterns in a machine translation system. Figure 1 shows an example of a transfer pattern in a Japanese-to-English machine translation system for the Japanese verb *ikimasu* ‘go’. Figure 1 shows how, if the Japanese verb is *ikimasu* ‘go’ and the noun phrase with a *ga* particle, which shows a subject, has the semantic attribute SUBJECT, VEHICLES OR ANIMALS, then the verb should be translated as ‘go’. In this pattern, if the subject N1 becomes a zero pronoun, the system tries to estimate the referent using semantic constraints. But, in this case, it is impossible to estimate the referent as one type, because there are three kinds of semantic constraints. In the transfer pattern, the semantic constraints are left unfulfilled if they are not used in selecting the appropriate translation. So, this method frequently poses difficulties in pinpointing elements to be estimated.

According to the results that were examined in section 2, this type of zero pronoun can be resolved by deducing their referents not only using semantic constraints to the cases but also using modality or categorized verbal semantic attributes. For example, in this case, it is effective to determine the referents corresponding to ‘I’ using the verbal semantic attributes of the pattern, N1’S PHYSICAL TRANSFER and the polite expression *-masu*.

N1(SUBJECTS, VEHICLES OR ANIMALS)-*ga*    *iki-masu*  
N1-SUBJ    go-POLITE  
⇒ N1 go.

Figure 1: Japanese-to-English transfer dictionary

#### 3.2 Deictic Resolution using Semantic and Pragmatic Constraints

According to the analysis of the results shown in section 2, we found that modal expressions and verbal semantic attributes are useful in determining the deictic referents of Japanese zero pronouns. Also, we can estimate the types of conjunctions that are effective in determining the ref-

crents in a complex sentence. In this section, we examine three kinds of semantic and pragmatic constraints, modal expressions, verbal semantic attributes and conjunctions.

### 3.2.1 Constraints Based on Modal Expressions

Modal expressions in Japanese are expected to be the most powerful constraints for estimating deictic reference. For example, in the case of zero pronouns in *ga*-cases 'subject', the referent becomes the writer or speaker, *I* or a group, *we* if the sentence has the modal expressions, *-sitai* ' $\phi$  want to -' HOPE or *-sitchosii* ' $\phi$  want  $\phi$  to -' CAUSATIVE HOPE; the referent becomes the reader or hearer, *you* if the sentence has the modal expressions, *-siteha-ikenai* ' $\phi$  must not -' PROHIBIT or *-subekida* ' $\phi$  should -' OBLIGATION. If there are no referent candidates found within the surrounding text, the referents can be determined using the previous constraints based on modal expressions.

### 3.2.2 Constraints based on Verbal Semantic Attributes

Constraints based on verbal semantic attributes can be divided into the following two types:

(1) **Constraints based on the types of verbs**  
 'Give and take' expressions such as the verbs *morau* 'get' and *yarau* 'give' and transfer expressions such as the verbs *iku* 'go' and *kuru* 'come' can determine the referents of zero pronouns without modal expressions. For example, if the *ga*-case (subject) of the sentence whose verb is *morau* 'get' becomes a zero pronoun, the referent becomes *I*. In the case of verb *kuru* 'come', the referent becomes an element other than *I*, for example *you*. These kinds of verbs implicitly indicate the relationship between the writer/speaker and the referent of the *ga*-case (for example, the empathy (Kuno, 1978) or the side of the territory of information (Kamio, 1985)). Based on these properties, the deictic referents of Japanese zero pronouns can be estimated.

#### (2) Constraints based on the types of verbs and modal expressions

Even if the referents of zero pronouns can not be determined using modal expressions or the types of verbs, the referents can sometimes be determined using a combination of modal expressions and the types of verbs. For example, in the following Japanese expression, the *ga*-case becomes a zero pronoun.

- (1) 

<i>hon-wo</i>	<i>yon-da</i>
$\phi$ -SUBJ	book-OBJ read-PAST
	I read a book.

In this sentence the experience of the writer/speaker, *I* is suitable for the reference of the zero pronoun. As shown in this sentence, if the *ga*-case in an expression with a verb whose semantic attribute is ACTION and modal expression is *-ta* PAST, becomes a zero pronoun, it will

be translated by a human translator as *I*. In a similar way, if the *ga*-case in an expression with a verb whose semantic attribute is ACTION and modal expression is *-darou* 'will' ESTIMATION, becomes a zero pronoun, the referent is *you*. Such constraints using both verbal semantic attributes and modal expressions can be used to determine the deictic reference of Japanese zero pronouns.

