Determination of referential property and number of nouns in Japanese sentences for machine translation into English

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Abstract

When translating Japanese nouns into English, we face the problem of articles and numbers which the Japanese language does not have, but which are necessary for the English composition. To solve this difficult problem we classified the referential property and the number of nouns into three types respectively. This paper shows that the referential property and the number of nouns in a sentence can be estimated fairly reliably by the words in the sentence. Many rules for the estimation were written in forms similar to rewriting rules in expert systems. We obtained the correct recognition scores of 85.5% and 89.0% in the estimation of the referential property and the 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.

1 Introduction

One of the difficult problems in machine translation from Japanese to English or other European languages is the treatment of articles and numbers. There are referential pronominals in Japanese such as KONO, ANO, etc., but these are used only in particular occasions where references are to be indicated definitely. As to the number the Japanese language has no plural form for nouns and no distinction in verb conjugation to indicate the number of subject or object of a verb. In English there are definite and indefinite articles for nouns and also the distinction between singular and plural. Therefore the correspondence of articles and numbers for nouns in Japanese to English translation is a very difficult problem.

To solve this problem to a certain extent, we have to estimate the referential properties of nouns in a sentential utterance. It is commonly believed that the language understanding mechanism is necessary to solve this problem, and certain contextual or inter-sentential information is to be grasped. It is true, but it is difficult at the present level of natural language analysis technology.

We propose here that lots of keys exist in the surface information of a sentence to determine the referential property and the number of a noun in the sentence. For example, "KARE-WA(he) GAKUSEI(student) DESU(is)" indicates that KARE is a specific person(singular), and is linked by a copula to GAKUSEI, which is a countable noun. Therefore the property, singular, is inherited to GAKUSEI from KARE, and the translation is "He is a student". When the above example is changed as "KARE-WA(he)
KINOU(yesterday) ITTO(first) SHOU-O(prize) MORATTAgive) GAKUSEI(student) DESU(is)”,
where “student” is modified by an embedded sentence “he was given the first prize yesterday”, this indicates that “student” in this sentence is strictly specified, and is definite. Therefore the English expression to this Japanese expression is “He is the student who was given the first prize yesterday”.

This sort of judgement is not absolutely reliable but just probable. This means that what we have to do is to construct a kind of expert system by incorporating large number of heuristic rules with certain reliable factors. In the following we will describe what kind of heuristic rules we have written for the articulation of the referential property and the number of a noun in a Japanese sentence.

2 Categories of Referential Property and Number

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.

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

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.

\[\text{Dogs are useful.} \quad (1)\]

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.

\[\text{The dog went away.} \quad (2)\]

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.

\[\text{There are three dogs.} \quad (3)\]

2.2 Categories of Number

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

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

3 How to Determine Referential Property and Number

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

\[\text{(condition for rule application)} \Rightarrow \{ \text{indefinite(possibility, value)} \; \text{definite(possibility, value)} \; \text{generic(possibility, value)} \} \]

Heuristic rules for the number are given in the form:
In condition for rule application, a surface expression is written in the form like in Figure 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 value is 0 for possibility. 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. 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 4.1.

When determining the referential property and the 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

(condition for rule application)

⇒ { singular(possibility, value) plural(possibility, value) uncountable(possibility, value) }
A sentence (Figure 1(a)) is shown in Figure 1(b) which is represented as Figure 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. There are many other expressions such as regular expressions, AND-, OR-, NOT-operators, MODee-operator for checking modifyer-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 4.1(c)(d) for example). For each noun, the referential property is first determined, and then the number. This brings the utilization of referential property of a noun when analyzing the number of the noun (see 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 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 identical nouns before. This information is useful for the determination of the referential property.

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[2][3][4], but there are many other heuristic rules which we have originally introduced ourselves. Some of the rules are given below.

Figure 3: The result of analyzing the sentence in Figure 1

1 This is the result transformed by the system[1].
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) 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 has past tense,
then  {  indefinite (1, 0) 2    definite (1, 3)    generic (1, 1) }
Example: INU-WA (dog) MUKOE (away there) IKIMASHITA (went)
The dog went away.

