

HOW TO DEAL WITH AMBIGUITIES WHILE PARSING: EXAM ---  
A SEMANTIC PROCESSING SYSTEM FOR JAPANESE LANGUAGE

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It is difficult for a natural language understanding system (NLUS) to deal with ambiguities. There is a dilemma: an NLUS must be able to produce plausible interpretations for given sentences, avoiding the combinatorial explosion of possible interpretations. Furthermore, it is desirable for an NLUS to produce several interpretations if they are equally plausible. EXAM, the system described in this paper, is an experimental text understanding system designed to deal with ambiguities effectively and efficiently.

## 1. INTRODUCTION

What is ambiguity? The term 'ambiguity' usually refers to the property that certain sentences may be interpreted in more than one way and that insufficient clues are available for the intended or optimal interpretation.<sup>5</sup>

The decision as to whether or not there are ambiguities in a given sentence is difficult; some systems with little knowledge may overlook the possibility of alternative interpretations in some sentences, and other systems may be puzzled as to which interpretation to choose even when there is only one plausible interpretation for human beings.

In general, the more knowledge a system has, the greater are its possibilities of interpretation. One solution is to generate all possible interpretations and ask the user to choose one of them. But this is obviously absurd. Another solution is as follows: in the parsing process, the system chooses one interpretation and if that one fails, looks for another, and in the semantic process it produces all plausible interpretations on the basis of certain criteria<sup>10</sup>.

A different approach is adopted in EXAM. The reasons for this are as follows:

- 1) In the processing of the Japanese language, it is undesirable to separate the parsing and the semantic process, since noun phrases, especially the subject are often omitted. Thus, we cannot parse Japanese sentences efficiently without using semantic information.
- 2) It is undesirable to ask the user to choose from among several interpretations whenever ambiguities occur in text understanding systems.

3) We may overlook the possibility of other interpretations if we adopt the strategy of making semantic interpretations after parsing, since such a strategy might exclude what turns out to be the proper interpretation when making a choice among several grammatically ambiguous alternatives. It would be awkward if there is another interpretation and we realize that it is the appropriate one only after having processed several sentences.

EXAM is an experimental text understanding system designed to deal with ambiguities effectively and efficiently. EXAM consists of three components: hierarchical knowledge sources, a semantic interpreter and a fundamentally breadth-first augmented context-free parser. The second version of EXAM is under development on the HLISP system using the HITAC 8700/8800 at the University of Tokyo.

## 2. CLASSIFICATION OF AMBIGUITIES

In this chapter, the ambiguities with which we are concerned are classified into three types: levels of word meaning, levels of grammar and levels of discourse. Examples are given for each of these types. We point out that these are among the ambiguities that an NLUS must deal with.

### 2.1 Levels of word meaning

There are many words in the Japanese language which are phonologically similar but correspond to different lexical entries in a dictionary. For example, *sisei* corresponds to 17 entries in a standard Japanese dictionary<sup>8</sup>. This is known as *homonymy* and should be distinguished from *polysemy*.

The referents of pronouns are often ambiguous. We call this ambiguity *referential ambiguity*. In Japanese, nouns are often used coreferentially, and so there may arise the problem of whether some noun is being used in the generic or in the specific sense. We also call this referential ambiguity.

## 2.2 Levels of grammar

Consider the following sentence.

- (1) *Taroo wa Ziroo ni wasato nagura-se-ta.*  
'Taroo made Ziroo beat him purposely.'

This sentence is ambiguous, because there are two possible interpretations, namely, *Taroo ga wasato nagura-se-ta* 'Taroo purposely made...' and *Ziroo ga wasato nagut-ta* 'Ziroo purposely beat.' This is called *grammatical ambiguity*, that is, (1) has two different parsing trees (or superficial syntactic structures), as follows:

- (1-a) [*Taroo ga Ziroo ni [(Ziroo ga)(Taroo o) wasato nagura]<sub>S</sub> se-ta]<sub>S</sub>  
(1-b) [*Taroo ga Ziroo ni wasato [(Ziroo ga)(Taroo o) nagura]<sub>S</sub> se-ta]<sub>S</sub>**

The ambiguity of coordinated noun phrases such as *wakai otoko to onna* 'young men and women' is also included in the grammatical ambiguity category.

The interpretation of the scope of negatives such as (2) also constitutes a problem.

