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THE BANYAN:
A PARTIALLY ORDERED SYNTACTIC STRUCTURE
WITH REINTERSECTION

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Context free phrase structure rules have long been used as a basis for parsing natural language sentences and describing their structure. The so-called non-configurational languages, those with relatively free word order, pose a problem for phrase structure rules because each of the possible orders requires a separate rule. Elements of a sentence which have more than one function also pose a problem, because a constituent's functional relationship to the remainder of the sentence is normally related to what it is immediately connected to above, and in a tree, there can be only one such connection.

Recent theories continue to have trouble with relatively free word order and elements with multiple functions. Lectures on Government and Binding, for example, insists that Japanese has a verb phrase constituent, and that the grammatical function subject is the noun phrase dominated by the sentence node, and the grammatical function object is the noun phrase dominated by the verb phrase node. The configurations that determine these grammatical functions, however, 'are not represented in the syntax in the X-bar system in D- or S- structures in Japanese.' (Chomsky 1982, p. 129). The problem stems from the fact that subject and object may appear in either order preceding the verb; according to the theory, the one case involves a discontinuous verb phrase constituent. But phrase structure trees simply cannot show discontinuous constituents. Government and Binding theory also has problems with elements with multiple functions. In the Japanese causative, the indirect object of the main clause is always the same as the subject of the subordinate clause. The Government and Binding analysis predicts that this element will be marked with the subject marking postposition ga, but it in fact appears with the indirect object marker ni. This incorrect prediction results from the faulty assumption that each element can have only one θ -role, an assumption necessitated by the fact that in the D-structure tree, an element can occupy no more than one position (Chomsky 1982, p. 131).

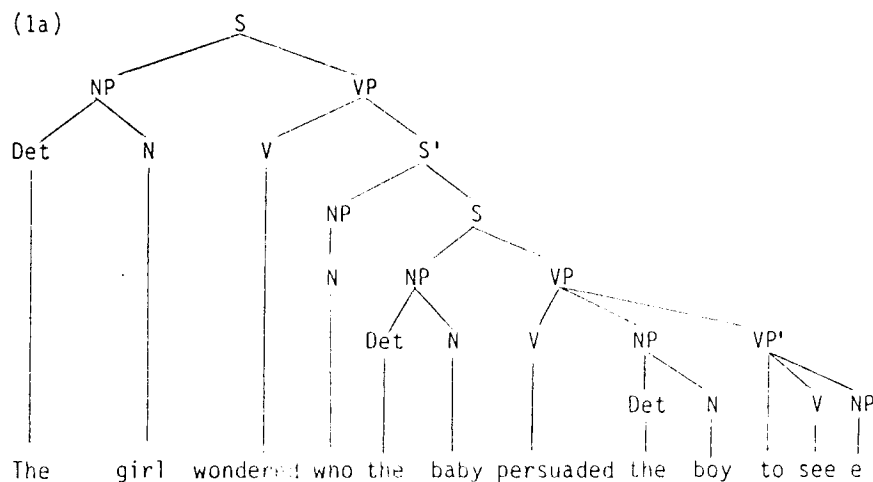
The inherent properties of trees themselves

appear to be at the root of these problems but nature itself has given us a cue to look beyond traditional restrictions. The banyan is a type of tree which grows to a certain size and then lets down vines from its branches. Some of these vines reach the ground and take root. The result, when a new root has grown, is a single branch connecting two roots. Banyans have been known to have forty or fifty trunks each over a foot in diameter, all interconnected with common branches. The banyan tree in nature is an organic acyclic connected directed graph which may have multiple roots.

