Resolution of Zero Pronouns in Japanese instruction Manuals and its Application

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Abstract

This paper describes a method of the zero pronouns resolution and shows the application of the method for estimating zero pronouns. In our related works, we have obtained the method of zero pronouns resolution which uses pragmatic properties of Japanese conditionals. We built a system based on our method. With our system, we examine Japanese manual sentences, and we confirmed that the method works effectively. Moreover, for instance of application of the method, we show a manual browsing system which uses the information of subjects.

1 Introduction

From simple electrical appliances to complex computer systems, almost all machines are accompanied by instruction manuals. Since recently there are many machines whose operating procedures are complicated, we have much more trouble in many including translating their manuals into other languages, maintaining consistency between the description in manuals and the actual behavior of the machines. To solve these problems, we have to have a computer assisted system for processing manual sentences. In processing instruction manuals written in Japanese, however, it is problematic that almost all subjects are omitted. They are called 'zero subjects'. For example, machine translation systems have to supply appropriate subjects to translate sentences. It is also important for intelligent manual systems to grasp proper subjects, because the information of subject is useful to show the users appropriate instructions. Therefore, we have focused on anaphora resolution of zero subjects in Japanese manual sentences.

A large number of researchers have come to grip with the method of understanding some types of text including instruction manuals (Abe et al., 1988; Nomura, 1992; Eugenio, 1992). This type of method, which uses a large amount of domain knowledge, seems to be dominant from the viewpoint of disambiguation. Moreover it scarcely depends on the language in use, because the way of disambiguation is based on the inference with a certain knowledge base. On the other hand, in order to use this method, we have to prepare the amount of knowledge being large enough to cope with various types of described objects. Unfortunately, so far we have not had such a commonsense knowledge base.

One of the ways to get rid of this situation is to adopt some knowledge which is independent of any particular domain. As such a kind of knowledge, we pay attention to pragmatic constraints, which have not been used sufficiently in the former methods. We expect that owing to pragmatic constraints the ambiguity in manual sentences would be resolved to some extent not in the process of inference but in the process of the translation of manual sentences into semantic representations.

We do not commit ourselves to the domain specific knowledge, but use some ontological knowledge of ordinary manuals. For example, the correspondence of objects in the manual sentences to the objects in linguistic constraints, namely linguistic roles like the speaker, the hearer, and so on. Note that the ontology in this paper does not refer to all of the objects in the world described by manuals, like a certain part of machine. Aiming at independence from the domain knowledge of objects, we adopt one of general ontologies which is applicable to almost all manuals.

In this paper, we have paid our attention to conditionals to capture pragmatic constraints. We will show that constraints of conditionals are useful for identification of zero subjects. We built a system based on constraints of conditionals, and examined the effectiveness of the system. Moreover, we study the application of the method for estimating zero subjects. As a instance of applications, we will show a manual browsing system which displays user's operations and the responses of machines related to the operations in two columns separately.

Now we have to define the term 'SUBJECT' which we used in this paper. We use the term 'SUBJECT' to denote the main participant of the sentence, namely ether the agent or the surface subject (in the case where the agent is not defined).

2 Zero pronouns in manual sentences

Let's consider the following Japanese sentence.

(1) ϕ_1 kono-botan-o osu -to,
ϕ_1-NOM this-button-ACC push -TO
ϕ_2 der -are -mas -u.
ϕ_2-NOM go out -can -POL -NONPAST.
If ϕ_1 push(es) this button, then ϕ_2 can go out.

Native speakers of Japanese have the following intuitive interpretation for (1) without any special context.

(2) $\phi_1 = \phi_2 =$ the hearer(=the user)

Here, 'TO' is a Japanese conjunctive particle which represents a causal relation, and 'ARE' shows ability or permission. The symbol ϕ denotes a zero pronoun.

On the other hand, the following sentence, which does not have the suffix 'ARE', has a different interpretation.

(3) ϕ_3 kono-botan-o osu -to,
ϕ_3-NOM this-button-ACC push -TO,
ϕ_4 de -mas -u.
ϕ_4-NOM come out -POL -NONPAST.[1]
If ϕ_3 push(es) this button, then ϕ_4 will come out.

