Analysis Grammar of Japanese in the Mu-Project

- A Procedural Approach to Analysis Grammar -

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Abstract

Analysis grammar of Japanese in the Mu-project is presented. It is emphasized that rules expressing constraints on single linguistic structures and rules for selecting the most preferable readings are completely different in nature, and that rules for selecting preferale readings should be utilized in analysis grammars of practical MT systems. It is also claimed that procedural control is essential in integrating such rules into a unified grammar. Some sample rules are given to make the points of discussion clear and concrete.

1. Introduction

The Mu-Project is a Japanese national project supported by grants from the Special Coordination Funds for Promoting Science & Technology of STA(Science and Technology Agency), which aims to develop Japanese-English and English-Japanese machine translation systems. We currently restrict the domain of translation to abstracts of scientific and technological papers. The systems are based on the transfer approach[1], and consist of three phases: analysis, transfer and generation. In this paper, we focus on the analysis grammar of Japanese in the Japanese-English system. The grammar has been developed by using GRADE which is a programming language specially designed for this project[2]. The grammar now consists of about 900 GRADE rules. The experiments so far show that the grammar works very well and is comprehensive enough to treat various linguistic phenomena in abstracts. In this paper we will discuss some of the basic design principles of the grammar together with its detailed construction. Some examples of grammar rules and analysis results will be shown to make the points of our discussion clear and concrete.

2. Procedural Grammar

There has been a prominent tendency in recent computational linguistics to re-evaluate CFG and use it directly or augment it to analyze sentences[3,4,5]. In these systems(frameworks), CFG rules independently describe constraints on single linguistic structures, and a universal rule application mechanism automatically produces a set of possible structures which satisfy the given constraints. It is well-known, however, that such sets of possible structures often become unmanageably large.

Because two separate rules such as

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NP -----> NP PREP-P
VP -----> VP PREP-P
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are usually prepared in CFG grammars in order to analyze noun and verb phrases modified by prepositional phrases, CFG grammars provide two syntactic analyses for

She was given flowers by her uncle.

Furthermore, the ambiguity of the sentence is doubled by the lexical ambiguity of "by", which can be read as either a locative or an agentive preposition. Since the two syntactic structures are recognized by completely independent rules and the semantic interpretations of "by" are given by independent processes in the later stages,it is difficult to compare these four readings during the analysis to give a preference to one of these four readings.

A rule such as

"If a sentence is passive and there is a "by"-prepositional phrase, it is often the case that the prepositional phrase fills the deep agentive case. (try this analysis first)"

seems reasonable and quite useful for choosing the most preferable interpretation, but it cannot be expressed by refining the ordinary CFG rules. This kind of rule is quite different in nature from a CFG rule. It is not a rule of constraint on a single linguistic structure(in fact, the above four readings are all linguistically possible), but it is a "heuristic" rule concerned with preference of readings, which compares several alternative analysis paths and chooses the most feasible one. Human translaters (or humans in general) have many such preference rules based on various sorts of cue such as morphological forms of words, collocations of words, text styles, word semantics, etc. These heuristic rules are quite useful not only for increasing efficiency but also for preventing proliferation of analysis results. As Wilks[6] pointed out, we cannot use semantic information as constraints on single linguistic structures, but just as preference cues to choose the most feasible interpretations among linguistically possible interpretations. We claim that many sorts of preference cues other than semantic ones exist in real texts which cannot be captured by CFG rules. We will show in this paper that, by utilizing various sorts of preference cues, our analysis grammar of Japanese can work almost deterministically to give the most preferable interpretation as the first output, without any extensive semantic processing (note that even "semantic" processing cannot disambiguate the above sentence. The four readings are semantically possible. It requires deep understanding of contexts or situations, which we cannot expect in a practical MT system).

In order to integrate heuristic rules based on various levels of cues into a unified analysis grammar, we have developed a programming langauage, GRADE. GRADE provides us with the following facilities.

- Explicit Control of Rule Applications : Heuristic rules can be ordered according to their strength(See 4-2).

- Multiple Relation Representation : Various levels of information including morphological, syntactic, semantic, logical etc. are expressed in a single annotated tree and can be manipulated at any time during the analysis. This is required not only because many heuristic rules are based on heterogeneous levels of cues, but also because the analysis grammar should perform semantic/logical interpretation of sentences at the same time and the rules for these phases should be written in the same framework as syntactic analysis rules (See 4-2, 4-4).

