A pragmatic approach to zero pronoun resolution in Japanese manual sentences

— The case of Japanese conditionals —

Tatsunori Mori and **Hiroshi Nakagawa**
Division of Electrical and Computer Engineering, Faculty of Engineering, Yokohama National University
Tokiwa-dai 156, Hodogaya-ku, Yokohama 240, JAPAN
Tel: +81-45-335-1451 ext.2903, E-mail: mori@forest.dnj.ynu.ac.jp, nakagawa@naklab.dnj.ynu.ac.jp

1 Introduction

From simple electrical appliances to complex computer systems, almost all machines are accompanied by some kind of instruction manuals. Since recently there are many machines whose operating procedures are complicated, we have much trouble in maintaining consistency between the description in their manuals and the actual behavior of the machines, translating their manual into other languages, and so on. To solve these problems, we study methods to understand Japanese manual sentences based on pragmatic constraints of Japanese. Especially, we concentrate upon anaphora resolution of zero pronouns, which is one of the most important problem in understanding of manual sentences.

A number of researchers have gotten to grip with the method of understanding some type of text including instruction manuals. In terms of knowledge acquisition from manual sentences, our approach may be the same as (Abe et al., 1988). Nomura(1992) treats law sentences and presents a method of extracting a logical relations between two clauses by the expressions that are attached at the end of the clauses. Eugenio(1992) takes note of the relation between purposes and actions to be done.

One of the most important matters of concern in these types of system is how we can fix ambiguities in semantic representations and complete underspecified parts of them. Generally speaking, almost all systems described above take the following scheme. Firstly, each sentence in a text is translated into a semantic representation. In this process, the system uses only non-defeasible knowledge like syntactic constraints and some extent of semantic information. Most of pragmatic information and commonsense knowledge are not used because these would be overridden by some other information such as context. Therefore the semantic representation would include some undetermined parts which will be fixed by some other information including context. This way of analysis is known as the *Nondefeasibility Thesis*(Kameyama, to appear). Secondly, all of undetermined parts of the semantic representation are filled or settled by some kind of inference about the representation based on the domain knowledge.

This type of method, which use a large amount of domain knowledge, seems to be dominant from the viewpoint of disambiguation. Moreover it scarcely depends on the language because the way of disambiguation is based on the inference with a knowledge base. On the other hand, in order to use the method, we have to prepare a large amount of knowledge enough to cope with various type of described objects. Unfortunately, so far we have not had such a commonsense knowledge base in the world.

One of the way to get rid of this situation is to adopt some knowledge which hardly depends on some particular domain. As such a kind of knowledge, we pay attention to pragmatic constraints, which have not been used sufficiently in the former methods. That is, by pragmatic constraints, ambiguity in manual sentences will be reduced to some extent not in the process of inference but in the process of the translation of manual sentences into semantic representations.

As far as pragmatic constraints we deal with so far, they do not depend on each other. Therefore, if we have a certain mechanism which can accumulate individual constraints and resolve them, it would be possible to derive some answer, even if we had a small set of pragmatic constraints. The power of derivation, of course, can be strengthen as often as a new constraint is added.

Even though we almost never commit ourselves to knowledge of some specific domains, we have to have some knowledge of the ontology of the world described in manuals, for example, the correspondence of the objects in linguistic constraints, like the speaker, the hearer, and so on, to objects in the manual sentences. Note that the ontology in this draft does not refer to all of objects in the manual world, like some parts specific to a certain machine. In the standpoint of independence from the domain knowledge of objects, we adopt one of general ontologies which is applicable to almost all manuals.

In short, our scheme consists of the following three parts: 1) a parser based on the nondefeasiblity thesis, 2) pragmatic constraints specific to linguistic expressions, and 3) the general ontology of the manual world. Especially, in this draft, we will focus on the zero pronoun resolution. In Japanese, zero pronouns frequently make a sentence ambiguous. Zero pronouns are ellipsis of obligatory cases, which appear usually in Japanese sentences. We, of course, have to find appropriate referents of zero pronouns when we understand manual sentences. In some sense, the resolution of zero pronouns' referents is the essential part of obtaining some knowledge from Japanese manuals, because it is not so hard to recognize the structure of sentence, like an IF-THEN sentence, and to map it to some knowledge representation. Accordingly, in this draft, we will show that linguistic constraints of some expressions including conditionals can be used to determine referents of zero pronouns. We will also mention an implementation of our scheme.