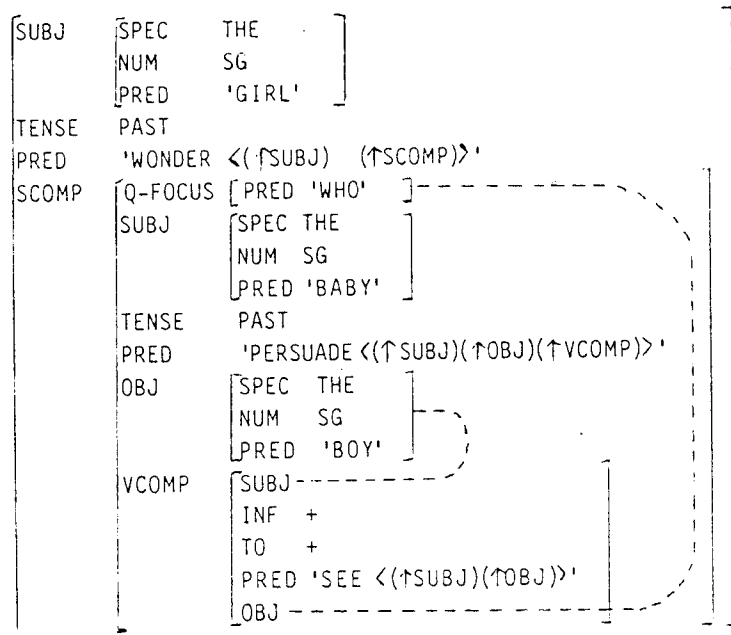
Just as the banyan in nature is a slight generalization of what is normally expected for a tree, the banyan structure in linguistics is a slight generalization of the traditional sentence tree. The banyan is an acyclic connected directed graph. Just as each trunk of a natural banyan may be the endpoint or origin of a number of branches, each node of a linguistic banyan may be the endpoint of several arcs, and the origin of several others.

Just as sentence trees are generated by phrase structure rules, linguistic banyans are generated using an enhanced version of the constituent rules, or c-rules, of Lexical Functional Grammar (Bresnan 1982).

Lexical Functional Grammar. The structures generated by the c-rules of Lexical Functional Grammar are the c-tree, or constituent tree, and the f-structure, or functional structure. The following pair of structures are taken from the book The Mental Representation of Grammatical Relations, edited by Bresnan (p. 221, 236, 238):



(1b) "The girl wondered who the baby persuaded the boy to see."



Although a full explanation of these structures is well beyond the scope of this paper, a few notes are in order. The c-tree of (1a) is a traditional phrase structure tree. In (1b), the material between each pair of brackets comprises one f-structure, and each f-structure corresponds to one or more nodes of the c-tree of (1a). The dashed line connecting the f-structure labelled OBJ in the SCOMP f-structure, to the SUBJ of VCOMP of SCOMP, means that the boy has two functions in the sentence; it is the object of persuade and also the subject of see. The dashed line connecting who to the OBJ of VCOMP of SCOMP means that who has two functions as well; it is the complementizer (or Q-FOCUS) of the relative clause, and also the object of see.

Some of the c-rules used to generate (1) are as follows:

(2a) $S \rightarrow NP \quad VP$
 $(\uparrow SUBJ) = \downarrow \quad \uparrow = \downarrow$

(b) $VP \rightarrow V \quad NP$
 $\uparrow = \downarrow \quad (\uparrow OBJ) = \downarrow$

(c) $VP \rightarrow V \quad NP \quad VP'$
 $\uparrow = \downarrow \quad (\uparrow OBJ) = \downarrow \quad (\uparrow VCOMP) = \downarrow$

$$(d) \text{ VP}' \rightarrow \left(\begin{array}{l} \text{to} \\ (\uparrow\text{TO}) = + \\ (\uparrow\text{INF}) =_c + \end{array} \right) \text{VP} \quad \uparrow = \downarrow$$

