AUTOMATIC PROGRAMMING GROUP
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Translation of English into MAPL Using Winograd's Syntax, State Transition Networks, and a Semantic Case Grammar

by

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A system has been partially worked out for translating from English into MAPL. A LISP program has been written to implement this system completely for the test sentence:

"How much did we sell to Sears in '72?"

The program involves a rewrite of Winograd's syntax into a set of state transition networks and the use of a case grammar.

CONTENTS

Introduction

In the Automatic Programming Group we require that a computer converse with a user in simple English. We want the user to be able to build world models and define new words. To do this, he should only have to know how to answer some simple questions about how his words fit into the English grammar the machine is using. He will have to know a lot about his world and how to build a good model of it, but the system should be able to access that world on its own to answer questions about English translation, without the user having to explain how to do this.

We assume that a series of input routines will transform the input English into the language in which the user world model is built. In designing such routines one has to consider the following points:

1. Some of the meaning of an English sentence is conveyed by the word order. For example, word order can determine whether a sentence is a declaration or a question, and what elements of the sentence the speaker wishes to emphasize. It also helps determine which elements of the sentence modify which other elements. It seems pretty clear that the user world model should not have to know English word order. Thus, we must find another method of describing the properties and relationships given by the word order.
2. The word order alone is not sufficient to determine what entities exist in the sentence and how they modify each other. Possibilities are given by a combination of word order, word meanings, and the situation being described. Here, one can make a rough classification with respect to how difficult it currently is to bring the appropriate information to bear. In doing this

one sees that the hard situations can involve issues of belief and complex deductions; problems which seem to belong in the domain of the world modeler. A reasonable goal would be to ask the the user to build his model so that it can answer yes-no questions asked by the English translator, discover if an expression in the world modelling language refers to a particular known concept, and accept more than one possible parsing of the input sentence.

3. Many words have more than one meaning. I believe that world models should be built using tokens which do not have multiple meanings. The English translator should select particular meanings for the words.

4. English allows the same or closely related thoughts to be expressed in two different ways which involve the use of different words as well as a change in surface word order. For example, we could say

(1) I went home to eat.

(2) I went home with the intention of eating.

(3) The bag was emptied of groceries.

(4) The groceries were taken out of the bag.

(5) I shot the gun at the rabbit.

(6) I shot the rabbit with the gun.

6a) That is a red ball.

6b) The color of that ball is red.

6c) That ball is red in color.

Most probably the distinctions between these sentences are too subtle to be useful to the automatic programming world models in the near future. It would be desirable for the English

input routines to transform them into a standard form. However, it is not clear whether this should be done in one step or after an internal form has been generated.

5. Entities in an English sentence often refer to other entities either in the user's world model or in the discourse. References to the stream of discourse may require a knowledge of English to evaluate, while references determined to be to the user's world model can be referred to him.

If we attempt to remove word order from the user's concern, then we must have another method of encoding that information. There appear to be four alternatives open. The first is to express the results as a combination of abstract properties and a procedure the way Winograd did. The second is to use a set of properties based where possible on the meanings of words like prepositions. The third is to use a set of properties based on a set of semantic cases. The fourth is to fill in some non-procedural "plex" which is present in the world model.

The first alternative seems unattractive with respect to the problem of combining smaller programs into larger ones. It seems unnecessary to represent the result as a program in simple dialogue and in more complex cases it is often necessary to analyze the current statement in light of the ongoing discourse before action is taken. Thus one will have the difficult task of analyzing a program as a data structure. This has the disadvantage that a program contains additional constraints as is pointed out in Sussman's work on HACKER [8]. Certainly a procedural form will often eventually have to be obtained, but HACKER

like routines will have to be present in the user's world in any event.

Use of a scheme based on the meanings of words such as prepositions encounters the following situations.

a) Prepositions have more than one meaning.

6. I walked a foot from the dragon. (ambiguous)

7. I obtained a foot from the dragon.

8. I parked the truck by the house by myself by 5 o'clock.

b) Two noun groups flagged by prepositions with different meanings can conflict by filling the same role in the sentence.

