Anaphora Resolution in Japanese Sentences
Using Surface Expressions and Examples

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Abstract

Anaphora resolution is one of the major problems in natural language processing. It is also one of the important tasks in machine translation and man/machine dialogue. We solve the problem by using surface expressions and examples. Surface expressions are the words in sentences which provide clues for anaphora resolution. Examples are linguistic data which are actually used in conversations and texts. The method using surface expressions and examples is a practical method.

This thesis handles almost all kinds of anaphora.

1. The referential property and number of a noun phrase
2. Noun phrase direct anaphora
3. Noun phrase indirect anaphora
4. Pronoun anaphora
5. Verb phrase ellipsis

Pronoun anaphora has been investigated by many researchers [Nagao et al 76] [Kameyama 86] [Yamamura et al 92] [Takada & Doi 94] [Nakaiwa & Ikehara 95]. We used their results in addition to our new methods. In other areas of anaphora resolution, there are scarcely any empirical works and thus this thesis breaks new ground. In this thesis, the above five computer anaphora resolutions are described in Chapter 2 through Chapter 5.

Chapter 2 shows that the referential property and number of noun phrases can be estimated fairly reliably by the words in Japanese sentences (surface expressions). The referential property and number of a noun phrase are basic factors in
anaphora resolution. The system can grasp the outline of the referent of the noun phrase by using the referential property and number of a noun phrase. Many rules for the estimation of the referential property and number are written in forms similar to rewriting rules in expert systems with scores. We tested and verified the effectiveness of this method.

Chapter 3 describes a method for estimating the referent of a noun phrase in Japanese sentences using referential properties, modifiers, and possessors of noun phrases. In this analysis, referential properties are very important. For example, if the referential property of a noun phrase is definite, the noun phrase can refer to a previous noun phrase, and if the referential property of a noun phrase is indefinite, the noun phrase cannot refer to a previous noun phrase. Furthermore, we more precisely estimated referents of noun phrases using modifiers and possessors of noun phrases. We verified in our experiment the effectiveness of using referential properties, modifiers, and possessors of noun phrases.

Chapter 4 describes how to resolve indirect anaphora resolution. A noun phrase can indirectly refer to an entity that has already been mentioned before. For example, “There is a house. The roof is white.” indicates that “the roof” is associated with “a house”, which was previously mentioned. When we analyze indirect anaphora, we need a case frame dictionary for nouns containing information about relationships between two nouns. But no noun case frame dictionary exists at present. Therefore, we used examples of “X of Y” and a verb case frame dictionary. We tested and verified that the information of “X of Y” is useful when we cannot make use of a noun case frame dictionary. We also proposed how to construct a noun case frame dictionary from examples of “X of Y”.

Chapter 5 describes how to estimate the referent of a pronoun in Japanese sentences. In conventional work, semantic markers have been used for semantic constraints. We used examples for semantic constraints and showed in our experiments that examples are as useful as semantic markers. We also proposed many new methods for estimating referents of pronouns. We experimented with pronoun resolutions on some texts and verified the effectiveness of our methods.

Chapter 6 describes the method of resolving verb phrase ellipsis using surface expressions and examples. When the referent of a verb phrase ellipsis appears
in the sentences, the structure of the elliptical sentence is commonly in a typical form and the resolution is done by using surface expressions. When the referent does not exist in the sentences, the system resolved the elliptical sentence using examples. As the result of the experiment, we obtained a high accuracy rate.
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Chapter 1

Introduction

1.1 Anaphora Resolution

Natural language understanding is one of many researchers’ dreams and has been investigated in many areas such as machine translation and man machine dialogue [Winograd 72] [Nagao 84] [Hirst 86] [Hobbs et al 88]. Let us consider what natural language understanding is. Although machines will eventually understand natural language and be able to talk with humans, they cannot do so at present. The first step for natural language understanding is that the machine understands the structure of a sentence. It has been investigated in some areas (morphological analysis, syntax analysis, and case analysis), and good results have been obtained in some papers [Matsumoto et al 92] [Kurohashi & Nagao 94] [Brill 95]. The next step is that the machine understands the object which a word refers to, which is called anaphora resolution. Although this has been investigated by many researchers, good results have still not been obtained. Therefore we devised a practical method to clarify how a word refers to an object.

What kind of tasks are involved in the resolution of the object which a word refers to? At first, the system must recognize what a noun phrase refers to. It must also understand whether a noun phrase refers to a specified object or to a generic object. When a noun phrase partly relates to a noun phrase which has already been mentioned, the system must detect the relation. It must also understand what a pronoun or an ellipsis refers to.
CHAPTER 1. INTRODUCTION

The above analyses are very important in machine translation and man-machine dialogue. If an ellipsis is not resolved, machine translation and dialogue processing cannot be performed. If the reference of a word is resolved, the precision of generating articles “the/a/an” and pronouns “I/you/he” in machine translation will increase. In dialogue system, the number of counter questions to users is smaller and the processing is becoming more smooth.

The following is handled in this thesis:

1. **The referential property and the number of a noun phrase**

   The system judges whether a noun phrase refers to a specific object or a generic object and estimates the number of the object.

   
   **HON-TOIUNOWA NINGEN-NO SEICHOU-NI KAKASEMASEN.**
   (book) (human being) (growth) (be necessary)
   (Books are necessary for the growth of the human being.)
   
   (Desired solution: “HON” refers to books in general.) (1.1)

2. **Noun phrase direct anaphora**

   The system estimates what a noun phrase represents.

   
   **OJIISAN-WA JIMEN-NI KOSHI-WO-OROSHIMASHITA.**
   (old man) (ground) (sit down)
   (The old man sat down on the ground.)

   **YAGATE OJIISAN-WA NEMUTTE-SHIMAIMASHITA.**
   (soon) (old man) (fall asleep)
   (The old man soon fell asleep.)

   (Desired solution: The underlined word “OJIISAN” refers to “OJI-ISAN” in the first sentence.) (1.2)
3. Noun phrase indirect anaphora

The system estimates the object which a noun phrase indirectly refers to. In other words, the system detects the object which a noun phrase relates to in context.

KINOU ARU HURUI IE-NI ITTA.
(yesterday) (a certain) (old) (house) (go)
(I went to an old house yesterday.)

YANE-WA HIDOI AMAMORIDE ...
(roof) (badly) (be leaking)
(The roof was leaking badly and ...) 
(Desired solution: The underlined word “YANE (roof)” is the roof of “IE (house)” in the first sentence.)

4. Pronoun anaphora

The system estimates what a pronoun represents.

KINOU MIKAN-WO KATTA.
(yesterday) (oranges) (buy)
(I bought some oranges yesterday.)

TAROU-NO IE-NI ITTE KORE-WO TABETA.
(Taroo’s) (house) (go) (this) (eat)
(I went to Taroo’s house and ate them.)
(Desired solution: “KORE” refers to “MIKAN”.)

5. Verb phrase ellipsis

The system recovers an omitted verb phrase.
CHAPTER 1. INTRODUCTION

The area of “4. Pronoun anaphora” has been investigated by many researchers [Nagao et al. 76] [Kameyama 86] [Yamamura et al. 92] [Takada & Doi 94] [Nakaiwa & Ikehara 95]. We used their results in addition to our new methods. In the other areas of anaphora resolution, there are scarcely any empirical works. So this thesis breaks new ground in this regard.

1.2 The Method Using Surface Expressions and Examples

In this thesis, we have used much available information available for anaphora resolution. We emphasize surface expressions and examples.

Examples are linguistic data which are actually used in conversations and texts. By using examples we can resolve many linguistic problems. For example, suppose that we want to clarify the thing which “KORE (this)” represents in the following sentences.

KINOU MIKAN-WO KATTA.
(yesterday) (oranges) (buy)
(I bought some oranges yesterday.)

TAROU-NO IE-NI ITTE KORE-WO TABETA.
(Taroo’s) (house) (go) (this) (eat)
(I went to Taroo’s house and ate them.)

In this case, we gather examples such as “RINGO-WO TABERU (I eat apples)” and “KEIKI-WO TABERU (I eat cakes)”, and extract “RINGO (apple)” and “KEIKI (cake)” as the things which correspond to “KORE (this)”. Since “MIKAN
(orange)” is semantically similar to “RINGO (apple)” and “KEIKI (cake)” in terms of food, we find that it is the antecedent of “KORE (this)”. The method using examples has a wide application. If we discover examples which are analogous to the form of a problem, we can immediately use examples to solve the problem\footnote{The method of using examples, which is called \textit{Example-based approach}, was proposed for the purpose of machine translation \cite{Nagao84}. Although this method is used by many researchers in machine translation, it is not used in anaphora resolution to our knowledge.}.

\textit{Surface expressions} are the clue words in sentences which are used in anaphora resolution. For example, suppose that we want to clarify the thing which “HON (book)” refers to in the following sentences.

\begin{verbatim}
HON-TOIUNOWA NINGEN-NO SEICHOU-NI KAKASEMASEN.
\end{verbatim}

(books) (human being) (growth) (be necessary) \hfill (1.7)

Since there is a surface expression such as “TOIUNOWA” in this sentence, we find that “HON (book)” does not refer to a specific book but refers to books in general. Using surface expressions also has a wide application.

The surface expressions and examples used in this work are as follows.

- **Surface Expression**
  - words
  - part-of-speech
  - syntax structure

- **Example**
  - the case frame of a verb phrase
  - the semantic relation between two nouns.
  - example sentences
1.3 The Overview of Later Chapters

This thesis describes how to resolve many problems in anaphora by using surface expressions and examples.

Chapter 2 shows that the referential property and number of noun phrases can be estimated fairly reliably by the words (surface expressions) in Japanese sentences. The referential property and number of a noun phrase are basic factors in anaphora resolution. The system can grasp the outline of the referent of the noun phrase by using the referential property and number of a noun phrase. Many rules for the estimation of the referential property and number are written in forms similar to rewriting rules in expert systems with scores. We tested and verified the effectiveness of this method.

Chapter 3 describes a method for estimating the referent of a noun phrase in Japanese sentences using referential properties, modifiers, and possessors of noun phrases. In the analysis, referential properties are very important. For example, if the referential property of a noun phrase is definite, the noun phrase can refer to a previous noun phrase, and if the referential property of a noun phrase is indefinite, the noun phrase cannot refer to a previous noun phrase. Furthermore, we estimated referents of noun phrases using modifiers and possessors of noun phrases more precisely. We made the experiment and verified that it is effective to use referential properties, modifiers, and possessors of noun phrases for estimating the referent of a noun phrase.

Chapter 4 describes how to resolve indirect anaphora resolution. A noun phrase can indirectly refer to an entity that has already been mentioned before. For example, “There is a house. The roof is white.” indicates that “the roof” is associated with “a house”, which was mentioned in the previous sentence. When we analyze indirect anaphora, we need a case frame dictionary for nouns containing the information about relations between two nouns. But no noun case frame dictionary exists at present. Therefore, we used examples of “X of Y” and a verb case frame dictionary, instead. We made some experiments and verified that the information of “X of Y” is useful when we cannot make use of a noun case frame dictionary. We also proposed how to construct a noun case frame dictionary from
1.3. THE OVERVIEW OF LATER CHAPTERS

examples of “X of Y”.

Chapter 5 describes how to estimate the referent of a pronoun in Japanese sentences. In conventional work, semantic markers have been used for semantic constraints. We used examples for semantic constraints and show by our experiments that examples are as useful as semantic markers. We also proposed many new methods for estimating referents of pronouns. We experimented with pronoun resolutions on some texts and verified the effectiveness of our methods.

Chapter 6 describes the method of resolving verb phrase ellipsis using surface expressions and examples. When the referent of a verb phrase ellipsis appears in the sentences, the structure of the elliptical sentence is commonly in a typical form and the resolution is done by using surface expressions. When the referent does not exist in the sentences, the system resolved the elliptical sentence using examples. As the result of the experiment, we obtained a high accuracy rate.

Chapter 7 is concluding remarks.
Chapter 2

An Estimate of the Referential Property and the Number of Noun Phrase

2.1 Introduction

This chapter describes a method for the estimation of the referential property and number of a noun phrase by using surface expressions. The referential property of a noun phrase represents how the noun phrase denotes the referent. The referential property is classified into three types: generic, definite and indefinite. A definite noun phrase refers to a given object. An indefinite noun phrase refers to a new object. They correspond to a noun phrase with a definite article and a noun phrase with an indefinite article in English, respectively. A generic noun phrase refers to all objects which the noun phrase denotes. The number of a noun phrase is the number of the referent denoted by the noun phrase. The number is classified into three types: singular, plural, and uncountable. The referential property and number of a noun phrase are basic factors in anaphora resolution. The system can grasp the outline of the referent of the noun phrase by using the referential property and number of a noun phrase. The referential property and number are also useful when the system generates the article in translating Japanese nouns.
into English.

This chapter shows that the referential property and number of noun phrases can be estimated fairly reliably by words (surface expressions) in the sentence. Many rules for the estimation were written in forms similar to rewriting rules in expert systems with scores. Since this method uses scores, it is good to deal with vague problems like referential properties and numbers. We made the experiment estimating the referential property and number of the noun phrase and verified that our method is effective.

### 2.2 Categories of Referential Property and Number

#### 2.2.1 Categories of Referential Property

Referential property of a noun phrase here means how the noun phrase denotes the subject. We classified noun phrases into the following three types from the referential property.

\[
\text{noun phrase} \begin{cases} 
\text{generic noun phrase} \\
\text{non generic noun phrase} \begin{cases} 
\text{definite noun phrase} \\
\text{indefinite noun phrase}
\end{cases}
\end{cases}
\]

**Generic Noun Phrase**  A noun phrase is classified as generic when it denotes all members of the class of the noun phrase or the class itself of the noun phrase. For example, “dogs” in the following sentence is a generic noun phrase.

\[
\text{Dogs are useful.} \quad (2.1)
\]

**Definite Noun Phrase**  A noun phrase is classified as definite when it denotes a contextually non-ambiguous member of the class of the noun phrase. For example, “the dog” in the following sentence is a definite noun phrase.

\[
\text{The dog went away.} \quad (2.2)
\]
CHAPTER 2. THE REFERENTIAL PROPERTY AND THE NUMBER

Indefinite Noun Phrase  An indefinite noun phrase denotes an arbitrary member of the class of the noun phrase. For example, the following “dogs” is an indefinite noun phrase.

There are three dogs.  \( (2.3) \)

\[ \text{2.2.2 Categories of Number} \]

The number of a noun phrase is the number of the subject denoted by the noun phrase. Categories of number are as follows.

\[
\text{noun phrase} \begin{cases} 
\text{countable} & \text{noun phrase} \\
\text{singular} & \text{noun phrase} \\
\text{plural} & \text{noun phrase} \\
\text{uncountable} & \text{noun phrase}
\end{cases}
\]

Singular Noun Phrase  A noun phrase is classified as singular when it denotes a singular member of the class of the noun phrase. For example, “a book” in the following sentence is singular.

She brought a book.  \( (2.4) \)

Plural Noun Phrase  A noun phrase is classified as plural when it denotes plural members of the class of the noun phrase. For example, “some books” in the following sentence is plural.

She brought some books.  \( (2.5) \)

Uncountable Noun Phrase  A noun phrase is classified as uncountable when it denotes part of the class of the noun phrase which cannot be divided into individuals. For example, “copper” in the following sentence is used as material and uncountable.

Copper conducts heat well.  \( (2.6) \)
2.3. HOW TO ESTIMATE

"KARE(he)-WA SONO(the)-BENGOSHI(lawyer)-NO(of)
MUSUKO(son)-NO(of) HITORI(one person)-DESU(is)."

(He is one of the sons of the lawyer.)

(a): Japanese sentence

KARE(he)-WA-----|
SONO(the)----|
BENGOSHI(lawyer)-NO(of)----|
MUSUKO(son)-NO--|
HITORI(one person)-DESU(is)

(b): Dependency structure of sentence (a)

( <[noun common-noun _ _ 'HITORI' 'HITORI']
  [copula _ copula DESU-line-basic-form 'DA' 'DESU']
  [punctuation-mark period _ _ ' ', ' . ']> )
( <[noun common-noun _ _ 'MUSUKO' 'MUSUKO']
  [postpositional-particle noun-connection-postpositional-particle
   _ _ 'NO' 'NO']> )
( <[noun common-noun _ _ 'BENGOSHI' 'BENGOSHI']
  [postpositional-particle
   noun-connection-postpositional-particle _ _ 'NO' 'NO']> )
( <[demonstrative-adjective _ _ 'SONO' 'SONO']> )
( <[noun common-noun _ _ 'KARE' 'KARE']
  [postpositional-particle topic-marking-postposition _ _ 'WA'
   'WA']> )
( [punctuation-mark komma _ _ ', ', ' ])> )

(c): Dependency structure representation of sentence (a)

Figure 2.1: Example of dependency structure representation
( <[noun -] - >
    ( <[demonstrative-adjective - 'SONO' 'SONO']> ) - )

Figure 2.2: An expression of the noun modified by “SONO (the)”

2.3 How to Estimate Referential Property and Number

Heuristic rules for the referential property are given in the form:

(condition for rule application)

\[ \Rightarrow \{ \text{indefinite}(\text{possibility, value}), \text{definite}(\text{possibility, value}), \text{generic}(\text{possibility, value}) \} \]

Heuristic rules for the number are given in the form:

(condition for rule application)

\[ \Rightarrow \{ \text{singular}(\text{possibility, value}), \text{plural}(\text{possibility, value}), \text{uncountable}(\text{possibility, value}) \} \]

In condition for rule application, a surface expression is written in the form as in Figure 2.2. Possibility has value 1 when the categories: indefinite, definite, generic, singular, plural or uncountable, are possible in the context checked by the condition. Otherwise the possibility value is 0. Value means that a relative possibility value between 1 and 10 (integer) is given according to the plausibility of the condition that the possibility is 1. A larger value means the plausibility is high.

The rules are all heuristic so that the categories are not exclusive. In a certain conditional situation both indefinite and generic are possible, and also both singular and plural can co-exist. In these cases, however, the possibility values may be different.

Several rules can be applicable to a specific noun in a sentence. In this case the possibility values are added for individual categories and the final decision of a category for a noun is done by the maximum possibility value. An example is given in Section 2.4.1.

When determining the referential property and number of nouns, the condition part is matched not for a word sequence but for a dependency structure of a
sentence. The dependency structure of a sentence (Figure 2.1(a)) is shown in Figure 2.1(b) which is represented as Figure 2.1(c) to which the condition is checked. In heuristic rules, this expression can include a wild card (represented by “~”) which can match any partial dependency structure representations. For example, a noun modified by “SONO(the)” is expressed as in Figure 2.2. There are many other expressions such as regular expressions, AND-, OR-, NOT-operators, MODee-operator for checking modifier-modifyee relation and so on.

Algorithm of the Determination of a Category

The following steps are taken for the decision of a category for the referential property and the number.

1. Sentences are transformed into dependency structure representations.

2. Decision is made for each noun from left to right in the sentences transformed into dependency structure representation. This process allows the decision process to make use of the referential property and the number already determined (see 2.4.1(c)(d) for example). For each noun, the referential property is first determined, and then the number. This enables the utilization of referential property of a noun when analyzing the number of the noun (see 2.4.2(3) for example). In these processes all the applicable rules are used, possibility and value of each category are computed, and the category for the maximum value is obtained. An example of the result is shown in Figure 2.3. We can also utilize the global information of a document to which a sentence belongs in the decision process. The condition part, for example, can check whether there are previous identical nouns. This information is useful for the determination of the referential property.

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1 This is the result transformed by the system.[Kurohashi & Nagao 94]
2.4 Heuristic Rules

We have written 86 heuristic rules for the referential property and 48 heuristic rules for the number. More than half of these rules are just the implementation of grammatical properties explained in standard grammar books of Japanese and English [Kumayama 85, Ikeuchi 85, Koizumi 89], but there are many other heuristic rules which we have created. All of the rules are described in Appendix A. Some of the rules are given below.

2.4.1 Heuristic Rules for Referential Property

(1) When a noun is modified by a referential pronoun, KONO(this), SONO(its), etc.,
then \{ indefinite (0, 0)\footnote{2} definite (1, 2) generic (0, 0) \}

Examples: KONO(This) HON-WA(book) OMOSHIROI(interesting)

This book is interesting.

(2) When a noun is accompanied by a particle (WA), and the predicate is in the past tense,
then \{ indefinite (1, 0) definite (1, 3) generic (1, 1) \}

\footnote{2}{(a, b) means the possibility(a) and the value(b).}
Example: **INU-WA** (dog) **MUKOUE** (away there) **IKIMASHITA** (went)

The dog went away.

(3) When a noun is accompanied by a particle (WA), and the predicate is in the present tense,

then \{ indefinite \((1, 0)\) definite \((1, 2)\) generic \((1, 3)\) \}

Example: **INU-WA YAKUNITATSU** (useful) **DOUBUTSU** (animal) **DESU** (is)

Dogs are useful animals.

(4) When a noun is accompanied by a particle HE (to), MADE (up to) or KARA (from),

then \{ indefinite \((1, 0)\) definite \((1, 2)\) generic \((1, 0)\) \}

Example: **KARE-WO** (he) **KUUKOU-MADE** (airport) **MUKAE-NI** (to meet) **YUKIMASHOO** (let us go)

Let us go to meet him at the airport.

(5) When a noun phrase is accompanied by a particle NO (of), and it modifies a noun phrase

\{ indefinite \((1, 0)\) definite \((1, 2)\) generic \((1, 3)\) \}

Example: **KARE-WA** (he) **KYOUIKU-NO** (education) **KACHI-WO** (value) **NINSHIKI-SHITE-IMASEN** (do not realize)

He doesn’t realize the value of education.

There are many other expressions which give some clues for the referential property of nouns, such as (i) the noun itself, “CHIKYUU (the earth)”[definite], “UCHUU (the universe)”[definite], etc., (ii) nouns modified by a numeral (Example: **KORE-WA** (this) **ISSATSUNO** (one) **HON-DESU** (book)[indefinite]. (This is a book)), (iii) the same noun presented previously (Example: **KARE-WA** (he) **JOYOU** (car)-**TO** (and) **TORAKKU-WO** (truck) **ICHIDAI-ZUTSU** (by ones)

---

3 Both “a dog” and “the dog” are possible because of the generic subject.

4 When a noun phrase is accompanied by a particle NO (of), it is not always a generic noun phrase. But “NO” is likely to accompany old information, a noun phrase with “NO” is commonly a definite noun phrase or a generic noun phrase. Since we think that a definite noun phrase can be estimated by the other information, we give a generic noun phrase a higher point value in this rule.
MOTTEIMASUGA (have), JOUYOUSHA-NIDAKE (car) [definite] HOKEN-WO-KAKETEIMASU (be insured). (He has a car and a truck, but only the car is insured.), (iv) adverb phrases, “ITSUMO (always)”, “NIHON-DEWA (in Japan)”, etc. (Example: NIHON-DEWA SHASHOU-WA (conductor) [generic] JOUKYAKU (passenger)-NO (of) KIPPU-WO (ticket) SHIRABEMASU (check). (In Japan, the conductor checks the tickets of the passengers.)), (v) verbs, “SUKE (like)”, “TANOSHI MU (enjoy)”, etc. (Example: WATASHI-WA (I) RINGO-GA (apple) [generic] SUKI-DESU (like). (I like apples.)).

In the case of no clues, “indefinite” is given to a noun as a default value.

Since noun phrases which signify family relationships or body-parts such as “MUSUKO (son)” “ONAKA (stomach)” are almost always definite noun phrases, we had better use the rule that when a noun phrase is a family relationship or a body-part, it is judged to be a definite noun phrase. Since this rule was made after the experiment on the test sentences in Section 2.3, we did not use it in the experiment. To test the effectiveness of this rule we made the experiment using this rule. The result is that the accuracy percentage decreased by 0.4% in training sentences and increased by 3% in test sentences. This is because in training sentences there are unexpectedly many cases that a noun phrase which indicates a relative or a body-part is used as non-definite. In common sentences, we should use this rule. We used Bunrui Goi Hyou [NLRI 64] in judging whether a noun phrase means kin or body-part. The noun phrase the prefix of whose bgh code is “121” is regarded as relative, and “157” is regarded as body-part.

Let us see an example which has several rule applications for the determination of the referential property of a noun. “KUDAMONO (fruit)” in the following sentence is an example.

WAREWARE-GA KINOU TSUMITOTTA KUDAMONO-WA AJI-GA IIIDESU
(We) (yesterday) (picked) (fruit) (taste) (be good)
(The fruit that we picked yesterday tastes delicious.)
2.4. **HEURISTIC RULES**

Seven rules are applied for the determination of the definiteness of this noun. These are the following:

(a) When a noun is accompanied by WA, and the corresponding predicate has no past tense

\[(\text{KUDAMONO-WA AZI-GA IIDESU}),\]

then \{ indefinite (1, 0) definite (1, 2) generic (1, 3) \}

(b) When a noun is modified by an embedded sentence which is in the past tense (TSUMITOTTA),

then \{ indefinite (1, 0) definite (1, 1) generic (1, 0) \}

(c) When a noun is modified by an embedded sentence which has a definite noun accompanied by WA or GA (WAREWARE-GA),

then \{ indefinite (1, 0) definite (1, 1) generic (1, 0) \}

(d) When a noun is modified by an embedded sentence which has a definite noun accompanied by a particle (WAREWARE-GA),

then \{ indefinite (1, 0) definite (1, 1) generic (1, 0) \}

(e) When a noun is modified by a phrase which has a pronoun (WAREWARE-GA),

then \{ indefinite (1, 0) definite (1, 1) generic (1, 0) \}

(f) When a noun has an adjective as its predicate (KUDAMONO-WA AZI-GA IIDESU),

then \{ indefinite (1, 0) definite (1, 3) generic (1, 4) \}

(g) When a noun is a common noun (KUDAMONO),

then \{ indefinite (1, 1) definite (1, 0) generic (1, 0) \}

As the result of the application of all these rules, we obtained the final score of \{ indefinite (1, 1) definite (1, 9) generic (1, 7) \} for KUDAMONO, and “definite” is given as the decision.
2.4.2 Heuristic Rules for Number

(1) When a noun is modified by SONO(its), ANO(that), KONO(this),
then \{ singular (1, 3) plural (1, 0) uncountable (1, 1) \}
Example: ANO(that) HON-WO (book) KUDASAI (give me)
Give me that book.

(2) When a noun is accompanied by a particle WA, GA, MO, WO, and there
is a numeral x which modifies the predicate of a sentence, and
if \( x = 1 \), then \{ singular (1, 2) plural (1, 0) uncountable (1, 0) \}
if \( x \geq 2 \), then \{ singular (1, 0) plural (1, 2) uncountable (1, 0) \}
Example: RINGO-WO(apple) NIKO(two) TABERU(eat)
I eat two apples.

(3) When a predicate, SUKI(like), TANOSHIMU(enjoy), etc. has a generic
noun as an object, and the noun is accompanied by GA(for SUKI), or
WO(for TANOSHIMU),
then \{ singular (1, 0) plural (1, 2) uncountable (1, 0) \}
Example: WATASHI-WA(I) RINGO-GA(apple) SUKI-DESU(like)
I like apples.

There are many other expressions which determine the number of a noun,
such as (i) nouns modified by a numeral (Example: KORE-WA(this) ISSAT-
SUNO(one) HON-DESU(book)[singular]. (This is a book.)), (ii) verbs such as
ATSUMERU(collect), AFURERU(be full with), (Example: WATASHI-WA(I)
NEKO-NO(about cat) HON-WO(book)[plural] ATSUMETEIMASU(collect). (I
collect books on cats.)) (iii) adverbs such as NANDO-DEMO(as many times as ...
), IKURA-DEMO(as much ...) (Example: RIYUU-WA(reason)[plural] IKURA-
DEMO(as much ...) SHIMESEMASU(give). (I can give you a number of rea-
sons.)).

In the case of no clues, “singular” is given as a default value.
2.5 Experiments and Results

Experiments for the determination of the referential property and for the number were done in the following three texts: typical example sentences in a grammar book “Usage of the English Articles” [Kumayama 85], the complete text of a Japanese popular folk tale “The Old Man with a Lump” [Nakao 85], a small fragment of an essay “TENSEI JINGO”. The rules were written by referring to these sentences which have good English translations. These sentences can be regarded as a training set. The results of the experiments are shown in Table 2.1. Here “correct” means that the result was correct. “Reasonable” means that the result is given, for example, as non-generic but the correct answer was definite, etc. “Partially correct” means that the result was included in the correct answer. “Undecidable” means that we could not judge which category is correct. We obtained 85.5% success rate for the determination of the referential properties and 89.0% success rate for the numbers for all these training sentences. The scores of these tables show that the heuristic rules are effective and applicable to these sentences.

The modification and addition of rules in the experiment of training sentences were performed as follows:

1. The modification and addition of rules were performed by examining errors. In other words, we looked at the surface expressions near a noun phrase which was incorrectly interpreted, and considered whether we can make a new rule. We also checked whether we could correct this error by modifying the condition and the point of the rule.