The top line of each of these rules appears like a traditional phrase structure rule, and is basically used as such to build the c-tree. The other lines refer to the associated f-structures. The notation $(\uparrow\text{SUBJ}) = \downarrow$ underneath NP in (2a) means that the NP node in the c-tree corresponds to an f-structure (\downarrow) which has the label SUBJ within the next higher f-structure (\uparrow), namely, the largest f-structure, or the one corresponding to the S node of the c-tree. The notation $\uparrow = \downarrow$ under the VP node means that the VP node corresponds to an f-structure (\downarrow) which is the same as the next higher f-structure (\uparrow); in other words, the S and VP nodes of the c-tree correspond to the same f-structure. Rules (2a) and (2b) generate SVO sentences; more complex verbs like persuade require rules such as (2c) and (2d). Although the to element of rule (2d) is optional, the lexical entry for persuade specifies that its VCOMP must have a feature TO with the value +. The notation $(\uparrow\text{INF}) =_c +$ means that the next higher f-structure (\uparrow) is required to have a feature INF with the value +; since the f-structure of the VP of VP' is the same as that of the next higher f-structure, this is a restriction that the verb of the VP' be in an infinitive form. The notation $=_c$ is used for constraint equations, which restrict both the construction of the c-tree and the forms of the related f-structures. A similar notation will be used in the rules generating banyans in this paper.

The main clause of Japanese. The arguments of Japanese verbs are marked with postpositions, which are similar in many ways to case markings. Since the postpositions marking subject and object clearly identify their grammatical function, the ordering of these elements is not nearly as fixed as in English. In fact, the only real ordering constraint dealing with the verb and its arguments, is that the verb must be last.

In mathematics, a set may be unordered, linearly ordered, or partially ordered. The situation of the main clause in Japanese seems to fall in the last category, since it is neither totally free; nor totally fixed. The mathematical definition of partial ordering is as follows:

- (3) A set Z is partially ordered with respect to a relation R if and only if
- R is a subset of $\{(x,y) \mid x,y \in Z\}$
 and $(x,y) \in R$ implies $x \neq y$
 and $(y,x) \notin R$
 and if $(y,z) \in R$ then $(x,z) \in R$.

Given any two elements x and y of the set Z , either x precedes y ($(x,y) \in R$), or y precedes x ($(y,x) \in R$), or x and y have no necessary ordering relationship.

This is precisely the case in the Japanese main clause. The subject and object must precede the verb, but the subject and object have no necessary ordering with respect to each other. This situation could be reflected by the following rule:

- (4) S NP NP V
- $(\uparrow\text{SUBJ})=\downarrow$ $(\uparrow\text{OBJ})=\downarrow$ $\uparrow=\downarrow$
- $(\uparrow\text{CASE})=_{\text{c}} \text{GA}$ $(\uparrow\text{CASE})=_{\text{c}} \text{O}$
- $\downarrow <_{\text{c}} (\uparrow\text{HEAD})$ $\downarrow <_{\text{c}} (\uparrow\text{HEAD})$

The subject is required to be marked with the postposition ga, and the object with the postposition o. The ordering restrictions are given by the notation $\downarrow <_{\text{c}} (\uparrow\text{HEAD})$. The head element is the one marked by $\uparrow=\downarrow$. Both subject and object are constrained to appear before the verb, but no ordering constraint is placed on the relative order of the subject and object; consequently, they may appear in either order. The actual order of elements in the rule reflects only the default order, or the order of highest frequency. The notation $>_{\text{c}}$ can be used in a similar way.

Since the ordering restriction is really a restriction on the placement of the verb, (4) could also be written as follows:

- (5) $S \rightarrow$ NP NP V
- $(\uparrow\text{SUBJ})=\downarrow$ $(\uparrow\text{OBJ})=\downarrow$ $\uparrow=\downarrow$
- $(\downarrow\text{CASE})=_{\text{c}} \text{GA}$ $(\downarrow\text{CASE})=_{\text{c}} \text{O}$ $\downarrow >_{\text{c}} @$

The constraint $\downarrow >_{\text{c}} @$ means that the verb must appear after all of the other elements in its domain.

