On Flattening Categories in Categorial Grammar

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1 Introduction: Pure Categorial Grammar and Its Problems

Categorial grammar (CG) was first developed by a Polish logician, Ajduciewicz, based upon the notion of 'semantic categories' invented by another Polish logician, Lesniewski, to define well-formed sentences of a language. It was introduced to the liguistic community by Bar-Hillel (1953) and was further investigated by Montague, Flynn, Dowty and other linguists.

Unlike other syntactic theories, categories in CG are defined recursively from a finite set of basic categories. Propositions and nouns (and noun phrases) are usually adopted as basic and the following is an example of category definition for a natural language.

(1) a. $BasCat = \{\mathrm{S}, \mathrm{N}, \mathrm{NP}\}$.
  b. i. $BasCat \subseteq Cat$.
   ii. If x and y are in Cat, then so are x/y and $x\backslash y$.
   iii. Nothing else is in Cat.

Verbs are defined as S\NPs (for intransitive verbs) or as S\NP/NPs[1] (for transitive ones). The intuition behind this category assignment is that an intransitive verb can be regarded as a functor that takes one argument (i.e. an NP) to its left to form a sentence, and that a transitive verb, on the other hand, can be regarded as a functor that takes two arguments. This intuition is realized by a set of rules called 'cancellation', 'reduction' or 'functional application'.

(2) a. $X/Y : f\ Y : x \Rightarrow X : f(x)$.[2]
  b. $Y : x\ X\backslash Y : f \Rightarrow X : f(x)$

The following is a simple example of analyzing *John loves Mary* under the category assignment given in (3).

(3) John, Mary := NP
  loves:= S\NP/NP

(4) John   loves   Mary
  NP   S\NP/NP   NP
  ———————————
     S\NP
  ———————————
    S

[1] \ and / are considered to be left associative.

[2] The right-hand side of ':' is the meaning of the phrase or lexical item.

A property of CG (and one of the advantages of the CG framework) is that we can connect the syntax and the semanitcs quite neatly. Syntactic categories are associated with semantic categories and syntactic analyses are usually mapped to semantic analyses by a homomorphic function. For example, an NP is mapped to an entity (of type **e**), and an S is mapped to a truth value (of type **t**). The syntactic reduction rules in (2) correspond to the functional application in semantics. Generally speaking, we can formalize the relationship as follows; $h(f_i(\alpha_1,\ldots,\alpha_n)) = g_i(h(\alpha_1),\ldots,h(\alpha_n))$, where f_i is a syntactic operation, g_i the semantic operation corresonding to it, and h, a function that maps a phrase to its meaning. This is quite a strict embodiment of the compositionality principle which says that the meaning of a complex expression is a function of the meanings of its parts, and which is usually accepted in semantic literature. Given a syntactic analysis, we can immediately calculate the meaning of that phrase. Though the strict validity of the compositionality principle may be controversial, such a syntax-semantics correlation would be desirable.

The pure formulation of CG, which is briefly sketched above was proved to be weakly equivalent to context-free grammar (CFG). Although some authors (Pullum and Gazdar (1982), for example) argue that CFG might be adequate for generating natural languages, it is usually accepted that natural languages need more powerful grammars than CFGs (at least to capture linguistc generalization). If so, pure CG itself should be inappropriate and therefore has been extended by many authors. The following are examples of problematic phenomena.

(5) [John loves] and [Bill hates] Nancy.

(6) I liked e_i very much [the city I visited]$_i$.

The first example is called 'non-constituent coordination' since the bracketed phrases do not form a constituent in the usual sense. The second is an example of 'extraction'. It is sometimes claimed that *the city I visited* is extracted from the place indicated by e_i. We might be able to generate these examples if we allow one and the same lexical item to have more than one categories. However, this does not capture linguistic generalization. In the next section, I will briefly sketch how Steedman (1991) analyzes these phenomena.

2 Steedman's Categorial Grammar

Ades and Steedman (1982), Steedman (1985), Dowty (1988), Steedman (1991), etc. extend pure CG by adding some rules for analyzing non-consituent coordination and/or Dutch cross-serial dependencies. One kind of those rules is called 'functional composition.' The other kind is called 'type-raising' (Dowty (1988)), 'type-shifting', and so forth. The former can be derived from Geach (1972)'s metarule (Geach rule). The latter may be attributed to Montague (1974b), in which all noun phrases are given a raised category from the beginning to account for the semantics of quantified noun phrases.