2. After some modifications and additions of rules were performed, we checked whether the overall precision was higher or lower. When the overall precision was higher, we formally adopted the modifications and additions which were performed in 1. When the overall precision was lower, we did not perform the modifications and additions, and repeated examinations in 1.

In addition to this procedure, when we roughly examined some errors and found out a rule by which we could correct these errors, we added the rule to the
rule set. Moreover, when we were not certain whether we should add a certain rule, we listed all parts which were used by the rule and decided by looking at them as a whole.

To test the quality of these rules, we applied them to the following three texts: a Japanese popular folk tale “TSURU NO ONGAESHI” [Nakao 85], three small fragments of an essay “TENSEI JINGO”, “Pacific Asia in the Post-Cold-War World” (A Quarterly Publication of The International House of Japan Vol.12,


Table 2.2: Test sentences

| Referential property | Number |                  |
|----------------------|--------|------------------|
|                      | indef  | def              |
|                      | gener  | other           |
|                      | total  | single          |
|                      | plural | uncount         |
|                      | other  | total           |
| a folk tale “TSURU NO ONGAESHI” (263 sentences, 699 nouns) | | |
| correct              | 109    | 363              |
|                      | 13     | 10               |
|                      | 495    | 610              |
|                      | 13     | 1                |
|                      | 1      | 1               |
|                      | 625    |                  |
| reasonable           | 6      | 25               |
|                      | 0      | 0               |
|                      | 31     | 12               |
|                      | 2      | 0               |
|                      | 0      | 0               |
|                      | 14     |                  |
| partially correct    | 0      | 0               |
|                      | 0      | 0               |
|                      | 0      | 0               |
|                      | 0      | 0               |
|                      | 1      | 1               |
| incorrect            | 32     | 135              |
|                      | 6      | 0               |
|                      | 173    | 2                |
|                      | 20     | 37              |
|                      | 0      | 59              |
| % of correct         | 74.2   | 69.4             |
|                      | 68.4   | 100.0            |
|                      | 70.8   | 97.8             |
|                      | 37.1   | 2.6             |
|                      | 50.0   | 89.4             |
| an essay “TENSEI JINGO” (75 sentences, 283 nouns) | | |
| correct              | 75     | 81               |
|                      | 16     | 0               |
|                      | 172    | 197             |
|                      | 13     | 2               |
|                      | 3      | 3               |
|                      | 215    |                  |
| reasonable           | 8      | 9               |
|                      | 1      | 0               |
|                      | 18     | 3               |
|                      | 1      | 0               |
|                      | 0      | 0               |
|                      | 4      |                  |
| partially correct    | 0      | 0               |
|                      | 0      | 0               |
|                      | 0      | 0               |
|                      | 0      | 0               |
|                      | 3      | 3               |
| incorrect            | 33     | 51              |
|                      | 9      | 0               |
|                      | 93     | 3               |
|                      | 55     | 3               |
|                      | 0      | 61              |
| % of correct         | 64.7   | 57.5             |
|                      | 61.5   | 60.8            |
|                      | 97.0   | 18.8            |
|                      | 40.0   | 50.0            |
|                      | 76.0   |                  |
| Pacific Asia in the Post-Cold-War World (22 sentences, 192 nouns) | | |
| correct              | 21     | 108             |
|                      | 11     | 2               |
|                      | 142    | 157             |
|                      | 6      | 1               |
|                      | 1      | 1               |
|                      | 165    |                  |
| reasonable           | 6      | 7               |
|                      | 0      | 0               |
|                      | 13     | 3               |
|                      | 0      | 0               |
|                      | 0      | 3               |
| partially correct    | 0      | 0               |
|                      | 0      | 0               |
|                      | 0      | 0               |
|                      | 0      | 0               |
| incorrect            | 11     | 24              |
|                      | 2      | 0               |
|                      | 37     | 3               |
|                      | 20     | 1               |
|                      | 0      | 24              |
| % of correct         | 55.3   | 77.7             |
|                      | 84.6   | 100.0            |
|                      | 74.0   | 96.3             |
|                      | 23.1   | 50.0             |
|                      | 100.0  | 85.9             |
| average              |        |                  |
| % of appearance      | 25.6   | 68.4            |
|                      | 4.9    | 1.0             |
|                      | 100.0  | 84.3            |
|                      | 3.8    | 3.8             |
|                      | 100.0  |                  |
| % of correct         | 68.1   | 68.7             |
|                      | 69.0   | 68.9            |
|                      | 97.4   | 24.6            |
|                      | 8.9    | 55.6            |
|                      | 85.6   |                  |

No.2 Spring 1992). These test sentences have good English translations. The results are shown in Table 2.2. The success rates for the referential property and the number decreased down to 68.9% and 85.6% respectively by these test sentences. These scores show, however, that the rules are still effective.
2.6 Discussion

Discussion on the Experiment of the Referential Property

With respect to referential property, the success rate was 85.5% in the training sentences by which we elaborated our rule set. There was no category which was very bad. This indicates that our method of using surface expressions can estimate the referential properties of many noun phrases.

The success rate was 68.9% in the test sentences on which we fixed our rule set. All the categories’ success rates were uniformly good and more than 60%. The appearance of the definite noun phrase was 74.8% in the experiment of “TSURU NO ONGAESHI”. Therefore, if we make rules which handle each noun phrase as a definite noun phrase, the success rate becomes 74.8%, and becomes higher than the success rate of 70.8% in the experiment. But this is not good, because the success rates of indefinite noun phrases and generic noun phrases become 0%. We think that it is important that all the categories’ success rates are uniformly good.

The success rate in training sentences is not good. If we modify the rule set, the success rate will easily rise. But when we try to increase the success rate in new sentences, it may be necessary to continue to make new rules for new sentences.

Table 2.3 and Table 2.4 are examples which are analyzed incorrectly, even if we modify the rule set. Table 2.3 is a set of examples which are analyzed incorrectly because no key surface expression exists and a noun phrase is a definite noun phrase. To solve this problem, we need the information on contexts and situations.

Table 2.4 are examples which are analyzed incorrectly when a noun phrase is a generic noun phrase. We describe the reason for the error in each example.

There were some cases where it is difficult to analyze using only surface expressions.

\[
\text{KORE-WA KARE-KARA KARITA JISHO DESU.} \\
\text{(this) (from him) (borrow) (dictionary) (be) (2.8)} \\
\text{(This is the dictionary that I borrowed from him.)}
\]

In this example, since “WATASHI-GA KARE-KARA KARITA JISHO (the
2.6. DISCUSSION

Table 2.3: Examples of definite noun phrases analyzed incorrectly (noun phrases whose head words are underlined)

| (1) KARE-WA SHACHOU-NO ONIISAN-DESU. |
| (he) (president) (brother) |
| (He is the brother of the president.) |

| (2) JHON-WA KURASU-NO NAKADE ICHIBAN SEGATAKATAI. |
| (John) (class) (in) (the most) (tall) |
| (John is the tallest in my class.) |

| (3) KANOJO-WA TEIBURU-WO HUKU-NONI HUKIN-WO TSUKATT A. |
| (she) (table) (to dust) (cloth) (use) |
| (She used a cloth to dust the table.) |

| (4) SHIGOTO-DE MUZUKASHII-TOKOROGA ATTA-GA KOKUHUKUSHITA. |
| (work) (difficulty) (exist) (overcome) |
| (I overcame a difficulty in my work.) |

| (5) WATASHI-WA SENSEI-TO ONAJI HON-WO MOTTE-IMASU. |
| (I) (teacher) (same) (book) (have) |
| (I have the same book as the teacher has.) |

| (6) KURUMA-WA MICHI-NO-WAKINI CHUUSA-SHITE-ARIMASU. |
| (car) (along the street) (be parked) |
| (Cars are parked along the street.) |

| (7) JONSONKYOUJU-WA GAKKAI-DE RONBUN-WO YOMIMASHITA. |
| (Professor Johnson) (convention) (technical paper) (read) |
| (Professor Johnson read his paper at the convention.) |

dictionary that I borrowed from him)” is modified by the embedded sentence, it was judged to be a definite noun phrase. But when “WATASHI (I)” borrowed some dictionaries from “KARE (him)” and “WATASHI-GA KARE-KARA KARITA JISHO (the dictionary that I borrowed from him)” is one of them, it is an indefinite noun phrase. Therefore it is difficult for the system to judge whether a noun phrase is a definite noun phrase or an indefinite noun phrase unless the system has certain information.
Table 2.4: Examples of generic noun phrases incorrectly analyzed (underlined noun phrases)

| Example                                                                 | Analysis                                                                 |
|------------------------------------------------------------------------|--------------------------------------------------------------------------|
| (1)When the noun phrase is incorrectly judged as definite because it is modified an embedded sentence. | SOREJITAL-WO MAMOROU-TO-SHINAI BUNKA-WA HOROBIMASU. (itself) (do not defend) (culture) (die) |
| (A culture that does not defend itself will die.)                      |                                                                          |
| (2)When the noun phrase is incorrectly judged as definite because the predicate is in the tense. | CHUUGOKUJIN-WA DOKUJI-NO MOJI-WO HATSUMEI-SHITA. (Chinese) (own) (writing system) (invent) |
| (The Chinese invented their own writing system.)                       |                                                                          |
| (3)When the noun phrase is incorrectly judged as indefinite because it is followed by a copula “DA”. | NIHON-NO SHAKAI-DEWA CHICHIOYA-WA KACHOU-DESU. (Japanese) (society) (father) (the head of the household) |
| (In Japanese society, the father is the head of the household.)         |                                                                          |
| (4)When the noun phrase is incorrectly judged as indefinite because there is no clue. | TABEMONO-GA OISHIKEREBA OISHIIHODO. TAKUSAN TABEMASU. (food) (good) (the more) (much) (eat) |
| (The better the food is, the more I eat.)                              |                                                                          |

Discussion on the Experiment of the Number

The success rate was 89.0% in training sentences. But the success rate of “plural” was low.

The success rate was 85.6% in test sentences. But the success rates of “plural” and “uncountable” were low.

The following example is for when the plural noun phrase was analyzed incor-
Table 2.5: Examples of verbs which may be used in the estimation of the number of the noun phrase

| Verb               | Meaning            |
|--------------------|--------------------|
| ABIRU (pour water) | HUKIKAKERU (sprinkle) |
| MABUSU (cover)     | WAKIDERU (well up)  |
| SOROERU (put in order) | UMORERU (be buried) |
| MORERU (leak)      | KOBORERU (drop, spill) |
| MURAGARU (crowd)   | NOMU (drink)       |

rectly.

CHUUMON-SHITA KENCHIKU-ZAIRYOU-GA KIMASHITA.
(order) (building material) (come) (2.9)
(The building materials you ordered have come in.)

The reason for the error is that there is no clue word. To judge this case to be “plural”, the system must judge it by the word “KENCHIKU-ZAIRYOU (building material)” itself. But “KENCHIKU-ZAIRYOU (building material)” is not always “plural”.

The following example is a plural noun phrase analyzed properly without quantifiers.

SONO JIKO-NO-A TO YAJIUMA-GA ATSUMARU (after the accident) (people) (gather) (2.10)
(people gathered after the accident)

“YAJIUMA” was judged to be “plural” using the verb “GA ATSUMARU (gather)”. If we make such a rule, we can occasionally analyze the number of a noun phrase which is not modified by a quantifier.

After the experiment on the training sentences and test sentences, we examined the rule using verbs such as “ATSUMARU (gather)”, “NARABERU (put in order)”, and “ABIRU (pour water)”. We gathered about 300 verbs from “Bunrui Goi Hyou” NLRI 64 which can be used in the estimation of the number. The examples are shown in Table 2.3. We also checked the occurrence of the noun phrases which can be analyzed properly by using these verbs. There were 21 noun phrases in the sentences (526 sentences, 2680 noun phrases, essays of two
months) of essays “TENSEI JINGO” which were analyzed properly by the syntactic parser. This frequency was low. But since the number of the noun phrase which can be analyzed properly still increases, we must use the rule using verbs as in Table 2.5 for the estimation of the number.

2.7 Summary of this Chapter

We obtained the correct recognition scores of 85.5% and 89.0% in the estimation of referential property and number respectively for the sentences which were used for the construction of our rules. We tested these rules for some other texts, and obtained the scores of 68.9% and 85.6% respectively.

There are two problems in the estimation of the referential property. One is that although a human can easily recognize the referential property from the situation, the system cannot estimate the referential property. If we can make use of situational information, we can analyze the problem properly.

Another problem is with respect to generic noun phrases. A generic noun phrase is difficult to be defined to discriminate other categories. The category may have to be reconstructed.

With respect to the number of a noun phrase, it is easily estimated, if it is modified by some surface expressions such as quantifiers. Since a noun phrase is not always modified by quantifiers, the estimation of the number is not so easy. There are some cases when the number is estimated properly by verbs such as “ATSUMERU (gather)” and adverbs such as “IKURADEMO (as much as one likes)”.

Chapter 3

An Estimate of Referent of Noun Phrases

3.1 Introduction

This chapter describes how to estimate the referent of a noun phrase in Japanese sentences. It is important to clarify referents of noun phrases in machine translation. For example, since the two “OJIISAN (old man)” in the following sentences have the same referent, the second “OJIISAN (old man)” should be pronominalized in translation into English.

\[
\text{OJIISAN-WA JIMEN-NI KOSHI-WO-OROSHIMASHITA.} \\
\text{(old man) (ground) (sit down)} \\
\text{(The old man sat down on the ground.)} \\
\text{(3.1)} \\
\text{YAGATE OJIISAN-WA NEMUTTE-SHIMAIMASHITA.} \\
\text{(soon) (old man) (fall asleep)} \\
\text{(He (= the old man) soon fell asleep.)}
\]

When dealing with a situation like this, it is necessary that a machine translation system should recognize that two “OJIISAN (old man)” have the same referents. In this chapter, we propose a method for determining referents of noun phrases using (1) referential properties of noun phrases, (2) modifiers in noun phrases, and (3) possessors of objects denoted by noun phrases.
For languages that have articles like English, we can guess by using articles whether two noun phrases refer to each other or not. In contrast, for languages that have no articles like Japanese, it is difficult to decide whether two noun phrases refer to each other. We estimated referential properties of noun phrases that correspond to articles shown in Chapter 2. By using these referential properties, our system determines referents of noun phrases in Japanese sentences. Noun phrases are classified by referential property into generic noun phrases, definite noun phrases, and indefinite noun phrases. When the referential property of a noun phrase is a definite noun phrase, the noun phrase can refer to a noun phrase that has already appeared. When the referential property of a noun phrase is an indefinite noun phrase or a generic noun phrase, the noun phrase cannot refer to a noun phrase that has appeared already.

It is insufficient to determine referents of noun phrases only using referential property. This is because even if the referential property of a noun phrase is a definite noun phrase, the noun phrase does not refer to a noun phrase which has a different modifier or a possessor. Therefore, we also use modifiers and possessors of noun phrases in determining referents of noun phrases.

### 3.2 Referential Property of Noun Phrase

The following is an example of noun phrase anaphora.

*OJIISAN* TO OBAASAN-GA SUNDEORIMASHITA.
(an old man) (and) (an old woman) (lived)
(There lived an old man and an old woman.)

*OJIISAN-WA YAMA-HE SHIBAKARI-NI IKIMASHITA.*
(old man) (mountain) (to gather firewood) (go)
(The old man went to the mountains to gather firewood.)

“OJIISAN (old man)” in the first sentence and “OJIISAN (old man)” in the second sentence refer to the same old man, and they are in anaphoric relation.

When the system analyzes the anaphoric relation of noun phrases like this, the referential properties of noun phrases are important. Referential property of a
noun phrase here means how the noun phrase denotes the referent. Since the second “OJIISAN (old man)” has the referential property of the definite noun phrase, indicating that it refers to the contextually non-ambiguous object, the system can recognize that it refers to the first “OJIISAN (old man). The referential property plays an important role in clarifying anaphoric relation.

We classified noun phrases by referential property into the following three types as shown in Chapter 2:

\[
\text{noun phrase} \begin{cases} 
\text{generic noun phrase} \\
\text{non generic noun phrase} \\
\text{definite noun phrase} \\
\text{indefinite noun phrase}
\end{cases}
\]

**Generic noun phrase**  A noun phrase is classified as generic when it denotes all members of the class of the noun phrase or the class itself of the noun phrase. For example, “INU(dog)” in the following sentence is a generic noun phrase.

\[
\text{INU-WA YAKUNI-TACHIMASU.} \\
\text{(dog) (useful)} \\
\text{(Dogs are useful.)} \\
\]

A generic noun phrase cannot refer to an indefinite/definite noun phrase. Two generic noun phrases can refer to each other.

**Definite noun phrase**  A noun phrase is classified as definite when it denotes a contextually non-ambiguous member of the class of the noun phrase. For example, “INU(dog)” in the following sentence is a definite noun phrase.

\[
\text{INU-WA MUKOUHE IKIMASHITA.} \\
\text{(dog) (away) (go)} \\
\text{(The dog went away.)} \\
\]

A definite noun phrase can refer to a noun phrase that has already appeared.

**Indefinite noun phrase**  An indefinite noun phrase denotes an arbitrary member of the class of the noun phrase. For example, the following “INU(dog)” is an
inddefinite noun phrase.

\textbf{INU-GA} SANBIKI IMASU.
(dog) (three) (there is)
(There are three dogs.) \hfill (3.5)

An indefinite noun phrase cannot refer to a noun phrase that has already appeared.

### 3.3 How to Estimate Referent of Noun Phrase

To determine referents of noun phrases, we made the following three constraints.

1. Referential property constraint
2. Modifier constraint
3. Possessor constraint

When two noun phrases which have the same head noun satisfy these three constraints, the system judges that the two noun phrases refer to each other. These three constraints are as follows:

#### 3.3.1 Referential Property Constraint

First, our system estimates the referential property of a noun phrase using the method in Chapter 2. The method estimates a referential property using surface expressions in the sentences. For example, since the second “OJIISAN (old man)” in the following sentences is accompanied by a particle “WA (topic)”, and the predicate is in the past tense, it is estimated to be a definite noun phrase.

\textbf{OJIISAN-WA} JIMEN-NI KOSHI-WO-OROSHIMASHITA.
(old man) (ground) (sit down)
(The old man sat down on the ground.) \hfill (3.6)

\textbf{YAGATE OJIISAN-WA} NEMUTTE-SHIMAISHINASHITA.
(soon) (old man) (fall asleep)
(He soon fell asleep.)
Next, our system determines the referent of a noun phrase using its estimated referential property. When a noun phrase is estimated to be a definite noun phrase, our system judges that the noun phrase refers to a previous noun phrase which has the same head noun. For example, the second “OJIISAN” in the above sentences is estimated to be a definite noun phrase, and our system judges that it refers to the first “OJIISAN”.

When a noun phrase is not estimated to be a definite noun phrase, the noun phrase can refer to a noun phrase that has already been mentioned, because estimating the referential property may fail. Therefore, when a noun phrase is not estimated to be a definite noun phrase, our system gets a possible referent of the noun phrase from topic and focus, and determines the referent of the noun phrase using the following three kinds of information.

- the plausibility of the estimated referential property that is a definite noun phrase
- the weight of a possible referent in the case of topic or focus
- the distance between the estimated noun phrase and a possible referent

### 3.3.2 Modifier Constraint

It is insufficient to determine referents of noun phrases by only using referential property. When two noun phrases have different modifiers, they commonly do not refer to each other. For example, “HIDARI(left)-NO HOO(cheek)” in the following sentences do not refer to “MIGI(right)-NO HOO(cheek)”.

\[
\text{KONO OJIISAN-NO KOBU-WA MIGI-NO HOO-NI ARIMASHITA.}
\text{(This old man's lump was on his right cheek.)}
\]

\[
\text{TENGU-WA, KOBU-WO HIDARI-NO HOO-NI TSUKETE-SHIMAIMASHITA.}
\text{(The "tengu" put a lump on his left cheek.)}
\]
Therefore, we made the following constraint: When a noun phrase has a modifier, it cannot refer to a noun phrase that does not have the same modifier. When a noun phrase does not have a modifier, it can refer to a noun phrase that has any modifier.

### 3.3.3 Possessor Constraint

When a noun phrase has a semantic marker \( \text{PAR} \) (a part of a body), our system tries to estimate the possessor of the object denoted by the noun phrase. We suppose that the possessor of a noun phrase is the subject or the noun phrase’s nearest topic that has a semantic marker \( \text{HUM} \) (human) or a semantic marker \( \text{ANI} \) (animal). For example, the possessor of the first “HOO (cheek)” in the following sentences is estimated to be “OJIISAN (old man)” because “OJIISAN (old man)” is followed by a particle “NIWA”, is the topic in the sentence, and has a semantic marker \( \text{HUM} \) (human).

\[
\text{OJIISAN-NIWA} [\text{OJIISAN-NO}] \text{HIDARI-NO} \, \text{HOO-NI} \text{KOBU-GA ARIMASHITA.}
\]

(This old man had a lump on his left cheek.)

\[
\text{SORE-WA} \, \text{HITO-NO} \, \text{KOBUSHI-HODOMO-ARU} \, \text{KOBU-DESHITA.}
\]

(It is about the size of a person’s fist.)

\[
[\text{OJIISAN-NO}] \, \text{HOO-WO} \, \text{HUKURAMASETE- IRUYOUNI MIERUNODESHITA.}
\]

(He looked as if he had puffed out his cheek.)

The possessor of the second “HOO (cheek)” is also estimated to be “OJIISAN (old man)” because “OJIISAN (old man)” is the subject in the sentence.

We made the following constraint by using possessors. When the possessors of

1. A tengu is a kind of monster.
2. In this thesis, we use Noun Semantic Marker Dictionary \cite{Watanabe et al. 1992} as a semantic marker dictionary.
3. The words in brackets [ ] are omitted in the sentences.
4. Omitted subjects are estimated by the method in Chapter 5.
a noun phrase is estimated, the noun phrase cannot refer to a noun phrase that
does not have the same possessor. When the possessor of a noun phrase is not
estimated, the noun phrase can refer to a noun phrase that has any possessor.

For example, since the two “HOO (cheek)” in the above sentences have the
same possessor “OJIISAN (old man)”, our system correctly judges that the two
“HOO (cheek)” have the same referent.

3.4 Anaphora Resolution System

3.4.1 Procedure

Before determining referents, sentences are transformed into a case structure by
the case structure analyzer [Kurohashi & Nagao 94].

Referents of noun phrases are determined by heuristic rules which are made
from such information as the three constraints mentioned in Section 3.3. Using
these rules, our system takes possible referents and gives them points. It judges
that the candidate having the maximum total score is the referent. This is because
a number of types of information is combined in anaphora resolution. We can
specify which rule takes priority by using points.

The heuristic rules are given in the following form.

\[
\text{Condition} \Rightarrow \{ \text{Proposal Proposal .. } \}
\]

\[
\text{Proposal} := ( \text{Possible-Referent Point} )
\]

In Condition, surface expressions, semantic constraints, referential properties, etc.
are written as conditions. In Possible-Referent, a possible referent, “indefinite”, or
other things are written. “indefinite” means that the noun phase is an indefinite
noun phrase, and it does not refer to a previous noun phrase. Point means the
plausibility value of the possible referent.

3.4.2 Heuristic Rule for Estimating Referents

We made 8 heuristic rules for noun phrase anaphora resolution. All the rules are
given below.
R1 When a noun phrase is like “IKA (the following)”
{(Next sentences, 50)}

R2 When a noun phrase is modified by the words “SOREZORE-NO (each)” and “ONOONO-NO (each)”
{(Indefinite, 25)}

R3 When a noun phrase is the word “JIBUN (oneself)”
{(The subject in the sentence, 25)}

R4 When a noun phrase is estimated to be a definite noun phrase, and satisfies modifier constraint and possessor constraint, and the same noun phrase X has already appeared,
{(The noun phrase X, 30)}

R5 When a noun phrase is estimated to be a generic noun phrase,
{(Generic, 10)}

R6 When a noun phrase is estimated to be an indefinite noun phrase,
{(Indefinite, 10)}

R7 When a noun phrase is like “ISSHO (together)” and “HONTOU (true)”, which is used as an adverb or an adjective,
{(No referent, 30)}

(Ex.) TENGU-TACHI-WA ISSHO(together)-NI WARAI DASHIMASHITA.
(tengu) (together) (laugh) (begin)
(The tengu began laughing together.)

R8 When a noun phrase X is not estimated to be a definite noun phrase,
{(A noun phrase X which satisfies modifier constraint and possessor constraint, $W - D + P + 4$)}

The values $W$, $D$, $P$ are defined as follows: The definition and the weight $(W)$ of topic and focus are given in Table 3.1 and Table 3.2 respectively. (In (a,b) means candidate(a) and point(b).
Table 3.1: The weight in the case of topic

| Surface Expression                     | Example                  | Weight |
|----------------------------------------|--------------------------|--------|
| Pronoun/Zero-Pronoun GA/WA             | (JohnGA (subject))SHITA (done). | 21     |
| Noun WA/NIWA                           | JohnWA (subject)SHITA (do). | 20     |

Table 3.2: The weight in the case of focus

| Surface Expression | Example                  | Weight |
|--------------------|--------------------------|--------|
| Pronoun/Zero-Pronoun WO(object)/NI(to) /KARA(from) | (JohnNI (to))SHITA (done). | 16     |
| Noun (subject)/MO/DA/NARA                  | JohnGA (subject)SHITA (do). | 15     |
| Noun WO (object)/NI/, /                      | JohnNI (object)SHITA (do). | 14     |
| Noun HE (to)/DE (in)/KARA (from)            | GAKKOU (school)HE (to)IKU (go). | 13     |

In this work, a topic is defined as a theme which is described, and a focus is defined as a word which is stressed by the speaker (or the writer). But we cannot detect topics and foci correctly. Therefore we approximated them by Table 3.1 and Table 3.2. When a possible referent is a topic, the distance \(D\) between the estimated noun phrase and the possible referent is the number of topics between them. When a possible referent is a focus, the distance \(D\) is the number of foci between them. The plausibility \(P\) that the referential property is a definite is given in Table 3.3. In the table “Difference score between definite and other referential property” is determined as follows. When the method in Chapter 2 estimates a referential property, it gives each category of referential property some points, and it outputs the score of each category. From these scores our system calculates “Difference score between definite and other referential property”. These values were determined by hand on training sentences mentioned in Section 3.5.1.
3.4.3 Example of Estimating the Referent of a Noun Phrase

An example of determining the referent of a noun phrase is shown in Figure 3.1. This figure shows that the underlined “HI (fire)” in the figure was interpreted properly. The process is as follows:

At first, our system estimated the referential property of the underlined “HI (fire)”. The referential property was incorrectly estimated to be a generic noun phrase as shown in the table “Estimate of referential property” in the figure. Since the estimated referential property was a generic noun phrase, the rule R5 proposed a possible referent “Generic”, and gave it 10 points. Also, the rule R8, which applies when the estimated referential property is incorrect, proposed a possible referent “HI (fire)” in the previous sentence. Since it does not have a modifier and a possessor, it satisfied modifier constraint and possessor constraint. It was given a value of the evaluation function $W - D + P$ in referential property constraint. The weight $W$ was given 15 by Table 3.2 because it is followed by a particle “GA (subject)”. The distance $D$ was given 4 because there are four foci “OTOKO (man)”, “KAO (face)”, “KI (notice)” and “<“HI (fire)” in the previous sentence> between the underlined “HI (fire)” and “<“HI (fire)” in the previous sentence>.

Since the difference score between definite and other referential property was 1 ($= 3($generic$) - 2($indefinite$))$, the plausibility ($P$) was given $-3$ by Table 3.3.

Therefore, the evaluation function $W - D + P + 4$ is $12 (= 15 - 4 - 3 + 4)$. “HI (fire)” in the previous sentence was 12. Since the value 12 of “HI (fire)” was higher than the value 10 of “Generic”, our system judged that the underlined “HI (fire)” refers to the “HI (fire)” in the previous sentence correctly. As the result, the referential property of the underlined “HI (fire)” was judged to be a definite noun phrase correctly.

| Difference score between definite and other referential property | 0 | 1 | 2 | 3 ~ |
|---------------------------------------------------------------|---|---|---|-----|
| The plausibility $P$                                         | 0 | -3| -6| $-\infty$ |
3.5 EXPERIMENT AND DISCUSSION

3.5.1 Experiment

Before estimating the referents of noun phrases, sentences were at first transformed into a case structure by the case structure analyzer [Kurohashi & Nagao 94]. The errors made by the case analyzer were corrected by hand. We show the result of estimating the referents of noun phrases in Table 3.4.
Table 3.4: Result

|                   | Recall  | Precision  |
|-------------------|---------|------------|
| Training sentences| 82%     | 85%        |
| Test sentences    | 79%     | 77%        |

Training sentences \{example sentences (43 sentences), a folk tale “KOBU-TORI JIISAN” [Nakao 85] (93 sentences), an essay in “TENSEIJINGO” (26 sentences), an editorial (26 sentences), an article in “Scientific American (in Japanese)” (16 sentences)\}

Test sentences \{a folk tale “TSURU NO ONGAESHI” [Nakao 85] (91 sentences), two essays in “TENSEIJINGO” (50 sentences), an editorial (30 sentences), articles in “Scientific American (in Japanese)” (13 sentences)\}

To verify that the three constraints (referential proper, modifier, and possessor constraint) are effective, we experimented with the changed condition and compared them. The results are shown in Table 3.5. The upper row and the lower row of this table show precision and recall respectively. **Precision** is the fraction of noun phrases which were judged to have the antecedents. **Recall** is the fraction of noun phrases which have the antecedents.

