JAPANESE CATEGORIAL GRAMMAR BASED ON TERM AND SENTENCE

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ABSTRACT

In this paper, I propose a japanese categorial grammar JCG which gives a foundation of semantic parsing of Japanese. JCG is not an orthodox categorial grammar with functional application, composition etc., but a hybrid system with HPSG based on term and sentence which correspond to the nominal head and verbal head in HPSG respectively. Construction rules of JCG are designed so as to be used as parsing rules of Japanese, but at the same time, they give the semantic correspondence of the japanese expressions via the homomorphism between syntax and semantics. The semantic output as such is a higher-order logical expression, but it's reduced to a Horn clause expression in its final form that constitutes a logic database on which a logical inference is executed.

1 Introduction

The phrase structure grammar which stems from the structural linguistics and was adopted by the generative transformational grammar has been the main grammatical theory of parsing of English. It is further applied - often without critical consideration - to other languages, also to Japanese. It certainly provides an effective tool for the syntactic parsing, but when it comes to the semantic parsing of Japanese, it seems preferable to adopt the categorial grammatical approach which reflects the semantics of Japanese in a direct form, all the more because the word order of Japanese is based on the inverse Polish notation, in contrast to English syntax based on the syntagmatic distribution of formatives.

There has also been a categorial grammatical approach to the parsing which originates in the exploring work of Bar-Hillel(1953) followed by Urzkoreit(1986), Moortgat(1988), Wood(1993), Carpenter(1997) to mention a few. But the strict categorial combinatorics contradicts the free word order of Japanese and the frequent elimination of sentence elements, to make it difficult to apply the original categorial grammatical method to Japanese. So, as to the essential part of Japanese, I abandon the simple categorial grammatical technique such as application, composition, division etc., and introduce the HPSG-like compositional principle based on term and sentence.[1]

One of the basic ideas for this stems from Sakai(1979) who advocates the view that japanese verbs and adjectives are all sentences as such, and missing arguments are implicitely complemented by the context. According to this view, the following sentence

(1) Taro-ga ringo-wo tabe-ta
(Taro-NomCM apple-AccCM eat-Past)
(Taro ate an apple.)
(NomCM: nominative case marker, AccCM: accusative case marker, Past: past tense marker)

is analyzed as follows:

(2) $[[\text{Taro-ga}]_t[[\text{ringo-wo}]_t[\text{tabe-ta}]_s]_s]_s$
(t: category of terms, s: category of sentences)

I.e., the term 'ringo-wo' is applied to the sentence 'tabe-ta' to form the sentence 'ringo-wo tabe-ta', further the term 'Taro-ga' is applied to the sentence 'ringo-wo tabe-ta' to form the sentence (1). Here, the expressions

(3) i) tabe-ta
ii) ringo-wo tabe-ta
iii) Taro-ga ringo-wo tabe-ta

are all grammatical sentences. And the sentence (the transitive verb in its usual terminology) 'tabe-ta' functions as the head of (3i,ii,iii). I call it their respective verbal head.

Conversely, there is a construction in Japanese where a sentence is applied to a term to form a new term. E.g.,

(4) Taro-ga tabe-ta ringo
(Taro-NomCM eat-Past apple)
(the apple which Taro ate)

(4) is analyzed as follows:

(5) $[[[\text{Taro-ga}]_t[\text{tabe-ta}]_s]_s\text{ringo}]_t$

Here, 'ringo' functions as the head of (5) as a whole. I call it the nominal head of (5). (The modifying sentence in (5) corresponds to a relative clause in English. But the modifier can also be a simple adjective, because an adjective as such is already a sentence in JCG.)

Such a duality between term and sentence is not too surprising a phenomenon with respect to the natural languages in the world. Some American Indian language reportedly expresses a sentence and its nominal correspondence in the same expression.[2]

I call the above-mentioned grammatical framework the Japanese Categorial Grammar (JCG), whose detail is stated below.