For each of these kinds, there are some variations according to the direction of slashes of inputs and outputs. The following are examples of rules admitted in Steedman's Categorial Grammar.

(7) a. Forward Type-Raising (>T)
$X : x \Rightarrow Y/(Y\backslash X) : \lambda y(y\ x)$

b. Backward Type-Raising (<T)
$X : x \Rightarrow Y\backslash(Y/X) : \lambda y(y\ x)$

c. Forward Composition (>B)
$X/Y : x\ Y/Z : y \Rightarrow X/Z : \lambda z(x\ (y\ z))$

d. Backward Composition (<B)
$Y\backslash Z : x\ X\backslash Y : y \Rightarrow X\backslash Z : \lambda z(x\ (y\ z))$

e. Forward Crossing Composition (>Bx)
$X/Y : x\ Y\backslash Z : y \Rightarrow_{\mathrm{B}} X\backslash Z : \lambda z(x\ (y\ z))$

2.1 Non-constituent coordination

Note that the first four rules above keep the orders originally admitted in pure CG and also produce the same meanings. Then these rules would give several different structures to a sentence with one meaning. That is, a sentence can be analyzed in several different ways. This enables us to coordinate new constituents that are not originally regarded as constituents. Suppose that we also add the English conjunction rule (8). Then we can analyze non-constituent coordination in the way indicated in (9).

(8) English Coordination Rule
X and $X \Rightarrow X$

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(9) John            loves          and        Bill hates        Mary
    --------                                                   ------
    NP       >T     S\NP/NP                       :              NP
    ----------
    S/(S\NP)
    -----------------------  >B
         S/NP                             S/NP
         -------------------------------------  &
                        S/NP
                        -----------------------------------------  >
                                         S
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Although Steedman (1991) does not specify what the semantic effect of the coordination rules is, we may tentatively adopt $MEET$ in Moortgat (1988) or the $\wedge$ operator in lattice theory and we may state the following relations: $f(x \wedge y) = f(x) \wedge f(y)$ and $f \wedge g(x) = f(x) \wedge g(x)$. [3] (9), then, will be given the following meaning.[4]

(10) $((\lambda x((love'\ x)\ john') \wedge \lambda x((hate'\ x)\ bill'))\ mary') =$
$((love'\ mary')\ john') \wedge ((hate'\ mary')\ bill')$

2.2 Extraction

One peculiar property of the crossing composition rule, compared to the the others, is that they permit some extra orders that are not allowed in pure CG. For example, $Z\ X/Y\ Y\backslash Z$ is not a permitted order in pure CG while crossing composition can produce such an order. This provides a way for 'extracting' Z from $X/Y\ Z\ Y\backslash Z$. We can now analyze a sentence that has undergone a heavy-NP shift like *John read yesterday a book about govornment and binding* if we are supplied with backward crossing composition (11).

(11) English Backward Crossing Composition (<Bx)
$Y/\ldots Z\ X\backslash Y \Rightarrow_{B^n} X/\ldots Z$
where $Y = S_x\backslash NP$

[3] $\wedge$ may be considered as a logical conjunctive connective if $f\ (x)$ is a truth value.

[4] If we take this analysis literally, we might face the same problem that transformation analysis did since we should conclude that the string shared by the conjuncts can always be distributed to them. For example, *John can't like Mary and dislike Susan* has a meaning different from *John can't like Mary and John can't dislike Susan*. The difference of our approach from the transformational one is that we first analyze a non-constituent coordination and then conclude that its meaning is equivalent to that of a coordination of certain two sentences while transformational grammars analyze in the opposite direction. The relations above are conventions and we may suppose they do not hold in some cases.

(12) read | yesterday | a book about government and binding

VP/NP   Adv $< Bx$ NP

VP/NP

VP

Read and *yesterday*[5] are composed by backward crossing composition to be a function over NP. Thus *read yesterday* can now be combined with an NP. This rule, again, requires a restriction to avoid overgeneration. Without the restriction, we cannot exclude *the walks dog* in which *dog* is extracted from the position after the determiner.