- Lexicon Driven Processing : We can write heuristic rules specific to a single or a limited number of words such as rules concerned with collocations among words. These rules are strong in the sense that they almost always succeed. They are stored in the lexicon and invoked at appropriate times during the analysis without decreasing efficiency (See 4-1).

- Explicit Definition of Analysis Strategies : The whole analysis phase can be divided into steps. This makes the whole grammar efficient, natural and easy to read. Furthermore, strategic consideration plays an essential role in preventing undesirable interpretations from being generated (See 4-3).

3 Organization of Grammar

In this section, we will give the organization of the grammar necessary for understanding the discussion in the following sections. The main components of the grammar are as follows.

(1) Post-Morphological Analysis
(2) Determination of Scopes
(3) Analysis of Simple Noun Phrases
(4) Analysis of Simple Sentences
(5) Analysis of Embedded Sentences (Relative Clauses)
(6) Analysis of Relationships of Sentences
(7) Analysis of Outer Cases
(8) Contextual Processing (Processing of Omitted case elements, Interpretation of 'Ha' , etc.)
(9) Reduction of Structures for Transfer Phase

Each component consists of from 60 to 120 GRADE rules.

47 morpho-syntactic categories are provided for Japanese analysis, each of which has its own lexical description format. 12,000 lexical entries have already been prepared according to the formats. In this classification, Japanese nouns are categorized into 8 sub-classes according to their morpho-syntactic behaviour, and 53 semantic markers are used to characterize their semantic behaviour. Each verb has a set of case frame descriptions (CFD) which correspond to different usages of the verb. A CFD gives mapping rules between surface case markers (SCM - postpositional case particles are used as SCM's in Japanese) and their deep case interpretations (DCI - 33 deep cases are used). DCI of an SCM often depends on verbs so that the mapping rules are given to CFD's of individual verbs. A CFD also gives a normal collocation between the verb and SCM's(postpositonal case particles). Detailed lexical descriptions are given and discussed in another paper[7].

The analysis results are dependency trees which show the semantic relationships among input words.

4. Typical Steps of Analysis Grammar

In the following, we will take some sample rules to illustrate our points of discussion.

4-1 Relative Clauses

Relative clause constructions in Japanese express several different relationships between modifying clauses (relative clauses) and their antecedents. Some relative clause constructions cannot be translated as relative clauses in English. We classified Japanese relative clauses into the following four types, according to the relationships between clauses and their antecedents.

(1) Type 1 : Gaps in Cases

One of the case elements of the relative clause is deleted and the antecedent fills the gap.

(2) Type 2 : Gaps in Case Elements

The antecedent modifies a case element in the clause. That is, a gap exists in a noun phrase in the clause.

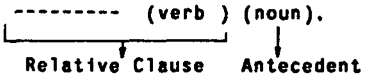
(3) Type 3 : Apposition

The clause describes the content of the antecedent as the English "that"-clause in 'the idea that the earth is round'.

(4) Type 4 : Partial Apposition

The antecedent and the clause are related by certain semantic/pragmatic relationships. The relative clause of this type doesn't have any gaps. This type cannot be translated directly into English relative clauses. We have to interpolate in English appropriate phrases or clauses which are implicit in Japanese, in order to express the semantic/pragmatic relationships between the antecedents and relative clauses explicitly. In other words, gaps exist in the interpolated phrases or clauses.

Because the above four types of relative clauses have the same surface forms in Japanese

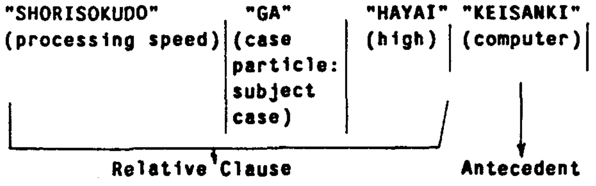


careful processing is required to distinguish them (note that the 'antecedents' -modified nouns- are located after the relative clauses in Japanese). A sophisticated analysis procedure has already been developed, which fully utilizes various levels of heuristic cues as follows.

(Rule 1) There are a limited number of nouns which are often used as antecedents of Type 3 clauses.