The zero pronoun ϕ_4 refers to not the hearer but the machine, even though ϕ_3 refers to the user as well as (1). Note that when only the matrix clause of (3) is used shown in (4), ϕ_5 can be interpreted as either the hearer or the machine.

(4) ϕ_5 de -mas -u.
ϕ_5-NOM go out -POL -NONPAST.
ϕ_5 will go out.

These example show that the expressions TO and ARE impose some constraints on the referents of SUBJECTS of the sentences. As described so far, there are many cases that linguistic expressions give us key information to resolve some type of ambiguity like the anaphora of zero pronouns.

3 General ontology of manuals

We should consider two types of information as the parts of ontology: the properties of the objects in manuals and the discourse situation that is characterized by linguistic roles like a writer and a reader. They are combined into the constraint of persons as follows.

Constraint 1

$$\begin{aligned} \textbf{First Person} &= \textit{Manufacturer} \\ \textbf{Second Person} &= \textit{User} \\ \textbf{Third Person} &= \textit{Machine} \end{aligned}$$

[1] The English translation of 'DERU' in (1) is different from the translation in (3). It is due to the difference of the viewpoint between Japanese and English. The difference has no effect on the selection of zero pronoun's referent.

4 Semantics of Japanese conditionals

Japanese has four conditional particles, TO, REBA, TARA, NARA, which are attached to the end of subordinate clauses as described in (1). The subordinate clause and the matrix clause conjoined by one of these particles correspond to the antecedent and the consequence, respectively. The difference of constraints of these expressions are shown in the following sentences, which are the variants of the sentence (3).

(5) ϕ_6 kono-botan-o ose -ba,
ϕ_6-NOM this-button-ACC push -REBA
ϕ_7 de -mas -u.
ϕ_7-NOM come out -POL -NONPAST.
If ϕ_6 push(es) this button, then ϕ_7 will come out.

(6) ϕ_8 kono-botan-o osi -tara
ϕ_8-NOM this-button-ACC push -TARA
ϕ_9 de -mas -u.
ϕ_9-NOM come out/go out -POL -NONPAST.
If ϕ_8 push(es) this button, then ϕ_9 will come out/go out.

(7) ϕ_{10} kono-botan-o osu -nara
ϕ_{10}-NOM this-button-ACC push -NARA
ϕ_{11} de -mas -u.
ϕ_{11}-NOM come out/go out -POL -NONPAST.
If ϕ_{10} push(es) this button, then ϕ_{11} will come out/go out.

As well as the sentence (3), for Japanese native speakers, the SUBJECTof the matrix clause of (5)(ϕ_7) should be a machine. On the other hand, in the case of the sentence (6) and (7), the SUBJECT of the matrix clauses(ϕ_9, ϕ_{11}) can be either users or machines. These phenomena probably due to the nature of each conditionals (Masuoka, 1993). Since a causal relation, which is shown by TO or REBA, expresses a general rule, the consequence cannot include speaker's attitude, like volition and request. Therefore, the SUBJECT of the matrix clause should be a machine. In contrast, in the case of assumptions, that is TARA and NARA, there are no such restrictions on the SUBJECT.

Based on these observation, Mori et al.(Mori et al., 1997) propose the defaults of SUBJECTS of sentences with these conditionals.

Default 1 (**SUBJECT of sentence with TO or REBA**)
The matrix clause does not express user's volitional action. Therefore, the SUBJECT *of the matrix clause is a machine, if the predicate of the matrix clause is able to express user's volitional action.*

Default 2 (**SUBJECT of sentence with TARA or NARA**)
The matrix clause expresses only user's volitional action. Therefore, the SUBJECT *of the matrix clause is a user.*

Since they depend on the volitionality of the verb whether a sentence shows a speaker's attitude or not, the defaults are described in terms of volitionality of each verb. Note that the electronic dictionary IPAL provides the information of volitionality for each Japanese verb entry(IPA, 1987). According to the classification in IPAL, all of Japanese verbs are classified into two types, *volitional verbs*, which usually express intentional actions, and *non-volitional verbs*, which express non-intentional actions. Although non-volitional verbs express non-volitional actions only (type NV, henceforth), some of volitional verbs have not only volitional use but also non-volitional use (type NV/V, henceforth). The rest of volitional verbs express volitional actions only (type V, henceforth). However, it is problem that IPAL has at least the following ambiguities.