To write constraints based on types of verbs effectively, we used the 97 verbal semantic attributes (VSA) proposed by Nakaiwa (1994).

### 3.2.3 Constraints based on Conjunctions

Sometimes the deictic referents of Japanese zero pronouns can be determined depending on the types of conjunctions. The constraints based on the Japanese conjunctions can be divided into the following two types.

#### (1) The constraints on case sharing depending on the types of conjunctions

Minami (1974) and Takubo (1987) proposed that different Japanese conjunctions cover or share different cases. For example Minami divided Japanese conjunctions into three kinds, A, B and C. A complex sentence which includes A type Japanese conjunctions, such as *tsutsu* 'while' and *nagara* 'while', shares one *ha*-case (Topic) and one *ga*-case (Subject). In the case of B type Japanese conjunctions, such as *node* 'because' or *tara* 'if', one *ha*-case is shared but not the *ga*-case. In the case of C type Japanese conjunctions, such as *keredo* 'but' or *kedo* 'but', neither the *ha*-case nor the *ga*-case are necessarily shared. According to this classification, if two *ga*-cases in a complex sentence joined by an A type Japanese conjunction were to become zero pronouns and the referent of one of the two zero pronouns was determined by the constraints proposed previously, then the referent of the other zero pronoun is the same referent. These characteristics of Japanese conjunctions can be used to determine the referents of zero pronouns.

#### (2) Constraints based on conjunctions, modal expressions and verbal semantic attributes

Sometimes co-occurrence of conjunctions, verbal semantic attributes and modal expressions in a complex sentence determines the meaning of the sentence, and sometimes they determine the deictic reference of zero pronouns in the sentence. For example, in the following Japanese expression, the subject of the verb *ika-nai* 'go-not' becomes a zero pronoun but the referent can be determined as the writer or speaker, *you*.

- (2) 

<i>tokoya-ni</i>	<i>ika-nai</i>	<i>to,</i>
$\phi$ -SUBJ	barber-IND-OBJ	go-not if
	If you don't go to the barber,	
<i>kami-ga</i>	<i>boubou-ni-naru</i>	
hair	begin to look untidy	
	your hair will begin to look untidy.	

This sentence has the meaning that the writer or speaker advises that if you do not do something, a situation will arise. The meaning type of a complex sentence can be determined using the rules that the conjunction is *to* 'if' and in the sub clause *ga*-case becomes a zero pronoun and the meaning of the verb is ACTION with negation and in the main clause the meaning of the verb is ATTRIBUTE with modal expression *ni-naru* 'become' ATTRIBUTE TRANSFER.

The meaning type of a complex sentence can be determined using the following rules: when the conjunction is 'if' and the sub clause *ga*-case becomes a zero pronoun, and the meaning of the verb is ACTION with negation, and in the main clause the meaning of the verb is ATTRIBUTE with modal expression, then *ni-naru* 'become' is an example of ATTRIBUTE TRANSFER. Using these kinds of rules, the meaning types of complex sentences can be determined, and the reference of zero pronouns can be determined.

### 3.3 Algorithm

In this subsection, we propose an algorithm for the deictic resolution of Japanese zero pronouns using the constraints proposed in this section. This algorithm was implemented in a Japanese-to-English machine translation system, so the only zero pronouns that must be resolved are those that become mandatory elements in English. To realize the previously proposed conditions in an algorithm, we must consider cases when these antecedents exist in the same sentence as well as when these antecedents exist in another sentences in the text, and we must design the algorithm to increase the overall accuracy of the resolution of zero pronouns.

Anaphora resolution of zero pronouns is conducted as follows. In each step in the algorithm, when the referential element within or without the text is determined, the system checks not only the conditions that are written in the following algorithm, but also the semantic conditions that verbs impose on zero pronouns in the case elements in each pattern of the Japanese-to-English transfer dictionaries.

- 1) Detection of zero pronouns.  
If they exist, proceed to step 2.
- 2) Examine whether there are antecedents within the same sentences. (For example, anaphora resolution is performed using Nakaiwa's method (Nakaiwa and Ikehara, 1995)).  
If their antecedents can be found, finish the resolution process. Else, proceed to step 3.
- 3) Examine whether there are antecedents within other sentences in the text. (For example, anaphora resolution is performed using Nakaiwa's method (Nakaiwa and Ikehara, 1992))  
If their antecedents can be found, finish the resolution process. Else, proceed to step 4.