2 Categories and Types

As in the normal categorial grammar, categorial grammatically constructed japanese expressions of JCG are translated to type-theoretical formulas which are interpreted with respect to a model. Categories are inductively constructed from s and n (category of individual) using / and \. In the same manner, types are inductively constructed from t (type of sentence) and e (type of individual) using $\langle$ and $\rangle$. n/n, $(n\backslash s)/n$ and $\langle e,t\rangle$, $\langle e,\langle e,t\rangle\rangle$ are examples for categories and types respectively.[3] The model is defined in a usual manner.

But the category of JCG is extended so as to treat the syntactic phenomena of Japanese. It is in a sense a subcategorization of normal categories, which is motivated as follows:

(6) i) syntactic subcategorization
ii) morphological subcategorization
iii) lexical subcategorization

(6i) corresponds to the subcategorization like X' in the X-bar theory. In JCG, this kind of subcategorization concerns terms and sentences which are subcategorized using superscripts as follows:

(7) i) subeteno onna-ga
(every woman-NomCM)
ii) $[[[\text{subeteno}]_q[\text{onna}]_{t^0}]_{t^0}[\text{ga}]_{cm}]_{t^1}$[4].
(q: category of quantifiers, cm: category of case markers)

(8) $[[[\text{Taro-wa}]_{t^1}\ [[\text{ko}]_{s^0}\ [\text{nakat}]_{neg}]_{s^1}]_{s^1}\ [\text{ta}]_{past}]_{s^2}$
(Taro-NomCM come not past)
(Taro did not come.)
(neg: category of auxiliary verb of negation; $past$: category of past tense marker)

In (7i), 'onna', 'subeteno onna', and 'subeteno onna-ga' are all treated as terms. But the case marker is applied to a term without case marker only once to form an argument of a sentence. In order to treat this constraint, I distinguish between terms without case marker and with a case marker using superscripts as in (7ii).

In the same manner, I introduce the three subcategories of sentences as in (8). Here, s^0, s^1 and s^2 represent the following categories respectively:

(9) i) s^0: category of nuclear sentences, i.e. sentences without polarity and tense
ii) s^1: category of sentences with a polarity, but without tense
iii) s^2: category of sentences with a polarity and a tense

The japanese auxiliary verb of negation ('nakat' in (8)) is treated as an operator which is applied to an element of P_{s^0} to form an element of P_{s^1}, which follows the view of Sakai(1979) that the japanese negation is applied only to nuclear sentences.[5]

As is seen from (8), several terms are applied to an element of P_{s^1} to form another element of P_{s^1}, to which the tense is applied to finally form an element of P_{s^2}, i.e. a complete sentence.

(6ii) concerns the inflexion, especially the conjugation. Japanese verbs conjugate in the following manner:

(10)

Conjugation	Example
mizen kei (ad-negative form)	ko nai (come not)
renyo kei (ad-verbial form)	ki masu (come + [aux. verb of politeness])
shushi kei (dictionary form)	kuru ('come' in its dictionary form)
rentai kei (ad-nominal form)	kuru toki (come time [= when (you) come])
katei kei (conditional form)	kure ba (come if [= if (you) come])
meirei kei (imperative form)	come!

Let $[mizen]$, $[renyo]$, $[shushi]$, $[rentai]$, $[katei]$, and $[meirei]$ be called conjugation markers, and $Cjm = \{[mizen], [renyo], [shushi], [rentai], [katei], [meirei]\}$. In order to treat the conjugation, I add an appropriate conjugation marker to the right of verbal categories[6] in necessary cases. (8) with conjugation markers looks like as follows:

(11) $[[[\text{Taro-wa}]_{t^1}[[\text{ko}]_{s^0[mizen]}[\text{nakat}]_{neg[renyo]}]_{s^1[renyo]}]_{s^1[renyo]}[\text{ta}]_{past[shushi]}]_{s^2[shushi]}$[7]

In the next section, I formulate the construction of Japanese in normal produciton rules. Then, as is appearent from (11), the conjugation of the last daughter in a production rule is propagated to the parent, which is formulated as Conjugation Propagating Principle (CPP) as follows:

Definition 1 Conjugation Propagating Principle (CPP)
Let $x, y_1, \cdots, y_n$ be categories. Further, $conj \in Cjm$. Then
$x[conj] \longrightarrow y_1 \cdots y_n[conj]$.