2.3 Limits on possible rules

We have seen various rules adopted in Steedman (1991). These rules, Steedman claims, are not arbitrary and obey the following three characteristics. They are claimed to be universal principles in Steedman (1985) and Steedman (1991).

(13) The Principle of Adjacency
Combinatory rules may only apply to entities which are linguistically realized and adjacent.

(14) The Principle of Directional Consistency
All syntactic combinatory rules must be consitent with the directionality of the principal function.

(15) The Principle of Directional Inheritance
If the category that results from the application of a combinatory rule is a function category, then the slash defining directionality for a given argument in that category will be the same as the one defining direcitionality for the corresponding argument(s) in the input function(s).

Take the forward crossing rule as an example. The principal function of the rule is the rightward-seeking category and is combined with something to its right. Therefore the rule obeys the principle of directional consistency, and the resultant function seeks its argument to its left, inheriting the direction specified by the subsidiary function of the inputs.

If we take these as universal principles, the following rules should be disallowed in any natural language.

(16) a. $Y/\ldots Z\; X/Y \;\Rightarrow\; X/\ldots Z$
b. $Y\backslash\ldots Z\; X/Y \;\Rightarrow\; X/\ldots Z$

2.4 Advantages of Steeman's Theory

In this section, I will state two advantageous properties of Steedman's CG taken from Steedman (1991), Milward (1991), etc.

[5] Adv is an abbreviation of VP\VP.

2.4.1 Syntactic Structures and Prosody

In the Steedman-style extension of CG, a sentence may have more than two syntactic structures with the same meaning. For example, *John likes Mary* has two structures even though it is not ambiguous. One is the structure which is usually assumed in the current syntactic theories: [John [likes Mary]$_{S\backslash NP}$]$_S$. The other is the one that is produced by type-raising and forward composition: [[John likes]$_{S/NP}$ Mary]$_S$. Such multiple structures are sometimes considered as spurious since they have the same meaning.

Steedman (1991) suggests that these are not spurious. A sentence may be pronounced in a variety of prosodic contours and prosodic grouping of words is sometimes incosistent with the ordinary syntactic grouping. Further, as Selkirk (1984) points out, intonational structure seems to be sensitive to discourse.

(17) What does MARY prefer?
(Mary prefers) (CORDUROY).

(18) Who prefers CORDUROY?
(MARY) (prefers corduroy).

In these examples, intonational contours seem to be constrained by the difference of focus, topic, and other discourse information.

If we have only one rigid structure for one unambiguous sentence, we might be forced to postulate another level in which intonational and/or informational structures are represented since syntactic structures themselves do not reflect those structures. In Steedman's theory, we can give several surface structures to one sentence and such structures may be thought to reflect informational/intonational structures. Thus "the theory therefore offers the possibility that phonology and syntax are one system, and that speech processing and parsing can be merged into a single unitary process."[6]

2.4.2 Incremental Parsing

From a viewpoint of comprehension of a sentence, we may want to construct a semantic representation or establish semantic dependencies as soon as possible. Namely, it is highly unlikely that we cannot begin to interpret a sentence until the very last word comes in. Consider the following totally right-branching sentence, of which initial substrings are listed in (20).

(19) [I [can [believe [that [she [will [eat [those cakes]]]]]]]

(20)
a. I can
b. I can believe
c. I can believe that
d. I can believe that she
e. I can believe that she will
f. I can believe that she will eat

None of the substrings in (20) constitute a syntactic constituent and therefore would not be given a complete tree. However, Ades and Steedman (1982) provide experimental evidence for incremental interpretation. The initial substrings in (20) seem to be given an interpretation before the subsquent words are encountered. Then, we may want to give a left-branching, rather than right-branching, structure to (19). Although we could add some set of phrase structure rules to produce such left-branching structures, it is an ad-hoc remedy and such a grammar lacks generality. Moreover, as Milward (1991) notes, there will always be a sentence

[6] Steedman (1991, p.154)

that cannot be parsed no matter how many rules are added since "a fully left-branching phrase structure grammar defines a regular language ... and English is generally regarded as being at least context-free."[7]