*9. I finished it in the afternoon at 3:00 o'clock.

c) A noun group flagged with a preposition can conflict with one without a preposition.

*10. I gave John a ball quickly to Bill.

11. I gave a ball quickly to Bill.

d) If the meaning of a preposition is defined independently of the verb it modifies, then a great many meanings will probably be defined for a preposition like on, most of which will not apply to any particular verb.

It is worth noting that these problems seem to arise mainly with the frequently occurring properties of a clause, such as those referring to time and location. An expression such as as if does not seem to have multiple meanings or conflict with other constructions; it could just as well be used directly as a property indicator.

The basic tenet of case grammar is that the sentence consists of a verb and one or more noun phrases, each associated with the verb in a particular case relationship. This view is useful in analyzing the sentences:

12. John opened the door with a stick.
13. A stick opened the door.
14. The door opened.

In 12) we take John as the agent, a stick as the instrument, and the door as the object. Sentences 12, 13, and 14 show how a verb like open takes the agent, object, or instrument as the surface subject. Thus, by recognizing cases, these three sentences can be passed to the user's world model in one standard form.

Adding cases is one method of representing the information about prepositions given in a), b), c), and d) above. The criteria on the cases are then:

a) For a given meaning of a given verb, different meanings of a given preposition would correspond to different cases.

b-c) No two noun groups in a simple sentence can be in the same case.

d) The way a given case is interpreted by the user's world model routines is a function of the verb meaning it modifies.

The same principles can be applied to secondary clauses as well as noun groups, and this appears to be the correct step.

15. I went home for food.
*16. I went home for food to get a book.
17. I went home for food and to get a book.
18. I went home for mother to get a book.

Our scheme would involve listing, for each verb meaning, what cases each preposition could flag and what predicate a noun group or other construction would have to pass in order to be acceptable for that case. It will work well if the verb meanings can be clustered so that specifications can be made that apply to many verbs at once and if there is not too much interdependency between the assignments made to various cases of the sentence.

The fourth method, filling in a "plex", can be superior if the cases are interdependent. It also looks interesting for sentences like

19. The coat was too big for John.

The phrase, for John, really seems to involve the thought John to wear the coat. It is not clear to what extent it is necessary to get into such matters on the initial input parse. It might be better to take a more surface oriented view until the possibilities have been pared down, or the reverse could be true. The filling in of the plex might be under the control of a user procedure based on a "deeper" form of meaning than our cases provide. We reject this fourth method in this memo because we do not have it worked out and because it could be more complex and require a better knowledge of English and thinking. It would also be more difficult to measure progress and conduct experiments than with the case approach, which may serve our immediate practical needs.

It is my view that understanding English will prove to require a large number of empirical facts. Any scheme which represents the inputs by throwing away information cannot succeed, and there is no reason to expect any small set of concepts to have great explanatory power. Thus, we shouldn't expect to find a small

However, a quick reading seems to show that there may be an interplay between the cases and the legal syntactic forms of complex sentences.

The Relation Between the Verbs and the Cases

Each verb meaning has certain MAPL objects which it will take for each of the cases. Most verb meanings do not take all of the cases and two different verb meanings do not necessarily "use" the cases in the same way. For example we say,

83) The traffic light changed from red to green.

84) I ran from my house to work.

85) I bought a box from Bob.

The verb change uses the source as the state before the change. Run uses the source as the starting point of the run, while buy uses the source as the responsibility center from which the purchase was made.

During parsing, the meaning of a verb is gotten from the stem and from obligatory cases, particles or prepositions. For example, change is not the same as change into. Consider

86) He changed into dry clothes.

This is ambiguous, either the verb is change and the destination is dry clothes or the verb is change into and the destination is dry clothes.

Next, consider

87) I shot a picture.

88) I shot the rabbit at the house with the gun.

89) I shot the gun at the house.

90) I shot the breeze in a whisper.