Finally, (6iii) concerns the subcategorization based on the lexical ideosyncracy. One of the traditional examples is the distinction between intransitive verbs and common nouns, whose categories Montague(1973) represented with S/N and $S//N$ respectively. But I also distinguish between copula and other verbs, both belonging to the atomic category s of sentences, so that Montague's method is unapplicable. I distinguish this kind of subcategorization with a subscript. E.g., the category of copula is represented by s_1, and the category of other sentences by s_0.

Categories with the subcategorizations of (6) are called extended categories. The assignment of a type to an extended category is defined as follows:

Definition 2 Let α be an extended category. Further, let $\tau(\alpha)$ be the result of eliminating all superscripts, subscripts, and conjugation markers for subcategorization in (6) from α. Then a type is assingned to each extended category by the funciton $f' \stackrel{\text{def}}{=} f(\tau(.))$ as follows:
i) If $\tau(\alpha) = n$, then $f'(\alpha) = e$. If $\tau(\alpha) = s$, then $f'(\alpha) = t$.
ii) If $\tau(\alpha) = A\backslash B$, then $f'(\alpha) = \langle f'(A), f'(B)\rangle$.
iii) If $\tau(\alpha) = B/A$, then $f'(\alpha) = \langle f'(A), f'(B)\rangle$.

I list the extended categories with their names, and examples in Table 1 below. (Extended categories are presented in the mnemonics defined in the Definition column. Further for simplicity, conjugation markers are omitted.):

Extended Category	Definition	Name	Example
n	n	individual	----
S	s_0^0	sentence	yomu (read)
S'	s^1	sentence	hon-wo yomu (read a book)
S''	s^2	sentence	hon-wo yon-da (red a book)
COP	s_1^0	copula	be
IV	$(n\backslash s)_0$	intransitive verb phrase	----
CN	$(n\backslash s)_1$	common noun	----
$Term$	(s/IV)	term	----
T	$(s/IV)_0^0$	term	shōnen (boy), aru shōnen (a boy)
T'	$(s/IV)^1$	term	aru shōnen-ga (a boy [subject])
$FACT$	$(s/IV)_1^0$	fact term	koto (fact)
CM	$T\backslash T'$	case marker	ga, wa, ni, wo, kara, e
Q	$Term/CN$	quantifier	subeteno, aru, sono
NEG	$S\backslash S'$	negation	nai
$PAST$	$(S'\backslash S'')_0$	past tense marker	ta, da
FUT	$(S'\backslash S'')_1$	future tense marker	darō
$TmAV$	S'/S'	temporal adverb	kinō, kyō, ashita

Table 1: Extended Categories

In JCG, no japanese expressions have the categories $n, IV, CN, Term$. They are listed in Table 1, in order to define other categories.

Expressions, constants, and variables of the type theory of JCG are also represented in mnemonics, which is defined as follows:

expression	constant	variable	type	corresponding categories
m	l, e	x, x_i^j, y	e	n
M	L	P, Q	$\langle e, t\rangle$	CN, IV
$\mathcal{M}$	$\mathcal{L}$	$\mathcal{P}, \mathcal{Q}$	$\langle\langle e, t\rangle, t\rangle$	T, T'
M	L	S, T	t	S, S', S'', COP
$\mathfrak{M}$	$\mathfrak{L}$	$\mathfrak{Q}, \mathfrak{R}$	$\langle\langle e, t\rangle, \langle\langle e, t\rangle, t\rangle\rangle$	Q

Table 2: expressions, constants, and variables of the type theory

Here, e is a special kind of constant called event constant (s. below). Like x_i^j (i, j represent integers (≥ 0)), other expressions, constants, and variables in Table 2 can also be used with a subscript. They are used as syntactic variables too.