- 4) Deictic resolution of Japanese zero pronouns using verbal semantic attributes, modal expressions and the types of conjunctions are conducted. The conditions to determine the referents are summarized in Table 2.

If their referents can be found, finish the resolution process. Else, proceed to step 5.

- 5) If referential elements can not be found and the text can be translated successfully in the passive voice, translate in the passive voice.  
Else, based on the semantic restrictions imposed on the zero pronoun by the verbs, deductively generate anaphora elements.  
Finish the resolution process.

Table 2: Resolution conditions of deictic referents

Location of Zero Pron.	Condition	Referents	Comment
<i>ga</i> -case (subj)	modal:hope(- <i>sitai</i> )	I or we	speaker/writer hopes
	modal:causal hope (- <i>sitchosii</i> )		speaker/writer hopes to hearer/reader
	modal:invite (- <i>simashou</i> )		speaker/writer invites
	VSA:under action +modal:polite (- <i>simasu</i> )		depending on the social relationship between speaker/writer and hearer/reader
	modal:prohibit (- <i>sitcha-ikenai</i> )	you	speaker/writer prohibits hearer/reader's action
	VSA:under action +modal:obligation (- <i>beki</i> )		speaker/writer make hearer/reader's action obligation
	VSA: bodily action thinking action emotive action emotive state bodily transfer	human (I, we, you, ...)	When the verb that show the action or emotion that only human can do appears in the sentence and when there are noother referent candidates, the referents of zero pronouns is human
VSA:copula sentence and the meaning is abstract	it	Pronoun of abstract noun should be it	
VSA:attribute and perceptual state		verbs that indicates weather such as <i>atsui</i> 'hot', <i>-samui</i> 'cold'	
<i>ni</i> -case (ind. obj.)	modal:causal hope (- <i>sitchosii</i> )	you	speaker/writer hopes to hearer/reader

## 4 Evaluation

### 4.1 Evaluation Method

In this section, we show the results of evaluation of the method that was proposed above. The method to resolve zero pronouns with deictic reference was tested using the Japanese-to-English machine translation system ALT-J/E (Ikehara et al., 1991). The criteria for the evaluation and procedures used were as follows.

### 4.1.1 Resolution Target

The target was to resolve successfully the five types of zero pronouns (ga-case ← “I” or “we”, ga-case ← “you”, ga-case ← HUMAN, ga-case ← “it”, ni-case ← “you”; 175 instances). These are the zero pronouns with deictic reference found within the 512 zero pronouns in the 3718 sentence set for the evaluation of Japanese-to-English machine translation systems.

### 4.1.2 Rules to Resolve Zero Pronouns

The rules to resolve 175 zero pronouns were created by examining these zero pronouns using the constraints discussed in section 3 (46 rules)<sup>1</sup>.

### 4.1.3 Tests for the Evaluation

To examine the relationship between conditions of resolution and accuracy of resolution, we conducted the following two tests.

#### (1) Resolution accuracy for conditions of resolution

We examined the accuracy of resolution depending on the types of conditions in anaphora resolution such as semantic constraints to the cases, modal expression, verbal semantic attributes and conjunctive expressions. We evaluated the accuracy depending on the types of constraints used.

#### (2) Resolution accuracy for rule complexity

We examined the accuracy of the resolutions to see how they were affected by the complexities of the rules that were used in the resolution. In this test we evaluated the accuracy using simple, easily created and universal rules.

## 4.2 Resolution Accuracy for Conditions of Resolution

To examine the resolution accuracy under different conditions, we examined the accuracy of the method proposed in this paper with the following 4 kinds of conditions:

- using conditions of semantic constraints on cases only
- using conditions of semantic constraints on cases and modal expression
- using conditions of semantic constraints on cases, modal expression and verbal semantic attributes
- using conditions of semantic constraints on cases, modal expression, verbal semantic attributes and conjunctions

Table 3 shows the results of the resolution depending on the types of the rules. As shown in

<sup>1</sup>At the moment, it is difficult to use sentences which were not successfully syntactically and semantically analyzed for the evaluation of our method. So, to evaluate the technical limitation of proposed method, we evaluated the resolution accuracy in the sentences which were examined to make the 46 rules (window test). We will conduct blind tests after we have finished debugging the whole system.

this table, all 175 zero pronouns can be resolved using the rules that were proposed in section 3. The introduction of verbal semantic attributes has achieved the same accuracy of resolution as the introduction of modal expressions (41 entries, 24%). From this result, we can say that the verbal semantic attributes are comparatively as effective as modal expressions. The results also show that, without using the constraints of conjunctions, the accuracy achieved is as high as 85%.