2 Zero pronouns in manual sentences

For example, let's consider the following Japanese sentence. The sentence shows a certain instruction.

(1) ϕ_a kono-botan-wo osu -to,
ϕ_a-NOM this-button-ACC push -TO,
If ϕ_a push(es) this button,
ϕ_b der -are -mas -u.
ϕ_b-NOM go out -can -POL -NONPAST.
then ϕ_b can go out.[1]

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

(2) $\phi_a = \phi_b =$ the hearer (= the user)

Here, 'TO' is a Japanese connective particle and it represents a causal relation, namely, an IF-THEN connection. 'MASU' shows speaker's attitude of politeness, which is expressed by POL in (1).

On the other hand, the following sentence, which does not have the voice of possibility '-ARE'[2] in the matrix clause, has the different interpretation.

(3) ϕ_c kono-botan-wo osu -to,
ϕ_c-NOM this-button-ACC push -TO,
If ϕ_c push(es) this button,
ϕ_d de -mas -u.
ϕ_d-NOM come out -POL -NONPAST.[3]
then ϕ_d will come out.[4]

The zero pronoun ϕ_d does not refer to the hearer(the user), even though ϕ_c refers to the user as well as (1). Native speakers of Japanese should feel it natural that ϕ_d refers to a machine or a certain part of a machine. To the contrary, in the case that only the matrix clause of (3) is used as shown in (4), ϕ_e can be interpreted as either the hearer or machine[5].

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

[2] Japanese has a voice form which shows possibility.

[3] The English translation of 'DERU' in (3) is different from the translation in (1). 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] The meaning of NONPAST depends on the property of each verb. The NONPAST form of 'DERU' means the future.

[5] It seems to be more natural that ϕ_e is interpreted as the hearer.

These example shows that the expressions TO and ARE impose some constraints on the subjects of the sentences. As described above, there are many cases that linguistic expressions give us a key information to resolve some type of ambiguity like the anaphora of a zero pronoun. In the rest of this draft, we will show several pragmatic constraints, which can explain the interpretations of these sentences described above.

Dohsaka(Dohsaka, 1994) proposes a similar approach, in which pragmatic constraints are used to determine referents of zero pronouns. While our targets are manual sentences, his approach treats dialogue. The approach utilizes honorific expressions and the speaker's point of view as linguistic constraints to identify the referents of Japanese zero pronouns. Since the constraints are effective in the different target from ours, the accuracy of identifying the referents of zero pronouns would be improved in the case that both his constraints and the constraint we proposed are applicable. As for the identifying method available in general discourses, the centering theory(Brennan et al., 1987; Walker et al., 1990) and the property sharing theory(Kameyama, 1988) are proposed. Although this kind of theory has a good point that it is independent of the type of discourse, the linguistic constraints specific to expressions like the pragmatic constraints proposed by Dohsaka and us are more accurate when the constraints are applicable.

3 General ontology in manuals

In this section, we consider a general ontology which can be used in almost all types of manuals. However, if a target manual is based on some special ontology, we have to incorporate the ontology into the knowledge[6]. Note that, even then, we will not use the domain knowledge of described objects appearing in individual manuals.

We should consider two types of information as the parts of ontology: the properties of the objects in manuals and the linguistic roles, namely, the discourse situation.

Constraint 1 *Objects*

User	*has intention.*
Manufacturer	*has intention.*
Machine	*has no intention.*

Constraint 2 *Discourse Situation*

Speaker*(Writer)*	=	*Manufacturer*
Hearer*(Reader)*	=	*User*

From these constraints of the ontology, we can obtain the constraint of persons as follows.