- (2) *Taroo wa Ziroo no youni rikoude nai.*

This sentence is ambiguous, having the following three readings:

- (2-a) Taroo, like Ziroo, is not clever.  
(2-b) Taroo is not as clever as Ziroo.  
(2-c) Ziroo is clever, but Taroo is not.

In Japanese, these three readings have the same superficial syntactic structure, but allow three different semantic analyses, according to the rule of interpretation used. We call this *interpretative ambiguity*.

## 2.3 Levels of discourse

The role of a sentence in discourse is often ambiguous. Consider the following sentence.

- (3) *Onaka ga sui-ta.*  
'I am hungry.'

This is merely an assertion, with no special implied meaning when used without any particular context. But if we have a certain context, for example, if Taroo and Ziroo were walking along the street at noon, and Ziroo uttered sentence (3) in front of a restaurant, then (3) might have a different meaning, that is, "let's have lunch." (In this case, one says that (3) has illocutionary force.) Consider another example:

- (4) *Taroo wa miti de koron-da. Banana no kawa ga soko ni at-ta.*  
'Taroo slipped and fell on the street. There was a banana skin there.'

It is difficult to interpret the second sentence

with assurance. We can interpret it as stating the cause of the event described by the first sentence, and also as stating a result of this event, that is, Taroo found the banana skin as a result of falling down in the street. We call this *cohesion ambiguity*.

## 2.4 Sense and meaning

In this paper, we distinguish 'sense' from 'meaning.' "Meaning" refers to the interpretation of linguistic expression, taking the context into account. "Sense" means, on the contrary, the interpretation of the expression in the absence of context. In other words, "sense" is literal meaning. In this account a variety of ambiguities, such as homonymy and grammatical ambiguity, are regarded as ambiguities in sense. Other ambiguities, such as referential ambiguity and cohesion ambiguity are those in meaning.

In EXAM, we adopt the strategy of first determining the sense of linguistic expression, and then the meaning. Therefore, the transformation of sense representation into meaning representation is carried out after disambiguating the "sense" ambiguity.

## 3. HOW TO DEAL WITH AMBIGUITIES IN PARSING

EXAM incorporates three sources of knowledge: frame memory, text memory and working memory. The frame memory holds prototype frames, script frames and other useful information such as metaknowledge. The text memory holds three components: the context, which is the so-called frame system connecting the frames produced by the semantic interpreter; the frame representing the sense of the last sentence (which constitutes the data for ellipsis), and the speaker's current view point. The working memory stores various interpretations of the sentence being processed during parsing.

In parsing process, EXAM translates linguistic expression into frames which represent their structure, such as word order. The transformation of sense representation into meaning representation is not necessarily carried out during the parsing process but may be done if required. Constructing the sense representation from the expression depends upon the knowledge contained in the frame memory. EXAM also takes the knowledge contained in the text memory into consideration when transforming sense representations into meaning representations and selecting the plausible interpretations.

The parsing process in EXAM is carried out by a parser called MELING and the knowledge representation language. In this chapter, we shall describe these and explain how EXAM deals with ambiguities.

### 3.1 MELING --- a parser

MELING stands for Modified Extended LINGol, which is slightly different from Extended LINGOL<sup>9</sup>. It is basically an augmented context-free parser using a bottom-up and top-down parsing algorithm



ing their prototype slots into semantic slots. In addition to this, several slots are added and removed. In instantiating units, the check-to-fill is evaluated when a candidate for the filler of the slot is provided, and returns either NIL or a number as the result. If the result is NIL, then the candidate is abandoned. Otherwise, the result, that is, a number, indicates the candidate's fitness and then the transformation from prototype slot into semantic slot is carried out. After this is completed, the when-filled is evaluated. The when-filled may consist of any kind of programs.

GIRL has another type of slot which specifies the definitions of the units and the global requirements applicable to the unit as a whole. However, we shall not describe it here.

### 3.3 Ambiguities and interpretation

As we have seen, the semantic processing is dependent upon the parsing tree. In more concrete terms, the interpretations, that is, frames, of a certain phrase consist of the interpretations of its syntactic constituents. In case the form of a grammatical rule is  $A \rightarrow B C$ , the frames of the constituents B and C form the arguments for the <cog> of the grammatical rule, and then the semantic interpreter produces the interpretations of the phrase A. In this manner, the semantic processing is carried out in a bottom-up and left-to-right fashion.

Here we have a problem: since MELING is a basically breadth-first parser, the number of interpretations which are senseless to human beings becomes very large as the length of the sentences increases, and the parser operates inefficiently. (In fact, the time required for the older version of MELING to process a sentence of length  $n$  is generally proportional to  $n^2$  and sometimes  $n^3$ .)