## 4.3 Resolution Accuracy against Rule Complexity

To examine how the resolution accuracy varied according to the complexity of rules, we tested the accuracy of the method proposed in this paper at different levels of complexity. The complexities C were evaluated using the following formula, and depended on the number of constraints used.

$$C = \# \text{ of modal const.} * 1 + \# \text{ of VSA const.} * 1 + \# \text{ of conjunctions const.} * 2$$

In this formula, 1 in the modal and VSA and 2 in the conjunction indicate the weights. Because conjunction constraints affect both sides of the unit sentence, we gave the conjunctions constraints a weight of 2. According to this formula, the complexity of a rule that has a constraint for conjunctions and for VSA in the main clause and for modal and VSA in the sub clause, becomes 5(= 1(modal)\*1 + 1(VSA)\*2 + 2(conjunction)\*1).

Table 4 shows the accuracy of the resolution depending on the complexities of the rules. 46 kinds of rules were used in the deictic resolution of 175 zero pronouns as shown in table 4. The accuracy of resolution using rules with complexities of 3 or less, is 90%, and the accuracy of resolution using rules with complexities of 4 or less, is 95%. This result shows that the use of the constraints based on modal expressions, VSA and conjunctions can achieve high accuracy using relatively simple rules.

## 5 Conclusion

This paper proposes a powerful method for the resolution of Japanese zero pronouns with deictic reference. It was found possible to resolve all of the sentences in the window test where the referential elements were not in the sentence resolved. This was achieved by the introduction of rules based on four kinds of constraints: semantic constraints on cases, modal expressions, verbal semantic attributes and conjunctions. In the future, we will examine the universality of the rules that have been discussed in this paper by applying them to other texts and examine a method for automatically acquiring the rules needed to resolve zero pronouns with deictic references.

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Table 3: Resolution accuracy for conditions of resolution

Location of Zero Pronouns	Referents	Resolution Condition								
		Semantic Constraints on Cases		+ Modal Expression	+ VSA		+ Conjunction			
ga-case (subj)	I or We	23%	(16)	58%(+35%)	(40)	93%(+38%)	(64)	100%(+7%)	(69)	
	you	0%	(0)	43%(+43%)	(12)	61%(+18%)	(17)	100%(+39%)	(28)	
	hu-man	I	0%	(0)	0%	(0)	67%(+67%)	(6)	100%(+33%)	(9)
		you	0%	(0)	0%	(0)	55%(+55%)	(6)	100%(+45%)	(11)
		one	0%	(0)	0%	(0)	0%	(0)	100%(+100%)	(3)
		Sum	0%	(0)	0%	(0)	49%(+49%)	(12)	100%(+51%)	(23)
it	100%	(50)	100%	(50)	100%	(50)	100%	(50)		
ni-case (ind.obj.)	you	0%	(0)	100%	(5)	100%	(5)	100%	(5)	
Sum		38%	(66)	61%(+24%)	(107)	85%(+24%)	(148)	100%(+15%)	(175)	

Table 4: Resolution accuracy for complexities of rules

Resolution Condition			Complexities of Rules	Number of Rules	Accuracy	
Modal Expression	VSA	Conjunctions				
0	0	0	0(Only semantic constraints to cases)	0	38%	(66)
1	0	0	1	11(+11)	61%(+24%)	(107(+41))
0	1	0	1	12(+1)	62%(+1%)	(108(+1))
1	1	0	2	29(+17)	85%(+24%)	(148(+40))
0	0	1	2	30(+1)	85%(+1%)	(149(+1))
1	0	1	3	31(+1)	86%(+1%)	(151(+2))
0	1	1	3	34(+3)	90%(+3%)	(157(+6))
1	1	1	4	36(+2)	93%(+3%)	(163(+6))
0	2	1	4	39(+3)	95%(+2%)	(167(+4))
2	1	1	5	40(+1)	96%(+1%)	(168(+1))
1	2	1	5	44(+4)	99%(+3%)	(173(+5))
2	2	1	6	46(+2)	100%(+1%)	(175(+2))

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