- Polysemy of lexical entries.
- Volitionality of the type NV/V.

5 Disambiguation of volitionality

The applicability of the defaults described in the last section depends on the volitionality of the matrix clause. Therefore we should determine whether the predicate of matrix clause is in volitional use or not. We mentioned volitionality of verbs in section 4. Of course, the classification of verbs does not cover all expressions of predicates in Japanese manuals. There are many expressions which affect volitionality of sentence, such as an aspect expressions, adjective and so on. Therefore we classify expressions, which are used in real Japanese manuals, in terms of volitionality.

Secondly, we solve the ambiguity of IPAL. Volitionality of verbs should be determined with IPAL. However, there is a problem that IPAL has polysemous entries as mentioned in section 4. For example, as for Japanese verb 'MODORU'(come back), IPAL has seven different entries. The entries are classified by the delicate nuance of meaning of MODORU, and the volitionalities of them are not the same. That is, 3 entries are classified into the type NV, 1 entry is classified into the type NV/V, and 3 entries are classified type into the V. Because of this ambiguity, we can not apply the default rules of 'TO' or 'REBA'.

We may have to solve this ambiguity according to the meaning of verb in the context, but it is very difficult. Therefore we adopt an approximation, that is, a simple default rule based on the statistics of volitionality. We examine the tendency of use of verbs in real Japanese manual sentences with respect to their volitionality. That is, we classified verbs in terms of volitionality based on the judgment by human, and we checked out the relation between the classification in IPAL and one by human. The examination shows that almost all of the verbs which have the volitional use express only volitional actions even if they also have non-volitional use. The verbs which have the volitional use like the verb 'MODORU' are judged volitional actions at the rate of 78%. From the result, we propose the following default.

Default 3 (Volitionality of verbs)
In Japanese manuals, verbs which have the volitional use express volitional actions even if they have multiple entries.

6 Zero SUBJECTS determination system

We built a system based on the defaults mentioned in the previous sections. This system consists of following two parts.

- Morphological analysis
- SUBJECTS determination

We use JUMAN[2] for morphological analysis. First of all, Japanese manual sentences are analyzed by JUMAN, and the analyzed morphemes are transfered to the SUBJECTS determination part. Determination part applies defaults to manual sentences with the conditional to determine SUBJECT. The process of each sentence is shown as follows.

1. Search for conditionals in morphemes.
2. If a conditional is found, search for expressions which affect volitionality from the end of the sentence to beginning in order to find the predicate of the matrix clause.
3. If the conditional is either TO or REBA, check the volitionality of the predicate.
4. Apply applicable default(s).

Note that our system does not parse sentences fully. Therefore, the system can process many Japanese Manual documents in a short time.

7 Evaluation of Zero SUBJECTS Determination System

In this section, we examine performance of our zero SUBJECTS determination system. The following are test examples: a home use VCR, a video game machine, a beeper, Japanese morphological analysis system JUMAN and Natural language parsing system SAX.

From these manuals, our system found 175 sentences with TO, 41 sentences with REBA, 11 sentences with TARA and 5 sentences with NARA.

7.1 Sentence with TO

As for 175 sentences with TO, there are 99 sentences whose predicates of the matrix clauses are processed as volitional actions. Default 1 is applied to these 99 sentences, and the SUBJECTS of matrix clauses are estimated to be Machine.

Among the 99 sentences whose SUBJECTS of matrix clauses are identified as Machine, we examine the correctness of the estimation according to the human's judgment. Table 1 shows the result of the verification for the 99 sentences to which Default 1 is applied. The term 'Correct' means that the judgment by human for zero SUBJECTS of matrix clauses is also Machine. The term 'Wrong' means

Table 1: Application of Default of TO

	Correct	Wrong	Total
Sentences with TO(total)	83 83.8%	16 16.2%	99 100%
SUBJECTS are omitted	68 81.0%	16 19.0%	84 100%

that the judgment by human is User. Default 1 of TO successfully determined zero SUBJECTS in manual sentences with TO with the precision of 81.0%. The precision of estimation for all sentences with TO is 83.3%.