3 Application to Japanese

In this section, I will try to apply the previous analyses on non-constituent coordination, crossing dependencies, etc. in English and Dutch to scrambling and non-constituent coordination in Japanese. Unlike English, arguments can be scrambled in Japanese as examples in (21a) show.[8]

(21) a. [Tarō ga $]_{NP_1}$ [Hanako ni $]_{NP_2}$ [hon o $]_{NP_3}$ ageta

[Tarō	ga]$_{NP_1}$	[Hanako	ni]$_{NP_2}$	[hon	o]$_{NP_3}$	ageta
Tarō	NOM	Hanako	DAT	book	ACC	gave

b. Tarō ga hon o Hanako ni ageta

c. Hon o Hanako ni Tarō ga ageta

In addition, non-constituent coordination is also possible as English and Dutch. Two or three NPs which do not usually form a constituent can form a conjunct. Such conjuncts are coordinated without a coordinator like 'and' in English.

(22) a.

Tarō	ga	Hanako	ni	, Jirō	ga	Yoshiko	ni	hon o ageta
Tarō	NOM	Hanako	DAT	Jirō	NOM	Yoshiko	DAT	

"Tarō gave a book to Hanako, and Jirō gave a book to Y oshiko."

b.

Tarō ga	Hanako	ni	hon	o,	Yoshiko	ni	zasshi	o	ageta
	Hanako	DAT	book	ACC	Yoshiko	DAT	magazine	ACC	

"Tarō gave a book to Hanako and a magazine to Yoshiko."

Although arguments of a verb can be scrambled and thus it must be combined with them in different orders, it is quite natural to assume that a verb is given only one category. We must, then, select one order as canonical from which the others may be derived by rules other than the functional application. The order of arguments in (21a) is assumed to be canonical hereafter. And then the category for a ditransitive verb like *ageru* may be (23)

(23) ageru/ageta := $S\backslash NP_1\backslash NP_2\backslash NP_3$

There are six possible orders for a sentence with three arguments like (21a) since arguments can, in general, occur in any order within a simple clause. Type-raising and (generalized) crossing composition can produce all the possible orders. Pure non-constituent coordination like (22) can also be explained in the same manner as proposed by Steedman. However, things are slightly different in the case of sentences in which both scrambling and non-constituent coordination have taken place.

(24) a. Tarō ga hon o Hanako ni, zasshi o Yoshiko ni ageta
"Tarō gave Hanako a book, and Yoshiko a magazine"

b. Hon o Tarō ga, zasshi o Jirō ga Hanako ni ageta
"Tarō gave a book, and Jirō gave a magazine to Hanako"

c. Hon o Hanako ni, zasshi o Yoshiko ni Tarō ga ageta
"Tarō gave a book to Hanako and a magazine to Yoshiko"

[7] Milward (1991, pp. 9–15)

[8] Since Japanese NPs are case-marked by particles like *ga, o, ni*, NP are indexed with numerical subscripts.

d. Hanako ni Tarō ga, Yoshiko ni Jirō ga hon o ageta
"Tarō gave Hanako and Jirō gave Yoshiko a book"

e. Hanako ni hon o Tarō ga, zasshi o Jirō ga ageta
"Tarō gave a book and Jirō gave a magazine to Hanako"

f. Tarō ga hon o, Jirō ga zasshi o Hanako ni ageta
"Tarō gave a book and Jirō gave a magazine to Hanako"

These scrambled non-constituent coordination require a version of the composition rule (25), which is prohibited by the principle of directional consistency repeated in (27). The analysis of (24a) is given in (26).

(25) $*Y/Z\ X/Y \Rightarrow X/Z$

(26)

$$\dfrac{\dfrac{\underline{\text{hon o}}}{\dfrac{\text{NP}_3}{v_3/(v_3\backslash\text{NP}_3)}>T} \qquad \dfrac{\underline{\text{Hanako ni}}}{\dfrac{\text{NP}_2}{v_2/(v_2\backslash\text{NP}_2)}>T}}{v_2/(v_2\backslash\text{NP}_2\backslash\text{NP}_3)}*$$

(27) The Principle of Directional Consistency (PDC)
All syntactic combinatory rules must be consistent with the directionality of the principal function.

Thus, all Japanese scrambled non-constituent coordination forces us to abandon the PDC if we try to analyze the sentences in (24) along the lines of the systems in Steedman. Abandoning the PDC would, however, proliferate the amount of possible rules.