In these experiments we used training sentences and test sentences. The training sentences were used to make the heuristic rules in Section 3.4.2 by hand. The test sentences were used to verify the effectiveness of these rules.

In Table 3.5, Method 1 “Only when it is estimated to be definite can it refer to another noun phrase” is a case when a noun phrase can refer to a noun phrase, only when the estimated referential property is a definite noun phrase, where modifier constraint and possessor constraint are used. Method 2 “The method of this work” is the method mentioned in Section 3.3, which uses all three constraints. Method 3 “No use of referential property” is a method without referential property, which uses only such information as distance, topic-focus, modifier, and possessor. Method 4 “No use of modifier constraint and possessor constraint” is a method without modifier constraint and possessor constraint. Method 5 “The same two nouns co-refer” is a case that a noun phrase always refers to a noun.
### Table 3.5: Comparison

| Method 1 | Method 2 | Method 3 | Method 4 | Method 5 |
|----------|----------|----------|----------|----------|
| **Training sentences** | | | | |
| 92% (117/127) | 82% (130/159) | 72% (123/170) | 65% (138/213) | 52% (134/260) |
| 76% (117/153) | 85% (130/153) | 80% (123/153) | 90% (138/153) | 88% (134/153) |
| **Test sentences** | | | | |
| 92% (78/85) | 79% (89/113) | 69% (79/114) | 58% (92/159) | 47% (102/218) |
| 68% (78/115) | 77% (89/115) | 69% (79/115) | 80% (92/115) | 89% (102/115) |

- **Method 1**: Only when it is estimated to be definite can it refer to another noun phrase.
- **Method 2**: The method of this work.
- **Method 3**: No use of referential property.
- **Method 4**: No use of modifier constraint and possessor constraint.
- **Method 5**: The same two nouns co-refer.

The table shows many results. In Method 2 “The method of this work”, both the recall and the precision were high. This indicates that the referential property was used properly in the method that is described in this chapter. Method 2 “The method of this work” was higher than Method 3 “No use of referential property” in both recall and precision. This indicates that the information of referential property is necessary. In Method 1 “Only when it is estimated to be definite can it refer to another noun phrase”, the recall was low. The reason is because there were many noun phrases that are definite but were estimated to be indefinite/generic, and the system estimated that the noun phrases cannot refer to noun phrases. In Method 4 “No use of modifier constraint and possessor constraint”, the precision was low. Since modifier constraint and possessor constraint were not used, and there were many pairs of two noun phrases that do not co-refer, such as “HIDARI(left)-NO HOO(cheek)” and “MIGI(right)-NO HOO(cheek)”, these pairs were incorrectly interpreted as co-reference. This indicates that it is necessary to use modifier constraint and possessor constraint. In Method 5 “The same
two nouns co-refer", the precision was lower than in Method 4. This is because referential properties were not used and the system judged that a noun phrase which is not a definite noun phrase refers to another noun phrase.

### 3.5.2 Examples of Errors

We found that it was necessary to use modifiers and possessors through the above experiments. But since the possessor of a noun was estimated incorrectly, the referent was also estimated incorrectly as follows.

OJIISAN-WA (OJIISAN-NO) ŬŠÈNÁKÁ-KARA SHIBA-WO OROSHIMASHITA.
(He took down the bundle of firewood from his back.)

OJIISAN-WA OTOKOTACHI-WO NINGEN-DATO OMOTTEIMASHITAGA,
(The old man thought they were human beings,

MAMONAKU TENGU-DEARU-KOTO-GA WAKARIMASHITA.
(but soon he realized that they were “tengu,” or supernatural beings.)

[TENGU-NO] ŬŠÈNÁKÁ NIWA OOKINA TSUBASA-GA ARUNODESU.
(They had large wings on their backs.)

Since the underlined “SENAKA (back)” in this example is a part of an animal, the possessor is estimated. Although the proper possessor is “TENGU (tengu)”, the system estimated incorrectly that the possessor was “OJIISAN (old man)” that is a topic of the previous sentence. For this reason, our system judged that this “SENAKA (back)” refers to the twice underlined “[OJIISAN-NO] ŬŠÈNÁKÁ (the old man’s back)” incorrectly.

Sometimes a noun can refer to a noun that has a different modifier. In such a case, the system made an incorrect judgment.
3.6. Summary

This chapter described the method of how to estimate the referents of noun phrases using the referential properties, the modifiers, and the possessors. As a result of using this method, we obtained a precision rate of 82% and a recall rate of 85% in the estimation of referents of noun phrases that have antecedents on training sentences, and obtained a precision rate of 79% and a recall rate of 77% on test sentences. We verified that it is effective to use referential properties, modifiers, and possessors of noun phrases.
Chapter 4

Indirect Anaphora Resolution in Noun Phrases

4.1 Introduction

Chapter 3 described the case when a noun phrase refers to an entity that has already been mentioned. Chapter 4 describes the case when a noun phrase refers to an entity that has not been mentioned yet, but an entity associated with an entity that has already been mentioned. For example, “I went into an old house last night. The roof was leaking badly and ...” indicates that “The roof” is associated with “an old house”, which has already been mentioned. This kind of reference (indirect anaphora) has not been thoroughly studied in natural language processing, but is important for coherence resolution, language understanding, and machine translation. We propose a method to resolve indirect anaphora in Japanese nouns using the relationships between two nouns.

When we analyze indirect anaphora, we need a case frame dictionary for nouns containing an information about relations between two nouns. For example, in the case of the above example, the knowledge that “roof” is a part of “house” is required to analyze the indirect anaphora. But no such noun case frame dictionary

\[^1\] Nagao et al. 76 made the investigation of resolving indirect anaphora in some nouns such as “TAISEKI (volume)” in sentences on chemistry. But there is no research resolving indirect anaphora in all the nouns.
exists at present. We considered whether we can use the example-based method to solve this problem. In this case, the knowledge that “roof” is a part of “house” is analogous to “house of roof”. Therefore we use examples of the form “X of Y” instead. In the above example, we use a linguistic data such as “the roof of a house”. In the case of verbal nouns, we do not use “X of Y” but a verb case frame dictionary. This is because a noun case frame is similar to a verb case frame and a verb case frame dictionary exists at present.

The next section describes a method of resolving indirect anaphora.

4.2 How to Resolve Indirect Anaphora

An anaphor and the antecedent in an indirect anaphora have a certain relation. For example, “YANE (roof)” and “HURUI IE (old house)” are in an indirect anaphoric relation which is a part-of relation.

\[
\text{SAKUBAN ARU HURUI IE-NI ITTA.}
\]

(last night) (a certain) (old) (house) (go)

(I went into an old house last night.)

\[
\text{YANE-WA HIDOI AMAMORIDE ...}
\]

(roof) (badly) (be leaking)

(The roof was leaking badly and ... )

When we analyze the indirect anaphora, we need a dictionary containing information about relations between antecedents and their antecedents.

We show examples of the relations between an anaphor and the antecedent in Table 4.1. The form of Table 4.1 is similar to the form of a verb case frame dictionary. We call a dictionary containing the relations between two nouns a noun case frame dictionary. But no noun case frame dictionary has been created so far. Therefore, we substitute it by examples of “X NO Y (Y of X)” and by a verb case frame dictionary. “X NO Y” is a Japanese expression. It means “Y of X”, “Y in X”, “Y for X”, etc.

Resolution of indirect anaphora is done by the following steps.
Table 4.1: Example of noun case frame dictionary

| Anaphor                  | Things which can be the Antecedent | Relation |
|-------------------------|-----------------------------------|----------|
| KAZOKU (family)         | HITO (human)                      | belong   |
| KOKUMIN (nation)        | KUNI (country)                    | belong   |
| GENSHU (the head of state) | KUNI (country)                    | belong   |
| YANE (roof)             | TATEMONO (building)               | part of  |
| MOKEI (model)           | SEISANBUTSU (product)             | object   |
|                         | (ex. HIKOIKI (air plain), HUNE (ship)) |          |
| GYOUJI (event)          | SOSHIKI (organization)            | agent    |
| JINKAKU (personality)   | HITO (human)                      | possessive |
| KYOUIKU (education)     | HITO (human)                      | agent    |
|                         | NOURYOKU (ability)                | recipient |
|                         | (ex. SUUGAKU (mathematics))       | object   |
| KENKYUU (research)      | HITO (human), SOSHIKI (organization) | agent |
|                         | GAKUMON BUN'YA (field of study)   | object   |

Table 4.2: Case frame of verb “KUICHIGAU (differ)”

| Surface Case | Semantic Marker | Examples                  |
|--------------|-----------------|---------------------------|
| Ga-case (subject) | abstract | DEETA (data), IKEN (opinion) |
| To-case (object)     | abstract | DEETA (data), MIKATA (viewpoint) |

1. We detect some elements which will be analyzed in indirect anaphora resolution using “X NO Y” and a verb case frame dictionary. When a noun is a verbal noun, we use a verb case frame dictionary. Otherwise, we use examples: “X NO Y”. For example, “KUICHIGAI (difference)” is a verbal noun, and we use a case frame of a verb “KUICHIGAU (differ)” for the indirect anaphora resolution of “KUICHIGAI (difference).” The case frame is shown in Table 4.2. In this table there are two case components, GA-case (subject) and TO-case (object). These two case components are elements
4.2. **HOW TO RESOLVE INDIRECT ANAPHORA**

which will be analyzed in indirect anaphora resolution.

Tom-WA DEETA-WO KONPYUUTA-NI UCHIKONDE-IMASHITA.  
(Tom) (data) (computer) (store)  
(Tom was storing the data in a computer.)

YATTO HANBUN YARIOEMASHITA.  
(Finally) (half) (finish)  
(Finally he was half finished.)

John-GA HURUI DEETA-WO MISEMASHITA.  
(John) (old) (data) (show)  
(John showed him some old data.)

IKUTSUKA-NO KUICHIGAI-WO SETUMEISHITE-KURE-MASHITA.  
(several) (difference) (explain)  
(Tom did John a favor of explaining several differences.)

(4.2)

2. We take possible antecedents from topics or foci in previous sentences. We give them some weight of topics and foci which means the plausibility of the antecedent because topics and foci have various plausibilities.

3. We determine the antecedent by combining the weight of topics and foci in 3, the weight of semantic similarity in “X NO Y” or a verb case frame dictionary, and the weight of the distance between an anaphor and its possible antecedent.

For example, when we want to clarify the antecedent of YANE (roof) in the sentences (4.1), we gather examples of “<noun X> NO YANE (roof)” (roof of <noun X>), and select a possible noun which is semantically similar to <noun X> as its antecedent. Also, when we want to have an antecedent of “KUICHIGAI (difference)” in the sentences (4.2), we select a possible noun which satisfies the semantic marker in the case frame of “KUICHIGAU (differ)” in Table 4.2 or is semantically similar to examples of components in the case frame as its antecedent.

We think that errors made by the substitution of a verb case frame for a noun case frame are rare, but many errors will happen when we substitute “X NO Y”
for a noun case frame. This is because “X NO Y (Y of X)” has many semantic relations, in particular a feature relation (ex. a man of ability), which cannot be an indirect anaphoric relation. To reduce the errors, we use the following procedure.

1. We do not use an example of the form “noun X NO noun Y (Y of X),” when the noun X is an adjective noun (ex. HONTOU (reality)), a numeral, or a temporal noun. For example, we do not use “HONTOU (reality) NO (of) HANNIN (criminal) (a real criminal)”.

2. We do not use an example of the form “noun X NO noun Y (Y of X),” when the noun Y is a noun that cannot be an anaphor of indirect anaphora. For example, we do not use “noun X NO TSURU (crane),” “noun X NO NINGEN (human being).”

We cannot completely avoid the errors by introducing the above procedure, but we can reduce the errors to a certain extent.

We need some more consideration for nouns such as “ICHIBU (part),” “TONARI (neighbor)” and “BETSU (other).” When such a noun is a case component of a verb, we use information on semantic constraint of the verb. We use a verb case frame dictionary.

\[
\text{TAKUSAN-NO KURUMA-GA KOUEN-NI TOMATTE-ITA.}
\]

(many) (car) (in the park) (there were)
(There were many cars in the park.)

\[
\text{ICHIBU-WA KITANI MUKATTA}
\]

(A part (of them)) (to the north) (went)
(A part of them went to the north.)

(4.3)

In this example, since “ICHIBU (part)” is a GA case (subject) of a verb “MUKAU (go),” we consult the GA case (subject) of the case frame of “MUKAU (go).” Some noun phrases which can be filled in the case component are written in the GA case (subject) of the case frame. In this case, “KARE (he)” and “HUNE (ship)” are written as examples of things which can be filled in the case component. This indicates that the antecedent is semantically similar to “KARE (he)” and
4.3. ANAPHORA RESOLUTION SYSTEM

“HUNE (ship).” Since “TAKUSAN NO KURUMA (many cars)” is semantically similar to “HUNE (ship)” in the meaning of vehicles, it is judged to be the proper antecedent.

When such a noun as “TONARI (neighbor or next)” modifies a noun X as “TONARI NO X”, we think that the antecedent is a noun which is similar to noun X in meaning.

OJIISAN-WA OYOOROKOBI-WO-SHITE IE-NI KAERIMASHITA.
(the old man) (in great joy) (house) (returned)
(The old man returned home (house) in great joy.)

OKOTTA KOTOWO HITOBITONI HANASHIMASHITA
(had happened to him) (all things) (everybody) (told)
(and told everybody all that had happened to him.)

TONARI-NO IE-NI OJIISAN-GA MOUHITORI SUNDE-ORIMASHITA.
(next) (house) (old man) (another) (live)
(There lived in the next house another old man.)

For example, when “TONARI (neighbor or next)” modifies “IE (house),” we judge that the antecedent of “TONARI (neighbor or next)” is “IE (house)” in the first sentence.

4.3 Anaphora Resolution System

4.3.1 Procedure

Analysis of indirect anaphora is performed in the same framework of Chapter 3. At first, sentences are transformed into a case structure by the case structure analyzer [Kurohashi & Nagao 94]. Next, antecedents in indirect anaphora are determined by heuristic rules for each noun from left to right. Using these rules, our system takes possible referents and gives them points. It judges that the candidate having the maximum total score is the desired antecedent.

The heuristic rules are given in the following form.

\[
\text{Condition} \Rightarrow \{ \text{Proposal, Proposal, ..} \}
\]

\[
\text{Proposal} := (\text{Possible-Antecedent, Point})
\]
Table 4.3: The weight (W) in the case of topic

| Surface Expression               | Example                   | Weight |
|----------------------------------|---------------------------|--------|
| Pronoun/Zero-Pronoun GA/WA      | (John GA (subject))SHITA (done). | 21     |
| Noun WA/NIWA                    | John WA (subject)SHITA (do). | 20     |

Table 4.4: The weight (W) in the case of focus

| Surface Expression               | Example                   | Weight |
|----------------------------------|---------------------------|--------|
| Pronoun/Zero-Pronoun WO(object)/NI(to)/KARA(from) | (John NI (to))SHITA (done). | 16     |
| Noun (subject)/MO/DA/NARA        | John GA (subject)SHITA (do). | 15     |
| Noun WO (object)/NI/, /          | John NI (object)SHITA (do). | 14     |
| Noun HE (to)/DE (in)/KARA        | GAKKOU (school)HE (to)IKU (go). | 13     |

Surface expressions, semantic constraints, referential properties, and so on, are written as conditions in Condition part. A possible antecedent is written in Possible-Antecedent part. Point means the plausibility of the possible antecedent.

4.3.2 Heuristic Rule for Estimating Antecedents

Resolution of indirect anaphora is performed by adding the rules for indirect anaphora resolution to the rules for direct anaphora resolution. We wrote 12 heuristic rules for noun phrase anaphora resolution in Chapter 3. The rules (from R1 to R8) for noun phrase direct anaphora are shown in Section 3.4.2. The rules for noun phrase indirect anaphora are shown as follows.

R9 When a noun phrase Y is not a verbal noun, ⇒

\{ (A topic which has the weight W and the distance D, \( W - D + P + S \)),

(A focus which has the weight W and the distance D, \( W - D + P + S \)),
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Table 4.5: The plausibility (P) that the referential property is a definite noun phrase

| The score in the estimation of the referential property | Plausibility P |
|--------------------------------------------------------|----------------|
| When the score of the definite noun phrase is the best  | 5              |
| When the score of the definite noun phrase is equal to the score of the indefinite noun phrase or the generic noun phrase | 0              |
| When the score of the definite noun phrase is 1 lower than the score of the indefinite noun phrase or the generic noun phrase | −5             |
| When the score of the definite noun phrase is 2 lower than the score of the indefinite noun phrase or the generic noun phrase | −10            |
| When the score of the definite noun phrase is more than 2 lower than the score of the indefinite noun phrase or the generic noun phrase | −∞             |

Table 4.6: Points given to non-verbal nouns by the semantic similarity

| Similarity Level | 0  | 1  | 2  | 3  | 4  | 5  | 6  | Exact Match |
|------------------|----|----|----|----|----|----|----|-------------|
| Point            | −10| −2 | 1  | 2  | 2  | 5  | 3  | 3.5         | 4           |

(A subject in a subordinate clause or a main clause of the clause, \(23 + P + S\))

The weights \(W\) of topics and foci are given in Table 4.3 and Table 4.4, respectively, and represent preference of the desired antecedent. The distance \(D\) is the number of the topics (foci) between the anaphor and a possible antecedent which is a topic (focus). The value \(P\) is given in Table 4.5 by the score of the definiteness in referential property analysis described in Chapter 2. This is because it is easier for a definite noun phrase to have the antecedent than for an indefinite noun phrase. The value \(S\) is the semantic similarity between a possible antecedent and a Noun X of “Noun X NO Noun Y”. The semantic similarity is given by the similarity level in “Bunrui Goi Hyou” [NLRI 64] as Table 4.6.
R10 When a noun phrase is a verbal noun, ⇒
   { (analyze in Zero Pronoun Resolution Module in Chapter 5, 20)}
In Zero Pronoun Resolution Module, indirect anaphora is resolved using
the semantic constraint in a verb case frame and the distance between an
anaphor and an antecedent.

R11 When a noun phrase is a noun such as “ICHIBU” and “TONARI”, and it
   modifies a noun X, ⇒
   { (the same noun as the noun X, 30)}

R12 When a noun phrase is a noun such as “ICHIBU” and “TONARI”, and it
   is a case component of a verb, ⇒
   { (analyze in the module similar to R10, 30)}

4.3.3 Example of Analysis

An example of resolution of indirect anaphora is shown in Figure 4.1. Figure 4.1
shows that the noun “KOUTEI BUAI (official rate)” is analyzed well. This is
explained as follows.

The system estimated the referential property of “KOUTEI BUAI (official
rate)” to be indefinite in the method described in Chapter 2. By the rule R6
in Section 3.4.2 the system took a candidate “Indefinite”. When the candidate
“Indefinite” has the best score, the system does not analyze indirect anaphora.
By the rule R9 in Section 4.3.2 the system took four possible antecedents, SEI-
DOKU (West Germany), JIKOKUTSUUKA (own currency), KYOUCOU (co-
operation), DORUDAKA (dollar’s surge). The possible antecedents were given
some points from the weight of topics and foci, the distance from the anaphor,
and so on. The system properly judged that SEIDOKU (West Germany), which
had the best score, was the desired antecedent.

4.4 Experiment and Discussion

Before determining antecedents in indirect anaphora, sentences were transformed
into a case structure by the case analyzer [Kurohashi & Nagao 94] as in Chapter
The dollar’s surge is straining the cooperation. (West Germany raised its official rate to protect the Mark.)

Examples of “noun X NO KOUTEIBUAI (official rate)”

“NIHON (Japan) NO KOUTEIBUAI (official rate),”

“BEIKOKU (USA) NO KOUTEIBUAI (official rate)”

Figure 4.1: Example of indirect anaphora resolution
CHAPTER 4. INDIRECT ANAPHORA RESOLUTION

Table 4.7: Result

| Non-verbal Noun | Total |
|-----------------|-------|
| Recall          | Precision |
| Experiment in the case that the system does not use any semantic information | |
| 85% (56/66)     | 67% (56/83) |
| 53% (20/38)     | 50% (20/40) |
| Experiment using “X NO Y” and verb case frame | |
| 91% (60/66)     | 86% (60/70) |
| 63% (24/38)     | 83% (24/29) |
| Estimation for the hypothetical case when we can use noun case frame dictionary | |
| 91% (60/66)     | 88% (60/68) |
| 79% (30/38)     | 86% (30/35) |

| Verbal Noun | Total |
|-------------|-------|
| Recall      | Precision |
| 40% (14/35) | 44% (14/32) |
| 47% (15/32) | 42% (15/36) |
| 69% (70/101)| 61% (70/115)|
| 44% (14/32)| 42% (15/36) |
| 50% (35/70) | 46% (35/76) |
| 60% (23/35) | 79% (23/29) |
| 63% (20/32) | 56% (20/36) |
| 82% (83/101)| 84% (83/99) |
| 63% (24/29) | 83% (24/27) |
| 63% (44/70) | 68% (44/65) |
| 89% (24/27) | 83% (84/101)|
| 77% (20/26) | 71% (50/70) |
| 82% (50/61) |

| Total          | |
| Recall         | Precision |
| 69% (70/101)   | 61% (70/115)|
| 63% (20/32)    | 56% (20/36) |
| 82% (50/61)    | |

The upper row and the lower row of this table show rates on training sentences and test sentences, respectively.

The training sentences are used to set by hand the values given in rules in Section 4.3.2.
Training sentences {example sentences [Walker et al 94] (43 sentences), a folk tale “KOBUTORI JIISAN” [Nakao 85] (93 sentences), an essay in “TENSEIJINGO” (26 sentences), an editorial (26 sentences)}

Test sentences {a folk tale “TSURU NO ONGAESHI” [Nakao 85] (91 sentences), two essays in “TENSEIJINGO” (50 sentences), an editorial (30 sentences)}

Precision is the fraction of the noun phrases which were judged to have the antecedents of indirect anaphora. Recall is the fraction of the noun phrases which have the antecedents of indirect anaphora. We use precision and recall to evaluate because the system judges that a noun which is not an antecedent of indirect anaphora is an antecedent of indirect anaphora, and we check these errors thoroughly.
performed by fixing all the semantic similarity values $S$ to 0.

Further, we made the estimation for the hypothetical case when we can use a noun case frame dictionary. The estimation was made as follows. We looked over the errors in the experience using “X NO Y” and a verb case frame dictionary. We regarded the errors made by one of the following three reasons as right answers.

1. Proper examples do not exist in examples of “X NO Y” or a verb case frame dictionary.

2. Wrong examples exist in examples of “X NO Y” or a verb case frame dictionary.

3. A noun case frame is different from a verb case frame.

If we will make a noun case frame dictionary by ourselves, the dictionary will have some errors, and the success ratio will be lower than the ratio in Table 4.7.

**Discussion of Errors**

Even if we have a noun case frame dictionary, there are certain pairs of nouns in indirect anaphoric relation that cannot be resolved by our framework.

KON‘NA HIDOI HUBUKI-NO NAKA-WO ITTAI DARE-GA KITA-NO-KA-TO IBUKARINAGARA, OBAASAN-WA IIMASHITA.

(Wondering who could have come in such a heavy snowstorm, the old woman said:)

“DONATA-JANA”

(“Who is it?”)

TO-WO AKETEMIRUTO, SOKO-NIW A ZENSHIN YUKI-DE MASSHI-RONI NATTA MUSUME-GA TATTE ORIMASHITA.

(She opened the door, and there stood before her a girl all covered with snow. )

The underlined “MUSUME (a daughter or a girl)” has two main meanings: a daughter and a girl. In the above example, “MUSUME” means girl and has no indirect anaphora relation. But the system incorrectly judged that it is the daughter of “OBAASAN (the old woman)”. This is a problem of noun role ambiguity and is a very difficult problem to solve.
CHAPTER 4. INDIRECT ANAPHORA RESOLUTION

The following example is also a difficult problem.

SHUSHOU-WA TEIKOU-NO TSUYOI SENKYOKU-NO KAISHOU-WO MIOKUTTA.

(Prime minister) (resistance) (very) (electoral district) (modification) (give up)

(The prime minister gave up the modification of some electoral districts where the resistances were very hard.)

The underlined “TEIKOU (resistance)” appears to refer indirectly to “SENKYOKU (electoral district)” from the surface expression. But actually “TEIKOU (resistance)” refers to the candidates of “SENKYOKU (electoral district)” not to “SENKYOKU (electoral district)” itself. To arrive at this conclusion it is necessary to use a two step relation, “an electoral district ⇒ candidates”, “candidates ⇒ resist” in sequence. However it is not easy to change our system to deal with two step relations because if we apply the use of two relations to nouns, many nouns which are not in an indirect anaphoric relation will be incorrectly judged as indirect anaphora. A new method is required to infer two relations in sequence.

4.5 Consideration of Construction of Noun Case Frame Dictionary

We used “X NO Y (Y of X)” to resolve indirect anaphora. But we will get a higher accuracy rate if we can utilize a good noun case frame dictionary. Therefore we have to consider how we can construct a noun case frame dictionary. A key is to get the detailed meaning of “NO (of)” in “X NO Y”. If it is automatically obtainable, a noun case frame dictionary will be constructed automatically. If the semantic analysis of “X NO Y” is not done well, how do we construct the dictionary? We think that it is still good to construct it using “X NO Y”. For example, we arrange “noun X NO noun Y” in the order of the meaning of “noun Y”, arrange them in the order of the meaning of “noun X”, delete some of them whose “noun X” are adjective nouns, and obtain Table 4.8. In this case, we use the thesaurus dictionary “Bunrui Goi Hyou” [NLRI 64] to get the meanings of nouns. We think that it is not difficult to construct a noun case frame dictionary from Table 4.8 by hand. We will make a noun case frame dictionary by removing
Table 4.8: Examples of arranged “X NO Y”

| Noun Y | Arranged Noun X |
|--------|-----------------|
| KOKUMIN (nation) | <Human> AITE (partner) <Organization> KUNI (country), SENSHINKOKU (an advanced country), RYOUKOKU (the two countries), NAICHI (inland), ZENKOKU (the whole country), NIHON (Japan), SOREN (the Soviet Union), EIKOKU (England), AMERIKA (America), SUISU (Switzerland), DENMAAKU (Denmark), SEKAI (the world) |
| GENSHU (the head of state) | <Human> RAIHIN (visitor) <Organization> GAIKOKU (a foreign country), KAKKOKU (each country), POORANDO (Poland) |
| YANE (roof) | <Organization> HOKKAIDO (Hokkaido), SEKAI (the world), GAKKOU (school), KOUJOU (factory), GASORINSUTANDO (gas station), SUUUPAA (supermarket), JITAKU (one’s home), HONBU (the head office) <Product> KURUMA (car), JUUTAKU (housing), IE (house), SHINDEN (temple), GENKAN (entrance), SHINSHA (new car) <Phenomenon> MIDORI (green) <Action> KAWARABUKI (tile-roofed) <Mental> HOUSHIKI (method) <Character> KEISHIKI (form) |
| MOKEI (model) | <Animal> ZOU (elephant) <Nature> FUJISAN (Mt. Fuji) <Product> IMONO (an article of cast metal), MANSION (an apartment house), KAPUSERU (capsule), DENSHA (train), HUNE (ship), GUNKAN (warship), HIKOUKI (airplane), JETTOKI (jet plane) <Action> ZOUSEN (shipbuilding) <Mental> PURAN (plan) <Character> UNKOU (movement) |
| GYOUJI (event) | <Human> KOUSHITSU (the Imperial Household), OUSHITSU (a Royal family), IEMOTO (the head of a school) <Organization> NOUSON (an agricultural village), KEN (prefecture), NIHON (Japan), SOREN (the Soviet Union), TERA (temple), GAKKOU (school) <Action> SHUUNIN (take up one’s post), MATSURI (festival), IWAI (celebration), JUNREI (pilgrimage) <Mental> KOUREI (an established custom), KOUSHIKI (formal) |
| JINKAKU (personality) | <Human> WATASHI (myself), NINGEN (human), SEISHOUNEN (young people), SEIJIKA (statesman) |
“AITE (partner)” in the line of “KOKUMIN (nation)”, “RAIHIN (visitor)” in the line of “GENSHU (the head of state)”, and noun phrases which mean characters and features. When we look over the noun phrases in a certain line and almost all of them mean countries, we will also include the feature that countries are easy to be filled by using semantic markers. When we make a noun case frame dictionary, we must remember that examples of “X NO Y” are insufficient, and must add examples. Since examples are arranged in the order of meaning in this method, it will not be so difficult to add examples.