91) I shot the gun with a pistol.

92) I shot at the rabbit at the house.

Here we have four different meanings: send a bullet toward an object (88 , 91); shoot a gun at (89 , 92); talk (90); and take a picture (87). Each meaning uses its cases in a different way. At flags the general location in 88) (or modifies rabbit), but the destination in 89). Note that in this view shoot the breeze is not any more idiomatic than the other three meanings. This is convenient because we must still conjugate the verb as if it wasn't idiomatic. Both [1] and [2] have pointed out that 88) and 89) can be considered to be one meaning of shoot, but we will not try for such economies if they complicate our recognition scheme. Note that such things as reflexive pronouns can be used in deciding what the different verb meanings are.

93) They threw a smoke screen around themselves.

* 94) They expected a smoke screen around themselves.

The difference between 93) and 94) is that throw around is a meaning while expect around is not.

Let us review. We have said that the cases are determined by the verb meaning. This meaning is found from the object, and any particle or preposition which that verb meaning must take. It is also the case, that for a given meaning the object can be used in some algorithmic way in determining the MAPL objects which the other cases can take. For example,

95) I obtained the milk from the cow.

96) I obtained the milk from the store.

* 97) I obtained the milk from the alligator.

98) I obtained the skin from the alligator.

The source case of obtain must be a legitimate place to get the object.

99) I rode down the street in the boat.

One could argue that the trajectory and the specific location should interact, as one cannot have a trajectory of street while in a boat.

To explain our position on this we will make the distinction between accepting something as possibly true and deciding we believe it. In deciding what can go with each case of a verb meaning we are doing semantic type checking to eliminate the obviously wrong parsings before making a more thorough analysis on the rest. There is no obvious way to draw the line between

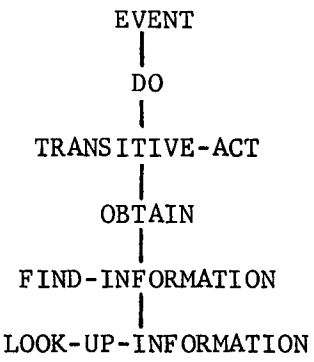
97) I obtained the milk from the alligator.

99) I rode down the street in the boat.

To me, 99) excites more hope for a possible explanation but I will make an arbitrary decision that in general only the verb meaning and object can be used in type checking. Further exploration may cause me to alter this stand. Exceptions to the rule will be made in comparing the agent and instrument, the specific and general location, and the specific and general time.

The Hierarchy of Verb Meanings

MAPL allows one to form a lattice of concepts under set inclusion [10]. The set inclusion relation is called A-K-O. It turns out that if we structure the verb meanings into an A-K-O tree we can achieve an economy in describing how they take the cases. For example, we might have:



To say that any EVENT takes a SPECIFIC-LOCATION which is a PHYSICAL-OBJECT we would declare to MAPL

(A-R-O SPECIFIC-LOCATION-OF PHYSICAL-OBJECT- EVENT).

Now suppose we have the sentence:

100) I looked up the number in the book in a minute.

One of the meanings of look will be LOOK-UP-INFORMATION. This meaning requires the particle up. The object must be a type of information and occurs after up or as the first surface object. The specific location is flagged by in and must be printed matter. We put these properties directly on LOOK-UP-INFORMATION. When the parser reaches in in 100) it will run up the A-K-O tree and find all the cases which in can flag LOOK-UP-INFORMATION. Thus, the SPECIFIC-LOCATION will be right on LOOK-UP-INFORMATION, while the other use of in in 100), the DURATION, will be found on EVENT. It will then run up again for each possible case until it comes to the first specification of that case. Thus, the SPECIFIC-LOCATION of PRINTED-MATTER on LOOK-UP-INFORMATION will override the more general one on EVENT. We now have a criterion for the structuring of the verb meanings. We must ask if it will work.