Hence admitting a violation of the PDC requires an explanation. The reason why rule (25) is adopted in Japanese while others[9] are not possible both in Japanese and in English may be a problem with respect to the universality of possible rules. Merely stating that (25) is an exception in Japanese is clearly ad hoc and therefore undesirable. Thus we should explore another possibility to explain (24), which is discussed in the next section. Further, since (24) is a complex phenomenon consisting of scrambling and non-constituent coordination, it is quite implausible to assume that, when occuring independently of one another, scrambling and non-constituent coordination are analyzed by means of type-raising and generalized composition while the composite of them is analyzed in a completely different way. The possibility that will be explored below, therefore, must also be applicable to scrambling and coordination separately. If the method is applicable to coordination in Japanese, in turn, we may hope it is also applicable to coordination in other languages like English, for example. These points must be kept in mind through the exploration below.

4 Flattening Categories

4.1 Non-constituent coordination without type-raising

We saw that Japanese scrambled non-constituent coordination cannot be explained by type-raising and functional composition. The reason why we needed type-raising is quite obvious. Categories are defined hierarchically and therefore objects must be combined with verbs prior to subjects. Then, to combine a subject and a verb first, we have to give the subject a functional category so that we can apply the functional composition to them.

[9] For example, $X\backslash Y\ Y \rightarrow X$ also violates the PDC, but this rule is not admitted in Japanese since arguments cannot occur to the right of the verb.

Thus my proposal is to flatten the category structures, making each argument equal to others, at least syntactically, with respect to the combinatory possibilities. No argument is priviledged to combine with the functor earlier than the others. Then it is sometimes the subject and sometimes the object that combines with the verb. This method is also desirable for Japanese, which is sometimes argued to be a flat language. If the order of arguments is not specified in the category, the subject and the direct and indirect objects can appear in any order as required. One possible way to flatten the functor categories may be to regard arguments as a multiset. Note that slashes are no longer reponsible for ordering. Then we need some other device for ordering since subjects appear to the left of verbs, and objects, to the right in English and arguments always appear to the left in Japanese. Let me tentatively assume that each argument contains some information as to which side of the verb phrase it can appear on. An argument can appear on either side if the information is unspecified. Now, English transitive verbs and Japanese ditransitive verbs may look like (28).

(28) a. $\mathrm{S}/\{\mathrm{NP}_{\leftarrow}, \mathrm{NP}_{\rightarrow}\}$[10]

b. $\mathrm{S}/\{\mathrm{NP}_{1\leftarrow}, \mathrm{NP}_{2\leftarrow}, \mathrm{NP}_{3\leftarrow}\}$

The new version of application rules may be the following since applicability of the rules depends on the membership of the argument. Directionality is determined by the information of the argument as intended.

(29) a. $X/Y \; Z_{\rightarrow} \;\Rightarrow\; X/Y'$ if $Z_{\rightarrow} \in Y$ and $Y' = Y - \{Z_{\rightarrow}\}$.

b. $Z_{\leftarrow} \; X/Y \;\Rightarrow\; X/Y'$ if $Z_{\leftarrow} \in Y$ and $Y' = Y - \{Z_{\leftarrow}\}$.

Given these rules and the category assignment above, we can now produce scrambled Japanese sentences quite easily. It is also quite simple to construct a subject-verb combination.[11]

(30) hon o | Hanako ni | Tarō ga | ageta

NP$_3$ | NP$_2$ | NP$_1$ | S/{NP$_1$, NP$_2$, NP$_3$}

NP$_1$ + S/{NP$_1$, NP$_2$, NP$_3$} ⇒ S/{NP$_2$, NP$_3$} <

NP$_2$ + S/{NP$_2$, NP$_3$} ⇒ S/{NP$_3$} <

NP$_3$ + S/{NP$_3$} ⇒ S <

(31) John | likes | Mary

NP | S/{NP, NP} | NP

NP + S/{NP, NP} ⇒ S/{NP, NP} <

S/{NP, NP} + NP ⇒ S >

Given that verbs are assigned flattened categories, we can now turn to analyzing non-constituent coordination without type-raising because the hierarchical category definition was the major reason of the need for a special apparatus. Here, we will consider how to express 'non-constituent' constituents and how the application rules should be altered.