(Rule 2) When nouns with certain semantic markers appear in the relative clauses and those nouns are followed by one of specific postpositional case particles, there is a high possibility that the relative clauses are Type 2. In the following example, the word "SHORISOKUDO"(processing speed) has the semantic marker AO (attribute).

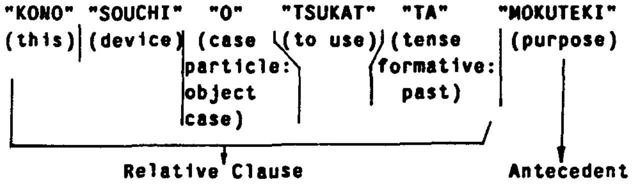
[ex-1] [Type 2]



-->(English Translation)
A computer whose processing speed is high

(Rule 3) Nouns such as "MOKUTEKI"(purpose), "GEN_IN"(reason), "SHUDAN"(method) etc. express deep case relationships by themselves, and, when these nouns appear as antecedents, it is often the case that they fill the gaps of the corresponding deep cases in the relative clauses.

[ex-2] [Type 1]

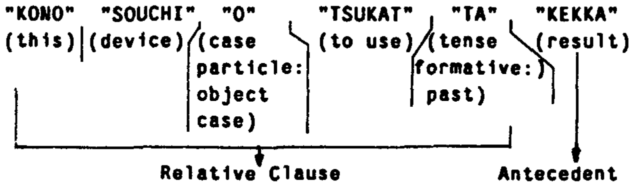


--> (English Translation)

The purpose for which (someone) used this device
The purpose of using this device

(Rule 4) There is a limited number of nouns which are often used as antecedents in Type 4 relative clauses. Each of such nouns requires a specific phrase or clause to be interpolated in English.

[ex-3] [Type 4]



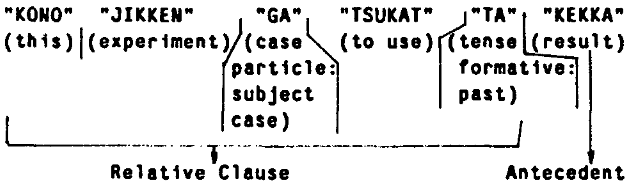
--> (English Translation)

The result which was obtained by using this device

In the above example, the clause "the result which someone obtained (the result : gap)" is ommited in Japanese, which relates the antecedent "KEKKA"(result) and the relative clause "KONO SOUCHI O TSUKAT_TA"(someone used this device).

A set of lexical rules is defined for "KEKKA"(result), which basically works as follows : it examines first whether the deep object case has already been filled by a noun phrase in the relative clause. If so, the relative clause is taken as type 4 and an appropriate phrase is interpolated as in [ex-3]. If not, the relative clause is taken as type 1 as in the following example where the noun "KEKKA" (result) fills the gap of object case in the relative clause.

[ex-4] [Type 1]



-->(English Translation)

The result which this experiment used

Such lexical rules are invoked at the beginning of the relative clause analysis by a rule in the main flow of processing. The noun "KEKKA" (result) is given a mark as a lexical property which indicates the noun has special rules to be invoked when it appears as an antecedent of a relative clause. All the nouns which require special treatments in the relative clause analysis are given the same marker. The rule in the main flow only checks this mark and invokes the lexical rules defined in the lexicon.

(Rule 5) Only the cases marked by postpositional case particles 'GA', 'WO' and 'NI' can be deleted in Type 1 relative clauses, when the antecedents are ordinary nouns. Gaps in Type 1 relative clauses can have other surface case marks, only when the antecedents are special nouns such as described in Rule (3).

4-2 Conjuncted Noun Phrases

Conjuncted noun phrases often appear in abstracts of scientific and technological papers. It is important to analyze them correctly, especially to determine scopes of conjunctions correctly, because they often lead to proliferation of analysis results. The particle "TO" plays almost the same role as the English "and" to conjunct noun phrases. There are several heuristic rules based on various levels of information to determine the scopes.