The topic in Javanese. In active sentences in Javanese, locative and temporal phrases can topicalize freely by being placed sentence initially; these same phrases, however, cannot be topicalized in the passive.

The subject of a passive is also required to be definite, leading to the conclusion that the subject of a passive in Javanese is also a topic. When speakers of Javanese want to topicalize a first or second object of the verb, they do so by making the sentence passive; in other words, topicalization triggers passivization.

(6a) ibu nambal kat?ku
 mother patch pants-my
 Mother patched my pants.

(b) Kat?ku ditambal ibu
 pants-my patched mother
 My pants were patched by mother.

(c) $S \rightarrow$ NP V NP
 (\uparrow SUBJ)= \downarrow \downarrow = \uparrow (\uparrow OBJ)= \downarrow
 \downarrow \langle_c (\uparrow HEAD) (\uparrow VOICE)= $_c$ ACTIVE \downarrow \rangle_c (\uparrow HEAD)

(d) $S \rightarrow$ NP V NP
 (\uparrow SUBJ)= \downarrow \uparrow = \downarrow (\uparrow OBJ-AG)= \downarrow
 \downarrow \langle_c (\uparrow HEAD) (\uparrow VOICE)= $_c$ PASSIVE \downarrow \rangle_c (\uparrow HEAD)

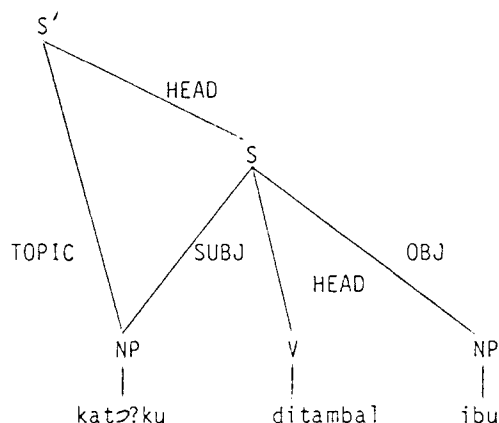
Rule (6c) is the rule for active sentences with one object, and (6d) is the corresponding passive. The element preceding the verb as SUBJ in (6c) appears in (6d) after the verb as the oblique agent OBL-AG, and the element that was OBJ in (6c) appears as the SUBJ in (6d).

The following rule can describe topicalization in nonstative sentences of Javanese:

(7) $S' \rightarrow$ NP S
 (\uparrow TOPIC)= \downarrow \uparrow = \downarrow
 (\uparrow SUBJ)= \downarrow
 \downarrow \langle_c @

This requires that the topic be first in its sentence, and must be the same element as the subject. This gives us the following banyan structure:

(8)



Notice that the additional ordering constraint of (8) makes (6d) the only choice if kat?ku 'my pants' is to be the topic. Also notice that the topic does not appear before all of the elements of the sentence, since it is one of them itself. The ordering constraints of (6d) and (7) are satisfied, however, if they are construed to apply to the arcs leaving each node of the banyan, rather than the destination nodes of these arcs. The TOPIC arc precedes the HEAD arc, from the S' node, and the SUBJ arc precedes the HEAD arc, from the S node.

The Japanese causative. In the Japanese causative construction, as discussed above, the indirect object of the main clause is also the subject of the subordinate clause.

- (9) Takahashi ga Michiko ni ringo o tabesasetta
 Takahashi SUBJ Michiko IOBJ apple OBJ eat-cause-past
 Takahashi made Michiko eat the apple.