3 Construction Rules

I list the construction rules of JCG below. A construction rule Ci. consists of a syntactic rule Si. and a translation rule Tri. in the following form:

(12) S0. $B_{cat} = \{w_1, \cdots, w_n\}$

Tr0. B_{cat}: $j(w_i) = exp_i$. $(1 \leq i \leq n)$

Si. $cat \longrightarrow cat_1 \ \cdots \ cat_n$ (i $\geq$ 1.)

$F_i(A_1, \cdots, A_n) = B$.

Tri. $k(F_i(A_1, \cdots, A_n)) = \alpha$.

C0. is a vocabulary rule, and S0. means that basic expressions of the category cat consist of B_{cat}, and cat can be expanded to an element of B_{cat}. Tr0. means that an element w_i of B_{cat} is translated to a type-theoretical expression with the type $f'(cat)$ via the function j.

Si. (i $\geq$ 1.) presents a production rule with category symbols as its nodes. F_i is always the concatenation of $A_1, \cdots, A_n$, so I omitt $F_i(A_1, \cdots, A_n) = B$ below. Tri. translates the compound expression $F_i(A_1, \cdots, A_n)$ of the category *cat* generated by the produciton rule to a type-theoretical expression α with the type $f'(cat)$ via the function $k(\supseteq j)$.

S0. (Vocabulary)

i) B_T = {Taro (male name), Hanako (female name); otoko (man), onna (woman), hon (book), hana (flower), $\cdots$, mono (thing)}[8]

a) B_{FACT} = {koto (the fact that $\cdots$)}

ii) B_{CM} = {ga (subject case marker), wa (subject case marker), ni (indirect object marker), wo (direct object marker), kara (from), he (to)}[9]

iii) B_Q = {subeteno (every), aru (some), sono (the)}

iv) B_S = {utsukusī (beautiful), hashiru (run), yomu (read), uru (sell), kau (buy), $\cdots$}

a) B_{COP} = {dearu (be)}

v) B_{NEG} = {nai (not)}

vi) B_{PAST} = {ta, da (past tense particle)}

vii) B_{FUT} = {darō (future tense particle)}

viii) B_{TmAV} = {kinō (yesterday), kyō (today), ashita (tomorrow)}

Tr0. i) B_T: $j(\text{Taro}) = \mathfrak{Q}_0(\lambda x(x = Taro))$, $j(\text{Hanako}) = \mathfrak{Q}_1(\lambda x(x = Hanako))$,
$j(\text{otoko}) = \mathfrak{Q}_{20}(\lambda x^1_{20} otoko(x^0_{20}, x^1_{20}))$, $j(\text{onna}) = \mathfrak{Q}_{21}(\lambda x^1_{21} onna(x^0_{21}, x^1_{21}))$,
$j(\text{hon}) = \mathfrak{Q}_{22}(\lambda x^1_{22} hon(x^0_{22}, x^1_{22}))$, $j(\text{hana}) = \mathfrak{Q}_{23}(\lambda x^1_{23} hana(x^0_{23}, x^1_{23}))$, $\cdots$
$j(\text{mono}) = \mathfrak{Q}_{24}(\lambda x(x = x))$.

a) B_{FACT}: $j(\text{koto}) = \mathfrak{Q}_{25}(\lambda x(x = y))$

ii) B_{CM}: For an arbitrary $A \in B_{CM}$, $j(A) = \lambda \mathcal{P}\mathcal{P}$

iii) B_Q: $j(\text{subeteno}) = subeteno$, $j(\text{aru}) = aru$, $j(\text{sono}) = sono$.