Figure 1 gives a tree of the verbs discussed in Shank [5] and other papers. Using this tree, I assigned the cases as high up as possible. (Shank's hierarchy did not fit my needs.) Figure 2 shows that many cases can be assigned high up and probably never overridden below. Figure 3 gives a summary of what to expect with the remaining cases. The fact that many cases are rather general is encouraging. Notice that DURATION has been assigned to EVENT. Consider the sentence

101) I milked the cow by hand for the first three buckets.

The duration property on event is a function which asks, is this a measure or a sequence which could measure time for the given verb meaning and object. It must consult the MAPL world model to answer this question. It may invoke user world model routines. It is by consulting the user world model that the English syntactic type checking can be generalized. Care must be taken not to trigger long searches. A trade off exists between the time spent on type checking and the number of parsings given the user. One would expect the user to need to know what objects his actions apply to in any case. Thus, if we can convince the user to construct his world model in terms of our cases, he will automatically supply most of the type checking information. Although we have not emphasized it here the reader should be aware that the final lattice of verb meanings will probably be organized on syntactic as well as semantic grounds.

Remember that the basis of our case scheme is that the user assigns meaning not to cases, but to verb meaning, case, case filling element triples. While this is essential, the hierarchy here suggests that case can be given useful heuristic interpretation.

EVENT

←EXIST

[redacted]

HAVE-AS-MODIFIER

HAVE-AS-CHARACTERISTIC

[redacted]

IS-A-KIND-OF

HAS-A-KIND-OF

HAVE

OWN

HAVE-AS-PART

HAVE-AS-PART-IN-COMMON

HAVE-IMMEDIATE-CONTROL-OVER

[redacted]

CONCEPTUALIZE

PONDER

MANIPULATE-THOUGHT-IN-CONTEXT

REASON

CONSIDER

WONDER

UNDERSTAND

THINK

REMEMBER-FORGET

BELIEVE

EXPECT

INTEND

WANT

RECALL

PERCEIVE-OBJECT

LISTEN-TO

LOOK-AT

SMELL

Figure 1

```
DO
    INTRANSITIVE-ACT
        CHANGE-STATE

    EMIT-A-PHYSICAL-DISTURBANCE
        TALK
        ROAR
    MOVE
        TRANSLATE
            RUN
            GO
        MOVE-IN-PLACE
            VIBRATE
        MUTUAL-MOTION
            COLLIDE

    TRANSITIVE-ACT
        EXPERIENCE-EMOTION-TOWARD
        MANIPULATE
            OPERATE
                DRIVE
            MOVE-IN-PLACE
                SHAKE
            TRANSLATE-OBJECT
            ALTER
                DESTROY
                DISASSEMBLE
                CHANGE-CHARACTERISTIC-OF
                    GIVE-CHARACTERISTIC
```

Figure 1 continued

MAKE

    EMIT

    ASSEMBLE

    GIVE-A-PART

INTERACT-WITH

    PLAY-A-GAME-WITH

TRANSFER-IMMEDIATE-CONTROL-OVER

    HIT

TRANSFER-OWNERSHIP

    SELL-GOODS

OBTAIN

    LOOK-UP-FACT

Figure 1., cont'd.

EVENT

- COMPLEMENT
- GENERAL-TIME
- SPECIFIC-TIME
- GENERAL-LOCATION
- DURATION
- ORDINAL
- CONDITION
- REASON
- CONTEXT
- DESPITE
- COMPARISON
- EDITORIAL-COMMENT

EXIST

- INDIRECT-SUBJECT
- RATE
- AGENT
- SOURCE

HAVE

- EXPECTED-EFFECT
- QUANTITY
- FOR-AGENT-TO-HAVE
- SOURCE

CONCEPTUALIZE

- AGENT
- CO-AGENT

DO

- AS-IF
- QUANTITY
- EXPECTED-EFFECT
- METHOD
- BENEFICIARY

Figure 2.
Assignment of Cases to Top Level Concepts.