[10] Multisets are expressed with $\{\ldots\}_m$ to distinguish them from ordinary sets. Throughout the thesis, however, we will use the usual set notation since that would not make confusion.

[11] Henceforth, X and $X/\{\}$ are considered to be identical.

One definite condition on the category of a (nonconstituent) conjunct to be an input of the application rules may be simply that each subconstituent[12] must be unified with a member of the argument set[13] and that each member must be unified with only one subconstituent. This condition was implicitly expressed by simple unification in the original application rules, in which only one argument had to be considered. In the case of nonconstituent coordination, however, we must be careful about the multiple unification of one member. For example, the condition might be expressed by $M_i \in Y$ for each i where M_i is a subconstituent of the coordinate phrase on the ananlogy of (29). Although *Mary the book* cannot be combined with *John killed* in this analysis, **John killed Mary Mary* could be derived since both tokens of *Mary* might be unified with the NP in the argument set without any discrepancy because the tokens themselves could be unified. If we do not or cannot distinguish the type-token difference, we cannot express the condition in terms of membership relation.

However, we could express the condition by the $\subseteq$ relation; namely by $\{M_1, \ldots, M_n\} \subseteq Y$. Since $\{M_1, \ldots, M_n\}$ is a multiset, $M_1, \ldots, M_n$ are different tokens. Then, $\{\mathrm{NP}, \mathrm{NP}\} \not\subseteq \{\mathrm{NP}\}$ and therefore if $\{\mathrm{NP}, \mathrm{NP}\} \subseteq Y$, there must be two NPs in Y to satisfy the condition. We might be able to block **John killed Mary Mary* thereby. The subset condition on the subconstituents of a 'non-constituent' phrase may tempt us to alter the application rule as follows.

(32) $X/Y\ Z \Rightarrow X/Y'$ where $Z \subseteq Y$ and $Y' = Y - Z$.

Note that Y, Y' and Z in this rule are multisets. Then a 'non-constituent' phrase which contains two NPs as its subconstituents might be assigned $\{\mathrm{NP}, \mathrm{NP}\}$.

That this analysis of 'non-constituent' phrases is incorrect is quite obvious. If we treat a non-constituent phrase as a multiset of the categories of its daughters, two phrases consisting of exactly the same kinds and numbers of daughters might be coordinated irrespective of the orders of them. This would cause *the book on the table and on the desk the magazine* to be grammatical since each conjunct would be given $\{\mathrm{NP}, \mathrm{PP}\}$ under the analysis above. Thus, as suggested in Barry and Pickering (1990), a conjunct might be considered to be a list, not a multiset, of the categories of its daughters. The listing rule may be the following. We will use the product operator '$\cdot$' to denote a list category.

(33) $X_1 \ldots X_n \Rightarrow X_1 \cdot \ldots \cdot X_n$

Remember that a certain inclusion condition must be imposed on the application rule. To state the condition, a list of categories must be converted into a multiset. Then the application rule with a list argument may be the following.

(34) $X/Y\ Z_1 \cdot \ldots \cdot Z_n \Rightarrow X/Y'$ where $\{Z_1, \ldots, Z_n\} \subseteq Y$ and $Y' = Y - \{Z_1, \ldots, Z_n\}$.

4.2 Problem of Ordering

Remember that the first version of the modified application rules in (29), in which the category of the argument is not a list type, deals with the ordering of the argument and the functor by virtue of the directional information on the argument (which is in fact inherited from a member in the argument set by unification). Since the argument in the new version of application rules may be a list category, directional information must be reconsidered.

We may face a serious problem immediately when we try to use the directional information to determine word order. First, what should the directional information for a list category be like? If the subconstituents of the list are unanimous with regard to directionality, the answer is obvious. The list as a whole must be to the left of the functor if all members insist that they should be to its left. Conversely, it must be to the right if all members insist so. But

[12]By 'subconstituents', I mean constituents of the usual sense that consistitute the conjunct. For instance, each of the conjuncts in *John gave Mary a book and Bill a magazine* consists of two NPs and the NPs are the subconstituents of the conjuncts.