<Scope Decision Rules of Conjuncted Noun Phrases by Particle 'TO'>

(Rule 1) Since particle "TO" is also used as a case particle, if it appears in the position:

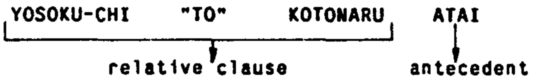
Noun 'TO' verb Noun,
Noun 'TO' adjective Noun,

there are two possible interpretations, one in which "TO" is a case particle and 'noun TO adjective(verb)' forms a relative clause that modifies the second noun, and the other one in which "TO" is a conjunctive particle to form a conjuncted noun phrase. However, it is very likely that the particle 'TO' is not a conjunctive particle but a post-positional case particle, if the adjective (verb) is one of adjectives (verbs) which require case elements with surface case mark 'TO' and there are no extra words between "TO" and the adjective (verb). In the following example, "KOTONARU(to be different)" is an adjective which is often collocated with a noun phrase followed by case particle "TO".

[ex-5]

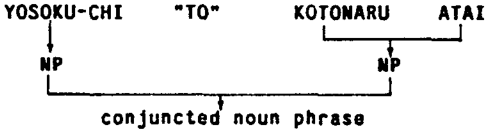
YOSOKU-CHI	"TO"	KOTONARU	ATAI
(predicted value)		(to be different)	(value)

[dominant interpretation]



= the value which is different from the predicted value

[less dominant interpretation]



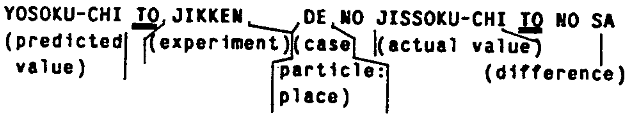
= the predicted value and the different value

(Rule 2) If two 'TO' particles appear in the position:

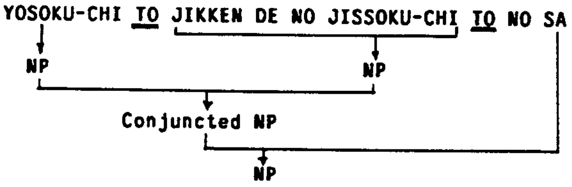
Noun-1 'TO' .... Noun-2 'TO' 'NO' NOUN-3

the right boundary of the scope of the conjuction is almost always Noun-2. The second 'TO' plays a role of a delimiter which delimits the right boundary of the conjunction. This 'TO' is optional, but in real texts one often places it to make the scope unambiguous, especially when the second conjunct is a long noun phrase and the scope is highly ambiguous without it. Because the second 'TO' can be interpreted as a case particle (not as a delimiter of the conjunction) and 'NO' following a case particle turns the preceding phrase to a modifier of a noun, an interpretation in which "NOUN-2 TO NO" is taken as a modifier of NOUN-3 and NOUN-3 is taken as the head noun of the second conjunt is also linguistically possible. However, in most cases, when two 'TO' particles appear in the above position, the second 'TO' is just a delimiter of the scope(see [ex-6]).

[ex-6]



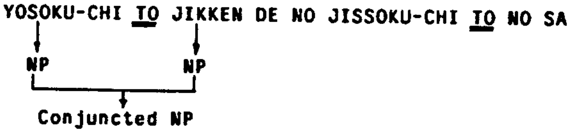
[dominant interpretation]



- the difference between the predicted value and the actual value in the experiment

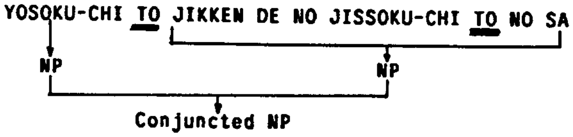
[less dominant interpretations]

(A)



- the difference with the actual value in the predicted value and the experiment

(B)



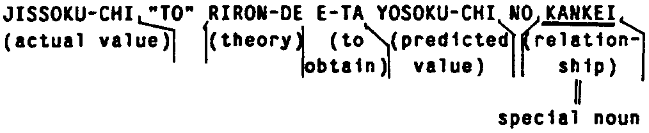
- the predicted value and the difference with the actual value in the experiment

(Rule 3) If a special noun which is often collocated with conjunctive noun phrases appear in the position:

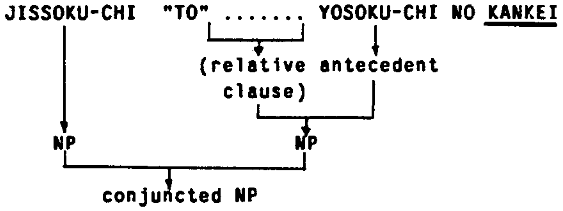
Noun-1 'TO' .... Noun-2 'NO'<special-noun>,

the right boundary of the conjunction is almost always Noun-2. Such special nouns are marked in the lexicon. In the following example, "KANKEI" is such a special noun.