4.6 Summary

We presented how to resolve indirect anaphora in Japanese nouns. When we analyze indirect anaphora, we need a noun case frame dictionary containing information about noun relations. But no noun case frame dictionary exists at present. Therefore, we used examples of “X NO Y (Y of X)” and a verb case frame dictionary. We experimented with the estimation of indirect anaphora by using this information, and obtained a recall rate of 63% and a precision rate of 68% on test sentences. This indicates that the information of “X NO Y” is useful when we cannot make use of a noun case frame dictionary. We made an estimation in the case that we can use a noun case frame dictionary, and obtained results with the recall and the precision rates of 71% and 82%, respectively. Finally we proposed how to construct a noun case frame dictionary from examples of “X NO Y”.
Chapter 5

An Estimate of Referents of Pronouns

5.1 Overview

We described in Chapter 3 and Chapter 4 how to estimate the referents of noun phrases. This chapter describes how to resolve the referents of pronouns: demonstrative pronouns, personal pronouns, and zero pronouns. Pronoun resolution is especially important for machine translation. For example, if the system cannot resolve zero pronouns, the system cannot translate sentences with them from Japanese into English. When the word order of sentences is changed and the pronominalized words are changed in translating into English, the system must detect the referents of the pronouns.

There has been much work done in pronoun resolution [Nagao et al 76] [Kameyama 86] [Yamamura et al 92] [Walker et al 94] [Takada & Doi 94] [Nakaiwa & Ikehara 95]. Major distinguishing features of our work are as follows:

• In conventional pronoun resolution methods, semantic markers have been used for semantic constraints. On the other hand, we use examples for semantic constraints and show in our experiments that examples are as useful as semantic markers. The result is important because the cost of

1Ellipses of noun phrases are called zero pronouns.
constructing the case frame using semantic markers is generally higher than the cost of constructing the case frame using examples.

- We use examples in the form “X of Y” for estimating referents of demonstrative adjectives.
- We deal with the case when a demonstrative refers to elements which appear later.
- We resolve a personal pronoun in quotation by estimating the speaker and the hearer.

In this work, we used almost all the potentials of conventional methods and proposed new method.

In Section 5.2, we explain how the system estimates the referent of a pronoun. Next, we explain the rules for demonstratives, personal pronouns, and zero pronouns in Sections 5.3, 5.4, and 5.5, respectively. In Section 5.6, we report the results of experiments using these rules. In Section 5.7, we conclude this chapter.

5.2 The Framework for Estimating the Referent

Pronoun resolution is performed in the framework similar to that in Chapter 3 and Chapter 4. The antecedents of pronouns are determined by heuristic rules from left to right. Using these rules, our system gives possible antecedents points, and it judges that the possible antecedent having the maximum total score is the desired antecedent.

Heuristic rules are classified into two kinds of rules: Candidate enumerating rules and Candidate judging rules. Candidate enumerating rules are used in enumerating candidate antecedents and giving them points (which mean plausibility of the proper antecedent). Candidate judging rules are used in giving the candidate antecedents taken by Candidate enumerating rules points. These rules are shown in Figure 5.1 and Figure 5.2. Surface expressions, semantic constraints, referential properties, etc., are written as conditions in Condition part. A possible antecedent is written in Possible-Antecedent part. Point means the plausibility of the possible antecedent.
5.3. HEURISTIC RULE FOR DEMONSTRATIVE

An estimation of the referent is performed by using the total scores of possible antecedents given by Candidate enumerating rules and Candidate judging rules. First, the system applies all Candidate enumerating rules to the anaphor and enumerates candidate antecedents having the points. Next, the system applies all Candidate judging rules to all the candidate antecedents and sums up the score of each candidate antecedent. Consequently, the system judges the candidate antecedent having the best score is the proper antecedent. If the candidate referents having the best score are plural, the candidate referent taken in the first order is judged as the proper antecedent.

We made 50 Candidate enumerating rules and 10 Candidate judging rules for analyzing demonstratives, 4 Candidate enumerating rules and 6 Candidate judging rules for analyzing personal pronouns, and 19 Candidate enumerating rules and 4 Candidate judging rules for analyzing zero pronouns. All of the rules are described in Appendix B. Some of the rules are described in the following sections.

5.3 Heuristic Rule for Demonstrative

We made heuristic rules for demonstratives by consulting the papers of [NLRI 81] [Hayashi 83] [Takahashi et al 90] [Kinsui & Takubo 92] and examining Japanese sentences by hand. Demonstratives have three categories: demonstrative pronouns, demonstrative adjectives, and demonstrative adverbs. In the following sections,

\[ \text{Condition} \Rightarrow \{ \text{Proposal Proposal .} \} \]
\[ \text{Proposal} := ( \text{Possible-Antecedent Points} ) \]

Figure 5.1: Form of Candidate enumerating rule

\[ \text{Condition} \Rightarrow ( \text{Points} ) \]

Figure 5.2: Form of Candidate judging rule

2 The order is based on the order applying rules.
Table 5.1: The weight in the case of topic

| Surface Expression | Example                  | Weight |
|--------------------|--------------------------|--------|
| Pronoun/Zero-Pronoun GA/WA | (JohnGA (subject))SHITA (done). | 21     |
| Noun WA/NIWA        | JohnWA (subject)SHITA (do). | 20     |

Table 5.2: The weight in the case of focus

| Surface Expression                | Example                  | Weight |
|-----------------------------------|--------------------------|--------|
| Pronoun/Zero-Pronoun WO(object)/NI(to) /KARA(from) | (JohnNI (to))SHITA (done). | 16     |
| Noun GA (subject)/MO/DA/NARA      | JohnGA (subject)SHITA (do). | 15     |
| Noun WO (object)/NI/, /          | JohnNI (object)SHITA (do). | 14     |
| Noun HE (to)/DE (in)/KARA        | GAKKOU (school)HE (to)IKU (go). | 13     |

we explain the rules for analyzing demonstratives.

5.3.1 Rule for Demonstrative Pronoun

Rule in the Case when the Referent is a Noun Phrase

Candidate enumerating rule1

When a pronoun is a demonstrative pronoun or “SONO (of it) / KONO (of this) / ANO (of that)”,
{(A topic which has the weight $W$ and the distance $D$, $W - D - 2$)
(A focus which has the weight $W$ and the distance $D$, $W - D + 4$)}
This bracket expression represents the lists of proposals in Figure 5.1. The
definition and the weight $W$ of topic and focus are shown in Table 5.1 and
Table 5.2. The distance ($D$) is the number of topics and foci between
the demonstrative and the possible referent. Since a demonstrative more often
refer to foci than a zero pronoun, we add the coefficient $-2$, $+4$ as compared
Rule when the Referent is a Verb Phrase

Candidate enumerating rule

When a pronoun is “SORE/ARE/KORE” or a demonstrative adjective,

{( The previous sentence (or the verb phrase which is a conditional form containing a conjunctive particle such as “GA (but)”, “DAGA (but)”, and “KEREDO (but)” if the verb phrase is in the same sentence), 15 )

The following is an example of a pronoun referring to the verb phrase of the previous sentence.

TENUGU-TACHI-WA MAMONAKU YATTEKITE
(The tengus) (presently) (came)
(Presently, they came)

MAENOBA-NO-YOUNI UTATTARI ODOTTARI SHI-HAJIMEMASHITA.
(the previous night) (sing) (dance) (begin to do) (5.1)
(and began singing and dancing just as they had done the previous night.)

OJIISAN-WA SORE-WO MITE, KON’NAHUUNI UTAI-HAJIMEMASHITA.
(the old man) (it) (see) (as follows) (begin to sing)
(When the old man saw this, he began to sing as follows. )

In these sentences, a demonstrative pronoun “SORE (it)” refers to the event “TENGU-TACHI-GA UTATTARI ODOTTARI SHI-HAJIMEMASHITA (tengu began singing and dancing just as they had done the previous night.)”.

The following is an example of a pronoun referring to a verb phrase (the event) containing a conjunctive particle such as “GA”, “DAGA”, and “KEREDO” in the
Table 5.3: Points given in the case of demonstrative pronouns

| Similarity Level | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Exact Match |
|------------------|---|---|---|---|---|---|---|-------------|
| Point            | 0 | 0 | -10 | -10 | -10 | -10 | -10 | -10         |

same sentence.

OJIISAN-WA ISSHOUKENMEINI UTAI SOSHITE ODORIMASHITAGA,
(the old man) (one’s best) (sing) (and) (dance)
(The man did his best singing and dancing.)

SORE-WA KOTOBADE-IIARA WASENAIHODO HETAKUSODESHITA.
(they) (unspeakably) (poor)
( but they were unspeakably poor.)

**Rule Using the Feature that Demonstrative Pronouns usually do not Refer to People**

**Candidate judging rule 1**

When a pronoun is a demonstrative pronoun and a candidate referent has a semantic marker HUM (human), it is given −10. We use Noun Semantic Marker Dictionary [Watanabe et al 92] as a semantic marker dictionary.

**Candidate judging rule 2**

When a pronoun is a demonstrative pronoun, a candidate referent is given the points in Table 5.3 by using the highest semantic similarity between the candidate referent and the codes \{5200003010 5201002060 5202001020 5202006115 5241002150 5244002100\} in “Bunrui Goi Hyou (BGH)” [NLRI 64] which signify human beings. When we calculate the semantic similarity, we use the modified code table in Table 5.4. The reason for this modification is that some codes in BGH [NLRI 64] are incorrect.

These rules use the feature that a demonstrative pronoun rarely refer to people, and reduce candidates of the referent. For example, we find “SORE (it)” in the following sentences refers to “KONPYUUUTA (computer)”, because “SORE (it)”
5.3. **HEURISTIC RULE FOR DEMONSTRATIVE**

Table 5.4: Modification of category number of “BUNRUI GOI HYOU”

| Semantic Marker            | Original code | Modified code |
|----------------------------|---------------|---------------|
| ANI (animal)               | 156           | 511           |
| HUM (human)                | 12[0-4]       | 52[0-4]       |
| ORG (organization)         | 125,126,127,128 | 535,536,537,538 |
| PLA (plant)                | 155           | 611           |
| PAR (part of living thing) | 157           | 621           |
| NAT (natural)              | 152           | 631           |
| PRO (products)             | 14[0-9]       | 64[0-9]       |
| LOC (location)             | 117,125,126   | 651,652,653   |
| PHE (phenomenon)           | 150,151       | 711,712       |
| ACT (action)               | 13[3-8]       | 81[3-8]       |
| MEN (mental)               | 130           | 821           |
| CHA (character)            | 11[2-58],158  | 83[2-58],839  |
| REL (relation)             | 111           | 841           |
| LIN (linguistic products)  | 131,132       | 851,852       |
| The others                 | 110           | 861           |
| TIM (time)                 | 116           | a11           |
| QUA (quantity)             | 119           | b11           |

“125” and “126” are given two category number.
Table 5.5: Points given demonstrative pronouns which refer to places

| Similarity Level | 0  | 1  | 2  | 3  | 4  | 5  | 6  | Exact Match |
|------------------|----|----|----|----|----|----|----|-------------|
| Point            | −10| −5 | 0  | 5  | 10 | 10 | 10 | 10          |

refers to only a thing which is not human and the noun which is near “SORE (it)” and which is not human is only “KONPYUUTA (computer)”.

TAROO-WA SAISHIN-NO KONPYUUTA-WO KAIMASHITA.

(Taroo) (new) (computer) (buy)

(Taroo bought a new computer.)

JON-NI SASSOKU SORE-WO MISEMASHITA.

(John) (at once) (it) (show)

([Taroo] showed it at once to John.)

**Rule with Feature that “KOKO” and “SOKO” Often Refer to Locations**

*Candidate judging rule 3*

When a pronoun is “KOKO (here) / SOKO (there) / ASOKO (over there)” and a candidate referent has a semantic marker LOC (location), the candidate referent is given 10 points.

*Candidate judging rule 4*

When a pronoun is “KOKO/SOKO/ASOKO”, a candidate referent is given the points in Table 5.5 by using the semantic similarity between the candidate referent and the codes \{6563006010 6559005020 9113301090 9113302010 6471001030 6314020130\} which signify locations in BGH \[NLRI 64]\.

“SOKO (there)” commonly refers to location. For example, “SOKO” in the
following sentences refers to “BAITEN (shop)” which signifies location.

TAROO-GA KOUEN-DE HON-WO YONDE-IMASHITA.
(Taroo) (in the park) (book) (be reading)
(Taroo was reading a book in the park.)

KOORA-WO KAINI BAITEN-NI HAIRIMASHITA.
(cola) (buy) (shop) (enter) (5.4)
(Taroo entered a shop to buy a cola.)

JIROO-WA SOKO-DE GUUZEN DEKUWASHIMASHITA.
(Jiroo) (there) (by chance) (meet)
(Jiroo met Taroo there by chance.)

Rule when “KOKODE” or “SOKODE” is Used as a Conjunction

Candidate enumerating rule3

When a pronoun is “KOKODE” or “SOKODE”,
{(the pronoun is used as conjunctions, 11)}

This rule is for when “KOKODE (here or then)” or “SOKODE (there or then)” is used as conjunctions. If a word which signifies location is not found near “KOKODE” or “SOKODE”, the candidate which is listed by this rule has the highest score, and “KOKODE” or “SOKODE” is judged as a conjunction. By using this rule, “SOKODE” in the following sentences is judged to be a conjunction.

OJIISAN-WA TENGU-GA KOWAKUNAKUNATTE-IMASHITA.
(old man) (tengu) (lose all fear of)
(The old man lost all fear of the “tengu.”) (5.5)

SOKODE OJIISAN-WA KAKURETEITA ANA-KARA DETEKIMASHITA.
(so) (old man) (be hiding) (hole) (leave)
(So, he left the hole where he had been hiding.)

This rule is necessary when the system translates “SOKODE” into English, judges whether it is used as a demonstrative or as a conjunction, and translates it into “there” or “then.”
CHAPTER 5. AN ESTIMATE OF REFERENTS OF PRONOUNS

Rule in the Case of Cataphora

Demonstrative pronouns can be intersentential cataphoric 3. In this case, we analyze a demonstrative pronoun by using rules based on Matsuoka’s method [Matsuoka et al 95]. This work [Matsuoka et al 95] also deals with cases in which demonstrative pronouns refer to the next sentences. But these cases rarely happen. When we do not use this rule, the precision increases. For this reason we do not use this rule.

The Other Rules

Candidate enumerating rule4

When a pronoun is “SORE/ARE/KORE” or a demonstrative adjective and the previous bunsetsu contains the expression of the predicative form of a verb or the expression of enumerating examples such as “TOKA (and so on),” 
{(the expression, 40)}

Candidate enumerating rule5

When a pronoun is a demonstrative pronoun, a demonstrative adverb, or a demonstrative adjective,
{(Introduce an individual, 10)}

This rule is used when there is no referent of a pronoun in the sentences. This rule makes the system introduce a certain individual.

5.3.2 Rule for Demonstrative Adjective

Demonstrative pronouns such as “KONO (this),” “SONO (the),” “ANO (that),” “KON’NA (like this),” and “SON’NA (like it)” are classified into two reference categories: gentei-reference and daikou-reference.

In a Gentei-reference although a demonstrative adjective does not refer to an entity by itself, the phrase of “demonstrative adjective + noun phrase” refers to

3 Cataphora is the phenomenon that an anaphor refers to elements which appear later.
the antecedent. For example “KONO OJIISAN (this old man)” in the following sentences:

\[
\text{OJIISAN-WA TENGUTACHI-NO-MAENI DETEITTE ODORI-HAJIMEMASHITA}
\]
(He appeared before the “tengu,” and began to dance.)

\[
\text{KEREDOMO KONO OJIISAN-WA UTA-MO ODORI-MO HETAKUSO-DESHITA}
\]
(But the old man was a poor singer, and his dancing was no better.)

In this example, although the demonstrative “KONO (this)” does not refer to “OJIISAN (old man)” in the first sentence, the noun phrase “KONO OJIISAN (this old man)” refers to “OJIISAN (old man)” in the first sentence.

*Daikou*-reference is a demonstrative adjective that refers to an entity. In this case, we can analyze “SONO (the)” as well as “SORE-NO (of it)”.

\[
\text{MATA KARASU-NO-YOUNA KAO-WO-SHITA TENGU-MO IMASHITA}
\]
(There were also some “tengu” with faces like those of crows.)

\[
\text{SONO KUCHI-WA TORINO-KUCHIBASHI-NOYOUNI TOGATTE-IMASHITA}
\]
(Their mouths were pointed like the beaks of birds.)

Rules for *gentei*-reference and *daikou*-reference are as follows:

**Rule for *Gentei*-Reference**

*Candidate enumerating rule* 6

When a pronoun is “so-series demonstrative adjective + noun \( \alpha \),”

\[
\{ \text{the noun phrase containing a noun } \alpha, \ 45 \}
\]

\[
\text{(the topic which is a subordinate of the noun } \alpha \text{ and which has the weight } W \text{ and the distance } D, \ W - D \times 2 + 10 \}
\]

\[
\text{(the focus which is a subordinate of the noun } \alpha \text{ and which has the weight } W \text{ and the distance } D, \ W - D \times 2 + 10) \}
\]
The definition and the weight \((W)\) of topic and focus are shown in Table 5.1 and Table 5.2.

When a possible referent is a topic, the distance \((D)\) between the estimated noun phrase and the possible referent is the number of topics between them. When a possible referent is a focus, the distance \((D)\) is the number of foci between them.

The relations between a super-ordinate word and a subordina te word is detected by the last word in the definition of the word \(\alpha\) in EDR Japanese word dictionary [EDR 95] is judged to be the super-ordinate of the word \(\alpha\) [Tsurumaru et al 91].

Since a so-series demonstrative refers to noun phrases nearer than a ko-series demonstrative, we give the coefficient 2 in the second term.

**Candidate enumerating rule 7**

When a pronoun is “ko-series demonstrative adjective + noun \(\alpha\),”

\[
\{ \text{the noun phrase containing a noun } \alpha, \ 45 \}
\]

\[
\text{(the topic which is a subordinate of the noun } \alpha \text{ and which has the weight } W \text{ and the distance } D, \ W - D + 30) \]

\[
\text{(the focus which is a subordinate of the noun } \alpha \text{ and which has the weight } W \text{ and the distance } D, \ W - D + 30) \}
\]

**Candidate enumerating rule 8**

When a pronoun is “a-series demonstrative adjective + noun \(\alpha\),”

\[
\{ \text{the noun phrase containing a noun } \alpha, \ 45 \}
\]

\[
\text{(the topic which is a subordinate of the noun } \alpha \text{ and which has the weight } W \text{ and the distance } D, \ W - D * 0.4 + 30) \]

\[
\text{(the focus which is a subordinate of the noun } \alpha \text{ and which has the weight } W \text{ and the distance } D, \ W - D * 0.4 + 30) \}
\]

Because of the above three rules, when a pronoun is “demonstrative adjective + noun phrase \(\alpha\)” and there is the same noun phrase \(\alpha\) near it, it is judged to be “gentei-reference” and is selected as a candidate of the referent. When there is a subordinate of a noun phrase \(\alpha\) near it, it is also selected as a candidate of the
5.3. HEURISTIC RULE FOR DEMONSTRATIVE

Table 5.6: Points given to so-series demonstrative adjective

| Similarity Level | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Exact Match |
|------------------|---|---|---|---|---|---|---|-------------|
| Point            | -10 | -2 | -1 | 0 | 1 | 2 | 3 | 4           |

referred. These rules give higher points to a candidate referent than in the other rules. The following is an example of the “demonstrative adjective + noun phrase α” referring to the subordinate of the noun phrase α.

OJIISAN-WA TOONOITEIKU TSURU-NO SUGATA-WO MIOKURIMASHITA.  
(Old man) (recede) (crane) (figure) (watch)  
(The old man watched the receding figure of the crane.)

“ANO TORI-WO TASUKETE YOKATTA” TO IIMASHITA.  
(that bird) (save) (glad) (say)  
(“I’m glad I saved that bird,” said the old man to himself.)

In this example, the underlined “ANO TORI (that bird)” refers to a subordinate “TSURU (crane)” in the previous sentence.

Rules for Daikou-Reference of So-Series Demonstrative Adjective

Candidate judging rule

When a pronoun is a so-series demonstrative adjective, the system consults examples of the form “noun X NO noun Y” whose noun Y is modified by the pronoun, and gives a candidate referent the point in Table 5.6 by the similarity between the candidate referent and noun X in “Bunrui Goi Hyou”[NLRI 64]. The Japanese Co-occurrence Dictionary[EDR 95c] is used as a source of examples of “X NO Y”.

This rule is for checking the semantic constraint (For a daikou-reference, candidates of the referent are selected by Candidate enumerating rule1 in Section 5.3.1).

We explain how to use the rule in the underlined “SONO (the)” in the sentences (5.7). First, the system gathers examples of the form “Noun X NO KUCHI (mouth of Noun X)”. Table 5.7 shows some examples of “Noun X NO KUCHI (}
Table 5.7: Examples of the form “the mouth of Noun X”

| Examples of Noun X                  |
|-------------------------------------|
| HUKURO (sack), RUPORAITA(documentary writer) IIN(member), |
| AKACHAN(baby), KARE(he)            |

Table 5.8: Points given in the case of non-so-series demonstrative adjective

| Similarity Level | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Exact match |
|------------------|---|---|---|---|---|---|---|-------------|
| Point            | -30 | -30 | -30 | -30 | -10 | -5 | -2 | 0           |

mouth of Noun X)” in the Japanese Co-occurrence Dictionary [EDR 95c]. Next, the system checks the semantic similarity between candidate referents and Noun X, and judges that the candidate referent which has a higher similarity is a better candidate referent. In this example, “TENGU” is semantically similar to Noun X in that they are living things. At last, the system selects “TENGU” as the proper referent.

Rules when Non-So-Series Demonstrative has Daikou-Reference

Candidate judging rule

When a pronoun is a non-so-series demonstrative adjective, the system consults examples of the form “Noun X NO(of) Noun Y (Y of X)” whose Noun Y is modified by the pronoun, and gives candidate referents the point in Table 5.8 by the similarity between the candidate referent and noun X in “Bunrui Goi Hyou” [NLRI 64]. Since a non-so-series demonstrative adjective rarely is a daikou reference [NLRI 81] [Yamamura et al 92], the point is lower than that in the case of so-series.
5.3. **HEURISTIC RULE FOR DEMONSTRATIVE**

**Rule when a Pronoun Refers to a Verb Phrase**

As in a demonstrative pronoun, a demonstrative adjective can refer to the meaning of the verb phrase in the previous sentence.

TSUMARI, NINGEN-NO NOU-YORI YUUSHUUNA PATAAN NINSHIKI PUROGURAMU-GA TSUKURENAI DANKAI-DEWA, HIJOUNI HUKUZAT-SUDE OMOSHIROSONA JISHOU-NITSUITEWA, MAZU SONO GAZOU WO TSUKUTTE, SONO DEETA-WO BUTSURIGAKUSA-NI GINMISASERU HITSUYOU-GA-ARU.

(Until scientists invent a pattern recognition program that works better than the human brain, it will be necessary to produce images of the most complicated and interesting events so that physicists can scrutinize the data.)

1980 NEN DAI-NO SHOTOU-NI LEP JIKKEN SOUCHI-GA HAJIMATTA-TOKI, KONO SENRYAKU-GA SAIYOU SARETANODATTA.

(This strategy was adopted by workers when they began to design the LEP detectors in the early 1980s.)

The referent of “KONO SENRYAKU (this strategy)” is the meaning of the previous sentence. The resolution in this case is performed as follows: When there are no noun phrases which are suitable for the referent of “KONO (this)” or the referent of “KONO SENRYAKU (this strategy)” near the demonstrative, the system judges that the meaning of the previous sentence is the proper referent, provided that, as in a demonstrative pronoun when the verb phrase containing a conjunctive particle such as “GA”, “DAGA”, and “KEREDO” or a conditional form exists in the same sentence, the verb phrase is judged to be the proper referent. The above procedure is done by *Candidate enumerating rule*2 in Section 5.3.1.

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4 It is necessary to distinguish between daikou-reference and gentei-reference even in the case when a pronoun refers to a verb phrase. But, in this thesis, we do not distinguish them because of the difficulty of the problem.
Table 5.9: The result of the investigation whether “KON’NA + noun (noun like this)” refers to the previous sentences or the next sentences

| Postpositional particle | the previous sentence | the next sentence |
|-------------------------|-----------------------|-------------------|
| WA (topic)              | 9                     | 0                 |
| WA-NAI                  | 5                     | 0                 |
| NI (indirect object)    | 17                    | 0                 |
| NI-MO                   | 1                     | 0                 |
| NI-WA                   | 2                     | 0                 |
| DE (place)              | 15                    | 0                 |
| DE-WA                   | 5                     | 0                 |
| NO (possessive)         | 9                     | 0                 |
| SURA                    | 2                     | 0                 |
| GA (subject)            | 27                    | 22                |
| WO (object)             | 43                    | 26                |
| MO (also)               | 2                     | 4                 |
| DE-WA-NAI               | 0                     | 1                 |
| Total                   | 137                   | 53                |

**Rule for “KON’NA + Noun (noun like this)”**

“KON’NA Noun” can also refer to the next sentences in addition to a noun phrase and the previous sentences.

OJIISAN-WA ODORINAGARA KON’NA UTA-WO UTAIMASHITA.
(old man) (dance) (song like this) (sing)
(As he danced, he sang the following song: )

“TENGU TENGU HACHI TENGU.
(tengu) (tengu) (eight tengu)
(“‘Tengu,’ ‘tengu,’ Eight ‘tengu.’”) (5.9)

In the above example, “KON’NA UTA (song like this)” refers to the next sentence “TENGU, TENGU, HACHI TENGU.”

But we cannot decide whether “KON’NA + noun (noun like this)” refers to the previous sentences or the next sentences only by the expression of “KON’NA
5.3. HEURISTIC RULE FOR DEMONSTRATIVE

To make the decision, we gather 317 sentences containing “KON’NA (like this)” from about 60,000 sentences in TENSEIJINGO and editorials (1986 and 1987), and count the total frequency that “KON’NA” refers to the previous sentences or to the next sentences. The result is shown in Table 5.9. This table indicates that “KON’NA + noun” followed by the other particles of the particles “GA” and “WO,” which are used when representing new information, very often refers to the previous sentence. Therefore, the system judges that the desired antecedent is the previous sentence. When “KON’NA + noun” followed by the particles “GA” and “WO,” the proper referent is determined by the expression of quotation marks (“,”) as well as Matsuoka’s method [Matsuoka et al 95].

5.3.3 Rule for Demonstrative Adverb

Rule when So-Series Demonstrative Adverb Refers to the Previous Sentences

Candidate enumerating rule

When an anaphor is a so-series demonstrative adverb such as “SOU (so),”
{(the previous sentences, 30)}
The example is as follows.

“TENGU TENGU HACHI TENGU.
(tengu) (tengu) (eight tengu)
(‘Tengu,’ ‘tengu,’ Eight ‘tengu.’)”

SOU UTATTA-NOWA SOKONI HACHIHIKI-NO TENGU-GA ITAKARA-DESU.
(sing so) (there) (eight) (tengu) (exist)
(He sang so because he counted eight of them there.)

“SOU (so)” refers to the previous sentence “TENGU TENGU HACHI TENGU”.

Rule when So-Series Demonstrative Adverb Cataphorically Refers to the Verb Phrase in the Same Sentence

Candidate enumerating rule
CHAPTER 5. AN ESTIMATE OF REFERENTS OF PRONOUNS

When an anaphor is “SOU/SOUSHITE/SONOYOUNI” and is in the subordinate clause which has a conjunctive particle such as “GA”, “DAGA”, and “KEREDO” or an adjective conjunction such as “YOUNI”,
{(the main clause, 45)}
This rule is based on Matsuoka’s method [Matsuoka et al. 95].

Rule when Ko-Series Demonstrative Adverb Refers to the Previous Sentences

Candidate enumerating rule 11
When an anaphor is a ko-series demonstrative adverb such as “KOU (in this way)”,
{(the previous sentences, 25)}

Rule when Ko-Series Demonstrative Adverb Refers to the Next Sentences

Candidate enumerating rule 12
When an anaphor is a ko-series demonstrative adverb,
{(the next sentences, 26)}

A ko-series demonstrative adverb can also refer to the next sentences in addition to the previous sentences.

TEN’GU-TACHI-WA   TOUTOU  KOU   IIMASHITA.
(tengu)    (finally)   (like this)  (say)
(The “tengu” finally said as follows:)

KYOU-NO  OMAE-WA   DAME-DANA. ...
(today)    (you)   (no good)
(“You’re no good today. ...”)