[13]We consider for the present only those cases in which conjuncts contain no adjuncts.

what will happen if some members disagree? Whether we place the whole phrase to the right or to the left of the functor, the canonical order should be disobeyed. Then we cannot tell what the direction of the list category as a whole would be even if we are given the directions of its elements.

This might not be a problem at all if such a situation never arose in the first place, since we have only to concern ourselves with unanimous cases. We can simply state the listing rule by parametrizing the directions of the whole phrase and its constituents with one variable. This assumption is compatible with (or corresponds to) the principl of adjacency ((13)) in Steedman's theory. The principle of adjacency prohibits linearly split elements to be combined by rules. This means that *John* and *Mary* cannot constitute a single phrase in *John killed Mary.* It is clearly true that *John* and *Mary* are not adjacent in the phonological form. However, it might be possible that some nonadjacent elements are adjacent or form a single constituent in an abstract mental representation.

Some authors propose an operation that admits a syntactic constituent to be split. Right wrap proposed in Dowty (1982) and Jacobson (1992) is such an operation which places an argument immediately to the right of the leftmost constituent of the functor. Apart from the rightwrap operation, it may be possible for separate elements to form one constituent if syntactic structures are equated with infomation structures as Steedman suggests. For example, one possible candidate for such an information structure may be the following.

(35) (Who killed whom?)
John killed Mary (and Bill, Nancy).
old information: X killed Y
new information: X=John and Y=Mary

Following Steedman's proposal of the relation between 'spurious' structures and the information structures of a string, the old information may be taken to correspond to the verb *killed* and the new one to *John, Mary.* If so, *killed* must be inserted between the NPs to form the grammatical sentence.[14] In (35), we might be able to derive the gapped sentence by first forming a conjoined phrase *John, Mary and Bill, Nancy*, which corresponds to the new information, and then inserting the verb into the first gap. In Steedman's theory, which respects the principle of adjacency, this analysis is impossible and hence the association of the grammatical structure and information structure is not complete.

Thus the complete association of syntactic structures with information (and intonation), which we may suppose is desirable for processing, and the observance of the principle of adjacency seem to be mutually exclusive. The principle, hence, might be dropped from our theory and we may allow separate elements to form a constituent. Accepting that possibility weakens the use of direction information on each argument.[15] It is relevant if the argument is treated alone, and irrelevant if some other arguments are associated with it to form a list category. Not only is the information sometimes irrelevant, but also it must coincide with the ordering constraints which would work when it is irrelevant. For example, the subject might have the information that it precedes the verb and this information coincides with the inserting operation postulated in connection with (35). To account for this coincidence, we may drop direction information on each argument and commit ordering to an independent component or principles, which may differ from language to language.

(36) may be a candidate for English ordering principles and (37), for Japanese.

(36) $NP_1 < S/\{\ldots NP_1 \ldots\}$[16]

[14]Such an observation is not new. Oehrle (1987) proposes similar analysis to explain the scope of negation, frequency word, etc. in gapped sentence.

[15]In fact, there are examples that violate the third principle, i.e., the principle of directional inheritance. Thus all of the three principles that concerns word order seem to be rejected. These facts support our proposal to separate word order from categories.

[16]Previously, we assumed that NPs in English have no subscripts since they bear no case marker. In stating word order constraints, however, we need to distinguish subjects from objects. And there is another word order problem that is considered in Chapter 7 of Ryōya (1993).

$S/\{\ldots NP_2 \ldots\} < NP_2$ (the same for NP_3)

(37) $NP_\alpha < S/\{\ldots NP_\alpha \ldots\}$

5 Summary

I first showed that simply applying Steedman's CG to Japanese scrambled non-constituent coordination would violate the PDC, which Steedman (1991) postulates. To avoid the problem, I proposed to flatten categories and to treat 'non-constituent' constituents as lists. This enables us to analyze Japanese examples. The desirable properties of Steedman's CG are also preserved.

If we insist on encoding information of ordering into categories, another problem arises, and therefore I proposed to separate ordering information. Constraints on word order might be stated by means of something like LP rules of GPSG. This makes the entire theory look like some of contemporary syntactic theories such as GPSG, HPSG, and so on. However, I suppose that rules in CG can be stated in a more general form and specific rules might not be needed.

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