Constraint 3 *Persons*

First Person	=	*Manufacturer*
Second Person	=	*User*
Third Person	=	*Machine*

Next, we consider the order of events in manuals. Since a manual is not a dialogue but a written

[6] For example, though we have not considered third parties except for machines, malicious third parties, or crackers, may appear in the manuals for computer networks. We also assume that machines do not have their own intention, but intelligent machines which have their own intention might be made in the future.

text, all actions of the speaker have been done by the reading time in principle. Therefore,

Constraint 4 *Time of Speaker's Action*
Time of speaker's action < Reading time

However, since many manuals are described as if the writer utters sentences at the reading time, speaker's action of utterance in manuals itself is not restricted by the above-mentioned constraint.

4 Pragmatic constraints

Since the knowledge of pragmatic constraints is open-ended essentially, we cannot enumerate such constraints completely. In our system, however, new pragmatic constraints can be added to the existing set of constraints whenever needed, because all constraints can be described independently and the constraint solver will manage them automatically [7]. So far we have found several pragmatic constraints which are useful to determine referents of zero pronouns. Note that we suppose all sentences appear in the text of explanation of operation procedures.

4.1 Agents of simple sentences

In Japanese, simple operation procedures, like those which do not include some conditions, are often described as simple sentences with no subjects whose verbs are of one of the following types: the RU form, the request form and the solicitation form.

First, we consider the case of the RU form. The RU form is the basic form of verbs and it denotes the non-past tense. Simple sentences without subjects in the RU form have the usage that "while a speaker does some action, in front of hearers, the speaker explains either the action or another action caused by the action"(Masuoka, 1993). By such an utterance, the speaker expresses one of the followings.

- The expectation that the hearer will do the same action as the speaker does.
- The description of the action that the speaker sees just now.

Since the former case expresses some kind of request, the agent must be the hearer. On the other hand, in the latter case, the agent is the third party like the object treated in the instruction. Unfortunately, since, at present, we have no way to find which of these two usages is used, the constraint for the agent has no effect to determine referents of zero pronouns. However, almost all of sentences of this type are used in the former use in the manuals which we examined, and the sentences in the latter use have their subjects explicitly. Consequently, we propose the following default rule, which might be defeated by other constraints.

Default 1 *Agents of* RU*-form sentences*
If a simple sentence in the RU*-form without a subject is used in the text of explanation of operation procedures, it is the usage of the request. Therefore, the agent is the hearer.*

In the case of the request form and the solicitation form. The speaker uses the sentences to prompt hearers to do the action described by the sentence. Therefore, we obtain the following constraint.

Constraint 5 *Agent of sentence in the request form*
The agent of a sentence in either the request form or the solicitation form is the hearer.

4.2 Agents of sentences with modalities

Manual sentences may have some modalities, which express the permission, the possibility, the obligation, and so on. Japanese has several suffixes, like -TEMOYO-I(may), -(AR)ER-U(can), -NAKEREBA-NARANA-I (must), as the modalities.

Sentences which have the possibility expression mean not only that it is possible for the agent of the sentence to do the action, but also that the agent can have their choice between to do the action or not to do it. Therefore,

Constraint 6 *Agent of Possibility expression*
An agent of a sentence in the possibility expression must have his/her intention to make a choice.

Sentences which have the obligation expression show that it is necessary for the agent to do the action. The necessity means that the agent can have his/her own choice, to do the action or not to do it. Consequently, we have the same constraint as that of possibility expressions.

4.3 Agents of complex sentences with conditionals

Japanese has four connective particles for conditionals, REBA, TARA, NARA and TO and they are slightly different from each other(Masuoka, 1993). TARA and NARA are very rarely used in manual sentences as far as we examined. For example, in several manuals, the rate of use of the conditionals is as follows: TO is 77.6 % of all conditionals, REBA is 19.4 %, TARA is 2.6 % and NARA is 0.4 %. Probably, it is due to that TARA and NARA strongly express some supposition and it is hard to express general rules with TARA or NARA. TO is used much more frequently than REBA. Therefore, we concentrate on the connective particle TO in this section. Of course we have examined the other connective particles and we have already obtained the pretty good default rules to determine the referent of zero pronouns based on the examination. We, however, do not have enough space to describe their properties. Roughly speaking, REBA has an almost same constraint as TO. On the other hand, TARA and NARA have a complementary usage to the usage of TO and REBA.