iv) B_S: $j(\text{utsukushī}) = utsukush\bar{\imath}(x^0_{40}, x^1_{40})$, $j(\text{hashiru}) = hashiru(x^0_{41}, x^1_{41}, *, *)$,
$j(\text{yomu}) = yomu(x^0_{42}, x^1_{42}, *, x^3_{42})$, $j(\text{uru}) = uru(x^0_{43}, x^1_{43}, x^2_{43}, x^3_{43})$,
$j(\text{kau}) = kau(x^0_{44}, x^1_{44}, *, x^3_{44})$.

a) B_{COP}: $j(\text{dearu}) == (x^1_{80}, x^c_{80})$

v) B_{NEG}: $j(\text{nai}) = \lambda \mathsf{S} \neg \mathsf{S}$

vi) B_{PAST}: $j(\text{ta}) = j(\text{da}) = \lambda \mathsf{S}[e <_t now \wedge \mathsf{S}[e/x^0_{i_1}, \cdots, e/x^0_{i_k}]]$[10]

vii) B_{FUT}: $j(\text{darō}) = \lambda \mathsf{S}[e >_t now \wedge \mathsf{S}[e/x^0_{i_1}, \cdots, e/x^0_{i_k}]]$

viii) B_{TmAV}: $j(\text{kinō}) = \lambda \mathsf{S}[kin\bar{o}(x^0_{90}) \wedge \mathsf{S}[x^0_{90}/x^0_{i_1}, \cdots, x^0_{90}/x^0_{i_k}]]$,
$j(\text{kyō}) = \lambda \mathsf{S}[ky\bar{o}(x^0_{91}) \wedge \mathsf{S}[x^0_{91}/x^0_{i_1}, \cdots, x^0_{91}/x^0_{i_k}]]$,
$j(\text{ashita}) = \lambda \mathsf{S}[ashita(x^0_{92}) \wedge \mathsf{S}[x^0_{92}/x^0_{i_1}, \cdots, x^0_{92}/x^0_{i_k}]]$.

S1 . (Term generation I) $T \longrightarrow Q\ T$

Tr1. If $k(B) = \mathfrak{Q}_i(\alpha)$, then
$k(F_1(A, B)) = \mathfrak{Q}_i(\alpha)[k(A)/\mathfrak{Q}_i]$, i.e. $k(A)(\alpha)$.

S2 . (Term generation II) $T' \longrightarrow T\ CM$

Tr2. $k(F_2(A, B)) = k(B)(k(A))$.

S3. (Sentence generation I) $S' \longrightarrow S[mizen]\ NEG$

Tr3. $k(F_3(A, B)) = k(B)(k(A))$

S4. (Sentence generation II) $S' \longrightarrow S$

Tr4. $k(F_4(A)) = k(A)$

S5. (Sentence generation III) $S' \longrightarrow T'\ S'$

Tr5. In $k(B)$, $x^j_{i_1}, \cdots, x^j_{i_k}$ $(j = 1, \cdots, 5; k \geq 1)$ must appear as free variables.[11]

$$k(F_5(A, B)) = \begin{cases} \text{If } A \doteq C \text{ ga } or\ C \text{ wa, } k(A)(\lambda x^1 k(B)[x^1/x^1_{i_1}, \cdots, x^1/x^1_{i_k}]) \\ \text{If } A \doteq C \text{ ni, } k(A)(\lambda x^2 k(B)[x^2/x^2_{i_1}, \cdots, x^2/x^2_{i_k}]) \\ \text{If } A \doteq C \text{ wo, } k(A)(\lambda x^3 k(B)[x^3/x^3_{i_1}, \cdots, x^3/x^3_{i_k}]) \\ \text{If } A \doteq C \text{ kara, } k(A)(\lambda x^4 k(B)[x^4/x^4_{i_1}, \cdots, x^4/x^4_{i_k}]) \\ \text{If } A \doteq C \text{ e, } k(A)(\lambda x^5 k(B)[x^5/x^5_{i_1}, \cdots, x^5/x^5_{i_k}]) \end{cases}$$