In the example, “KOU (in this way)” refers to the next sentences. When “KOU (in this way)” is a part of the typical form such as “KOU SHITE” and “KOU SUREBA,” it often refers to the previous sentences. Therefore if “KOU (in this
way)” is a part of this typical form, the system judges that the desired antecedent is the previous sentence. Otherwise, the system judges that the desired antecedent is the next sentence. To implement this procedure, we made the following rules.

*Candidate enumerating rule* 13

When an anaphor is a part of “KOU/KO’N’NAHUUNI” + conditional form or “KOU SHITE” and is not the last word in the sentence,

{(the previous sentence, 7)}

## 5.4 Heuristic Rule for Personal Pronoun

*Candidate enumerating rule* 1

When an anaphor is a first personal pronoun,

{(the first person (the speaker) in the context, 25)}

*Candidate enumerating rule* 2

When an anaphor is a second personal pronoun,

{(the second person (the hearer) in the context, 25)}

A first or second personal pronoun is often presented in quotation, and can be resolved by estimating the first person (speaker) or the second person (hearer) in advance. The estimation of the first person and the second person is performed by regarding *ga*-case component and *ni*-case component of the verb phase which represents the speaking action of the quotation as the first person and the second person, respectively. The detection of the verb phase representing the speaking action is performed as follows. If the quotation is followed by a speaking action verb phrase such as “TO ITTA (was said),” the verb phrase is regarded as the verb phase representing the speaking action. Otherwise, the last verb phrase in the previous sentence is regarded as the verb phase representing the speaking action

---

5 There are some errors in the detection of the verb phrase representing the speaking action in this method. But in the sample texts used in the experiment of this thesis, all detection could be performed properly in this method.
following sentences refers to the second person "OJIISAN (the old man)" in this quotation.

"ASU, MATA MAIRIMASUYO." TO,
(tomorrow) (again) (come)
(“I’ll come again tomorrow,”)

OJIISAN-WA YAKUSOKU-SHIMASHITA.
(old man) (promise)
(promised the old man.)

“MOCHIRON OMAESAN-WO UTAGAUWAKEDEWANAINODAGA,”
(of course) (you) (don’t mean to doubt)
(“Of course, we don’t mean to doubt you.”)

TENGU-GA OJIISAN-NI IIMASHITA.
(tengu) (old man) (said)
(said one of the “tengu” to the old man.)

The fact that the second person in the quotation is “OJIISAN” is estimated by the fact that ni-case component of the verb phrase “IIMASHITA (said)” representing the speaking action of the quotation is “OJIISAN”.

Candidate enumerating rule\textsuperscript{3}

When an anaphor is a third personal pronoun,
\{(a first person, \(-10\)) (a second person, \(-10\))\}

Personal pronouns are generally analyzed by the following three rules: The system lists candidate referents with the scores (the certification value) considering topic/focus and the distance between the anaphor and the candidate referents by Candidate enumerating rule\textsuperscript{4}, and increases the score of the candidate referents which signify human beings by Candidate judging rule\textsuperscript{1} and Candidate judging rule\textsuperscript{2}.

Candidate enumerating rule\textsuperscript{4}

When an anaphor is a personal pronoun,
\{(A topic which has the weight $W$ and the distance $D$, $W - D - 2$)\}
Table 5.10: Points given in the case of personal pronoun

| Similarity Level | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Exact Match |
|------------------|---|---|---|---|---|---|---|-------------|
| Point            | 0 | 0 | 3 | 7 | 10| 10| 10| 10          |

(A focus which has the weight $W$ and the distance $D$, $W - D + 4$)

*Candidate judging rule 1*

When an anaphor is a personal pronoun and a candidate referent has a semantic marker HUM, the candidate referent is given 10 points.

*Candidate judging rule 2*

When an anaphor is a personal pronoun, a candidate referent is given the points in Table 5.10 by using the highest semantic similarity between the candidate referent and the code \{5200003010 5201002060 5202001020 5202006115 5241002150 5244002100\} which signifies human being in BGH [NLRI 64].

## 5.5 Heuristic Rule for Zero Pronoun

### Rule Proposing Candidate Referents of General Zero Pronoun

*Candidate enumerating rule 1*

When a zero pronoun is a *ga*-case component,

{(A topic which has the weight $W$ and the distance $D$, $W - D * 2 + 1$)
(A focus which has the weight $W$ and the distance $D$, $W - D + 1$)
(A subject of a clause coordinately connected to the clause containing the anaphor, 25)
(A subject of a clause subordinately connected to the clause containing the anaphor, 23)
(A subject of a main clause whose embedded clause contains the anaphor, 22)}
Candidate enumerating rule 2
When a zero pronoun is not a ga-case component,
{(A topic which has the weight $W$ and the distance $D$, $W - D \ast 2 - 3$)
(A focus which has the weight $W$ and the distance $D$, $W - D \ast 2 + 1$)}

Rule for Analyzing Complex Sentences

Candidate enumerating rule 3
When a zero pronoun is ga-case of the main (or subordinate) clause in a complex sentence, the complex sentence is connected by the conjunctive particle indicating the disagreement of the subjects in a complex sentence such as “NODE (because)” and “NARABA (if)” and the subject of the subordinate (or main) clause is not omitted and is followed by the particle “GA,”
{(the subject of the subordinate (or main) clause, $-30$)}

For a ga-case zero pronoun of the main (or subordinate) clause in a complex sentence, if there is a ga-case noun phrase in the subordinate (or main) clause, the system commonly judges that the ga-case noun phrase is the antecedent of the ga-case zero pronoun. But it is known that there are conjunctive particles which produce disagreement of subjects in a complex sentence [Minami 74] [Yoshimoto 86] [Hirai 86] [Nakaiwa & Ikehara 95]. When a complex sentence is connected by these conjunctive particles, the system does not judge that the noun phrase of the subordinate (or main) clause is the desired antecedent. Candidate enumerating rule 3 is for this procedure.

Rule Using Semantic Relation to Verb Phrase

Candidate judging rule 1
When a candidate referent of a case component (a zero pronoun) does not satisfy the semantic marker of the case component in the case frame, it is given $-5$.

Candidate judging rule 2
5.5. **HEURISTIC RULE FOR ZERO PRONOUN**

| Similarity Level | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Exact Match |
|------------------|---|---|---|---|---|---|---|-------------|
| Point            | −10| −2| 1 | 2 | 2.5| 3 | 3.5| 4           |

Table 5.11: Points given from a verb-noun relationship

| OJIISAN-WA JIMEN-NI KOSHI-WO-OROSHIMASHITA. |
|--------------------------------------------|
| (old man) (ground) (sit down) |
| (The old man sat down on the ground.) |

| YAGATE (OJIISAN-WA) NEMUTTE-SHIMAISHITA. |
|------------------------------------------|
| (soon) (old man) (fall asleep) |
| (He soon fell asleep.) |

**Semantic Marker** HUM/ANI GA(agent) NEMURU (sleep)

**Example** KARE (he)/ INU (dog) GA(agent) NEMURU (sleep)

Figure 5.3: Example of how to check semantic constraint

A candidate referent of a case component (a zero pronoun) is given points in Table 5.11 by using the highest semantic similarity between the candidate referent and examples of the case component in the case frame.

These two rules are for checking the semantic constraint between the candidate referent and the verb phrase which has the candidate referent in its case component. **Candidate judging rule1** checks semantic constraints by using semantic markers. **Candidate judging rule2** checks semantic constraints by using examples. We explain how to check semantic constraints in the example sentences in Figure 5.3.

In the method using semantic markers, a candidate referent is the proper referent if one of the semantic markers which the candidate referent has is equal or subordinate to the semantic marker of the case component. For example, with respect to the zero pronoun in Figure 5.3, since the *ga*-case component in the verb “NEMURU (sleep)” has the semantic markers HUM (human being) and ANI...
(animal) and “OJIISAN (old man)” has the semantic marker HUM, “OJIISAN” is judged to be the proper referent.

In the example-based method, the validity of a candidate referent is decided by the semantic similarity between the candidate referent and the examples of the case component in the verb case frame. The higher the semantic similarity is, the higher the validity is. For example, with respect to a zero pronoun in Figure 5.3, since the examples of ga-case are “KARE (he)” and “INU (dog)” and “OJIISAN (old man)” is semantically similar to “KARE (he)”, “OJIISAN (old man)” is the proper referent.

These rules, which use semantic relations to verbs, are also used in the estimation of the referent of demonstratives and personal pronouns.

**Rule Using the Feature that it is Difficult for a Noun Phrase to be Filled in Plural Case Components of the Same Verb**

*Candidate enumerating rule 4*

When there is “Noun X” in another case component of the verb which has the analyzed case component (the analyzed zero pronoun), \{\text{(Noun X, −20)}\}

**Rule Using Empathy**

*Candidate enumerating rule 5*

When an anaphor is a *ga*-case zero pronoun whose verb is followed by the auxiliary verbs such as “KURERU” and “KUDASARU” and there is a *ni*-case zero pronoun in the verb, the *ni*-case zero pronoun is analyzed first. With respect to the *ga*-case zero pronoun, \{\text{(do not fill a zero pronoun, −5)}\}

This rule is based on empathy theory [Kameyama 86].

When an anaphor is a *ga*-case zero pronoun whose verb is followed by the auxiliary verbs such as “KURERU” and “KUDASARU,” the *ni*-case zero pronoun is analyzed first, and it is filled with the noun phrase which has high empathy such as topic, and a *ga*-case zero pronoun is filled with the other noun phrase.

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6 HUM and ANI are the semantic markers which indicate human being (HUMAN) and animal (ANIMAL), respectively.
5.5. **HEURISTIC RULE FOR ZERO PRONOUN**

**Rule for Zero Pronoun in the Quotation**

*Candidate enumerating rule* 6

In the quotation, when an anaphor is a *ga*-case zero pronoun which is easily filled with a first person, whose verb is such as “YARU (give)”, “SHITAI (want)”, and “IKU (go),” {(the first person, 5)}

*Candidate enumerating rule* 7

In the quotation, when an anaphor is a *ga*-case zero pronoun which is easily filled with a second person, whose verb is such as “KURERU (give)”, “NASARU (do)”, and “KURU (come)”, or whose verb is in an imperative or interrogative form, {(the first person, −30)(the second person, 25)}

*Candidate enumerating rule* 8

In the quotation, when an anaphor is a *ga*-case zero pronoun, {(the first person, 15)}

A zero pronoun in a quotation can often be resolved by the surface expression of the last words in the sentence. A zero pronoun can be resolved by estimating the first person (speaker) or the second person (hearer) as in a personal pronoun 7. For example, in the next quotation, we find that the first person is “TENGU TACHI (tengu)” and that the second person is “OJIISAN (old man)” by checking

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7 *Kudou & Tomokiyo 93* estimates the person of a zero pronoun in a conversational corpus. But in this work, quotations in the novel are dealt with, and it is necessary to estimate the speaker and the hearer of the quotation.
CHAPTER 5. AN ESTIMATE OF REFERENTS OF PRONOUNS

*ga*-case component and *ni*-case component of the verb “IU (say),”

\[\text{TENGU-TACHI-WA TOUTOU KOU IIMASHITA.} \]
\((\text{tengu}) \ (\text{finally}) \ (\text{like this}) \ (\text{say})\)

(The “tengu” finally said:)

\[\text{“KYOU-NO OMAE-WA DAME-DANA.} \]
\((\text{today}) \ (\text{you}) \ (\text{no good})\)

(“You’re no good today.”)

\[\text{KORE-WO [TENGU-TACHI-GA] [OJIISAN-NI] KAESHITE-YARU-KARA} \]
\((\text{this}) \ (\text{tengu}) \ (\text{old man}) \ (\text{give back to})\)

(“[We’ll give this back [to you].”)

\[\text{[OJIISAN-GA] KAETTE-SHIMAE.} \]
\((\text{old man}) \ (\text{go home})\)

(“[You should] Now go home.”)

The referent of the *ga*-case zero pronoun of the verb “KAESHITE YARU” is the first person “TENGU TACHI (‘tengu’s)” because “KAESHITE YARU” contains “YARU.” The referent of the *ni*-case zero pronoun of the verb “KAESHITE YARU” is the second person “OJIISAN (old man)” because “KAESHITE YARU” contains “YARU.” The referent of the *ga*-case zero pronoun of the verb “KAETTE SHIMAE” is the second person “OJIISAN (old man)” because “KAETTE SHIMAE” is the imperative sentence.

The Other Rules

*Candidate enumerating rule* 9

When an anaphor is a *ga*-case zero pronoun of “Y DA (is Y)” in the expression of “X WO Y DA TO MINASU (consider X as Y), \{(Noun X, 50)\}”

5.6 Experiment and Discussion

5.6.1 Experiment

Before pronoun resolution, sentences were transformed into a case structure by the case structure analyzer [Kurohashi & Nagao 94] as in the experiments of the other
5.6. EXPERIMENT AND DISCUSSION

(Dollar) (the expectations) (130 yen) (surge)
(The dollar has since rebounded to about 130 yen because of the expectations.)

(KONO DORU-DAKA-WA OUSHUU-TONO KANKEI-WO GIKUSHAKU-SASETEIRU.
(The dollar’s surge) (Europe) (relation) (strain)
(The dollar’s surge is straining the relations with Europe.)

| Rule                              | The score of each candidate (points) |
|-----------------------------------|-------------------------------------|
|                                   | the previous sentence | new individual | 130 YEN (130 yen) | KITAI (expectations) | DORUSOUBA (dollar) |
| Candidate enumerating rule2       | 15                     | 10             | 17               | 15                  | 15                  |
| Candidate enumerating rule5       |                         |                |                  |                     |                     |
| Candidate enumerating rule1       |                         |                |                  |                     |                     |
| Candidate judging rule6           |                         |                |                  |                     |                     |
| Total Score                       | 15                     | 10             | -13              | -15                 | -15                 |

Figure 5.4: Example of resolving demonstrative “KONO (this)”

chapters. The errors made by the structure analyzer were corrected by hand. We used IPAL dictionary [IPAL 87] as a verb case frame dictionary. We put together the case frames of the verb phrases which were not contained in this dictionary by consulting a large amount of linguistic data.

An example of resolution of the demonstrative “KONO (this)” is shown in Figure 5.4. Figure 5.4 shows that the referent of the noun phrase “KONO DORU-DAKA (this dollar’s surge)” was properly judged to be the previous sentence.

By Candidate enumerating rule2 in Section 5.3, the system took a candidate “The previous sentence” and gave it 15 points. By Candidate enumerating rule5 in Section 5.3, the system took a candidate “New individual” and gave it 10 points. By Candidate enumerating rule1 in Section 5.3, the system took three candidates, “130 YEN (130 yen)”, “KITAI (expectations)”, and “DORUSOUBA (dollar)”, and gave them 17, 15, and 15 points, respectively. The system applied Candidate judging rule6 to them. Candidate judging rule6 uses examples of “X NO Y”. In this case, Candidate judging rule6 used examples of “X NO DORUDAKA (the
CHAPTER 5. AN ESTIMATE OF REFERENTS OF PRONOUNS

Table 5.12: Result

| text       | demonstrative | personal pronoun | zero pronoun | total score |
|------------|---------------|------------------|--------------|-------------|
| Training   | 87% (41/47)   | 100% (9/9)       | 86% (177/205)| 87% (227/261)|
| Test       | 86% (42/49)   | 82% (9/11)       | 76% (159/208)| 78% (210/268)|

The point given in each rule is manually adjusted by using the training sentences. Training sentences {example sentences (43 sentences), a folk tale “KOBUTORI JIISAN” [Nakao 85] (93 sentences), an essay in “TENSEIJINGO” (26 sentences), an editorial (26 sentences), an article in “Scientific American (in Japanese)” (16 sentences)}

Test sentences {a folk tale “TSURU NO ONGAESHI” [Nakao 85] (91 sentences), two essays in “TENSEIJINGO” (50 sentences), an editorial (30 sentences), articles in “Scientific American (in Japanese)” (13 sentences)}

Table 5.13: The detailed result of demonstrative

| text       | demonstrative pronoun | demonstrative adjective | demonstrative adverb | total score |
|------------|-----------------------|-------------------------|----------------------|-------------|
| Training   | 83% (15/18)           | 86% (19/22)             | 100% (7/7)           | 87% (41/47) |
| Test       | 82% (14/17)           | 88% (23/26)             | 83% (5/6)            | 86% (42/49) |

dollar’s surge of X”). The noun phrase X of this form “X NO DORUDAKA” was only “SAIKIN (recently)” in EDR occurrence dictionary. All three candidates, “130 YEN (130 yen)” , “KITAI (expectations)”, and “DORUSOUBA (dollar)”, were low in similarity to “SAIKIN (recently)” in “Bun Rui Goiyou”, and were given −30 points by Table 5.8. Two candidate, “The previous sentence” and “New individual” , are not noun phrases, and were not given points by Candidate judging rule6. As a result, “the previous sentence” had the highest score and was judged to be the proper referent.

We show the result of our resolution of demonstratives, personal pronouns, and zero pronouns in Table 5.12. The detailed result of demonstrative is shown in Table 5.13. When a demonstrative refers to some sentences, even if the scope of
the referent cannot be estimated and a demonstrative can be correctly judged to be anaphoric or cataphoric, it is regarded as correct. This is because we think that the estimation of the scope of the referent should be analyzed after the analysis of the relation of the sentences such as *cause–effect* and *exemplification*. The precision rate of zero pronouns is in the case when the system knows whether the zero pronoun has the referent or not in advance.

5.6.2 Discussion

With respect to demonstratives, the precision rate was over 80% even in the test sentences. It indicates that the rule used in this system is effective. But since Japanese demonstratives are classified into many kinds, the precision may increase by making more detailed rules. In this work we used the feature that “KONO (this)” rarely functions as a *daikou*-reference. There were four cases analyzed correctly because of this rule.

With respect to personal pronouns, since only first personal pronouns and second personal pronouns appeared in texts used by the experiment, almost all of the personal pronouns were resolved correctly by estimating the first persons and the second persons in the quotation. The main reason for the errors in the personal pronoun resolution is that *ni*-case zero pronoun was resolved incorrectly and the second person was estimated incorrectly.

Reasons for the errors of the zero pronoun resolution are that there are errors in “Bunrui goi hyou”, Noun Semantic Marker Dictionary, and Case Frame Dictionary, and that rules are insufficient although they can be improved by making new rules using syntax structures and auxiliary expressions.

An example of errors necessary for understanding and reasoning is as follows:

> SONNA JOUKYOU NANONI, WASHINTON-DE HIRAKARERU SHUYOU-SENSHIN-7-KAKOKU-NO ZOUSHOU CHUUOU GINKOU SOUSAI KAIGI (G7) NI TSUITE KAKKOKU-NO TSUUKA TOUKYOKU-WA “OOKINA MONDAI-WA NAI-NODE KYOUDOU KOMINYUKE-WA DANAI KAOAWASE CHUUSHIN-NO KAIGOU-DA”-TO, MARUDE KAIGI-NO IGI-WO USUMEYOU-TO-SHITEIRUYOUNA IIKATA-DA.

(Despite these problems that plague the global economy, the monetary authorities of the Group of Seven nations seem to be trying to downplay the
upcoming G-7 meeting in Washington. The participants regard the meeting as just a "get-acquainted session" and have decided against issuing a joint communique.)

(...)

(omission)

(...)

BEI-SHINSEIKEN-WA CHIKAKU, ZAISEI AKAJI SAKUGEN-NO GUTAITEKI-KOKUSOU-WO GIKAI-NI SHIMESU-YOTEI-DEARU.
(The administration will shortly indicate its specific deficit-cutting plans to Congress.)

[TSUUKA TOUKYOKU GA] KYOUDOU KOMINYUKE-NO HAPPYOU-WO HIKAERUNOWA, KAWASE SHIJHO-NI KADAINA KITAI-WO ATAETAKU-NAI-TAME-DAROU.
(The reason for [the monetary authorities’] doing away with a joint communique this time seems to be to avoid arousing any false hopes in the foreign exchange market.)

The \textit{ga}-case of “HIKAERU (do away with)” in this example refers to “KAKKOKU NO TSUUKA TOUKYOKU (the monetary authorities)”. But the system incorrectly judged that the referent was “BEI-SHINSEIKEN (administration)”. To correct result, it is necessary to understand that the thing which does away with a joint communique is the monetary authorities.

\subsection*{5.6.3 Comparison Experiment}

As we mentioned before, we use both the example rule and the semantic marker rule as judging rules. To check which rule is more effective, we made a comparison between the example method and the semantic marker method. The result is shown in Table 5.14. The upper and lower row of this table show the accuracy rates for training sentences and test sentences, respectively. The rules using examples are \textit{Candidate judging rule}2,4 for demonstratives, \textit{Candidate judging rule}2 for personal pronouns, and \textit{Candidate judging rule}2 for zero pronouns. The rules using semantic markers are \textit{Candidate judging rule}1,3 for demonstratives, \textit{Can-
Table 5.14: Result of comparison between semantic marker and example-base

| Method 1 | Method 2 | Method 3 | Method 4 | Method 5 |
|----------|----------|----------|----------|----------|
| **Demonstrative** | | | | |
| 87% (41/47) | 83% (39/47) | 87% (41/47) | 83% (39/47) | 79% (37/47) |
| 86% (42/49) | 88% (43/49) | 88% (43/49) | 84% (41/49) | 86% (42/49) |
| **Personal pronoun** | | | | |
| 100% (9/9) | 100% (9/9) | 100% (9/9) | 100% (9/9) | 89% (8/9) |
| 82% (9/11) | 64% (7/11) | 82% (9/11) | 55% (6/11) | 64% (7/11) |
| **Zero pronoun** | | | | |
| 86% (177/205) | 83% (171/205) | 86% (176/205) | 82% (169/205) | 66% (135/205) |
| 76% (159/208) | 76% (158/208) | 79% (164/208) | 75% (155/208) | 63% (131/208) |

Method 1: Using both Semantic Marker and Example
Method 2: Using Semantic Marker
Method 3: Using Example (using modified codes of BUNRUI GOI HYOU)
Method 4: Using Example (using original codes of BUNRUI GOI HYOU)
Method 5: Using neither Semantic Marker nor Example

Employed judging rule 1 for personal pronouns, and Candidate judging rule 1 for zero pronouns. We used the example rules of “X NO(of) Y (Y of X)” on all of these comparison experiments, because there are no rules using semantic markers which correspond to rules of “X NO(of) Y”. The precision of the method using examples was equivalent or superior to the precision in the method using semantic markers as Table 5.14. This indicates that we can use examples as well as semantic markers. Since some codes in BGH are incorrect, we modified the codes. Since the precision using modified codes was higher than using original codes, this indicates that the modification of codes is valid.

There were some cases when the example method is still effective in the expression somewhat semantically far from those written in a case frame. For example, since the ni-case in the case frame of “IU (say)” is given only the semantic marker HUM (human), the system cannot fill “TSURU (crane bird)” in the ni-case of the
following example sentences by the semantic marker method.

\[ \text{OJIISAN-WA TSURU-WO NIGASHI-NAGARA [TSURU-NI] IIMASHITA.} \]

(old man) (crane) (let loose) (to crane) (say) \( (5.14) \)

(The old man let the crane loose, and said [to crane]. )

But by the example method the system can fill “TSURU (crane bird)” in the
\( ni \)-case because the similarity level between human beings and animals is 1 and
the subtraction of the score is low.

5.6.4 Examining Which Rules are Important

We used many rules in this work. We examined the importance of various rules.

In zero pronoun resolution, the information of the semantic relation between
verbs and case components is important because there are few key surface expres-
sions.

On the contrary, in demonstrative resolution, the information of the semantic
relation between verbs and case components is not so important because there
are many surface expressions and referents limited to things which are not hu-
man. In demonstrative resolution, all the rules are important, because Japanese
demonstratives are classified into many kinds and we must make many detailed
rules.

In first and second personal pronoun resolution, the rules using first persons
and second persons were very effective.

5.7 Summary

In this chapter, we presented a method of estimating referents of demonstra-
tive pronouns, personal pronouns, and zero pronouns in Japanese sentences using
examples, surface expressions, topics and foci. In conventional work, semantic
markers have been used for semantic constraints. In contrast, we used exam-
pies for semantic constraints and showed in our experiments that examples are as
useful as semantic markers. We also proposed many new methods for estimating
referents of pronouns. For example, we use the form “X of Y” for estimating refer-
ents of demonstrative adjectives. In addition to our new methods, we used many
conventional methods. As a result, experiments using these methods obtained a precision rate of 87% in the estimation of referent of demonstrative pronouns, personal pronouns, and zero pronouns on training sentences, and obtained a precision rate of 78% on test sentences.
Chapter 6

Verb Phrase Ellipsis Resolution

6.1 Introduction

In the previous chapters, we have discussed anaphora resolution in Japanese noun phrases and pronouns. The remaining problem is anaphora resolution in Japanese verb phrases. Verb phrase anaphora is classified into two categories: (i) anaphora in pro-verbs such as “SOU SURU (do so)” and (ii) the ellipsis of a verb phrase. In this thesis, (i) anaphora by pro-verbs is handled already in Chapter 5 as demonstrative adverbs such as “SOU (so)” and “KOU (like this)”. This chapter describes (ii) how to resolve the verb phrase ellipsis.

Verb phrases are sometimes omitted in Japanese sentences. It is necessary to resolve verb phrase ellipses for purposes of language understanding, machine translation, and dialogue processing. This chapter describes a practical method to resolve omitted verb phrases by using surface expressions and examples. In short, (1) when the referent of a verb phrase ellipsis appears in the sentences, we use surface expressions (clue words); (2) when the referent does not appear in the sentences, we use examples (linguistic data). We define the verb phrase to which a verb phrase ellipsis refers as the complemented verb phrase. For example, “[KOWASHITA] (broke)” in the second sentence of the following example is a verb phrase ellipsis. “KOWASHITA (broke)” in the first sentence is a comple-

\footnote{A phrase in brackets “[,]” represents an omitted verb phrase.}
6.1. INTRODUCTION

The matching part  The latter part

KON’NANI  **UMAKU IKUTOWA**  OMOENAI.
(like this)  (it succeeds)  (I don’t think)
(I don’t think that it succeeded like this)

ITUMO  **UMAKU IKUTOWA**  KAGIRANAI.
(every time)  (it succeeds)  (cannot expect to)
(You cannot expect to succeed every time.)

KANZENNI  **UMAKU IKUTOWA**  IENAI.
(completely)  (it succeeds)  (it cannot be said)
(It cannot be said that it succeeds completely)

Figure 6.1: Sentences containing “UMAKU IKUTOWA (it succeeds)” in a corpus (examples)

(1) When a complemented verb phrase exists in the sentences, we use surface expressions (clue words). This is because an elliptical sentence in the case (1) is in one of several typical patterns and has some clue words. For example, when the end of an elliptical sentence is the clue word “MO (also)”, the system judges that the sentence is a repetition of the previous sentence and the complemented verb ellipsis is the verb phrase of the previous sentence.

(2) When a complemented verb phrase does not appear in the sentences, we
Chapter 6. Verb Phrase Ellipsis Resolution

In the sentences

- Inverted sentence

- Question-Answer

- Relation

- Supplement

Outside the sentences

- Interrogative sentence

- da-ellipsis

- suru-ellipsis

- Other ellipses (use of common sense)

Figure 6.2: Categories of verb phrase ellipsis

We handle only ellipses in the ends of sentences. Although there are some ellipses in the inner part of sentences, we think that they should be solved as problem of...
6.2. CATEGORIES OF VERB PHRASE ELLIPSES

syntax and we do not deal with them.

We classified verb phrase ellipses from the viewpoint of machine processing. The classification is shown in Figure 6.2. First, we classified verb phrase ellipses by checking whether there is a complemented verb phrase in the sentences or not. If there is a complemented verb phrase in the sentences, we classified verb phrase ellipses by checking whether the complemented verb phrase is in the same sentence or in the previous sentence. Finally, we classified verb phrase ellipses by meaning. “In the sentences”, “Outside the sentences”, “In the sentence”, and “In the previous sentence” in Figure 6.2 represent where the complemented verb phrase exists, respectively. Although the above classification is not perfect and needs modification, we think that it is useful to understand the outline of verb phrase ellipses in machine processing.

The feature and the analysis of each category of verb phrase ellipsis are described in the following sections.

6.2.1 When a Complemented Verb Phrase Ellipsis Appears in the Sentences

Inverted Sentence

Inverted sentences have expressions which are normally at the end of a sentence in the inner part of the sentence. For example, the following sentence has the words “DARE DESUKA (Who is)”, an inverted expression normally at the end of a sentence.

\[
\begin{align*}
\text{DARE DESUKA, KITA-NO-WA} \\
(\text{who}) & \quad (\text{is}) \quad (\text{the person that came here}) \\
(\text{Who was the person that came here?})
\end{align*}
\]

(6.3)

Therefore, we analyze inverted sentences as followed. When a sentence has an expression which is normally at the end of a sentence and followed by a comma, the system judges the sentence to be an inverted sentence.
Question–Answer

In question–answer sentences verbs in answer sentences are often omitted, when answer sentences use the same verb as question sentences. For example, the verb of “KORE WO (this)” is omitted and is “KOWASHITA (break)” in the question sentence.

\[
\begin{align*}
\text{NANI-WO KOWASHITANO} & \\
(\text{what}) & (\text{break}) \\
(\text{What did you break?}) & \\
\text{KORE-WO [KOWASHITA].} & \\
(\text{this}) & (\text{break}) \\
(\text{[I broke] this.}) & 
\end{align*}
\]

The system judges whether the sentences are question–answer sentences or not by using surface expressions such as “NANI (what)”, and, if so, it judges that the complemented verb phrase is the verb phrase of the question sentence.