However, EXAM does not produce all combinations of possible interpretations. The semantic interpreter is evoked in two cases (see 3.1): in the first case, it determines the sense representation and eliminates some interpretations; in the second case, EXAM attempts to produce the meaning representation and also produces certain "anticipations".

In the first semantic interpretation, the traditional and most powerful tool is so-called semantic marker. EXAM implements this tool using the generalization hierarchy. For some "cases", such as locative and time, the semantic marker functions as the selection restrictions. However, for other "cases" it does not, and in such cases, it is regarded as an indicator of the "likelihood" of various interpretations. Furthermore, the Japanese language has many homonyms which have the same categories, especially nouns. We group such homonyms into several special frames whose category is "GROUP" in accordance with their semantic category. If there is sufficient information to determine the sense of the semantic interpretation, the "GROUP" frames are re-

placed by the frames corresponding to the appropriate sense.

The "case ordering" is also an indicator of "likelihood". Inoue<sup>4</sup> points out that in Japanese, there is a certain ordering of cases in thematization and relativization, such as:

subject>object>dativ>locative>goal>source...

We have adopted this notion and have applied it to the disambiguation of certain grammatical ambiguities. For example, consider the following phrase:

*Taroo no kenkyuu*

In the absence of any particular context, the system is more likely to interpret this phrase as *Taroo ga suru/sita kenkyuu* 'the research carried out by Taroo' than *Taroo ni tuite no kenkyuu* 'research concerning Taroo'.

These devices are very effective in dealing with homonymy, polysemy and grammatical ambiguity. EXAM chooses the most plausible interpretations depending upon their "likelihoods". If there are several interpretations whose "likelihoods" are equally great, then EXAM retains all of them. That is, "likelihood" is used to indicate the order of preference of interpretations.

In the semantic interpretation, if the "PROTO" frames are instantiated with some slot filler, then the category "PROTO" is replaced by the category "INSTANT". The distinction between these categories, that is, "PROTO" and "INSTANT", is important. For example, *akai iro no kuruma* 'a red car' and *sonna iro no kuruma* 'a car with such a color' are well-formed expressions, but *iro no kuruma* 'a car with color' is rather ill-formed. We explain this phenomenon as follows: the frame with the "INSTANT" category is, as it were, a specified frame, and is therefore preferred to "PROTO" frames in the modification of other frames. This distinction is also used as an indicator of "likelihood".

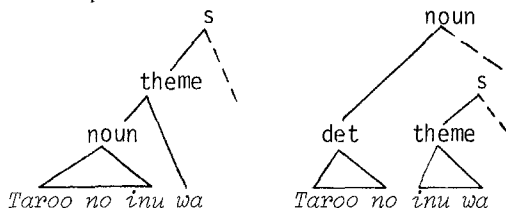
[We must note that the frames with categories such as "PROTO", "INSTANT" and "GROUP" are merely temporary in the working memory, and these categories are replaced by appropriate ones such as "CLASS" (which means generic), "INDIVIDUAL" (which means specific object) or "SOME" (which means indefinite object) in the meaning interpretation process.]

In the second semantic interpretation, dealing with referential ambiguity constitutes the most important phase of the process. Usually, candidates for the referent are not uniquely determined in the local context where the ambiguity occurs. Therefore, EXAM delays the disambiguation until after the entire sentence has been processed. EXAM collects the requirements of the referent from the interpretation of the complete sentence. In particular, some predicates such as *hosii* 'want' produce opaque contexts, and in such cases the category determination<sup>11</sup> should be carried out after processing the entire sentence.

Another task involved in the second interpretation is the elimination of unnecessary parsed trees. For example, consider the following sentence:

- (5) *Taroo no inu wa korii da.*  
'Taroo's dog is a collie.'

When MELING has processed the sentence (5) up through the word *wa*, it produces the following partial parsed trees:



In this case, only the first is plausible, and the second is unnecessary. (In fact, the second partial parsed tree is plausible only when the sentence is of a form such as: *Taroo no, inu wa* ...) Therefore, EXAM eliminates unnecessary parsing trees in accordance with the result of the semantic interpretation, that is, "likelihood". This method makes the parsing process more efficient, but involves some risk of misinterpretation. Hence, the elimination of parsing trees is carried out on the basis of certain linguistic evidence<sup>7</sup>, and the number of the parsed trees which are retained may sometimes be greater than one.