[ex-7]



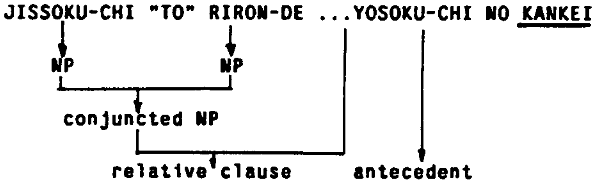
[dominant interpretation]



- the relationship between the actual value and the predicted value obtained by the theory

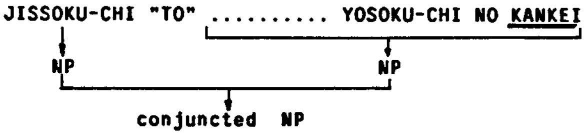
[less dominant interpretations]

(A)



- the relationship of the predicted value which was obtained by the actual value and the theory

(B)



- the actual value and the relationship of the predicted value which was obtained by the theory

(Rule 4) In

Noun-1 'TO' Noun-2,

if Noun-1 and Noun-2 are the same nouns, the right boundary of the conjunction is almost always Noun-2.

(Rule 5) In

Noun-1 'TO' Noun-2,

if Noun-1 and Noun-2 are not exactly the same but nouns with the same morphemes, the right boundary is often Noun-2. In [ex-7] above, both of the head nouns of the conjuncts, JISSOKU-CHI(actual value) and YOSOKU-CHI(predicted value), have the same morpheme "CHI" (which meams "value"). Thus, this rule can correctly determine the scope, even if the special word "KANKEI"(relationship) does not exist.

(Rule 6) If some special words (like 'SONO' 'SORE-NO' etc. which roughly correspond to 'the', 'its' in English) appear in the position:

Phrases which modify noun phrases	Noun-1 'TO' <special word> Noun-2,

the modifiers preceding Noun-1 modify only Noun-1 but not the whole conjuncted noun phrase.

(Rule 7) In

...... Noun-1 'TO' Noun-2,

if Noun-1 and Noun-2 belong to the same specific semantic categories, like action nouns, abstract nouns etc, the right boundary is often Noun-2.

(Rule 8) In most conjuncted noun phrases, the structures of conjuncts are well-balanced. Therefore, if a relative clause precedes the first conjunct and the length of the second conjunct (the number of words between 'TO' and Noun-2) is short like

[Relative Clause] Noun-1 'TO' Noun-2

length of the
2nd conjunct

the relative clause modifies both conjuncts, that is, the antecedent of the relative clause is the whole conjuncted phrase.

These heuristic rules are based on different levels of information (some are based on surface lexical items, some are based on morphemes of words, some on semantic information) and may lead to different decisions about scopes. However, we can distinguish strong heuristic rules (i.e. rules which almost always give correct scopes when they are applied) from others. In fact, there exists some ordering of heuristic rules according to their strength. Rules (1), (2), (3), (4) and (6), for example, almost always succeed, and rules like (7) and (8) often lead to wrong decisions. Rules like (7) and (8) should be treated as default rules which are applied only when the other stronger rules cannot decide the scopes. We can define in GRADE an arbitrary ordering of rule applications. This capability of controlling the sequences of rule applications is essential in integrating heuristic rules based on heterogeneous levels of information into a unified set of rules.

Note that most of these rules cannot be naturally expressed by ordinary CFG rules. Rule (2), for example, is a rule which blocks the application of the ordinary CFG rule such as

NP ---> NP <case-particle> NO N

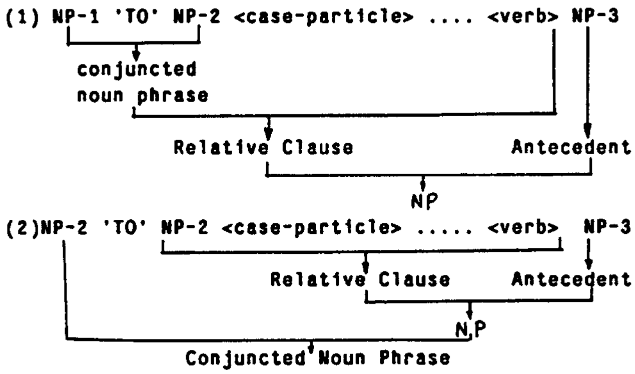
when the <case-particle> is 'TO' and a conjunctive particle 'TO' precedes this sequence of words.