Relation

In verb phrase ellipsis, there is a phenomenon that an elliptical sentence whose end is a conjunctive particle relates causatively, contrastingly or conditionally to the previous sentence, and they make inverted sentence across two sentences. For example, “DENKI-WO TSUKETA-KARA (Because I switched the light on.)” is the reason for the previous sentence “AKARUI (bright)” and the omitted element of “DENKI-WO TSUKETA-KARA” is “AKARUI (bright)”.

\[
\begin{align*}
\text{AKARUI.} & \\
(\text{bright}) & \\
(Bright.) & \\
\text{DENKI-WO TSUKETA-KARA.} & \\
(\text{the light}) & (\text{switch on}) \\
(\text{Because I switched the light on.}) & 
\end{align*}
\]
When a sentence has a conjunctive particle at the end, the system normally judges that the complemented verb phrase is the verb at the end of the previous sentence. But, there are some cases that a conjunctive particle is used for indicating hesitation, the sentence is not in contrast to the previous sentence.

**OKIKI-SHITE IINOKA WAKARIMASENGA.**
(ask) (whether it is all right) (do not know) (6.6)
(Although I don’t know whether you mind I ask you, ...)

Therefore, in the case of “NONI (but)” which is easy to relate to the previous sentence, the system judges that the complemented verb phrase is the previous sentence. In the case of the other particles if the previous sentence is an interrogative sentence, the system judges that the sentence contrasts to the previous sentence, and otherwise, the system judges that the sentence does not contrast to the previous sentence and indicates a kind of feeling.

**Supplement**

In sentences which play a supplementary role to the previous sentence, verb phrases are sometimes omitted. For example, the second sentence is supplementary, explaining that “the things I lost” is “keys”.

**MONO-WO NAKUSHITA.**
(things) (lost)
(I lost things.)

**KAGI-WO [NAKUSHITA.]**
(keys) (lost)
([I lost] keys.)

To solve this, we present the following two methods using word meanings. The first method is when the word at the end of the elliptical sentence is semantically similar to the word of the same case element in the previous sentence, they correspond, and the omitted verb is judged to be the verb of the word of the same case element in the previous sentence. In this case, since “MONO (thing)” and “KAGI
(key)” are semantically similar in the sense that they are both objects, the system
decides they correspond, and the verb of “KAGI (key)” is “NAKUSHITA (lost)”.

The second method is for when the same case element in the previous sentence
is omitted.

\[
\text{NAKUSHITA.} \\
\text{(lost)} \\
\text{(I lost.)}
\]

\[
\text{KAGI-WO} \ [\text{NAKUSHITA.}] \\
\text{(keys) (lost)} \\
\text{(I lost] keys. )}
\] (6.8)

In this case, the system checks the semantic distance between “KAGI (key)” and
the words which are easily filled in the WO case (object) of the “NAKUSU (lose)”
by using the case frame of the verb “NAKUSU (lose)”\(^2\). If they are semantically
similar, the system judges that the omitted verb phrase is “NAKUSU (lose)”.

In addition to these methods, we use methods using surface expressions. For
example, when a sentence has clue words such as the particle “MO” (which in-
dicates repetition), the sentence is judged to be the supplement of the previous
sentence.

There are many cases when an elliptical sentence is the supplement of the
previous sentence. In this work, if there is no clue, the system judges that an
elliptical sentence is the supplement of the previous sentence.

\subsection{When a Complemented Verb Phrase does not Appear in
the Sentences}

\textbf{Interrogative Sentence}

Sometimes, in interrogative sentences, the particle “WA” is at the end of the
sentence and the verb phrase is omitted. For example, the following sentence is

\(^2\) IPAL case frame dictionary [IPAL 87] has the information of what kind of words can be filled
in each case frame. In this work, we use this information.
an interrogative sentence and the verb phrase is omitted.

\[
\text{NAMAE-WA} \ [\text{NANI-DESUKA}]. \\
\text{(name)} \quad \text{(what?)} \quad (6.9)
\]

(What is your name?)

If the end is of the form “Noun + WA”, the sentence is probably an interrogative sentence, and thus the system judges it to be an interrogative sentence.

\textit{da-Ellipsis}

When the end of the previous sentence is a noun phrase, the copula “DA (be)” is often omitted.

\[
\text{WATASHI-WA} \quad \text{GAKUSEI} \quad [\text{DESU}]. \\
\text{(I)} \quad \text{(student)} \quad \text{(be)} \quad (6.10)
\]

(I [am] a student.)

In this example, the copula “DA (be)” is omitted from the sentence “WATASHI-WA GAKUSEI DESU (I am a student.).

The analysis of this case is performed by checking whether the end of the sentence is a noun phrase and by using syntactic structures such that there is a subject.

\textit{suru-Ellipsis}

When the end of the previous sentence is a noun phrase, the basic verb “SURU (do)” is often omitted.

\[
\text{WATASHI-WO} \quad \text{KODOMO-ATSUKAI} \quad [\text{SURU}]. \\
\text{(I)} \quad \text{(to treat as child)} \quad \text{(do)} \quad (6.11)
\]

(He [does] treat me as child.)

\footnote{Since this work is verb phrase ellipsis resolution, the system must complement a verb phrase such as “NANI-DESUKA (what?)”. But the expression of the verb phrase changes according to the content of the interrogative sentence and we do not deal with this problem in this work.}
In this example, the verb “SURU (do)” is omitted from the sentence “WATASHI-WO KODOMO-ATSUKAI SURU. (He treats me as child.)”.

The analysis of this problem is done by checking whether the end of the sentence is a verbal noun and whether the rentai-form modifier modifies the verbal noun.

**Other Ellipses (Resolved Using Common Sense)**

In the case of “Outside the sentences” the following example exists besides “Interrogative sentence”, “da-ellipsis”, and “suru-ellipsis”.

\[
\text{JITSU-WA CHOTTO ONEGAIGA [ARU-NO-DESUGA].}
\]

(To tell you the truth, [I have] a request.)

This kind of ellipsis does not have the complemented expression in sentences. The form of the complemented expression has various types. This problem is difficult to analyze.

To solve this problem, we estimate a complemented content by using a large amount of linguistic data.

When Japanese people read the above sentence, they naturally recognize the omitted verb is “ARIMASU (I have)”. This is because they empirically have the sentence “JITSU-WA CHOTTO ONEGAIGA ARU-NO-DESUGA. (To tell the truth, I have my request.)” in their mind. When we perform the same interpretation using a large amount of linguistic data, we detect the sentence containing an expression which is semantically similar to “JITSU-WA CHOTTO ONEGAIGA. (To tell you the truth, (I have) a request.)”, and the latter part of “JITSU-WA CHOTTO ONEGAIGA” is judged to be the content of the ellipsis. In this work, we solve this problem by using the above method.

**6.3 Verb Phrase Ellipsis Resolution System**

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\(^4\) A modifier is in the rentai-form, when it modifies a nominal phrase.
6.3. VERB PHRASE ELLIPSIS RESOLUTION SYSTEM

6.3.1 Procedure

In this work, verb phrase ellipses are resolved in the same framework as Chapter 3. Before the verb phrase ellipsis resolution process, sentences are transformed into a case structure by the case structure analyzer [Kurohashi & Nagao 94]. Verb phrase ellipses are resolved by heuristic rules for each sentence from left to right. Using these rules, our system gives possible complemented verb phrases some points, and it judges that the possible complemented verb phrase having the maximum point total is the desired complemented verb phrase.

The heuristic rules are given in the following form.

\[
\text{Condition} \Rightarrow \{ \text{Proposal}, \text{Proposal}, .. \} \\
\text{Proposal} := ( \text{Possible complemented verb phrase}, \text{Point} )
\]

Surface expressions, semantic constraints, referential properties, etc., are written as conditions in the Condition section. A possible complemented verb phrase is written in the Possible complemented verb phrase section. Point means the plausibility of the possible complemented verb phrase.

6.3.2 Heuristic Rule

We made 22 heuristic rules for verb phrase ellipsis resolution. We show all the rules in Table 6.1. These rules are made by examining training sentences in Section 6.4 by hand. When the system analyzes verb phrase ellipsis, it also analyzes anaphora in noun phrases and pronouns. The rules for this resolution are shown in Chapter 3, Chapter 4, and Chapter 5.

For these rules a semantic marker dictionary [Watanabe et al 92] is used to determine whether a word means a human, time, etc.

The value \(s\) in Rule 12 and Rule 13 is given from the semantic similarity between “Noun X and Noun Y” in EDR concept dictionary [EDR 95b]. This similarity is given \((nz + nz)/(nx + ny)\), let \(nx\) stand for the number of links between the top node and the node of Noun X, let \(ny\) stand for the number of links between the top node and the node of Noun Y, let node \(Z\) stand for the intersection node from Noun X and Noun Y to top node, and let \(nz\) stand for the number of the links between the top node and the node of Noun Z [Nagao et al 96].
MURI-MO-ARIMASENW A.
(You may well do so.)

HAJIMETE OAISURU-NO-DESUKARA.
(for the first time) (I meet you)
(I meet you for the first time)

JITSU-WA CHOTTO ONEGAIGA (ARU-NO-DESUGA).
(the truth) (a little) (request) (I have)
(To tell you the truth, [I have] a request.)

| Candidate       | the end of the previous sentence | “ARIMASU (I have)” |
|-----------------|----------------------------------|-------------------|
| Rule 16         |                                  | 0 point           |
| Rule 22         |                                  | 1 point           |
| Total score     |                                  | 1 point           |

The corpus (linguistic data) used in Rule 22 is a set of newspapers (one year, about 70,000,000 characters). The method detecting a similar sentence is performed by sorting the corpus in advance and using a binary search.

6.3.3 Example of Verb Phrase Ellipsis Resolution

We show an example of a verb phrase ellipsis resolution in Figure 6.3. Figure 6.3 shows that the verb phrase ellipsis in “ONEGAI (request)” was analyzed well.

Since the end of the sentence is not an expression which can normally be at the end of a sentence, Rule 1 was not satisfied and the system judged that a verb phrase ellipsis exists. By Rule 16 the system took the candidate “the end of the previous sentence”. Next, by Rule 22 using corpus, the system took the candidate “ARIMASU (I have)”. Although there are “ARU (I have)” and “ARIMASU (I
6.3. **VERB PHRASE ELLIPSIS RESOLUTION SYSTEM**

Table 6.1: Rule for verb phrase ellipsis resolution

| Condition | Candidate | Point | Example sentence |
|-----------|-----------|-------|------------------|
| Rule in the case that a verb ellipsis does not exist | | | |
| 1 | When the end of the sentence is a formal form of a verb or terminal post-positional particles such as “YO” and “NE”, | | |
| | the system judges that a verb phrase ellipsis does not exist. | 30 | SONO MIZUUMI WA, KITANO KUNINI ATTA. (The lake was in a northern country.) |
| 2 | When the end of the sentence is a person’s name or a word signifying a human being, | | |
| | a verb phrase ellipsis does not exist. | 30 | “HAI, SENSEI.” (“Yes, sir.”) |
| 3 | When the end is an imperative form of a verb, | | |
| | the sentence is an imperative sentence and a verb phrase ellipsis does not exist. | 30 | “SAA, MEWO TSUBUTTE” (Here, close your eyes.) |
| 4 | When the end is the conjunctive particle “GA”, | | |
| | a verb phrase ellipsis does not exist. | 5 | “CHOTTO SHITSUMON-GA ARUNO DESUGA” (Well, I have some questions.) |
| Rule in the case of “Inverted sentence” | | | |
| 5 | When the sentence has an expression normally at the end of a sentence in the inner part, | 10 | “DARE DESUKA, KITANO-WA” (“Who was the person that came here?”) |
| Rule in the case of “Question–Answer” | | | |
| 6 | When the sentence has an expression which indicates a reply and the previous sentence has an expression which indicates an interrogative sentence such as “KA (?)”, | 5 | “CHIKAYOTTE KANSATSU SHITEMO IDESHOUKA.” “DOUZO, GOJIYUUNI...” (“Can I approach and look at this?” “Yes, please.”) |
Table 6.1: Rule for verb phrase ellipsis resolution (cont.)

| Condition                                                                 | Candidate                                                                 | Point | Example sentence                                                                 |
|---------------------------------------------------------------------------|---------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------|
| **Rule in the case of “Question–Answer”**                                |                                                                           |       |                                                                                |
| 7  When the previous sentence has an interrogative pronoun such as “DARE (who)” and “NANI (what)” | the verb modified by the interrogative pronoun                           | 5     | “DARE-WO KOROSHI-TANDA” “WATASHI-GA KATTE-ITA SARU-WO [KOROSHITA]” (“Who did you kill?” “[I killed] my monkey”) |
| **Rule in the case of “Relation”**                                        |                                                                           |       |                                                                                |
| 8  When the end is postpositional particles which indicates cause such as “NODE” and “KARA”, | the sentence is interpreted to be the reason for the previous sentence    | 5     | “TOCHI-WO AGERU-WAKE-NIWA- IKANAI. SOKONI, YASHIRO-WO TATE-NAKUTEWA- NARANAI- NODAKARA” (“We can’t give you the lot. Because we must build a shrine there.”) |
| 9  When the end is a postpositional particle such as “NONI” and “KEREDOMO”, | the sentence is interpreted to contrast with the previous sentence.       | 5     | “KORE-GA AKUMA-TOWA-NEE. MOU-SUKOSHI DOUDOU-TO SHITA MONO-KA-TO OMOTTE- ITA-NONI” (“This is a devil. Although I thought it was majestic.”) |
| 10 When the end is a conditional form of a verb or postpositional particles indicating conditions, | the sentence is interpreted to be the condition of the previous sentence. | 5     | “SORENARA, IJANAIAKA. NANIMO, KOUBAN-NI-MADE KONAKUTEMO.” (“It is good. Unless you came to the police office.”) |
Table 6.1: Rule for verb phrase ellipsis resolution (cont.)

| Condition | Candidate | Point | Example sentence |
|-----------|-----------|-------|------------------|
| 11        | When the end is an infinitive form of a verb, the sentence is interpreted to be the supplement of the previous sentence and the verb phrase at the end of the previous sentence is judged to be the complemented verb phrase | 5 | MESHITSUKAI-WA HEYA-NI HAIRI, ESA-WO TORIKAETA. SHUUKURIIMU-MO KUWAETE [TORIKAETA]. (A servant came into the room and changed the pet food. [He changed it] with a cream puff. ) |
| 12        | When the end is Noun X followed by a case post-positional particle, there is a Noun Y followed by the same case postpositional particle in the previous sentence, and the semantic similarity between Noun X and Noun Y is a value s, the verb phrase modified by Noun Y | s * 20 -2 | SUBETENO AKU-GA NAKUNATTEIRU. GOUTOU-DA-TOKA SAGI-DA-TOKA, ARAYURU HANZAI-GA [NAKUNATTEIRU]. (All the evils have disappeared. All the crimes such as robbery and fraud [have disappeared]. ) |
| 13        | When the end is Noun X followed by a case post-positional particle, there is a zero pronoun of a verb phrase Y in the same case element in the previous sentence, and the semantic similarity between Noun X and the words which is easy to be filled in the zero pronoun, described in the case frame | s * 20 -2 | WATASHI-WA [JUUTAKU-WO] DOURYOU-NI YUBISASHITE MISETA. OOKINA NIRE-NO-KI NO SHITA-NI ARU KOHUUNA TSUKURI-NO JUUTAKU-WO. (I pointed my colleague [to the house]. An old-fashioned house under the big elm.) |
## Table 6.1: Rule for verb phrase ellipsis resolution (cont.)

| Condition | Candidate | Point | Example sentence |
|-----------|-----------|-------|------------------|
| 14        | When the end is the post-positional particle “MO” or there is an expression which indicates repetition such as “MOTTOMO”, the repetition of the same speaker’s previous sentence is interpreted, | 5     | “OTONATTE WARUI KOTO BAKARI SHITEIRUNDAYO. YOKU WAKARANAIZEREDO, WAIRO NANTE KOTO-MO [SHITEIRUNDAYO].” (“Adults do only bad things. I don’t know, but [they do] bribe.”) |
| 15        | When the previous sentence is an interrogative sentence, | 1     | “NAMAE-WA [NANI-DESUKA]” (“[What is] your name?”) |
| 16        | In all cases, | 0     | “KORE-WA WATASHI-NO KANCHIGAI [DESU]” (“This [is] my mistake.”) |
| 17        | When the end is a noun followed by postpositional particle “WA”, | 3     | “NAMAE-WA [NANI-DESUKA]” (“[What is] your name?”) |
| 18        | When the end is a noun or a postpositional particle such as “BAKARI (only)”, “DAKE (only)”, and there is a noun phrase followed by a postpositional particle “WA (topic)”, “MO (subject)”, and “GA (subject)” which corresponds to the subject in the sentence, | 2     | “KORE-WA WATASHI-NO KANCHIGAI [DESU]” (“This [is] my mistake.”) |
| 19        | When the end is a noun which signifies time, | 5     | “KORE-WA WATASHI-NO KANCHIGAI [DESU]” (“This [is] my mistake.”) |
Table 6.1: Rule for verb phrase ellipsis resolution (cont.)

| Condition | Candidate | Point | Example sentence |
|-----------|-----------|-------|------------------|
| Rule in the case of “da-ellipsis” | | | |
| 20 When the end is a noun or a postpositional particle such as “BAKARI (only)”, “DAKE (only)” | the system judges it as da-ellipsis | 1 | ATO-WA KOUGEKI-WO MAT-SUBAKARI [DESU]. (What I do [is] only wait for the attack.) |
| Rule in the case of “suru-ellipsis” | | | |
| 21 When the end is a verbal noun which is not modified the rentai modifier | the system judges it as suru-ellipsis | 2 | WATASHI-WO KODOMO-ATSUKAI [SURU]. (He [does] treat me like a child.) |
| Rule in the case of use of common sense | | | |
| 22 When the system detects a sentence containing the longest expression at the end of the sentence from corpus, (If the highest frequency is much higher than the second highest frequency, the expression is given 9 points, otherwise it is given 1 point.) | the expression of the highest frequency in the latter part of the detected sentences | 1 or 9 | SOU UMAKU IKUTOWA [OMOENA]. ([I don’t think] it will succeed.) |
have)”, the frequency of “ARIMASU (I have)” is more than the others and it was
selected as a candidate. The candidate “ARIMASU (I have)” having the best
score was properly judged to be the desired complemented verb phrase.

6.4 Experiment and Discussion

We ran the experiment on the novel “BOKKOCHAN” [Hoshi 71]. This is because
novels contain various verb ellipses. In the experiment, we divided the text into
training sentences and test sentences. We made heuristic rules by examining
training sentences. We tested our rules by using test sentences. We show the
results of verb phrase ellipsis resolution in Table 6.2.

To judge whether the result is correct or not, we used the following evaluation
criteria. When the complemented verb phrase is correct, even if the tense, aspect,
etc. are incorrect, we regard it as correct. For ellipses in interrogative sentences, if
the system estimates that the sentence is an interrogative sentence, we judge it to
be correct. When the desired complemented verb phrase appears in the sentences
and the complemented verb phrase chosen by the rule using corpus is nearly equal
to the correct verb phrase, we judge that it is correct.

6.4.1 Discussion

As in Table 6.2 we obtained a recall rate of 84% and a precision rate of 82% in the
estimation of indirect anaphora on test sentences. This indicates that our method
is effective.

The recall rate of “In the sentences” is higher than that of “Outside the sen-
tences”. For “In the sentences” the system only specifies the location of the
complemented verb phrase. But in the case of “Outside the sentences” the sys-
tem judges that the complemented verb phrase does not exist in the sentences
and gathers the complemented verb phrase from other information. Therefore
“Outside the sentences” is very difficult to analyze.

The accuracy rate of “Other ellipses (use of common sense)” was not so high.
But, since the analysis of the case of “Other ellipses (use of common sense)” is
very difficult, we think that it is valuable to obtain a recall rate of 56% and a
### Table 6.2: Result of resolution of verb phrase ellipsis

|                                | Training sentences | Test sentences |
|--------------------------------|--------------------|---------------|
|                                | Recall             | Precision     | Recall       | Precision     |
| Total score                    | 92% (129/140)     | 90% (129/144) | 84% (125/148) | 82% (125/152) |
| In the sentences               |                    |               |              |               |
| Inverted sentence              | 100% (13/13)      | 85% (3/3)     | 94% (13/14)  | 74% (3/3)     |
| Question–Answer                | 100% (24/24)      | 89% (24/27)   | 80% (24/27) | 85% (23/27)   |
| Relation                       | 100% (17/17)      | 74% (17/23)   | 56% (13/18) | 74% (10/18)   |
| Supplement                     | 100% (54/54)      | 100% (2/2)    | 56% (10/18) | 59% (10/17)   |
| Outside the sentences          | 87% (72/83)       | 94% (72/77)   | 76% (61/80) | 84% (61/73)   |
| Interrogative sentence         | 100% (3/3)        | 75% (3/4)     | 94% (0/0)   | 0% (0/3)      |
| da-ellipsis                    | 100% (54/54)      | 100% (2/2)    | 56% (10/18) | 59% (10/17)   |
| suru-ellipsis                  | 100% (2/2)        | 76% (13/17)   | 0% (0/11)  | 0% (0/0)      |
| Impossible                     | 0% (0/6)          | 0% (0/0)      | 0% (0/11)  | 0% (0/0)      |

The training sentences are used to make the set of rules in Section 6.3.2.

Training sentences {the first half of a collection of short stories “BOKKO CHAN” [Hoshi 71] (2614 sentences, 23 stories)}

Test sentences {the latter half of novels “BOKKO CHAN” [Hoshi 71] (2757 sentences, 25 stories)}

*Precision* is the fraction of the ends of the sentences which were judged to have verb phrase ellipses. *Recall* is the fraction of the ends of the sentences which have the verb phrase ellipses. The reason why we use precision and recall to evaluate is that the system judges that the ends of the sentences which do not have the verb phrase ellipses have the verb phrase ellipses and we check these errors properly.

We made a new category “Impossible” which is not in Figure 6.2. This category represents when the utterance is interrupted in the middle of the sentence, or the reader cannot recognize the omitted content. Since they are difficult to be resolved and we want to properly evaluate the method of “use of common sense”, we separated the category from “Other ellipses (use of common sense)”.
precision rate 59%. In both training sentences and test sentences, about half of all the error cases occurred because the solution proposed by the rule using corpus is correct and the point is lower than that of the other rule or because the correct answer does not have the highest frequency but the second or third highest. This indicates that there is room for improving the method by using corpus. We think that when the size of corpus becomes larger, this method becomes very important. Although we calculate the similarity between the input sentence and the example sentence in the corpus only by using simple character matching, we think that we must use the information of semantics and the parts of speech when calculating the similarity. Moreover we must detect the desired sentence by using only examples of the type (whether it is an interrogative sentence or not) whose previous sentence is the same as the previous sentence of the input sentence.

Although the accuracy rate of the category using surface expressions is already high, there are some incorrect cases which can be corrected by refining the use of surface expressions in each rule. There is also a case which requires a new kind of rule in the experiment on test sentences.

\begin{align}
\text{SONOTOTAN} & \quad \text{WATASHI-WA} \quad \text{OOKINA HIMEI-WO} \quad \text{KIITA.} \\
& \quad \text{(at the moment)} \quad \text{(I)} \quad \text{(a scream)} \quad \text{(hear)} \\
& \quad \text{(At the moment, I heard a scream?)} \\
\end{align}

\begin{align}
\text{NANIKA-NI} & \quad \text{OSHITSUBUSARERU-YOUNA OSOROSHII KOE-NO.} \\
& \quad \text{(something) \quad (be crushed)} \quad \text{(fearful)} \quad \text{(voice)} \\
& \quad \text{(of a fearful voice such that he was crushed by something)} \\
\end{align}

In these sentences, “OSOROSHII KOE-NO (of a fearful voice)” is the supplement of “OOKINA HIMEI (a scream)” in the previous sentence. To solve this ellipsis, we need the following rule.

\begin{align}
\text{When the end is the form of “noun X + NO(of)” and there is a noun Z which is semantically similar to noun Y in the examples of “noun X + NO(of) + noun Y”, the system judges that the sentence is the supplement of noun Z.} \\
\end{align}

We experimented on novels in order to detect various ellipses. To check what kind of phenomena exist in other texts, we counted the number of ellipses in
6.5. SUMMARY

Table 6.3: The number of ellipses in essays in “TENSEI JINGO”

| Category                      | In quotations | Outside quotations | Total |
|-------------------------------|---------------|--------------------|-------|
| Total                         | 5             | 34                 | 39    |
| In the sentences              | 1             | 1                  | 2     |
| Inverted sentence             | 0             | 0                  | 0     |
| Question–Answer                | 0             | 0                  | 0     |
| Relation                      | 1             | 0                  | 1     |
| Supplement                     | 0             | 1                  | 1     |
| Outside the sentences         | 4             | 33                 | 37    |
| Interrogative sentence        | 0             | 0                  | 0     |
| da-ellipsis                   | 0             | 28                 | 28    |
| suru-ellipsis                  | 0             | 0                  | 0     |
| Other ellipses                 | 4             | 5                  | 9     |

essays “TENSEI JINGO” (79 stories, 1871 sentences). The results are shown in Table 6.3. We find that the number of ellipses is small in essays where there are few conversational sentences. Although there are five cases in “Other ellipses” outside conversational sentences, they are all in the form of “TO + human being” such as “... TAISHO-SURU TO SHUSHOU [GA-ITTA]. (‘I will take ...’, [said] the prime minister)”. There are not many different kinds of elliptical phenomena in essays.

6.5 Summary

This chapter described a practical way to resolve omitted verb phrases by using surface expressions and examples. We obtained a recall rate of 84% and a precision rate of 82% in the resolution of verb phrase ellipsis on test sentences. The accuracy rate of the case of complemented verb phrase appearing in the sentences was high. The accuracy rate of the case of using corpus (examples) was not so high. Since the analysis of this phenomena is very difficult, we think that it is valuable to
have proposed a way of solving the problem to a certain extent. We think that when the size of corpus becomes larger and the machine performance becomes greater, the method of using corpus will become effective.
Chapter 7

Conclusion

Anaphora resolution is important for language understanding, machine translation, and dialogue processing. We resolved varieties of anaphora by using surface expressions and examples. We experimented on several kinds of texts to test our methods. The results of these experiments indicate that our methods are effective.

7.1 Summary

Chapter 2 described a method of determining the referential property and number of noun phrases in Japanese sentences using surface expressions. The referential property of a noun phrase is how the noun phrase denotes the referent. The referential property is classified into three types: generic, definite and indefinite. A definite noun phrase refers to a given object. An indefinite noun phrase refers to a new object. In English, they correspond to a noun phrase with a definite article and a noun phrase with an indefinite article, respectively. A generic noun phrase refers to all objects which the noun phrase denotes. The number of a noun phrase is the number of the referent denoted by the noun phrase. The number is classified into three types: singular, plural, and uncountable. The referential property and the number of a noun phrase are basic factors in anaphora resolution. The system can grasp the outline of the referent of the noun phrase by using the referential property and the number of a noun phrase. The referential property and the number are also useful when the system generates the article.
in translating Japanese nouns into English. Many rules for the estimation of the referential property and the number of a noun phrase were written in forms similar to rewriting rules in expert systems with scores. We obtained the correct recognition scores of 85.5% and 89.0% in the estimation of referential property and number respectively for the sentences which were used for the construction of our rules. We tested these rules for some other texts, and obtained the scores of 68.9% and 85.6%, respectively.

Chapter 3 gave a method for estimating the referent of a noun phrase in Japanese sentences using referential properties, modifiers, and possessors of noun phrases. Since there are no articles in the Japanese language, it is difficult to decide whether two noun phrases have the same referent in Japanese. But we researched referential properties of noun phrases that correspond to articles using words in the sentences as in Chapter 2. We estimated referents of noun phrases using these referential properties. For example if the referential property of a noun phrase is definite, the noun phrase can refer to a noun phrase that appears previously, and if the referential property of a noun phrase is indefinite, the noun phrase cannot refer to a noun phrase that appears previously. Furthermore we estimated referents of noun phrases using modifiers and possessors of noun phrases more precisely. As a result, we obtained a precision rate of 82% and a recall rate of 85% in the estimation of referent of noun phrases that have antecedents on training sentences, and obtained a precision rate of 79% and a recall rate of 77% on test sentences. We verified that it is effective to use referential properties, modifiers, and possessors of noun phrases through experiments.