There are 16 sentences whose SUBJECTS of matrix clauses are determined wrongly. These 16 sentences are classified into two types.

The first type is the group of sentences which have more than 2 clauses and whose clauses related to conditionals are identified wrongly.

(8) ϕ_{12} dengen-o on-ni-suru -to,
ϕ_{12}-NOM switch-ACC turn(s)_on -TO,
hiita-ga hataraki mas u node
heater-NOM work(s) -POL -NONPAST SO
ϕ_{13} juubunn-ni ϕ_{14} kansousase-te kara
ϕ_{13}-NOM well ϕ_{14} dry after
ϕ_{15} ϕ_{16} o-tukai kudasai.
ϕ_{15}-NOM ϕ_{16}-ACC POL-use(s) POL.
If ϕ_{12}(=User) turn(s) on switch, then the heater will work. So ϕ_{15}(=User) use(s) ϕ_{16}(=Machine) after ϕ_{13}(=User) dry(es) ϕ_{14}(=Machine) well.

Our system applies Default 1 to 'ϕ_{15} use(s) ϕ_{16}', and estimate ϕ_{15} to be Machine. This type of fault is caused by the method of identification of matrix clause. The sentence (8) of Japanese consists of the following 4 clauses.

1. ϕ_{12} turn(s) on switch.
2. the heater will works.
3. ϕ_{13} dry(es) ϕ_{14} well.
4. ϕ_{15} use(s) ϕ_{16}.

Our system searches a sentence from the end to the beginning of sentence for the predicate of matrix clause. Since our system does not parse sentences, it wrongly identifies 'use' as the predicate of matrix clause, and ϕ_{15} is estimated to be Machine according to Default 1. However, (8) shows the correct pair of the conditional is the following part.

(9) If ϕ_{12}(=User) turn(s) on switch, then the heater will works.

It is 'the heater will works' that our system should apply Default 1 to, and the SUBJECT of the clause is 'the heater'. Since the heater is the part of the Machine, (8) is not an exception of Default 1, There are 7 sentences of this type of failure.

[2] JUMAN is the Japanese morphological analysis system which is developed by 'Nara Institute of Science and Technology' and 'Kyoto University'.

The second type is the group of sentences whose word of conditionals have another interpretation. This type of failures is by polysemous words like the followings.

1. The word 'to' can be interpreted not only as the conditional we are considering but also the postpositional particle of quotation.
2. The word 'are' is interpreted as both the ability expression and the passive expression.

The case 1 is a type of sentence which is interpreted in 2 ways as follows.

(10) 'Bunnmatsu'-to yobareru
'the_end_of_sentence'-QUOTE be_called
keitaiso-ga aru -to
morpheme-NOM there_is -TO
ϕ_{17} kateisuru.
ϕ_{17}-NOM make_an_assumption.
If there is the morpheme called 'the end of sentence', then ϕ_{17}(=Machine) will make an assumption.

(11) 'Bunnmatsu'-to yobareru
'the end of sentence'-QUOTE be_called
keitaiso-ga aru -to
the morpheme-Nom there_is -QUOTE
ϕ_{18} kateisuru.
ϕ_{18}-NOM assume.
ϕ_{18}(=We) assume that there is the morpheme called 'the end of sentence'.

In the sentence (10) the second 'to' expresses the conditional, and ϕ_{17}, which is the SUBJECT of matrix clause, is estimated to be Machine with Default1 successfully. On the other hand, in the sentence (11) the second 'to' expresses the quotation, and ϕ_{18}, which is the SUBJECT of matrix clause, expresses 'we'(=Manufacturer and User). The sentences (11) and (10) shows that the interpretation of the SUBJECTS of the matrix clause depends on the interpretation of the word 'to'. Our system applies Default 1 to matrix clause and estimates the SUBJECT of matrix clause to be Machine wrongly, because it can not deal with the ambiguity of word meaning. According to the context, the interpretation of this sentence should be (11). That is, this is not a sentence with conditionals, and Default 1 should not be applied to the sentence. There are 7 sentences of this type of failure.