The other task is to produce "anticipations" in the second semantic interpretation. Consider the following sentence:

- (6) *Taroo wa terebi o mi-nagara benkyousi-ta.*  
'Taroo studied while watching television.'

When EXAM observes *nagara*, it anticipates that the agent of *mi(ru)* 'watch' will be coreferential with the agent of the verb of the matrix sentence, that is, in this example, *benkyousi* 'study'. In this manner, "anticipations" also serve to produce plausible interpretations and eliminate some ambiguities.

As for ambiguities in meaning, EXAM does not deal with these in an entirely conclusive manner. However, we should note that "cohesion relations"<sup>3</sup> play an important role in disambiguation. Dealing with ambiguities in meaning requires comprehension of the structure of the text and the determination of the topic. The structure of the text is determined by the cohesion relations. First, EXAM attempts to recognize how sentences are related. In particular, conjunctions and sentences which are provided to support the reader's comprehension are employed in the recognition of these relations. If EXAM succeeds in recognizing these relations, then the inference mechanism attempts to explain why these sentences are related. In this manner, EXAM deals with ellipsis and properly disambiguates some sentences. For example,

- (7) *Kaeru wa hiatari no yoi mizu no naka ni tamago o umi-masu. Atatakai tokoro no hou ga*

*yoku sodatu kara desu.*

'Frogs lay their eggs in water which is well exposed to sunshine. Because they grow well in warm places.'

The second sentence is related to the first by the "explanation relation" and this is indicated by *kara* 'because'. Then EXAM attempts to clarify the question of why the second sentence constitutes an explanation of the first. In this case, *mizu no naka* 'in water' and *tokoro* 'place' correspond to one another, and EXAM discovers the omitted element (*kaeru ga un-da*) *tamago* 'eggs (which are layed by frogs)'

#### 4. DEALING WITH AMBIGUITIES AFTER PARSING

So far, we have discussed the question of dealing with ambiguities while parsing. However, ambiguities may still remain! Furthermore, in some sentences, such as the headings of news articles, we often find ambiguities which we cannot eliminate for lack of a preceding context. How can we deal with such situations? In this section, we describe some strategies which are still under development now.

In such cases, we must delay the disambiguation and provide some mechanism for selecting the appropriate interpretation when sufficient information has been supplied. One solution is to introduce a kind of Truth Maintenance System<sup>2</sup>. For example, consider the following sentence:

- (8) Every man loves a woman.

As is well known, sentence (8) has two interpretations. These interpretations are stated in the first order predicate calculus as follows:

- (8-a)  $\forall x[\text{man}(x) \rightarrow \exists y[\text{woman}(y) \wedge \text{love}(x,y)]]$   
(8-b)  $\exists y[\text{woman}(y) \wedge \forall x[\text{man}(x) \rightarrow \text{love}(x,y)]]$

This sentence should not be regarded as meaningless, even if we have no context and hence can not disambiguate it. Since we can deduce (8-a) from (8-b), we surely have at least the information described in (8-a). Hence, we enter (8-a) into the text memory as a "premise" and (8-b) as a "hypothesis". If some information contradicting (8-b) exists, the Truth Maintenance System will delete (8-b) from the text memory.

Here, we adopt the following standpoint: if the disambiguation is essential for the understanding of the text, the text (or the writer) will certainly provide clues adequate to disambiguate the sentence, and if this is not the case, the system may adopt any interpretation consistent with the context.

In fact, sentences which follow ambiguous ones are often paraphrases of or explanations for them. For example,

- (9) John says that everyone loves a woman. Whom does John think everyone loves?

The first sentence of (9) is ambiguous, but we can disambiguate it by means of the second. Thus, we had better delay the interpretation of ambiguous sentences after having processed

several subsequent sentences.

#### 5. CONCLUSION

We have discussed the procedures by which EXAM deals with ambiguities. This constitutes a difficult task for an NLUS and the trivial method of asking the user to choose one of several possible interpretations has been adopted.

In dealing with ambiguities, EXAM avoids the combinatorial explosion of possible interpretations by means of several devices. We classify ambiguities into two categories, that is, ambiguity in sense and ambiguity in meaning. EXAM adopts the strategy of first processing sense representations, and secondly meaning representations; the parsing process is carried out in an essentially breadth-first manner.

However, EXAM does not completely clarify ambiguities in meaning, especially ambiguities which are not resolved by the preceding context. This constitutes a problem which still awaits solution.

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