4-3 Determination of Scopes

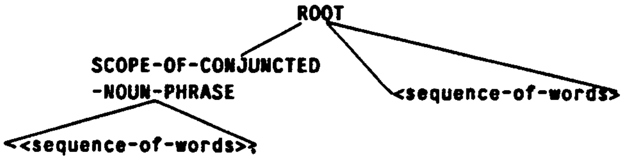
Scopes of conjuncted noun phrases often overlap with scopes of relative clauses, which makes the problem of scope determination more complicated. For the surface sequence of phrases like

NP-1 'TO' NP-2 <case-particle> ..... <verb> NP-3

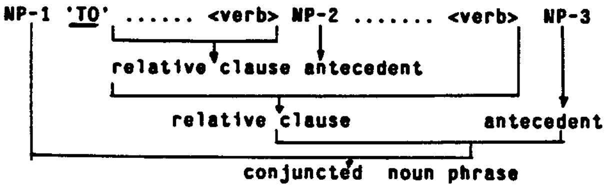
there are two possible relationships between the scopes of conjuncted noun phrase and the relative clause like


(1) NP-1 'TO' NP-2 <case-particle> .... <verb> NP-3
conjuncted
noun phrase
Relative Clause
Antecedent
NP
(2)NP-2 'TO' NP-2 <case-particle> ..... <verb> NP-3
Relative Clause
Antecedent
NP
Conjuncted Noun Phrase

This ambiguity together with genuine ambiguities in scopes of conjuncted noun phrases in 4-2 produces combinatorial interpretations in CFG grammars, most of which are linguistically possible but practically unthinkable. It is not only inefficient but also almost impossible to compare such an enormous number of linguistically possible structures after they have been generated. In our analysis grammar, a set of scope decision rules are applied in the early stages of processing in order to block the generation of combinatorial interpretations. In fact, the structure (2) in which a relative clause exists within the scope of a conjuncted noun phrase is relatively rare in real texts, especially when the relative clause is rather long. Such constructions with long relative clauses are a kind of garden path sentence. Therefore, unless strong heuristic rules like (2), (3) and (4) in 4-2 suggest the structure (2), the structure (1) is adopted as the first choice (Note that, in [ex-7] in 4-2, the strong heuristic rule[rule (3)] suggests the structure (2)). Since the result of such a decision is explicitly expressed in the tree:



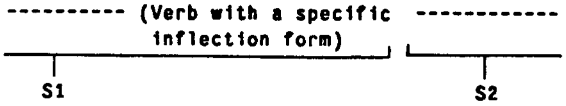
and the grammar rules in the later stages of processing work on this structure, the other interpretations of scopes will not be tried unless the first choice fails at a later stage for some reason or alternative interpretations are explicitly requested by a human operator. Note that a structure like

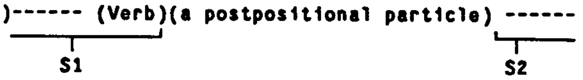

NP-1 'TO' ...... <verb> NP-2 .... <verb> NP-3
relative clause antecedent
relative clause
antecedent
conjuncted noun phrase

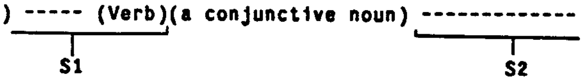
which is linguistically possible but extremely rare in real texts, is naturally blocked.

4-4 Sentence Relationships and Outer Case Analysis

Corresponding to English sub-ordinators and co-ordinators like 'although', 'in order to', 'and' etc., we have several different syntactic constructions as follows.