The case 2 is a type of sentence which is interpreted in 2 ways as follows.

(12) ϕ_{19} '+'botan-o osu -to
ϕ_{19}-NOM '+'_button-ACC push(es) -TO
ϕ_{20} saisei-no-hayasa-o
ϕ_{20} playback_speed-ACC
kaer are mas -u.
change can -POL -NONPAST
If ϕ_{19}(=User) push(es) '+' button, then ϕ_{20}(=User) can change the playback speed.

(13) ϕ_{21} '+'botan-o osu -to
ϕ_{21}-NOM '+'button-ACC push(es) -TO
saisei-no-hayasa-o kaer are
playback_speed-ACC change -PASS by ϕ_{22}

mas -u.
-POL -NONPAST
If ϕ_{21}(=User) push(es) this button, then playback speed will be changed by ϕ_{22}(=Machine).

This is the same type as the sentence which is shown in (1). In fact, this type of sentences is interpreted in 2 ways as shown in (12) and (13). In the sentence (12) the word 'are' expresses the ability, and ϕ_{20}, which is the SUBJECT of the matrix clause, is interpreted as User. On the other hand, in the sentence (13) shows that 'are' expresses the passive, and ϕ_{22}, which is the SUBJECT of the matrix clause, is estimated to be Machine. Since our system does not have the ability expression currently, it applies Default 1 to the matrix clause and estimates the SUBJECT of the matrix clause to be Machine wrongly. According to the context, the interpretation of the sentence should be (12). That is, Default 1 should not be applied to the sentence, since the predicate of the matrix clause is a non-volitional expression. There were 2 sentences of this type of failure.

7.2 Sentence with REBA

As for 41 sentences with REBA, there are 11 sentences whose predicates of the matrix clauses are processed as volitional actions, and the SUBJECTS of the matrix clauses are estimated to be Machine according to Default 1.

Among the 11 sentences whose SUBJECTS of matrix clauses are estimated to be Machine, we examine the correctness of the estimation according to the human's judgment. As Table 2 shows, Default 1 of REBA successfully determined zero SUBJECTS of manual sentences with REBA with the precision of 80.0%, although there are only 8 examples. The precision of estimation for all sentences with REBA is 81.8%.

Table 2: Application of Default of REBA

	Correct	Wrong	Total
Sentences with REBA(total)	9 81.8%	2 18.2%	11 100%
SUBJECTS are omitted	8 80.0%	2 20.0%	10 100%

Next, let us consider 2 sentences whose SUBJECTS of matrix clauses are determined wrongly. First one is the same type of sentences as (12) and (13). Second one is one of the exceptions of Default 1 as follows.

(14) hinshi-sai-bunrui-ga are -ba
detailed_POS-NOM there_is -REBA
ϕ_{23} hinshi-sai-bunrui-mei-o
ϕ_{23} name_of_detailed_POS-ACC
kijutusur -u.
make_an_entry_of -NONPAST
If there is a detailed POS is existent, then ϕ_{23}(=User) make the entry of the name of the detailed POS.

Our system applies Default 1 to the matrix clause and estimates ϕ_{23} to be Machine. However, the correct interpretation is that ϕ_{23} is User. This fault is due to the property of REBA, which is not took into account in Default 1. When the subordinate clause of sentence with REBA describes not an action but a state, the matrix clause can express not only machine's action but also user's volitional action (Masuoka, 1993). Since the subordinate clause of the sentence (14) shows some kind of state, the matrix clause can express user's volitional action and, in fact, the interpretation is the user's volitional action according to the context.

7.3 Sentence with TARA

Default 2 is applied to all 11 sentences with TARA, since the application of Default 2 does not depend on the predicate of the matrix clause, and the SUBJECTS of matrix clauses are identified as User.

We examine the correctness of the estimation according to the human's judgment. As Table 3 shows, Default 2 of TARA determined all SUBJECTS of matrix clauses correctly. This result shows that Default 2 of TARA works effectively.