S6. (Sentence coordination) $S' \longrightarrow S'[renyo]\ S'$
Tr6. $k(F_6(A,B)) = k(A) \wedge k(B)$

S7. (Generation of adnominal phrase I) $T \longrightarrow S''[rentai]\ T$
Tr7. In $k(A)$ below, $x^j_{i_1}, \cdots, x^j_{i_k}$ $(j = 1, \cdots, 5; k \geq 1)$ must appear as free variables. Further, the essential predicate[12] in $k(B)$ be M.
$k(F_7(A,B)) = k(B)[\lambda x[k(A)[x/x^j_{i_1}, \cdots, x/x^j_{i_k}] \wedge M(x)]/M]$.

S7a. (Generation of adnominal phrase II) $T \longrightarrow S''[rentai]\ FACT$
Tr7a. In the following, e be the left-most event constant in $k(A)$, and $k(B) = j(koto) = \mathfrak{Q}_{25}(\lambda x(x = y))$.
$k(F_{7a}(A,B)) = \mathfrak{Q}_{25}(\lambda x[k(A) \wedge k(B)[e/y](x)])$.

S8. (Past Tense Introduction) $S''[shushi] \longrightarrow S'[renyo]\ PAST$
Tr8. $k(F_8(A,B)) = k(B)(k(A))$

S9. (Present Tense Introduction) $S''[shushi] \longrightarrow S'$
Tr9. $k(F_9(A)) = e =_t now \wedge k(A)[e/x^0_{i_1}, \cdots, e/x^0_{i_k}]$

S10. (Future Tense Introduction) $S''[shushi] \longrightarrow S'[renyo]\ FUT$
Tr10. $k(F_{10}(A,B)) = k(B)(k(A))$

S11. (Temporal adverbs) $S' \longrightarrow TmAV\ S'$
Tr11. $x^0_{i_1}, \cdots, x^0_{i_k}$ $(k \geq 1)$ occur free in $k(B)$ below.
$k(F_{11}(A,B)) = k(A)(k(B))$

S12. $S \longrightarrow T\ COP$
Tr12. $k(F_{12}(A,B)) = k(A)(\lambda x^c_{80} k(B))$.

4 Examples

By construction rules of JCG, the following sentence

(13) Taro-ga uru hana-wo Hanako-ga kau.
(Taro-NomCM sell flower-AccCM Hanako-NomCM buy)
(Hanako buys the flowers which Taro sells.)

is translated to

(14) $e =_t now \wedge \mathfrak{Q}_{23}(\lambda z(e_1 =_t now \wedge \mathfrak{Q}_0(\lambda x(x = Taro))(\lambda y\, uru(e_1, y, x^2_{43}, z)) \wedge \lambda x_{23} hana(e, x^1_{23})(z)))$
$(\lambda x \mathfrak{Q}_1(\lambda y(y = Hanako))(\lambda z\, kau(e, z, *, x)))$,

and reduced to

(15) $e =_t now \wedge uru(e, Taro, x^2_{43}, l) \wedge hana(e, l) \wedge kau(e, Hanako, *, l)$.

In (15), the tense is represented in an event calculus style. Further in JCG, terms with 'aru' ('some'), 'sono' ('the'), and without article are all skolemized (l in (15) is a Skolem-constant.), although terms with 'subeteno' ('every') are treated with the universal quantificational force, so that (15) looks like a conjunction of DRT-conditions.[13]

JCG is implemented by Prolog. The reduction in the above-mentioned style enables to represent (15) in Prolog clauses. The program outputs which correspond to (14) and (15) are as follows:

(16)
```
sent([kau,1,pres,term([ga,prop,espred([hanako,1,pres,_471])]),*,
term([wo,_286,espred([hana,1,pres,_288,
sent([uru,1,pres,term([ga,prop,espred([taro,1,pres,_48])]),_288,_179])])])])
```

(17)
```
uru(1,pres,taro,_288,k(0)).
kau(1,pres,hanako,*,k(0))
hana(1,pres,k(0)).
```

(Here, `k(0)` is the 0th Skolem-constant, and `pres` is the abbreviated notation of $e =_t now$.)