(1)


(2)


(3)


(1) roughly corresponds to English co-ordinate constructions, and (2) and (3) to English sub-ordinate constructions. However, the correspondence between the forms of Japanese and English sentence connections is not so straightforward. Some postpositional particles in (2), for example, are used to express several different semantic relationships between sentences, and therefore, should be translated into different sub-ordinators in English according to the semantic relationships. The postpositional particle 'TAME' expresses either 'purpose-action' relationships or 'cause-effect' relationships. In order to disambiguate the semantic relationships expressed by 'TAME', a set of lexical rules is defined in the dictionary of 'TAME'. The rules are roughly as follows.

(1) If S1 expresses a completed action or a stative assertion, the relationship is 'cause-effect'.

(2) If S1 expresses neither a completed event nor a stative assertion and S2 expresses a controllable action, the relationship is 'purpose-action'.

[ex-8]
(A) S1: TOKYO-NI IT- TEITA TAME
(Tokyo) (to go) (aspect formative)

S2: KAIGI-NI SHUSSEKI DEKINAKA- TA
(meeting) (to attend) (cannot)(tense formative : past)

S1: completed action
(the aspect formative "TEITA" means completion of an action)

---> [cause-effect]
= Because I was in Tokyo, I couldn't attend the meeting.

(B) S1: TOKYO-NI IKU TAME
(Tokyo) (to go)

S2: KAIGI-NI SHUSSEKI DEKINAI
(meeting) (to attend) (cannot)

S1: neither a completed action nor a stative assertion
S2: "whether I can attend the meeting or not" is not controllable.

---> [cause-effect]
= Because I go to Tokyo, I cannot attend the meeting.

(C) S1: TOKYO-NI IKU TAME
(Tokyo) (to go)

S2: KIPPU-O KAT- TA
(ticket) (to buy) (tense formative: past)

S1: neither a completed action nor a stative assertion
S2: volitional action

---> [purpose-action]
= In order to go to Tokyo, I bought a ticket.

Note that whether S1 expresses a completed action or not is determined in the preceding phases by using rules which utilize aspectual features of verbs described in the dictionary and aspect formatives following the verbs (The classification of Japanese verbs based on their aspectual features and related topics are discussed in [8]). We have already written rules (some of which are heuristic ones) for 57 postpositional particles for conjuctions of sentences like 'TAME'.

Postpositional particles for cases, which follow noun phrases and express case relationships, are also very ambiguous in the sense that they express several different deep cases. While the interpretation of inner case elements are directly given in the verb dictionary as the form of mapping between surface case particles and their deep case interpretations, the outer case elements should be semantically interpreted by referring to semantic categories of noun phrases and properties of verbs. Lexical rules for 62 case particles have also been implemented and tested.

5 Conclusions

Analysis Grammar of Japanese in the Mu-project is discussed in this paper. By integrating various levels of heuristic information, the grammar can work very efficiently to produce the most natural and preferable reading as the first output result, without any extensive semantic processings.

The concept of procedural grammars was originally proposed by Winograd[9] and independently persued by other research groups[10]. However, their claims have not been well appreciated by other researchers (or even by themselves). One often argues against procedural grammars, saying that: the linguistic facts Winograd's grammar captures can also be expressed by ATN, and the expressive power of ATN is equivalent with that of the augmented CFG. Therefore, procedural grammars have no advantages over the augmented CFG. They just make the whole grammars complicated and hard to maintain.

The above argument, however, misses an important point and confuses procedural grammar with the representation of grammars in the form of programs (as shown in Winograd[9]). We showed in this paper that: the rules which give structural constraints on final analysis results and the rules which choose the most preferable linguistic structures (or the rules which block "garden path" structures) are different in nature. In order to integrate the latter type of rules in a unified analysis grammar, it is essential to control the sequence of rule applications explicitly and introduce strategic knowledge into grammar organizations. Furthermore, introduction of control specifications doesn't necessarily lead to the grammar in the form of programs. Our grammar writing system GRADE allows us a rule based specification of grammar, and the grammar developed by using GRADE is easy to maintain.

We also discuss the usefulness of lexicon driven processing in treating idiosyncratic phenomena in natural languages. Lexicon driven prcessing is extremely useful in the transfer phase of machine translation systems, because the transfer of lexical items (selection of appropriate target lexical items) is highly dependent on each lexical item[11].

The current version of our analysis grammar works quite well on 1,000 sample sentences in real abstracts without any pre-editing.

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