Table 3: Application of Default of TARA

	Correct	Wrong	total
Sentences with TARA(total)	11 100%	0 0%	11 100%
SUBJECTS are omitted	11 100%	0 0%	11 100%

7.4 Sentence with NARA

Default 2 describes that the matrix clause of sentence with NARA expresses only user's volitional action. Although, we have only 5 sentences with NARA in the examples, there are 3 sentences whose matrix clauses express user's volitional action.

We also have other 9 sentences with NARA which is found in the process of finding the default, and we found 5 sentences in this examination. That is, we have 14 sentences with NARA. Among these 14 sentences, there are 11 sentences (78.6%) which express user's volitional action in the matrix clauses. Although Default 2 seems to work well, there is room for some further examination of Default 2 of NARA.

8 An application of information of SUBJECTS to manual browser

With the system mentioned above, we can obtain the proper referents of the zero SUBJECTS in the matrix clauses of conditionals systematically. Of course, although not all referents of zero SUBJECTS can be solved by the default for conditionals, we have already had new defaults and constraints to solve the remaining referents of zero subjects(Mori et al., 1997). As one of effective applications of information of SUBJECTS, we consider utilizing the information of SUBJECTS in a manual browsing system.

In general, the instruction manuals consist of some serieses of user's operations and machine's responses to them. In ordinary manuals written

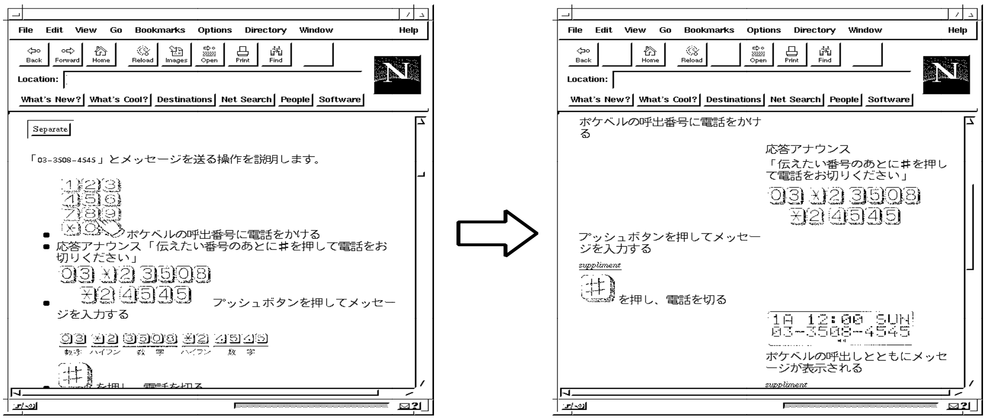

Figure 1: Manual browsing system (The left side shows the normal browsing. The right side shows the browsing in the separation mode. User's operations can be seen in the left column in the right side, and the responses of machine to the operations are in the right column.)

on paper, all of the serieses are written only from the viewpoint of the order of time. However this type of manuals is hard for users to understand, since users do not have a clear grasp of what they should do. That is, it is necessary to emphasize the user's operation. Therefore we use information of SUBJECTS for the manual browser to do that. For example, the manual browser which uses the information of SUBJECTS can show selectively a series of user's operations, that is, the browser can show only what a user should do to accomplish his purpose. Furthermore, the manual browser can show user's operations and the response of the machine in two columns.

In order to realize this type of browsing, the information of SUBJECTS, which are obtained our system, should be encoded in the manuals. We adopt SGML for encoding.

We built a manual browsing system based on the flame work described above. Figure 1 shows an example display of our browsing system. If 'Separate' button, which is on the left side of Figure 1, is pushed, the browsing system shows users operations and the response of the machine separately like right side of Figure 1.

9 Conclusion

We show that we can determine the referents of zero pronouns by linguistic constraints of the Japanese Conditionals, and the defaults of TO, REBA and TARA works effectively. This method uses only the linguistic constraints and the general ontology of the world described by manuals. Moreover, for instance of application of SUBJECTS, we show the manual browsing system which display user's operations and machine's response to them separately according to the SUBJECTS.

However, as for NARA, the constraint does not work well. Therefore, There is room for some further examination about the constraint of NARA. We should examine other types of manual sentences.

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