5 Conclusion

In this paper, I presented the framework of semantic parsing of Japanese by means of a categorial grammar JCG based on term and sentence. JCG also has some advantage in the treatment of copula where $=, \in, \subseteq$ – which are assumed to constitute the meaning of copula – are all treated with $=$; it can further treat indefinite relative clause, and that-clause adequately. (S7a. is the construction rule for the latter.)

On the other hand, there is a theoretical limitation due to Prolog. E.g., it cannot treat the disjunction, and the existential quantifier. The latter is the reason for the skolemization. However, I believe that it is enough to give a semantic database of Datalog[14], and to construct an ordinary Q&A system.

JCG in the present paper can cover only a small portion of syntactic constructions and semantic phenomena of Japanese. In the literature of Categorial Grammar, various problems about coordination, unbounded dependency, quantification, modal contexts etc. constitute its topics. But very few research on them is done to Japanese. However, JCG can be extended to cover an enough part of them. E.g., according to Heim(1982), we can assign a new Skolem-constant to an indefinite term, and one which has already been introduced to the discourse to a definite term. Further, the *de re* reading can be treated by extending C5. such that a term is also applied to an element of S'', i.e. to a tensed sentence. Such extenstions are the next research objectives.

Notes

1 As to HPSG, cf. Pollard, C./ Sag, I.(1987, 1994).

2 In Nootka - the American Indian language in Vancouver Island, the sentence
i) Several small fires are burning in the house,
and its nominal correspondence
ii) several small fires burning in the house
are expressed in the same expression
iii) inikw-ihl-'minih-'is.
(Cf. Sapir(1921:134).)

3 In the present paper, the convention of directionality of slash follows Lambek(1958), but not Steedman(1987). So for example, the category $n\backslash s$ presents the category of that expression which is applied to an expression of the category n on the left, and forms an expression of the category s.

4 We could further distinguish between 'onna' and 'subeteno onna', i.e., between a term without case marker and quantifier and a term without case marker but with a quantifier. However, I abandon this method because of the frequent occurence of terms without quantifier in Japanese. The ungrammatical generation of terms with more than one quantifier is semantically blocked. (Cf. S1. below.)

5 In general, B_{cat} and P_{cat} present the set of basic expressions (i.e. vocabulary) and the set of basic and complex expressions of JCG with the category *cat* respectively. Complex expressions are constructed by the construction rules stated below.

6 I call $s, neg, past, fut$, i.e., the category of sentences, auxiliary verb of negation, past and future tense marker together the verbal category.

7 In general, there are many assimilations in Japanese. As to the past tense marker, there are two forms 'ta' and 'da', and which of the two is used is determined by the assimilation of the tense marker and the verb immediately before it. E.g., the past form of 'yomu' ('read') is expressed by 'yon-da'. In order to treat such phenomena, we must classify the japanese conjugation more precisely. E.g., we must classify $[renyo]$ into $[renyo1]$ and $[renyo2]$, and restrict the concatenation of a verb and the tense marker so that 'ta' coincides only with $[renyo1]$ of the preceding verb, 'da' only with $[renyo2]$; e.g., $[\cdots[\text{nakat}]_{neg[renyo1]}]_{s^1}[\text{ta}]_{past}]_{s^2}$, and $[\cdots[\text{yon}]_{neg[renyo2]}]_{s^1}[\text{da}]_{past}]_{s^2}$ are acceptable, but not $[\cdots[\text{nakat}]_{neg[renyo1]}]_{s^1}[\text{da}]_{past}]_{s^2}$, or $[\cdots[\text{yon}]_{neg[renyo2]}]_{s^1}[\text{ta}]_{past}]_{s^2}$. However, I omit the detail here.