The connective particle TO expresses some causal relation between two specific states of affairs, which described in the subordinate clause and the matrix clause respectively, based on the knowledge of connections among states of affairs, which has been known[8]. In general, the subor-

[7] In the case that several constraints have some dependency, we should make those constraints enough specific to keep independency.

[8] Though the particle TO has another usage, which expresses the temporary relation between two states of affairs which have already happened, it is not used in manuals because of its nature. Since the usage is the case that the matrix clauses have the past tense, we do not treat the past tense in this section.

dinate clause of a complex sentence with TO expresses a certain cause and the matrix clause expresses its consequence as we have already shown in the examples of Section 1. Consequently, in matrix clauses, we can use only either the mood of the description of facts or the mood of evidentials like conjectures, judgment and so on[9]. To the contrary, we may not use the expressions which express some volition, invitations, requests, injunctions and so on. Since the property can be used as the constraint for the agents in the matrix clauses, we focus on the types of the matrix clauses. Because of the property described above, the matrix clauses have only either the mood of the description of facts or the mood of evidentials. It is hard for manual sentences to have the mood of evidentials, because manual sentences should describe only facts and must not include speaker's attitude. Therefore, we consider only the mood of the description of facts.

The sentences having the mood are classified into two types: the description of an action and the description of the state related to an action like a sentence with a possibility expression. The former type is problematic, because the RU-form, which describes an action, can express one of the followings: speaker's volition, speaker's request to hearers as described in Section 4.1, or the action done by a third party. Let us consider the interpretations of the sentences in each setting of the agent. If the agent is the speaker, the RU-form expresses speaker's volition. If the agent is the hearer, the RU-form expresses a request. Consequently, the agent should be neither the speaker nor the hearer because of the constraint on the usage of the matrix clause in a TO sentence, that is, the constraint that we cannot express some volition or request in the matrix clause, as described before. On the other hand, a third party is allowed to be the agent, because the RU-form whose agent is a third party does not express any volition, invitations, requests and injunctions. Since the speaker is the manufacture and the hearer is the user according to the constraint of the discourse situation, manufactures and users cannot be the agents of the matrix clause. Therefore, the possible interpretation is only that the agent of the clause is the machine according to the constraint of persons.

If, however, the verb of the clause has the non-volitional use, that is, if it is possible for the action to be done unconsciously, the constraint is not applied, because the RU-form in the non-volitional use does not express any volition, invitations, requests and injunctions. For example, the agent of the matrix clause of the following sentence refers to the users.

(5) ϕ_f ϕ_g fureru-to,
ϕ_f-NOM ϕ_g-ACC touch-TO,
If ϕ_f touch(es) ϕ_g,
ϕ_h kandenshi-mas-u.
ϕ_h-NOM get_an_electric_shock-POL-NONPAST.
then ϕ_h will get an electric shock.

[9] Japanese has several evidentials to express the evidential modalities, like -SOUDA(They say ...), -YOUDA (It seems that ...).

As for a state description like a sentence with a possibility expression, we may use it in any case, because it does not express any volition, invitations, requests and injunctions.

Constraint 7 *Agent of sentence with* TO
In a complex sentence with the connective particle TO*, the agent of the matrix clause should be a third party, if the verb of the matrix clause is in the* RU*-form and does not have the non-volitional use.*

4.4 Examination of our constraints

Now we can explain the differences between (4), (3) and (1), by the constraints and the default rule described in the last section. We have the following interpretation of (4) by applying Default 1 (RU-form) and Constraint 2(discourse situation).

(6) ϕ_e = the hearer = the user

As for (3), Default 1 is applied to the subordinate clause and Constraint 7(TO) is applied to the matrix clause. The default rule, however, is not applicable to the matrix clause because the result obtained by applying the default rule conflicts with that of Constraint 7. Consequently, we obtain the following interpretation with Default 1, Constraint 7, 2 and 3(persons).