Chapter 4 described how to resolve indirect anaphora resolution. A noun phrase can indirectly refer to an entity that has already been mentioned. For example, “There is a house. The roof is white.” indicates that “the roof” is associated with “a house”, which was mentioned in the previous sentence. This kind of reference (indirect anaphora) has not been studied well in natural language processing, but is important for coherence resolution, language understanding, and machine translation. When we analyze indirect anaphora, we need a case frame dictionary for nouns containing an information about relationships between two nouns. But no noun case frame dictionary exists at present. Therefore, we used
examples of “X of Y” and a verb case frame dictionary instead. We estimated indirect anaphora by using this information, and obtained a recall rate of 63% and a precision rate of 68% on test sentences. This indicates that the information of “X of Y” is useful when we cannot make use of a noun case frame dictionary. We made a hypothetical estimation that we can use a good noun case frame dictionary, and obtained the result with the recall and the precision rates of 71% and 82%, respectively. Finally we proposed how to construct a noun case frame dictionary from examples of “X of Y”.

Chapter 5 described how to estimate the referent of a pronoun in Japanese sentences. It is necessary to clarify referents of pronouns in machine translation and dialogue processing. We presented a method of estimating referents of demonstrative pronouns, personal pronouns, and zero pronouns in Japanese sentences using examples, surface expressions, topics and foci. In conventional work, semantic markers have been used for semantic constraints. On the other hand, we used examples for semantic constraints and showed in our experiments that examples are as useful as semantic markers. We also proposed many new methods for estimating referents of pronouns. For example, we used examples of the form “X of Y” for estimating referents of demonstrative adjectives. We used many useful conventional methods in addition to our new methods. When we experimented using these methods, we obtained a precision rate of 87% in the estimation of referent of demonstrative pronouns, personal pronouns, and zero pronouns on training sentences, and obtained a precision rate of 78% on test sentences.

Chapter 6 described the method of resolving verb phrase ellipsis using surface expressions and examples. When a complemented verb phrase appears in the sentences, the structure of the elliptical sentence is commonly in a typical form and the resolution is done by using surface expressions. When a complemented verb phrase does not appear in the sentences, the system resolved the elliptical sentence using examples. The analysis using examples is performed by gathering sentences containing the expression of the end of the elliptical sentence from linguistic data and judging the latter part of the matching expression in the gathered sentences to be the desired complemented verb phrase. As a result, we obtained a recall rate of 84% and a precision rate of 82% in the resolution of verb phrase ellipsis.
on test sentences.

7.2 Future Work in Anaphora Resolution

- **Refinement of heuristic rules using large collection of sentences**
  
  It is necessary to refine heuristic rules in this work. Although the points (certainty value) given by heuristic rules are set in the training sentences, it is necessary to set them automatically by using a computational learning algorithm. At this time, we require large scale linguistic data for refinement of heuristic rules and learning the parameters of the points. The construction of the linguistic data need a syntactic structure analysis and a case structure analysis. But since a syntactic structure analysis and a case structure analysis cannot be done with high accuracy at present, we cannot collect large amounts of linguistic data. We must improve a syntactic structure analyzer and a case structure analyzer before refining heuristic rules.

- **Anaphora resolution using knowledge and reasoning**
  
  In this work, we resolved anaphora by using only information which is available at present. But, there are problems which require knowledge and reasoning as in the following example [Nagao et al 76].

  \[
  \text{KARE-WA MIZU-TO SHOKUEN-WO MAZET A.}
  \]
  \[(he) (water) (salt) (mixed)\]
  \[(\text{He mixed water and salt.})\]  
  \[(7.1)\]

  \[
  \text{KORE-WO RUTSUBO-NI SOSOIDA.}
  \]
  \[(this) (melting pot) (advice) (poured)\]
  \[(\text{He poured this into the melting pot.})\]

  What “KORE (this)” refers to is salty water which comes from mixing water and salt. To solve this problem, we need the knowledge that if we mix water and salt, salty water results. Solving this kind of problem requires many complicated analyses. Although this problem is very difficult, we must solve it for anaphora resolution to improve.
Appendix A

Rule for Referential Property and Number of Noun Phrase

We have written 86 heuristic rules for the referential property and 48 heuristic rules for the number. All the rules are given in Table A.1 and Table A.2.
## Table A.1: Rule for referential property

| Condition | Indef | Def | Gener | Example |
|-----------|-------|-----|-------|---------|
| 1 When a noun is a personal pronoun, | 0 0 1 2 0 0 | | KARE-WA SONO BENGOSHI-NO MUSUKO-NO HITORI-DESU. (He is a son of that lawyer.) |
| 2 When a noun is an unique entity which does not have a modifier such as “CHIKYU (the earth)”, | 0 0 1 2 0 0 | | OOKU-NO HITOBITO-NO MOKUHYOU-WA CHIKYUU-NO HEIWA-DESU. (The goal of many groups is peace on earth.) |
| 3 When a noun is a proper noun which does not have a modifier, | 0 0 1 2 0 0 | | |
| 4 When a noun is modified by a noun which signifies time, | 1 0 1 2 1 0 | KYOU-NO GOGO-NO YOTEI-WA DOU-DESUKA. (What is your plan in the afternoon today?) |
| 5 When a noun is “HOU (on the part)”, | 0 0 1 0 1 0 | | |
| 6 When a noun is followed by a particle “WA” which does not have a modifier, | 1 0 1 1 1 1 | SEKIYU-JIGYO-WA WATASHI-GA TE-WO DASHITAKU NAI JIGYO-NO HITOTSU-DESU. (The oil business is one business that I don’t wish to get involved with.) |
| 7 When a noun is accompanied by a particle (WA), and the predicate is in the past tense, | 1 0 1 3 1 1 | IINKAI-WA ZEN’IN SONO MONDAI-WO KAIKETSU SURUTAME-NI SHIGOTO-WO SHIMASHITA. (Everyone on the committee worked to solve that problem.) |

*P: possibility, V: value
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                 |
|---------------------------------------------------------------------------|-------|-----|-------|-------------------------------------------------------------------------|
| 8 When a noun is accompanied by a particle (WA), and the predicate is not in the past tense, | 1 0   | 1 2 | 1 3   | DAIGAKU-WA KOUDO-NO KYOIKU-WO UKERU TOKORODESU. (A college is an institution of higher learning.) |
| 9 When a noun is followed by “NIWA (topic)” or “DEWA (topic)”            | 1 0   | 1 2 | 1 2   | MAINICHI CHUUSHOKU-NO TOKI-NIWA BLIJINESUKAINIWA NAGOYAKANA HITOTOKI-GA ARIMASU. (There is a bit of the piece of the business world every day at lunch time.) |
| 10 When a noun is followed by “GA (subject)”                             | 1 2   | 1 1 | 1 0   | KARE-NO ME-NO NAKA-NIWA KANASHIMA-GA ARIMASHITA. (There was sadness in his eyes.) |
| 11 When a noun has a coordinate noun followed by “GA”                    | 1 2   | 1 1 | 1 0   | HITORI-NO OTOKO-NO HITOTO HITORI-NO ONNA-NO HITO-GA ANATA-NO GAISHUTSUCHUU-NI TAZUNETE KIMASHITA. (A man and a woman came to see you when you were gone.) |
| 12 When a noun is modified by a pronoun                                  | 0 0   | 1 3 | 0 0   | SONO JIKO-GA HASSEI-SHITE-KARA YAJIIUMA-GA ATSUMATTE KIMASHITA. (A crowd gathered after the accident.) |
| 13 When a noun is modified by “SUBETENO (all)”                           | 1 0   | 1 0 | 1 2   | SUBETE-NO GELJUTSU-KA- GA UTSUKUSHI MONO-WO BYOUSHA SHIYOU-TO SURU-TOWA KAGIRIMASEN. (Not all artists seek to portray the beautiful.) |
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                 |
|---------------------------------------------------------------------------|-------|-----|-------|-------------------------------------------------------------------------|
| 14 When a noun is modified by “SUBETE-NO (all)” and is followed by a particle “GA (subject)”, | 1     | 0   | 1     | SUBETE-NO GEIJUTSKA-GA UTSUKUSHI MONO-WO BY-OUSHA SHIYOU-TO SURU-TOWA KA-GIRIMASEN. (Not all artists seek to portray the beautiful.) |
| 15 When a noun is modified by “DOKUJI-NO (of one’s own)” or “ONAJI-NO (the same)”, | 0     | 0   | 1     | CHUUGOKUJIN-WA DOKUJI-NO MOJI-WO HATSUMEI SHI-MASHITA. (The Chinese invented their own writing system.) |
| 16 When a noun is adjacent to and modified by a pronoun,                  | 1     | 0   | 3     | KARE-NO OKUSAN-WA FUJIWARAKE-NO SHUSSHIN-DESU. (His wife is a Fujiwara.)  |
| 17 When a noun is modified by a pronoun,                                | 1     | 0   | 2     |                                                                 |
| 18 When a noun is modified by a word which indicates location such as “UE (the upper)” and “TONARI (the neighbor)”, | 1     | 0   | 2     |                                                                 |
| 19 When a noun is a word which indicates a location such as “NEMOTO (the base)”, | 1     | 0   | 2     |                                                                 |
| 20 When a noun is “JIKOKU (one’s country)” or “HATSU (first)”,           | 1     | 0   | 2     |                                                                 |
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                                           |
|---------------------------------------------------------------------------|-------|-----|-------|---------------------------------------------------------------------------------------------------|
| 21 When a noun is modified by the past form of the verb + “ATO (after)”   | 1     | 0   | 1     | KOKO-NI ARU KURUMA-NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA DESU. (This is the most expensive car in this lot.) |
| 22 When a noun is modified by a word which indicates the superlative such as “MOTOMO (the best)” and “ICHIBAN (the first)”, | 0     | 0   | 1     | KOKO-NI ARU KURUMA-NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA DESU. (This is the most expensive car in this lot.) |
| 23 When a noun is modified by an ordinal number,                          | 0     | 0   | 1     | KOKO-NI ARU KURUMA-NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA DESU. (This is the most expensive car in this lot.) |
| 24 When a noun is as “HUTATSU-NO-UCHI-NO OOKIHOU (the bigger one of two things)”, | 0     | 0   | 1     | KOKO-NI ARU KURUMA-NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA DESU. (This is the most expensive car in this lot.) |
| 25 When a noun is modified by a past predicative clause,                  | 1     | 0   | 1     | KOKO-NI ARU KURUMA-NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA DESU. (This is the most expensive car in this lot.) |
| 26 When a noun is modified by a past predicative clause which contains a definite noun phrase followed by a particle such as “GA” or “WA”, | 1     | 0   | 1     | KOKO-NI ARU KURUMA-NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA DESU. (This is the most expensive car in this lot.) |
| Condition                                                                 | Indef | Def | Gener | Example                                                                 |
|---------------------------------------------------------------------------|-------|-----|-------|-------------------------------------------------------------------------|
| 27  When a noun is modified by a verb modified by a definite noun phrase followed by a particle such as “GA” or “WA”, | 1     | 1   | 3     | KARE-GA WATASHI-NI KURETA JOGEN-WA HIYOU-NI YAKUDACHI-MASHITA. (The advice he gave me was very helpful.) |
| 28  When a noun is modified by a verb which contains a definite noun phrase followed by a particle such as “GA” or “WA”, | 1     | 0   | 1     | WATASHI-GA AGETA SHOUSASSHI-WO MADA MOTTE IMASU-KA. (Do you still have the booklet I gave you?) |
| 29  When a noun is modified by a clause which contains a definite noun phrase followed by a particle such as “NI” or “DE”, | 1     | 0   | 1     | KOKO-NI KURUMA-NO NAKA-DE ARU KURUMA-NO NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA-DESU. (This is the most expensive car of all the cars in this lot.) |
| 30  When a noun is modified by a verb “ARU” which contains a definite noun phrase followed by a particle “NI” or “DE”, | 1     | 0   | 1     | KOKO-NI ARU KURUMA-NO NAKA-DE ARU KURUMA-NO NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA-DESU. (This is the most expensive car of all the cars in this lot.) |
| 31  When a noun is modified by a verb modified by a definite noun phrase followed by a particle “GA” or “NO”, | 1     | 0   | 2     | |
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                                                                                   |
|---------------------------------------------------------------------------|-------|-----|-------|------------------------------------------------------------------------------------------------------------------------------------------|
| 32  When a noun is adjacent to and modified by a definite noun followed by a particle “NO”, | 0     | 1   | 1     | KARE-WA SONO BENGOSHI-NO MUSUKO-NO HITORI-DESU. (He is one of the sons of that lawyer.)                                               |
| 33  When a noun is modified by a definite noun followed by a particle “NO”, | 1     | 0   | 1     | KARE-WA SONO BENGOSHI-NO MUSUKO-NO HITORI-DESU. (He is one of the sons of that lawyer.)                                               |
| 34  When a noun is modified by an expression containing a pronoun,         | 1     | 0   | 1     | SEKIYU JIGYOU-WA WATASHI-GA TE-WO DASHITAKU-NAI JIGYOU-NO HITOTSU-DESU. (The oil business is a business that I don’t wish to get into.) |
| 35  When a noun is followed by a particle “MADE (to)”, “KARA (from)”, or “HE (to)”, | 1     | 0   | 2     | SHIAWASE-SOUNA DAIANA-JOU-WA KEKKON-SHIKI-GA OWARU-TO JIJIN-KARA DETE KIMASHITA. (A radiant Lady Diana came out of the cathedral after the wedding.) |
| 36  When a noun is followed by a particle “GA”, “MADE”, “KARA”, or “HE”, and the topic of the sentence is a person’s name, | 1     | 0   | 2     | SHIAWASE-SOUNA DAIANA-JOU-WA KEKKON-SHIKI-GA OWARU-TO JIJIN-KARA DETE KIMASHITA. (A radiant Lady Diana came out of the cathedral after the wedding.) |
| 37  When a noun has a coordinate noun followed by a particle “MADE”, “KARA” or “HE”, | 1     | 0   | 2     |                                                                                                                                           |
Table A.1 Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                                                                                 |
|---------------------------------------------------------------------------|-------|-----|-------|----------------------------------------------------------------------------------------------------------------------------------------|
| 38 When a noun is followed by “YOU (for)”,                                | 1     | 0   | 1     | 2 | SOUGON-NA FUJISAN-WA TAKUSAN-NO RYOKOUYOU-NO PANHURETTO-NI NIHON-NO SHOUCHOU-TO SHITE DETE IMASU. (A majesty Mt.Fuji appears as a symbol of Japan on many brochures for travel.) |
| 39 When a noun is a clause containing a generic noun phrase followed by a particle “WA” and is not a pronoun or a numeral, | 1     | 0   | 1     | 2 | DAIGAKU-WA KOUDO-NO KYOUJIKU-WO UKERU TOKORO-DESU. (A college is an institution of higher learning.) |
| 40 When a noun is followed by a particle “WA” and it modifies an adjective, | 1     | 0   | 1     | 3 | KONO HEYA-NI HAITTE-KURU KUUKI-WA TSUMETAI-DESU. (The air that is being blown into this room is cold.) |
| 41 When a noun is followed by a particle “YORI” and modifies an adjective, | 1     | 0   | 1     | 3 | KIKAI-DE SEIHUN-SARETA KONA-YORI ISHIUSU-DE TSUKURARETA KONA-NO HOU-GA ANATA-NIWA HINO-DESU. (Stone grand flour is better for you than machine processed flour.) |
| 42 When a noun is followed by a particle “GA” and modifies an adjective “YOI (good)”, | 1     | 0   | 1     | 3 | KIKAI-DE SEIHUN-SARETA KONA-YORI ISHIUSU-DE TSUKURARETA KONA-NO HOU-GA ANATA-NIWA YOINO-DESU. (Stone grand flour is better for you than machine processed flour.) |
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                                                                                   |
|---------------------------------------------------------------------------|-------|-----|-------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 43 When a noun is followed by a particle “GA” and modifies an adjective “SUKIDA (like)” , | 1     | 0   | 1     | 2                                                                                                                                        |
| 44 When a noun is followed by a particle “WO” and modifies a verb “TANOSHIMU (enjoy)” , | 1     | 0   | 1     | 2                                                                                                                                        |
| 45 When a noun is “HOU (be more ... than ...)” and modifies an adjective,   | 1     | 0   | 1     | 1                                                                                                                                        |
| 46 When a noun is followed by a particle “TOWA” or “TOIUNOWA” which easily follows a generic noun phrase, | 0     | 0   | 1     | 1                                                                                                                                        |
| 47 When a noun is followed by a particle “WA” or “MO” and modifies a verb modified by an adverb such as “ITSUMO (always)” and “IP-PAN (generally)”, | 0     | 0   | 1     | 2                                                                                                                                        |

- **Example** 
  - OITA JONSON-HUJIN-WA SOUCHO-NO SANPO-WO TANOSHIMI-MASU. (Old Mrs Johnson enjoys her early morning walks.)
  - KIKAI-DE SEIHUN-SARETA KONA-YORI SHIUSU-DE TSUKURARETA KONA-NO HOU-GA ANATA-NIWA IINO-DESU. (Stone ground flour is better for you than machine processed flour.)
  - SHINSHI-WA HUTSUU SHUKUJO-NO TAME-NI DOA-WO AKEMASU. (The gentleman usually opens the door for the lady.)
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                      |
|---------------------------------------------------------------------------|-------|-----|-------|----------------------------------------------|
| 48  When a noun is followed by a particle “WA” or “MO” and modifies a verb modified by an adverb such as “DENTOU (traditionally)”, | 0     | 0   | 1     | 2                                            |
| 49  When a noun is followed by a particle “WA” or “MO” and modifies a verb modified by a word such as “MUKASHI-WA (in earlier times)” and “IMA-WA (at present)”, | 0     | 0   | 1     | 2                                            |
| 50  When a noun is followed by a particle “WA” or “MO” and modifies a verb modified by a word such as “MUKASHI (in earlier times)” and “IMA (at present)”, | 0     | 0   | 1     | 2                                            |
| 51  When a noun is followed by a particle “WA” or “MO” and modifies a verb modified by a word followed by “DEWA (topic)”, | 0     | 0   | 1     | 2                                            |
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                                                           |
|----------------------------------------------------------------------------|-------|-----|-------|-------------------------------------------------------------------------------------------------------------------|
| 52  When a noun is followed by a particle “WA”, “MO”, or “GA” and modifies a verb “DEKIRU (can)” or a noun followed by a copula “DA (be)” | 1     | 0   | 1     | **RAKUDA-WA** **MIZU-WO NOMANAKU-TEMO NAGAI AIDA ARUKU-KOTO-GA DEKI-MASU.** (A camel can go for a long time without water.) |
| 53  When a noun is followed by a particle “WA”, “MO”, or “GA” and modifies a progressive form of a verb,                                 | 1     | 2   | 2     | **KURUMA-WA MICHI-NO WAKI-NI CHUUSHA-SHITE ARIMASU.** (Cars are parked along the street.)                           |
| 54  When a noun modifies a verb modified by a word such as “ITSUMO (always)” and “IPPAN (generally)”                                    | 1     | 0   | 1     | **NIHON-DEWA SHINDA HITO-WA TAITEI KASOU SAREMASU.** (In Japan, the dead are usually cremated.)                    |
| 55  When a noun is a common noun or a verbal noun,                                                                                | 1     | 1   | 1     | **KANOJO-WA TEEBURU-NO HOKORI-WO TORINOZOKU-TAME-NI HUKIN-WO TSUKAI-MASHITA.** (She used a cloth to dust the table.) |
| 56  When a noun is followed by “DEWA-NAI (be not)”,                                                                                | 1     | 4   | 1     |                                                                                                                  |
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                 |
|---------------------------------------------------------------------------|-------|-----|-------|-------------------------------------------------------------------------|
| 57  When a noun is “BAAI (when)”, “TOKORO (where)” and “KOTO (that)”      | 1     | 1   | 1     | SHITSUBOU-SHITA FOUDO-DAITOURYOU-WA JIBUN-GA DAITOURYOU SENKYO-NI YABURETA KOTO-WO MITOME-MASHITA. (A disappointed President Ford admitted that he was defeated in the election.) |
| 58  When a noun is modified by an adjective “ARU (a certain)”             | 1     | 2   | 0     | ARU-GAKUDAN-WA SONO KOUEN-DE ONGAKU-WO ENSOU SHIMAISHITA. (A band gave a performance at the park.) |
| 59  When a noun is modified by a word such as “HOKA-NO (other)” and “BETSU-NO (another)” | 1     | 2   | 0     | KARE-WA SONO-BENGOSHI-NO MUSUKO-DESU. (He is a son of that lawyer.)     |
| 60  When a noun is followed by a copula “DA (be)” and it is not modified by a generic noun phrase followed by a particle “WA” | 1     | 1   | 1     | INU-WA YAKU-NI TATSU DOUBUTSU-DESU. (A dog is an useful animal.)         |
| Condition                                                                 | Indef | Def | Gener | Example                                                                                                                                         |
|---------------------------------------------------------------------------|-------|-----|-------|------------------------------------------------------------------------------------------------------------------------------------------------|
| 62 When a noun is followed by a copula “DA (be)” and is not modified       | 1     | 2   | 1     | Sono Resutoran-Dewa Ichinichi-Ni Hito-Hukuro-No Tamanegi-wo Tsukaimasu. (That restaurant uses a bag of onions a day.)                         |
| by a generic noun phrase followed by a particle “WA”,                      | 0     | 1   | 1     |                                                                                                                                               |
| 63 When a noun is modified by a numeral,                                  | 1     | 10  | 0     | Kare-Wa Sono Bengoshi-No Musuko-No Hitori-Desu. (He is one of the sons of that lawyer.)                                                     |
| and is not followed by a particle “WA”,                                   | 0     | 0   | 0     | KARE-WA                                                                                                                                 |
| 64 When a noun is a numeral and is not followed by a particle “WA”,        | 1     | 10  | 0     | Kare-Wa Sono Bengoshi-No Musuko-No Hitori-Desu. (He is one of the sons of that lawyer.)                                                     |
| and is not followed by a particle “WA”,                                   | 1     | 0   | 1     | KURASU-NI Ikeda-Toiu Hito-Ga Hitori-Iru. (We have one person called Ikeda in our class.)                                                   |
| 65 When a noun is modified a bunsetsu followed by a particle “TOIU (called)”,| 1     | 2   | 1     | Sono IE-NIWA SHININ-GA HITORI DEMASHITA. (There was a death in the family.)                                                                |
| 66 When a noun is followed by a particle “WA”, “MO”, “GA”, or “WO”, and it  | 1     | 10  | 0     |                                                                                                                                               |
| modifies a verb modified by a numeral,                                    | 0     | 1   | 0     |                                                                                                                                               |
Table A.1: Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                 |
|---------------------------------------------------------------------------|-------|-----|-------|-------------------------------------------------------------------------|
| 68  When the same noun appears previously in the same sentence and is indefinite, | 1     | 0   | 1     | KARE-WA JOYOU-SHA-TO TORAKU-WO ICHIDAI-ZUTSU MOTTE IMASU-GA KARE-WA JOYOU-SHA-NISHIKA HOKEN-WO KAKETE IMASEN. (He has a car and a truck but only the car is insured.) |
| 69  When the same noun appears previously in the same sentence and is definite, | 1     | 0   | 1     | KIKAI-DE SEIHUN-SARETA KONA-YORI ISHIUSU-DE TSUKURARETA KONA-NO-HOU-GA ANATA-NIWA IINO-DESU. (Stone ground flour is better for you than machine processed flour.) |
| 70  When the same noun appears previously in the same sentence and is generic, | 1     | 0   | 1     | KARE-WA JOYOU-SHA-TO TORAKU-WO ICHIDAI-ZUTSU MOTTE IMASU-GA KARE-WA JOYOU-SHA-NISHIKA HOKEN-WO KAKETE IMASEN. (He has a car and a truck but only the car is insured.) |
| 71  When the same noun appears previously in a coordinate structure in the same sentence and is not generic, | 1     | 0   | 1     | KARE-WA JOYOU-SHA-TO TORAKU-WO ICHIDAI-ZUTSU MOTTE IMASU-GA KARE-WA JOYOU-SHA-NISHIKA HOKEN-WO KAKETE IMASEN. (He has a car and a truck but only the car is insured.) |
| 72  When the same noun appears in the previous five sentences and is indefinite, | 1     | 1   | 1     | KARE-WA JOYOU-SHA-TO TORAKU-WO ICHIDAI-ZUTSU MOTTE IMASU-GA KARE-WA JOYOU-SHA-NISHIKA HOKEN-WO KAKETE IMASEN. (He has a car and a truck but only the car is insured.) |
| 73  When the same noun appears in the previous five sentences and is definite, | 1     | 0   | 1     | KARE-WA JOYOU-SHA-TO TORAKU-WO ICHIDAI-ZUTSU MOTTE IMASU-GA KARE-WA JOYOU-SHA-NISHIKA HOKEN-WO KAKETE IMASEN. (He has a car and a truck but only the car is insured.) |
| Condition                                                                 | Indef | Def | Gener | Example                                                                                                                                  |
|---------------------------------------------------------------------------|-------|-----|-------|------------------------------------------------------------------------------------------------------------------------------------------|
| 74  When the same noun appears in the previous five sentences and is generic, | 1     | 0   | 1     | 2                                                                                                                                        |
| 75  When the same noun appears in a coordinate structure in the previous five sentences and is not generic, | 1     | 0   | 1     | 0                                                                                                                                        |
| 76  When a noun is followed by a particle “DE” or “TO”, it modifies a verb, and the noun modified by the verb is generic, | 1     | 0   | 1     | 2                                                                                                                                        |
| 77  When a noun is followed by a particle “GA” and modifies a clause containing a word such as “IT-SUMO (always)” and “IPPAN (generally)”, | 1     | 0   | 1     | 2                                                                                                                                        |
| 78  When a noun is followed by a particle “GA” and is modified by a definite noun phrase followed by a particle “NO”, | 1     | 0   | 1     | 0                                                                                                                                        |
Table A.1 Rule for referential property (cont.)

| Condition                                                                 | Indef | Def | Gener | Example                                                                 |
|---------------------------------------------------------------------------|-------|-----|-------|-------------------------------------------------------------------------|
| 79  When a noun is “HAIKEI-NI (background)” or “TAISHOU-NI (target)” and follows a noun followed by a particle “WO”, | 1     | 0   | 1     | 0                                                                      |
| 80  When a noun is “HAIKEI-NI (background)” or “TAISHOU-NI (target)” and modifies a verb modified by a noun followed by a particle “WO”, | 1     | 0   | 1     | 0                                                                      |
| 81  When a noun is followed by a particle “NO” and modifies a proper noun, | 1     | 0   | 1     | 1                                                                      |
| 82  When a noun is followed by a particle “NO” and modifies a noun,       | 1     | 0   | 1     | 3 OOKU-NO WAKAI OTOKO-NO HITOTO-TACHI-WA RIKUGUN-NI HEIEKI-SHIMASU. (Many young people serve in the army.) |
| 83  When a noun is followed by a particle “TO-IU”,                        | 1     | 0   | 1     | 0 KURASU-NI IKEDA-TO IUU HITQ-GA HITORI IRU. (We have an Ikeda in our class.) |
| 84  When a noun is “NANI (what)”,                                        | 1     | 3   | 1     | 0                                                                      |
| 85  When a noun is followed by a particle “NO-YOUNA (such as or like)”,   | 1     | 0   | 1     | 3                                                                      |
| 86  When a noun is followed by a particle “WA” and modifies a numeral,    | 1     | 1   | 1     | 0                                                                      |
Table A.2: Rule for number

| Condition                                                                 | Sing | Plur | Uncnt | Example                                                                                      |
|---------------------------------------------------------------------------|------|------|-------|--------------------------------------------------------------------------------------------|
| 1  When a noun is a noun predicate, and the subject of the noun predicate  | 1    | 3    | 1     | KARE-WA                                                                                     |
| 2  When a noun is a noun predicate, and the subject of the noun predicate  | 1    | 0    | 1     | KORE-WA JUNKIN-DESU. (This is pure gold.)                                                   |
| 3  When a noun is a noun predicate, and the subject of the noun predicate  | 1    | 0    | 1     | KANOJO-WA KEeki-WO IKKO PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.) |
| 4  When a noun is a singular pronoun such as “KARE (he)” and “WATASHI (we)” | 1    | 3    | 0     | KOKO-NI ARU KURUMA-NO NAKA-DE KORE-WA ICHIBAN TAKAI KURUMA-DESU. (This is the most expensive car in this lot.) |
| 5  When a noun is a singular demonstrative such as “KORE (this)” and “ARE (that)” | 1    | 3    | 1     | KARE-WA                                                                                  |
| 6  When a noun is “HITORI (one person)”, “HITOTSU (one)”, or “IPPIKI (one)” | 1    | 3    | 1     | KARE-WA                                                                                  |
| 7  When a noun is a singular numeral,                                     | 1    | 3    | 1     | WATASHI-WA KONO KINJO-NO ICHI-KAZOKU-SAE SHIRI-MASEN. (I don’t know a family in this neighborhood.) |
Table A.2: Rule for number (cont.)