3. When a noun is accompanied by a particle (WA), and the predicate has present tense,
then  {  indefinite (1, 0) 2    definite (1, 2)    generic (1, 3) }
Example: INU-WA YAKUNITATSU (useful) DOBUTSU (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) 2    definite (1, 2)    generic (1, 0) }
Example: KARE-O (he) KUUKOU-MADE (airport) MUKAE-NI (to meet) YUKIMASHOO (let us go)
Let us go to meet him at the airport.

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], "UCY UU (the universe)" [definite], etc., (ii) nouns mod-
ified 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) JOUYOUSHA (car)-
TO (and) TORAKKU-O (truck) ICHIDAI-ZUTU (by ones) MOTTEIMASUGA (have), JOUYOUSHA-
NIDAKE (car) [definite] HOKEN-O-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-O (ticket)
SIRABEMASU (check). (In Japan, the conductor checks the tickets of the passengers.),) (v) verbs,
"SUKI (like)“, "TANOSHIMU (enjoy)“, etc. (Example: WATASHI-WA (I) RINGO-GA (apple) [generic]
SUKI-DESU (like). (I like apples.)).

In the case of no clues, "definite" is given to a noun as a default value.

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 (We) KINOU (yesterday) TSUMITOTTA (picked) KUDAMONO-WA (fruit) AZI-GA (taste)
IIDESU (be good).

The fruit that we picked yesterday tastes delicious.

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

(i) When a noun is accompanied by WA, and the corresponding predicate has no past tense
(KUDAMONO-WA AZI-GA IIDESU),
then  { indefinite (1, 0) 2    definite (1, 2)    generic (1, 3) }

2 (a, b) means the possibility (a) and the value (b).

3 Both "a dog" and "the dog" are possible because of the generic subject.
(ii) When a noun is modified by an embedded sentence which has the past tense (TSUMITOTTA),
then \{ indefinite (1, 0) definite (1, 1) generic (1, 0) \}

(iii) 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) \}

(iv) 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) \}

(v) When a noun is modified by a phrase which has a pronoun (WAREWARE-GA),
then \{ indefinite (1, 0) definite (1, 1) generic (1, 0) \}

(vi) When a noun has an adjective as its predicate (KUDAMONO-WA AZI-GA IIDESU).
then \{ indefinite (1, 0) definite (1, 3) generic (1, 4) \}

(vii) 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.

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-O (book) KUDASAI (give me)
Give me that book.

2. When a noun is accompanied by a particle WA, GA, MO, O, 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-O (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 O(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) ISSATSUNO(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-O(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 ...) SIMESEMASU(give). (I can give you a number
of reasons.)).

In the case of no clues, "singular" is given as a default value.
5 Experiments and Results

Experiments of the determination of the referential property and the number were done for the following three texts: typical example sentences in a grammar book "Usage of the English Articles" [2], the complete text of a Japanese popular folktale "The Old Man with a Wen" [5], a small fragment of an essay "TENSEI JINGO". The rules were written by referring to these sentences which have good established English translations. These sentences can be regarded as a training set. The results of the experiments are shown in Table 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, and so on. "Partially correct" means that the result was included in the correct answer. "Undecidable" means that we could not judge which category is correct by our linguistic intuitions. We obtained 85.5% success rate for the determination of the referential properties and 89.0% success rate for the numbers for all these learning samples. The scores of these tables show that the heuristic rules are well adjusted to these sentences, and are effective.

To testify the goodness of the rules we applied these heuristic rules to the following three other texts: a Japanese popular folktale "TURU NO ONGAESHI" [5], 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, No.2 Spring 1992). These test samples have good English translations. We used them to check the correctness of the results. The results are shown in Table 2. The success rates for the referential property and the number decreased down to 68.9% and 85.6% respectively by these test samples. These scores show, however, that the rules are still effective.

The success ratio will decrease greatly for the text areas which handle abstract notions such as philosophy and politics. We may have to change and increase heuristic rules for these text areas. At this moment we cannot say anything about whether we can write proper heuristic rules for such complex situations where delicate abstract notions are handled and the denotation is ambiguous.