(7) ϕ_c = the hearer = the user
ϕ_d = the third party = the machine

As for (1), since the matrix clause has the voice of possibility and is a state description, Constraint 7(TO) is not applicable. To the contrary, Constraint 6 (possibility expressions) is applied to the matrix clause. Therefore, we obtain the following interpretation with Default 1, Constraint 6, 2 and 4(Time of Speaker's Action).

(8) ϕ_c = the hearer = the user
ϕ_d = the agent who has own intention and is not the speaker = the user

As described so far, our constraints can explain the difference of interpretations.

To examine the accuracy of interpretations expected from our constraints, we have collected about 400 sentences, which include TO and some of which include possibility expressions, from several types of manuals. By these sentences, We check Constraint 7 and 6, which are the main constraints in this draft. As the result, it is confirmed that our constraints work correctly and there are no exception to our constraints, at least in the collected sentences.

5 An implementation

5.1 Overview

Our system consists of two subsystems, that is, *the translation system* and *the interpretation system*, as shown in Figure 1. The function of the translation system is to extract a semantic representation based on the nondefeasibility thesis. In the approach, the result of analysis is non-defeasible. Therefore, the process of analysis has no interaction with succeeding processes.

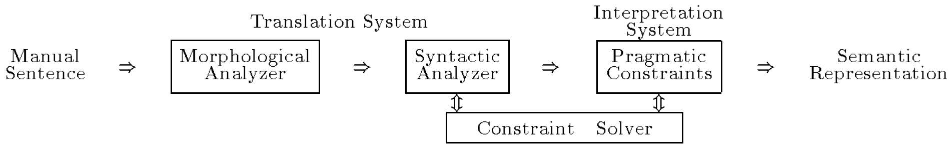

Figure 1: System Configuration

Since our system needs the lexicon which has various kinds of information, like subcategorizations, the volitional/non-volitional use of verbs, and so on, we adopt the lexicon *IPAL*(IPA Technology center, 1987; IPA Technology center, 1990) as the dictionary of the translation system. As the scheme of the syntax, we use the constraint-based grammar, which is based on *JPSG(Japanese Phrase Structure Grammar)*(Gunji, 1987) which is a kind of the head-driven unification based grammar. The output of the translation system is represented as a feature structure. Since the output semantic representation generally includes undetermined parts and ambiguous parts, we must represent them in the semantic representation. In our system, this kind of information is expressed as constraints attached to the semantic representation.

Next, we will describe the interpretation system. The system applies the following constraints to the output of the translation system to reduce the ambiguity of the output.

- Knowledge of the ontology of the manual world
- Pragmatic constraints which linguistic expressions are supposed to have.

In both of the systems, several kinds of constraints have to be processed. Accordingly, we introduce a logic-based constraint solver based on the Prolog program transformation(Tamaki and Sato, 1984). We also extend the semantics of Prolog to treat feature structures. This scheme of constraint description has almost the same expressive power as one of the pure Prolog, because goal sequences of the pure Prolog are used as constraints. In this scheme, constraints, that is, Prolog goal sequences, are not executed at a time as Prolog interpreters do, but transformed into the simplified equivalent goal sequences. The system called *cu-Prolog* (Tsuda, 1992), which is based on the notion of *conditioned unification* (Hashida, 1986), is one of the systems in this scheme. Our system has the same foundation as cu-Prolog, but our system has its own features including *negations*.