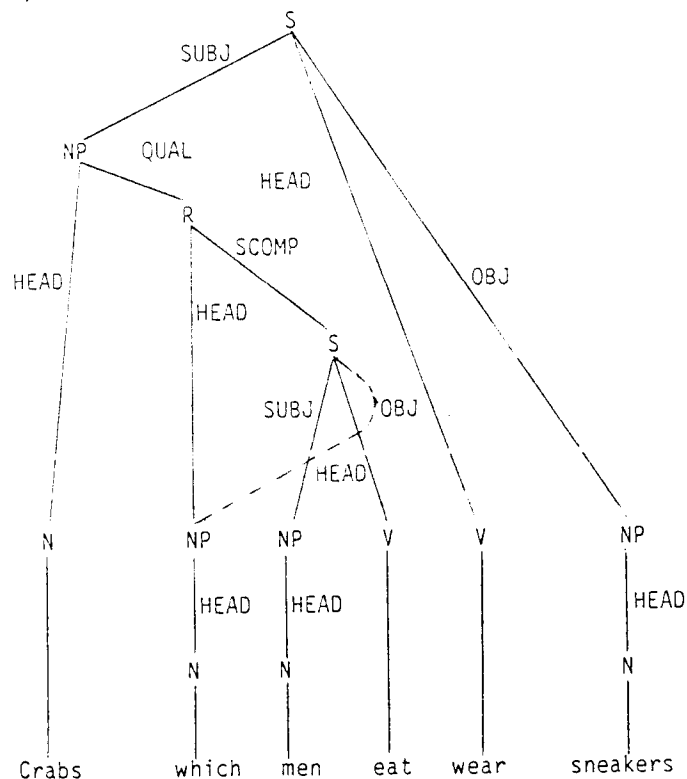
The fact that one noun phrase functions as both the indirect object of the main clause and the subject of the embedded clause, can be captured by the following rule:

- (10) $S \rightarrow NP$ NP S V
- | | | | |
|---------------------------------------|--|-----------------------------------|--|
| (\uparrow SUBJ)= \downarrow | (\uparrow IOBJ)= \downarrow | (\uparrow SCOMP)= \downarrow | \uparrow = \downarrow |
| (\downarrow CASE)= _c GA | (\uparrow SCOMP SUBJ)= \downarrow | | (\uparrow SCOMP HEAD)= \downarrow |
| | (\downarrow CASE)= _o NI | | (\uparrow CAUSE)= _c + |
| | | | \downarrow > _c @ |

The relative clause of English. Above, we saw a case where the value of a feature on a reintersection node was required to have two conflicting values, and one constraint took precedence. The same can occur with partial ordering features.

A relative pronoun in English has two functions; it is the complementizer of the relative clause, and also one of the arguments of the verb. When the relativized element is the subject, no ordering constraints conflict. When the relativized element is the object, however, there are conflicting constraints. Complementizers in English must occur clause initially, but objects follow verbs.

(12)



In this structure, the subordinate OBJ arc is ordered after the subordinate SUBJ and HEAD arcs, but the position of the terminal element, the relative pronoun, is determined not by the $(\uparrow\text{OBJ}) >_c (\uparrow\text{HEAD})$ restriction, but by the overriding $(\uparrow\text{HEAD}) <_o @$ restriction of the R(egative) level.

Treating ordering with partial ordering features allows us to view the unusual features of reintersection nodes in a uniform way. The reintersection node in the Japanese causative was constrained to have two

conflicting postpositions, but only one prevailed. The reintersection node in the English relative was required to have two conflicting positions, but only one prevailed. The notations \langle_c , \rangle_c , $=_o$, \langle_o , and \rangle_o allow us to capture these generalizations in a rather simple way.

Conclusion. This paper has introduced partially ordered phrase structure rules and the banyan in order to simplify the analysis of relatively free word order languages and cases where a single element has more than one function. This has simplified the analysis of cases where a multi-functioned element appears with an unexpected feature, because there have been two conflicting constraints, and one has taken precedence over the other.

Among the mechanisms used by language to convey structural information are inflection, order, and prepositions or postpositions. Partially ordered phrase structure rules and the banyan allow all of these to be described in an analogous way. This unification of perspective should prove to provide many new insights.

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