As a conclusion we can say the following, There are of course many expressions and situations where inter-sentential information is necessary, but without utilizing it we can achieve a proper guess about the referential property and the number to a certain extent. By incorporating this mechanism into a machine translation system from Japanese into English we will be able to obtain better translation quality.

References

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### Table 1: Learning sample

| Referential property | Number | Usage of the English Articles (140 sentences, 380 nouns) | 
|----------------------|--------|--------------------------------------------------------|
| value                | indef  | def | gen | other | total | singl | plural | uncount | other | total |
| correct              | 96     | 184 | 58  | 1     | 339   | 274   | 32     | 18      | 25    | 349   |
| reasonable           | 0      | 3   | 1   | 0     | 4     | 1     | 1      | 1       | 0     | 3     |
| partially correct    | 0      | 0   | 0   | 0     | 0     | 0     | 0      | 0       | 11    | 11    |
| incorrect            | 4      | 25  | 7   | 1     | 37    | 3     | 10     | 0       | 4     | 17    |
| % of correct         | 96.0   | 86.0| 87.9| 50.0  | 89.2  | 98.6  | 74.4   | 94.7    | 62.5  | 91.8  |

The Old Man with a Wen (104 sentences, 267 nouns)

| Referential property | Number | an essay “TENSEI JINGO” (23 sentences, 98 nouns) |
|----------------------|--------|--------------------------------------------------|
| value                | indef  | def | gen | other | total | singl | plural | uncount | other | total |
| correct              | 73     | 140 | 6   | 1     | 222   | 205   | 24     | 3       | 0     | 234   |
| reasonable           | 3      | 4   | 0   | 0     | 7     | 2     | 0      | 0       | 0     | 2     |
| partially correct    | 0      | 0   | 0   | 0     | 0     | 0     | 0      | 0       | 7     | 7     |
| incorrect            | 11     | 23  | 4   | 0     | 38    | 1     | 22     | 1       | 0     | 24    |
| % of correct         | 83.9   | 84.0| 60.0| 100.0 | 83.2  | 98.7  | 52.2   | 83.3    | 0.0   | 87.6  |

### Table 2: Test sample

| Referential property | Number | a folktale “TURU NO ONGAESHÍ” (263 sentences, 699 nouns) |
|----------------------|--------|-----------------------------------------------------------|
| value                | indef  | def | gen | other | total | singl | plural | uncount | other | total |
| correct              | 109    | 363 | 13  | 10    | 495   | 610   | 13     | 1       | 1     | 625   |
| reasonable           | 6      | 25  | 0   | 0     | 31    | 12    | 2      | 0       | 0     | 14    |
| partially correct    | 0      | 0   | 0   | 0     | 0     | 0     | 0      | 0       | 1     | 1     |
| incorrect            | 32     | 135 | 6   | 0     | 273   | 2     | 20     | 37      | 0     | 59    |
| % of correct         | 74.2   | 69.4| 68.4| 100.0 | 70.8  | 97.8  | 37.4   | 26      | 50.0  | 89.4  |

| Referential property | Number | an essay “TENSEI JINGO” (75 sentences, 283 nouns) |
|----------------------|--------|--------------------------------------------------|
| value                | indef  | def | gen | other | total | singl | plural | uncount | other | total |
| correct              | 75     | 81  | 15  | 0     | 172   | 197   | 13     | 2       | 3     | 215   |
| reasonable           | 8      | 9   | 1   | 0     | 18    | 3     | 1      | 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| 100.0 | 60.8  | 97.0  | 18.8   | 40.0    | 50.0  | 76.0  |

Pacific Asia in the Post-Cold War World (22 sentences, 192 nouns)

| Referential property | Number | correct | reason | partially correct | incorrect |
|----------------------|--------|---------|--------|-------------------|-----------|
| value                | indef  | def | gen | other | total | singl | plural | uncount | other | total |
| correct              | 21     | 108 | 12  | 2     | 142   | 157   | 6      | 1       | 1     | 165   |
| reasonable           | 6      | 7   | 0   | 0     | 13    | 3     | 0      | 0       | 0     | 3     |
| partially correct    | 0      | 0   | 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 | % of correct |
|-----------------|--------------|
| 25.6            | 68.1         |

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