In our system, each data is expressed as a *restricted feature structure* `F|C`, which consists of the feature structure `F` and the constraint `C` for `F`. The constraint `C` is a Prolog goal sequence, which will be processed by the constraint solver. For example, the output of the translation system for (3) is the restricted feature structure `F1|[]` in figure 2. The null list `[]` means that the feature structure `F1` does not have any restriction. In our system, a feature structure is a list which consists of feature-value pairs. The label for a feature structure is placed in front of the list with the separator symbol `#`, if that feature is referred to elsewhere. The application of a new constraint is also performed by the unification procedure. For example, the result of the application of the constraint `cnstrnt_TO`/1, which is an implementation of the constraint of the connective particle 'TO', to `F1|[]` will be $F_n|C_n$ obtained from the following unification. Here, `funify`/3 is the unification procedure and `solve`/2 is the constraint solver.

```
F#[sem:[type: modification,
    way_of_mod:[class:conj_particle,word: TO],
    modifier:[type:state_of_affair,
     soa:[relation: OSU( push),agent:A,
          object:[type:object,
           property:[referred_to_by: BOTAN( button)]]],
     soa_info:[type:soa_info_verb,
      contents:[volitional_use:+,non_volitional_use:-,
       tense:[past:-]]]],
    sem_head:[type:state_of_affair,
     soa:[relation: DERU( come out),agent:A],
     soa_info:[type:soa_info_verb,
      contents:[volitional_use:+,non_volitional_use:-,
       tense:[past:-]]]]]]
```

Figure 2: Feature structure for the sentence (3)

(9)

$$\texttt{unify(F1|[],X|[cnstrnt\_TO(X)],}F_n|C_n\texttt{)} \Leftrightarrow \texttt{funify(F1,X,}F_n\texttt{)} \wedge \texttt{solve([cnstrnt\_TO(X)],}C_n\texttt{)}$$

5.2 Constraint Management by Negative expressions

Our constraint system can deal with constraints with negations. Since the Prolog program transformation is only for programs without goals which have some side effects like the cut operator, we have not been able to treat the negation. Accordingly, we introduce the goal '*not equal*', which expresses that two terms are not able to be unify and which can be quantified by universal quantifiers, in a suitable way for the Prolog program translation. With the goal, we can express the negation by the negation technique to some extent(Sato and Tamaki, 1986).

The negation not only improves the power of expression in constraint descriptions, but also functions as a manager of application of a constraint. Since it is impossible to give all of the linguistic constraint at the first stage, we need a way to accumulate individual constraints incrementally and compute them as a whole. In order to accumulate individual constraints incrementally, we have to manage the application of constraints. However, if we can use negative expressions for a constraint, the management mechanism is internalized as a part of the constraint. For example, the constraint of TO is expressed as the program in Figure 3. Note that the first clause expresses the case that the constraint is applicable and the second clauses expresses the case that the constraint is not applicable[10]. When only one of them is available, the constraint takes effect.

```
cnstrnt_TO(
  [sem:[type:modification,
        way_of_mod:[class:conj_particle,word: TO],
        sem_head:[type:state_of_affair,
         soa:[agent:X],
         soa_info:[type:soa_info_verb,
          contents:[non_volitional_use:-,
           tense:[past:-]]]]]]) :- third_party(X).
cnstrnt_TO(F) :-
  forall([R,S,T,U,V,W,Y,Z],
    F \= R#[sem:S#[
             type:modification,
             way_of_mod:T#[
              class:conj_particle,word: TO],
             sem_head:U#[type:state_of_affair,
              soa_info:W#[type:soa_info_verb,
               contents:Y#[non_volitional_use:-,
                tense:Z#[past:-]]]]]]).
third_party([type:object,prop:[class:machinery]]).
```

Figure 3: Constraint of the connective particle TO

6 Conclusion

In this draft, we proposed a scheme which closely depends not on domain knowledge of objects described in manual but on pragmatic constraints which linguistic expressions innately have. This method is almost independent from the domain knowledge, because it uses only the linguistic constraint and the general ontology of the world of manuals. Especially, we have shown that we can determine the referents of zero pronouns to some extent with our linguistic constraints, like the constraint of the Japanese Conditionals. However, we do not have enough knowledge about the following points. They are important portions of our future work.

- Full-fledged implementation. Although we confirmed *by hand* that our constraints determine the referents of zero pronouns properly, our implementation described the section 5 actually works only for a *part of the example* because of the parsing ability. We have to improve our parser in order to parse all example sentences.

- The postposition WA, which marks a topic and is sometimes used to express a conditional.

- The other types of manual sentences, like definitions.

[10] In the program, the goal `\=` means 'not equal,' and `forall/2` expresses the universal quantification of variables, which may include labels of feature structures.

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