| Condition                                                      | Sing | Plur | Uncnt | Example                                                                 |
|----------------------------------------------------------------|------|------|-------|-------------------------------------------------------------------------|
| 8 When a noun is not generic,                                  | 1    | 1    | 0     | KARE-WA  
SONO BENGOSHI-NO MUSUKO-NO HITORI-DESU. (He is one of the sons of that lawyer.) |
| 9 When a noun is definite,                                     | 1    | 1    | 0     | KARE-WA  
SONO BENGOSHI-NO MUSUKO-NO HITORI-DESU. (He is one of the sons of that lawyer.) |
| 10 When a noun is modified by a demonstrative adjective such as  | 1    | 3    | 1     | KARE-WA  
SONO (the), ANO (of that) and KONO (of this),                         |
| 11 When a noun is modified by “HITORI (one person)”, “HI-     | 1    | 3    | 1     | KURASU-TOWA JUGYOU-WO ISSHO-NI TOTTE-IRU GAKUSEI-TACHI-NO HITOTSU-NO GURUUPU-DESU.(A class is a group of students taking a course together.) |
| 12 When a noun is modified by a singular numeral,              | 1    | 3    | 0     | SONO RESUTORAN-DEWA ICHINICHI-NI HITO-HUKURO-NO TAMANEGI-WO TSUKAIMASU. (That restaurant uses a bag of onions a day.) |
| 13 When a noun contains a prefix which is a singular numeral, | 1    | 2    | 1     | WATASHI-WA KONO KINNO-NO ICHI-KAZOKU-SAE SHIRIMASEN. (I don’t know a family in this neighborhood.) |
| Condition | Sing | Plur | Uncnt | Example                                                                 |
|-----------|------|------|-------|-------------------------------------------------------------------------|
| 14        | 1    | 1    | 1     | KANOJO-WA KEEKI-WO IKKO                                                |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
|           | 1    | 1    | 0     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
| 15        | 0    | 0    | 1     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
|           | 1    | 1    | 0     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
| 16        | 0    | 0    | 1     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
|           | 0    | 0    | 3     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
| 17        | 0    | 0    | 2     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
|           | 0    | 0    | 1     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
| 18        | 0    | 0    | 1     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
| 19        | 0    | 0    | 1     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
| 20        | 0    | 0    | 1     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
|           | 0    | 0    | 2     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |
|           | 0    | 0    | 0     | KEEKI-WO IKKO                                                          |
|           |      |      |       | PIKUNIKKU-HE MOTTE YUKIMASHITA. (She took a cake to the picnic.)        |

Table A.2: Rule for number (cont.)
### Table A.2: Rule for number (cont.)

| Condition                                                                 | Sing | Plur | Uncnt | Example                                                                 |
|----------------------------------------------------------------------------|------|------|-------|-------------------------------------------------------------------------|
| 21 When a noun is a plural numeral,                                        | 0    | 0    | 1     | 2                        | 0                      | 0                  |
| 22 When a noun is a plural pronoun,                                        | 0    | 0    | 1     | 3                        | 0                      | 0                  |
| 23 When a noun is followed by a suffix which indicates plurality such as “TACHI” and “RA”, | 1    | 0    | 1     | 3                        | 0                      | 0                  |
| 24 When a noun is followed by a particle “DE” and modifies a verb modified by a generic noun phrase followed by a particle “WA”, | 1    | 0    | 1     | 2                        | 1                      | 1                  |
| 25 When a noun is followed by a particle “WA” or “GA”, and modifies a verb such as “KOERU (be over)”, “KOSU (be over)”, and “TASSURU (amount to)”, | 1    | 0    | 1     | 3                        | 1                      | 0                  |
| 26 When a noun is followed by a particle “WO” and modifies a verb “ATSUMERU (gather)”, | 0    | 0    | 1     | 3                        | 0                      | 0                  |
| 27 When a noun is followed by a particle “GA” and modifies a verb such as “ATSUMARU (come together)” and “RANRITSU SURU (be flooded)”, | 0    | 0    | 1     | 3                        | 0                      | 0                  |
| Condition                                                                 | Sing | Plur | Uncnt | Example                                                                 |
|---------------------------------------------------------------------------|------|------|-------|-------------------------------------------------------------------------|
| 28 When a noun is followed by a particle “WO” and modifies a verb such as “SAITEN SURU (mark)” and “MOTORASU (bring))”, | 1    | 0    | 1     | 2 1 0                                                                 |
| 29 When a noun is followed by a particle “WO” or “NI” and modifies a verb modified by “IKURADEMO (as much ...)” or “NANKAIDEMO (as many times as ...))”, | 1    | 0    | 1     | 2 1 0                                                                 |
| 30 When a noun is followed by a particle “WA”, “WO”, “GA”, or “MO”, and modifies a verb modified a plural noun, | 1    | 0    | 1     | 2 1 0                                                                 |
| 31 When a noun is followed by a particle “WA”, “WO”, “GA”, or “MO”, and modifies a verb modified a plural noun, | 1    | 0    | 1     | 2 1 0                                                                 |
| 32 When a noun is followed by a particle “WA”, “WO”, “GA”, or “MO”, and it modifies a verb modified by “OOZEI” etc., | 1    | 0    | 1     | 2 1 0                                                                 |
| 33 When a noun is Noun X in “Noun X NO HITORI (one of Noun X)”,         | 0    | 0    | 1     | 3 0 0                                                                 |
### Table A.2: Rule for number (cont.)

| Condition                                                                 | Sing | Plur | Uncnt | Example                                                                 |
|---------------------------------------------------------------------------|------|------|-------|-------------------------------------------------------------------------|
| 34 When a noun follows “... NO ICHIBU (part of)” or “... NO UCHINO (of)”  | 1    | 0    | 1 3   |                                                                          |
| 35 When a noun is followed by a particle “GA” and modifies a verb “SUKIDA (like)” | 1    | 0    | 1 2   |                                                                          |
| 36 When a noun is followed by a particle “WO” and modifies a verb “TANOSHIMU (enjoy)” | 1    | 0    | 1 2   | OITA JONSON-HUJIN-WA SOUCHO-NO SANPO-WO TANOSHIMI-MASU. (Old Mrs Johnson enjoys her early morning walks.) |
| 37 When a noun is an uncountable noun which does not have a modifier,    | 1    | 0    | 1 0   | RAKUDA-WA MIZU-WO NOMANAKU-TEMO NAGAI ARUKU-KOTO-GA DEKI-MASU. (A camel can go for a long time without water.) |
| 38 When a noun is an uncountable noun such as water,                     | 1    | 0    | 1 0   | RAKUDA-WA MIZU-WO NOMANAKU-TEMO NAGAI ARUKU-KOTO-GA DEKI-MASU. (A camel can go for a long time without water.) |
| 39 When a noun is an uncountable noun modified by “HODO-NO (extent)” or “... TEKI-DA (-cal)”, | 1 2  | 1 2  | 1 0 | KANOJO-WA SONO MOUJIN-GA WASURE-RARE-NAI HODO-NO MAGOKORO-NO KOMOTTA SHINSETSU-WO SONO MOUJIN-NI SHITE YARIMASHITA. (She showed a kindness toward the blind man that he never forget.) |
| Condition                                                                                           | Sing | Plur | Uncnt | Example                                                                                           |
|----------------------------------------------------------------------------------------------------|------|------|-------|---------------------------------------------------------------------------------------------------|
| 40 When a noun is “MONO (thing)” modified by an adjective,                                          | 1    | 0    | 1     | SUBETE-NO GEIJUTSU- GA UTSUKUSHI-MONO-WO BYOUSHA SHIYOU-TO SURU-TOWA KAGIR-IMASEN. (Not all artists to portray beautiful-things.) |
| 41 When a noun is followed by a particle “WA”, “WO”, “GA”, or “MO”, and follows an adverb such as “TAKUSAN (a lot)” and “IPPAI (a lot)”, | 1    | 0    | 1     |                                                                                                  |
| 42 When a noun is followed by a particle “WA”, “WO”, “GA”, or “MO”, and modifies a verb modified by an adverb such as “TAKUSAN (a lot)” and “IPPAI (a lot)”, | 1    | 0    | 1     |                                                                                                  |
| 43 When a noun is modified by “TAKUSAN-NO (a lot of)” or “IPPAI-NO (a lot of)”,                     | 0    | 0    | 1     | SOUGON-NA FUJISAN-WA TAKUSAN-NO RYOKOUYOU-NO PANHURETTO-NI NIHON-NO SHOUCOYOU-TO SHITE DETE IMASU. (A majestic Mt.Fuji appears as a symbol of Japan on many travel brochures.) |
| 44 When a noun is modified by “TAKUSAN-NO (a lot of)”,                                               | 0    | 0    | 1     |                                                                                                  |
| 45 When a noun is followed by a particle “WO” and modifies a verb “ABIRU (be covered)”,              | 0    | 0    | 1     |                                                                                                  |
Table A.2: Rule for number (cont.)

| Condition                                                                 | Sing | Plur | Uncnt | Example |
|---------------------------------------------------------------------------|------|------|-------|---------|
| 46  When a noun is followed by a particle “GA” and modifies a verb such as “NARABU (be in line)” and “ZOKUSHUTSU SURU (appear one after another)” | 0    | 0    | 1     |         |
| 47  When a noun is followed by a particle “WA” and modifies a noun predicate such as “Noun X DA (be Noun X)”, and Noun X is plural, | 1    | 0    | 1     | 0       |
| 48  When a noun is followed by a particle “WA” and modifies a noun predicate such as “Noun X DA (be Noun X)”, and Noun X is uncountable, | 1    | 0    | 0     | 1       |

KORE-WA JUNKIN-DESU. (This is pure gold.)
Appendix B

Rule for Pronouns

B.1 Rule for Demonstratives

We made 50 Candidate enumerating rules and 10 Candidate judging rules for analyzing demonstratives. All the rules are given below.

B.1.1 Candidate Enumerating Rule

1. When a pronoun is a demonstrative followed by the particle “GA” and a non-ga-case zero pronoun is not yet recovered, the system analyzes the non-ga-case zero pronoun before the analysis of the demonstrative.

2. When a pronoun is “so-series demonstrative adjective + noun $\alpha$,”
   
   $\{$(the noun phrase containing a noun $\alpha$, 45)
   (the topic which is a subordinate of the noun $\alpha$ and which has the weight $W$ and the distance $D$, $W - D \times 2 + 10$)
   (the focus which is a subordinate of the noun $\alpha$ and which has the weight $W$ and the distance $D$, $W - D \times 2 + 10$)$\}$

3. When a pronoun is “ko-series demonstrative adjective + noun $\alpha$,“
   
   $\{$(the noun phrase containing a noun $\alpha$, 45)
   (the topic which is a subordinate of the noun $\alpha$ and which has the weight $W$ and the distance $D$, $W - D + 30$)
APPENDIX B. RULE FOR PRONOUNS

4. When a pronoun is “a-series demonstrative adjective + noun α,”
   \{ (the noun phrase containing a noun α, 45)
   (the topic which is a subordinate of the noun α and which has the weight
   \(W\) and the distance \(D\), \(W - D \times 0.4 + 30\))
   (the focus which is a subordinate of the noun α and which has the weight
   \(W\) and the distance \(D\), \(W - D \times 0.4 + 30\)) \}\n
5. When a pronoun is “SORE (it)/ARE (that)/KORE (this)” or a demonstrative adjective and the previous bunsetsu contains the expression of the predicative form of a verb or the expression of enumerating examples such as “TOKA (and so on),” \{(the expression, 40)\}

6. When a pronoun is “SORE/ARE/KORE” or a demonstrative adjective,
   \{( The previous sentence (or the verb phrase in the conditional form containing
   a conjunctive particle such as “GA (but)”, “ DAGA (but)”, and
   “KEREDO (but)” if the verb phrase is in the same sentence), 15) \}\n
7. When a pronoun is “KORE-WA/SORE-WA/KORE-DE/SORE-DE”, is the
   first word of the sentence, and is not a case component of a verb,
   \{( The previous sentence (or the verb phrase in the conditional form containing
   a conjunctive particle such as “GA (but)”, “ DAGA (but)”, and
   “KEREDO (but)” if the verb phrase is in the same sentence), 5) \}\n
8. When a pronoun is “KORE-WA/SORE-WA/KORE-DE/SORE-DE” and is
   the first word of the sentence,
   \{( The previous sentence (or the verb phrase in the conditional form containing
   a conjunctive particle such as “GA (but)”, “ DAGA (but)”, and
   “KEREDO (but)” if the verb phrase is in the same sentence), 5) \}\n
9. When a pronoun is “(KORE (this)/SORE (it))(HODO (extent)/DAKE
   (only)/DEMO (even)/KOSO (just))”,
   \{( The previous sentence (or the verb phrase in the conditional form con-
B.1. RULE FOR DEMONSTRATIVES

10. When a pronoun is “KOUIU (like this)”, “SOUIU (like it)”, “KON’NA (like this)”, etc.,
{(the previous sentence (or the verb phrase in the conditional form containing a conjunctive particle such as “GA (but)”, “DAGA (but)”, and “KEREDO (but)” if the verb phrase is in the same sentence), 5)}

11. When a pronoun is “KON’NA (like this)”,
{(the next sentences, 20)}

12. When a pronoun is “KON’NA (like this)” and “KON’NA (like this)” + noun is followed by a particle “NI/DE/SURA/WA/NO”,
{(the next sentences, 1)}

13. When a pronoun is “KON’NA (like this)” and “KON’NA (like this)” + noun is followed by a particle “WO/MO/DENAI”,
{(the previous sentences, 1)}

14. When a pronoun is “(SONO (the)/KONO (this))(TAME (for)/UE (in)/HOKA (other)/KOTO (thing)/BAAI (case)/TSUDO (every time))”,
{(the previous sentence (or the verb phrase in the conditional form containing a conjunctive particle such as “GA (but)”, “DAGA (but)”, and “KEREDO (but)” if the verb phrase is in the same sentence), 30)}

15. When a pronoun is “(SONO (its)/KONO (this))(IMI (meaning)/GEN’IN (cause)/KEKKA (result)/HAIKEI (background)/KOUKA (effect))”,
{(the previous sentence (or the verb phrase in the conditional form containing a conjunctive particle such as “GA (but)”, “DAGA (but)”, and “KEREDO (but)” if the verb phrase is in the same sentence), 5)}

16. When a pronoun is “ANO/SONO/AN’NA/SON’NA (like it)” + noun which indicates time,

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1 This rule is based on Yanagi’s method [Yanagi 94].
17. When a pronoun is “KONO/KON’NA” + noun which indicates time,
   {(the present time, 5)}

18. When a pronoun is “(KONO/KON’NA)(CHI (place)/ KUNI (country)/
   SHAKAI (society))”,
   {(the present place, 5)}

19. When a pronoun is “SONO (the or its)” in “Noun X TO SONO Noun (Noun
   X and the Noun)” or “Noun X YA SONO Noun (Noun X or the Noun)
   {(Noun X, 50)}

20. When a pronoun is “SONO(its)” in “Noun X NO(of ) SONO(its) Noun”,
   {(Noun X, 30)}

21. When a pronoun is “AA (oh)/SORE/KORE/ARE” followed by a comma,
   {(it is regarded as an exclamation, 30)}

22. When a pronoun is “SOU/KON’NA/KON’NANI/SON’NANI/SOREHODO”
    and it modifies an adjective or an adverb,
    {(Introduced as indefinite, 30)}

23. When a pronoun is such as “ARE-YA KORE-YA”,
    {(an idiomatic expression, 50)}

24. When a pronoun is a demonstrative pronoun, a demonstrative adverb, or a
    demonstrative adjective,
    {(Introduce an individual, 10)}

25. When a pronoun is a demonstrative in quotations,
    {(Introduce an individual, 5)}

26. When a pronoun is a ə-series demonstrative,
    {(Introduce an individual, 5)}
B.1. RULE FOR DEMONSTRATIVES

27. When a pronoun is “KOU/KON’NAHUUNISHITE/KOUSHITE”,
   {((the previous sentences, 25))}

28. When a pronoun is “KOU/KON’NAHUUNISHITE/KOUSHITE”,
   {((the next sentences, 26))}

29. When a pronoun is a part of “KOU/KON’NAHUUNI” + conditional form
    or “KOU SHITE” and is not the last word in the sentence,
    {((the previous sentences, 7))}

30. When a pronoun is “KON’NA HUUNI (like this)”, and is not the last word
    in the sentence,
    {((the previous sentences, 2))}

31. When a pronoun is “KOUDA” or “KON’NA-HUUDAN”,
    {((the next sentences, 3))}

32. When a pronoun is a demonstrative which does not indicate location and
    the previous sentence is a quotation, {((the previous sentences, 3))}

33. When a pronoun is a demonstrative which does not indicate location,
    {((the previous sentences, 1))}

34. When a pronoun is a demonstrative which does not indicate location and
    the next sentence is a quotation,
    {((the next sentences, 3))}

35. When a pronoun is a demonstrative which does not indicate location,
    {((the next sentences, 1))}

36. What a pronoun is “AA (like that)”,
    {((the previous sentence, 20))}

37. When an anaphora is “SOU (so)/SOUSHITE (do so)/SONOYOUINI (like it)”,
    {((the previous sentences, 30))}
APPENDIX B. RULE FOR PRONOUNS

38. When an anaphor is “SOU/SOUSHITE/SONOYOUNI” and is in the subordinate clause which has a conjunctive particle such as “GA (but)”, “DAGA (but)”, and “KEREDO (but)” or an adjective conjunction such as “YOUNI (as)”,
{(the main clause, 45)}

39. When a pronoun is “KON’NANI/AN’NANI/SON’NA-HUUNI/AN’NA-HU-UNI” and does not modify an adjective or an adverb,
{(the previous sentence, 25)}

40. When a pronoun is “KOKODE (here)/SOKODE (there)” and the first word of the sentence,
{(the previous sentence, 5)}

41. When a pronoun is “KOKODE (here)/SOKODE (there)”, is the first word of the sentence, and is not a case component of a verb,
{(the previous sentence, 5)}

42. When a pronoun is “KOKO (here)/SOKO (there)”,
{(the present place, 15)}

43. When a pronoun is “KOKO (here)/SOKO (there)” + noun which indicates time,
{(the present time, 50)}

44. When a pronoun is “(ARE/KORE/SORE)(KARA (from)/MADE (to))”,
{(the present time, 15)}

45. When a pronoun is “KOCHIRA (this gentleman)” and is in a quotation,
{(the first person, 25)}

46. When a pronoun is “KOCHIRA (this gentleman)” which is not in a quotation,
{(the first person, 13)}

2 This rule is based on Matsuoka’s method [Matsuoka et al 95].
47. When a pronoun is “SOCHIRA (the other)” which is in a quotation,
{(the second person, 13)}

48. When a demonstrative is the subject of a noun/adjective predicative sentence and the predicate is a word which signifies judgment such as “JISSEKI-DA (result)”, “ZAN’NEN-DA (unfortunate)”, “KAKUJITSU-DA (sure)”, and “...TEKI-DA (-cal)”,
{(the previous sentences, 50)}

49. When a demonstrative is in a subordinate clause containing “YOUNI (as)”, “GA (but)”, and “KEREDOMO (but)”,
{(the main clause, 10)}

50. When a pronoun is a demonstrative pronoun or “SONO (of it) / KONO (of this) / ANO (of that)”,
{(A topic which has the weight $W$ and the distance $D$, $W - D - 2$)
(A focus which has the weight $W$ and the distance $D$, $W - D + 4$)}

B.1.2 Candidate Judging Rule

1. When a pronoun is a demonstrative pronoun and a candidate referent has a semantic marker $\text{HUM}$ (human), it is given $-10$. We use Noun Semantic Marker Dictionary $\text{[Watanabe et al 92]}$ as a semantic marker dictionary.

2. When a pronoun is a demonstrative pronoun, a candidate referent is given the points in Table 5.3 by using the highest semantic similarity between the candidate referent and the codes \{5200003010 5201002060 5202001020 5202006115 5241002150 5244002100\} in BGH $\text{[NLRI 64]}$ which signify human beings.

3. When a pronoun is “KOKO (here) / SOKO (there) / ASOKO (over there)” and a candidate referent has a semantic marker $\text{LOC}$, which indicates location, the candidate referent is given 10 points.

4. When a pronoun is “KOKO/SOKO/ASOKO”, a candidate referent is given the points in Table 5.3 by using the semantic similarity between the candi-
Table B.1: Point given by the similarity of the verb

| Similarity level | 0   | 1   | 2   | 3   | 4   | 5   | 6   | Exact Match |
|------------------|-----|-----|-----|-----|-----|-----|-----|-------------|
| Point            | 0   | 0   | 1.5 | 2   | 3   | 3.5 | 4   |             |

date referent and the codes \{6563006010 6559005020 9113301090 9113302010 6471001030 6314020130\} which indicate locations in BGH [NLRI 64].

5. When a pronoun is a so-series demonstrative adjective, the system consults examples of the form “noun X NO noun Y” whose noun Y is modified by the pronoun, and gives a candidate referent the point in Table 5.6 by the similarity between the candidate referent and noun X. The Japanese Co-occurrence Dictionary [EDR 95d] serves as a source of examples for “X NO Y”.

6. When a pronoun is a non-so-series demonstrative adjective, the system consults examples of the form “Noun X NO(of) Noun Y (Y of X)” whose Noun Y is modified by the pronoun, and gives a candidate referent the point in Table 5.8 by the similarity between the candidate referent and noun X.

7. When a candidate referent of a pronoun does not satisfy the semantic marker of the case component in the case frame, it is given −5.

8. A candidate referent of a pronoun is given the points in Table 5.11 by using the highest semantic similarity between the candidate referent and examples of the case component in the case frame.

9. When a pronoun is a demonstrative followed by “GA Noun X NI-NARU (become Noun X)”, it is given the points in Table 5.11 by using the semantic similarity between the candidate referent and Noun X.

10. When a pronoun is given the points in Table B.1 by using the semantic similarity between the verb modified by the demonstrative and the verb modified by a candidate referent.
B.2 Rule for Personal Pronouns

We made 4 Candidate enumerating rules and 6 Candidate judging rules for analyzing personal pronouns. All the rules are given below.

B.2.1 Candidate Enumerating Rule

1. When an anaphor is a first personal pronoun,
   \{(the first person (the speaker) in the context, 25)\}

2. When an anaphor is a second personal pronoun,
   \{(the second person (the hearer) in the context, 25)\}

3. When an anaphor is a third personal pronoun,
   \{(a first person, −10) (a second person, −10)\}

4. When an anaphor is a personal pronoun,
   \{(a topic which has the weight \(W\) and the distance \(D\), \(W − D − 2\))
   (a focus which has the weight \(W\) and the distance \(D\), \(W − D + 4\))\}

B.2.2 Candidate Judging Rule

1. When an anaphor is a personal pronoun and a candidate referent has a semantic marker HUM, the candidate referent is given 10 points.

2. When an anaphor is a personal pronoun, a candidate referent is given the points in Table 5.10 by using the semantic similarity between the candidate referent and the code \{5200003010 5201002060 5202001020 5202006115 5241002150 5244002100\} which indicates human being in BGH\[^{NLRI 64}\].

3. When a candidate referent of a personal pronoun does not satisfy the semantic marker of the case component in the case frame, it is given −5.

4. A candidate referent of a personal pronoun is given the points in Table 5.11 by using the highest semantic similarity between the candidate referent and examples of the case component in the case frame.
5. When a pronoun is a personal pronoun followed by “GA Noun X NI-NARU (become Noun X)”, it is given the points in Table B.1 by using the semantic similarity between the candidate referent and Noun X.

6. When a pronoun is given the points in Table B.1 by using the semantic similarity between the verb modified by the demonstrative and the verb modified by a candidate referent.

### B.3 Rule for Zero Pronouns

We made 19 *Candidate enumerating rules* and 4 *Candidate judging rules* for analyzing zero pronouns. All the rules are given below.

#### B.3.1 Candidate Enumerating Rule

1. When an anaphor is a *ga*-case zero pronoun whose verb is followed by the auxiliary verbs such as “KURERU” and “KUDASARU” and there is a *ni*-case zero pronoun in the verb, the *ni*-case zero pronoun is analyzed first. With respect to the *ga*-case zero pronoun, {do not fill a zero pronoun, −5}

2. When a zero pronoun is not in a quotation and is a case component of a verb whose *ga*-case is easily filled by a first person (speaker) such as “OMOU (think)” and “HOSHII (want)”, {a first person, 50}

3. In a quotation, when an anaphor is a *ga*-case zero pronoun which is easily filled with a first person, whose verb is such as “YARU (give)”, “SHITAI (want)”, and “IKU (go),” {the first person, 5}

4. When a zero pronoun is a *ga*-case zero pronoun which is not easily filled with a first person, whose verb is such as “DAROU”, “YOUDA”, and “SOUDA”, {the first person, −20}

5. In a quotation, when an anaphor is a *ga*-case zero pronoun which is easily filled with a second person, whose verb is such as “KURERU (give)”, “NASARU (do)”, and “KURU (come)”, or whose verb is in an imperative
B.3. **RULE FOR ZERO PRONOUNS**

sentence or an interrogative sentence,
\{(the first person, −30)(the second person, 25)\}

6. In a quotation, when an anaphor is a ga-case zero pronoun,
\{(the first person, 15)\}

7. When an anaphor is a *ga*-case zero pronoun of “Y DA (is Y)” in the expression of “X WO Y DA TO MINASU (consider X as Y),
\{(Noun X, 50)\}

8. When a zero pronoun is the subject of a noun predicative sentence and the predicate is “KU (phrase)”, “HAIKU (haiku)”, “UTA (song)” and “TANKA (tanka),
\{(the previous sentence, 25)\}

9. When a zero pronoun is the subject of a noun predicative sentence and the predicate is a word which indicates time,
\{(the time of the previous sentence, 25)\}

10. When a zero pronoun is a *ga*-case of the main (or subordinate) clause in a complex sentence, the complex sentence is connected by the conjunctive particle indicating disagreement of subjects in a complex sentence such as “NODE (because)” and “NARABA (if)” and the subject of the subordinate (or main) clause is not omitted and is followed by the particle “GA,”
\{(the subject of the subordinate (or main) clause, −30)\}

11. When a zero pronoun is the subject of a noun predicative sentence and the predicate is a word which indicates action,
\{(the previous sentence, 21)(the next sentence, 21)\}

12. When the next sentence is a quotation,
\{(the next sentence, 1)\}

13. When a zero pronoun is a *ga*-case component,
\{(A topic which has the weight W and the distance D, W − D * 2 + 1)
(A focus which has the weight W and the distance D, W − D + 1)\}
(A subject of a clause coordinately connected to the clause containing the anaphor, 25)
(A subject of a clause subordinately connected to the clause containing the anaphor, 23)
(A subject of a main clause whose embedded clause contains the anaphor, 22)}

14. When a zero pronoun is not a \textit{ga}-case component,
\{(A topic which has the weight $W$ and the distance $D$, $W - D \times 2 - 3$)
(A focus which has the weight $W$ and the distance $D$, $W - D \times 2 + 1$)\}

15. When there is “Noun $\alpha$” in another case component of the verb which has the analyzed case component (the analyzed zero pronoun),
\{(Noun $\alpha$, $-20$)\}

16. When a zero pronoun is a case component of a verb which modifies a noun phrase and is not modified by any phrase,
\{(the system does not analyze the zero pronoun, 3)\}

17. When a zero pronoun is an optional case component,
\{(the system does not analyze the zero pronoun, 3)\}

18. When a zero pronoun is a \textit{ga}-case component,
\{(the system does not analyze the zero pronoun, 15)\}

19. When a zero pronoun is not a \textit{ga}-case component,
\{(the system does not analyze the zero pronoun, 18)\}

\textbf{B.3.2 Candidate Judging Rule}

1. When a candidate referent of a case component (a zero pronoun) does not satisfy the semantic marker of the case component in the case frame, it is given $-5$.

2. A candidate referent of a case component (a zero pronoun) is given the points in Table 5.11 by using the highest semantic similarity between the candidate referent and examples of the case component in the case frame.
3. When a zero pronoun is a subject of “GA Noun X NI-NARU (become Noun X)”, it is given the points in Table 5.11 by using the semantic similarity between the candidate referent and Noun X.

4. When a zero pronoun is given the points in Table B.1 by using the semantic similarity between the verb having the zero pronoun and the verb modified by a candidate referent.
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Abbreviations

COLING International Conference on Computational Linguistics

IEICE The Institute of Electronics, Information and Communication Engineers

WGNLC Natural Language Processing and Models of Communication

IPSJ Information Processing Society of Japan

WGIM Information Media

WGNL Natural Language

JSAI Japan Society for Artificial Intelligence

ANLP The Association for Natural Language Processing