8 The english translation of each basic expression of JCG is given in parentheses.

9 The difference between 'ga' and 'wa' is a famous problem in Japanese. And 'wa' also functions as an emphasized form of other grammatical roles than the subject. But in the present paper, I don't go into the detail.

10 $\alpha[Y/X]$ presents the result of substituting Y for all occurences of X in α.

11 This method of applying a term to a sentence is essentially the same as the treatment of a term as a scope constructor of Moortgat(1990).

12 In general, the type-logical translation of a term is presented in the following scheme:

$\langle quantifier \rangle (\langle predicate \rangle)$

Here, $\langle predicate \rangle$ is called the essential predicate of (the type-logical translation of) the term. E.g., the essential predicate of (the type-logical translation) of the term

aru onna-ga (some woman-NomCM)

$(aru(\lambda x^1_{21} onna(x^0_{21}, x^1_{21})))$

is

$\lambda x^1_{21} onna(x^0_{21}, x^1_{21})$.

13 As to DRT, cf. Kamp(1981), Kamp/ Ryle(1993).

14 Cf. Yokota/Miyazaki(1994), Das(1992) etc.

Bibliography

Bar-Hillel, Y.(1953), "A quasi-arithmetical notation for syntactic descriprion", *Language*, 29, 47-58.

Carpenter, B.(1997), *Type Logical Semantics*, Cambridge(MIT Pr.).

Das, S.K.(1992), *Deductive Databases and Logic Programming*, Wokingham(Addison-Wesley).

Heim, I.(1982) " The Semantics of Definite and Indefinite Noun Phrases", Ph.D. Thesis, Amhest, Univ. of Massachusetts.

Kamp, Hans(1981), "A Theory of truth and semantic representation", in Groenendijk et al.(eds.), *Formal Methods in the Study of Language*, pp.277-322, Amsterdam(Mathematisch Centrum Tracts).

Kamp, Hans/ Ryle, Uwe(1993), *From Discourse to Logic*, Dordrecht(Kluwer).

Lambek, J.(1958), "The mathematics of sentence structure", *American Mathematical Monthly*, 65, 154-170.

Montague, R.(1973), "The Proper Treatment of Quantification in Ordinary English", in Hintikka, J./ Moravcsik, J./ Suppes, P.(eds.), *Approaches to Natural Language*, Dordrecht(Reidel).

Moortgat, M.(1988), *Categorial Investigations: Logical and Linguistic Aspects of the Lambek Calculus*, Dordrecht(Foris).

Moortgat, M.(1990), "The quantification calcusus: questions of axiomatization.", in Deliverable R1.2.A of DYANA: Dynamic Interpretation of Natural Language. ESPRIT Basic Research Action BR3175. Centre for Cognitive Science, Edinburgh.

Pollard, C./ Sag, I.(1987), *Information-based Syntax and Semantics, vol. 1*, Stanford(CSLI).

Pollard, C./ Sag, I.(1994), *Head-Driven Phrase Structure Grammar*, Stanford(CSLI).

Sakai, H.(1979), *Nihongo no Bunpō to Ronri (Grammar and Logic of Japanese)*, Tokyo(Keisō).

Sapir, E.(1921), *Language*, New York(Harcourt, Brace & World).

Steedman, M.(1987), "Combinatory grammars and parasitic gaps", *Natural Language and Linguistic Theory*, 5, 403-439.

Uszkoreit, H.(1986), "Categorial Unification Grammars", *Proc. of International Conference on Computational Linguistics.*

Wood, M.Mc.(1993), *Categorial Grammars*, London(Routledge).

Yokota, K./ Miyazaki, N.(1994), *Shin Dēta Bēsu Ron (A New Database Theory)*, Tokyo(Kyoritsu).