SEMI-DETAILED-LEVEL

AGENT

RECIPIENT

SOURCE

DESTINATION

CO-AGENT

MANNER

[redacted]

DETAILED-LEVEL-FOR-SOME-VERBS

[redacted]

INSTRUMENT

TRAJECTORY

DEGREE-OF-COMPLETION

SPECIFIC-LOCATION

RATE

WITH-RESPECT-TO

EXCHANGE

DETAILED-LEVEL-FOR-MANY-VERBS

OBJECT

PREREQUSITE-USED

Figure 3.

Classification of Cases

The Cases of the Noun Group

In MAPL [10] we state that all fruit may have color with the declaration

(A-R-O COLOR-OF COLOR FRUIT)

When this is declared along with

(A-K-O COLOR NOMINAL-CHARACTERISTIC)

(A-K-O RED COLOR)

(A-K-O GREEN COLOR)

(A-K-O APPLE FRUIT)

then we may assert

(COLOR-OF RED APPLE)

to state that apples are red.

Suppose that the parser gets the sentence

A green apple is tasty.

It will recognize green as an adjective and apple as a noun. Let NG1 be the name of the noun group. It will declare (A-K-O NG1 APPLE). It will then check to see what (A-R-O ? GREEN APPLE) instantiates, and find

(A-R-O COLOR-OF COLOR FRUIT).

It will then declare

(H-R-O-F R1 COLOR-OF GREEN NG1)

which declares (COLOR-OF GREEN NG1) and gives it the name R1. It will then declare

(MODIFIER-OF R1 NG1).

Bach (6) points out that there is considerable ambiguity in statements constructed like R1. First, we don't know if NG1 is to evaluate to a specific apple or applies to all apples which are green. Second, in the sentence

The Russians will put a tall man on the moon.

we do not know for sure that the man is currently tall. Thus, there is a question of the time of R1. Finally, in the sentence

Every man wants to love some good woman.

we do not know what the mapping is between men and women.

These ambiguities are not the concern of the type checking mechanism. As we have constructed R1 above it is correct, it must be further modified by other relations in order to remove the ambiguities. This can be done in the user's world.

Winograd gives the sequence

DETERMINER ORDINAL NUMBER ADJECTIVE CLASSIFIER NOUN MODIFIER

for the normal noun group. The determiner, ordinal, and number are rather specific to English and we will cover them later when we discuss word order. Let us now turn to modifiers, and then classifiers.

It is popular in transformational grammar [6,7] to discuss the derivation of the noun group from a clause.

Sentences like

I know someone who sells cactuses.

I know a seller of cactuses.

I know a cactus-seller.

and

This is good land for cotton.

We can grow cotton on this land.

appear to have a lot in common semantically and this leads to the derivation of the noun group. The transformational grammarians first derive a clause, and then transform it to produce a noun group. We will not follow the reverse of this on recognition, but rather we will access the same underlying MAPL structure for the cases of the clause and the modifiers of the noun group. For example, consider the sentence

I bought some books for girls.

Our analysis of the preposition <u>for</u> modifying a noun group shows that the noun modified can be the object, specific-location, or prerequisite-used of some event for which the object of the preposition is another highly constrained case. For example, if we take books as the prerequisite used, then we must take girls as the object. A look in our MAPL model might find

Educate girls with books.

Entertain girls with books.

If we take books as the specific location we must again take girls as the object. Here our MAPL model would probably draw a blank. If we take books as the object, girls can be either the agent or the specific location.

This might produce

Girls own books.

Girls read books.

Girls have-immediate-control-over books.

Finally, taking books as the agent, we must take girls as the object. This would probably be fruitless. Thus we could come up with as many as five interpretations which would have to be selected between. It is not clear whether we should force a choice or just pass for to the user if there are any possibilities. Fortunately, several things can simplify our task. First, the speaker can give us more help. He might say

I bought some books for educating girls.

in which case we are faced only with attaching books to the clause educating girls. Second, he may use the for construction only where there are few interpretations as in

A grave for a dead body should be six feet deep.

Third, many prepositions don't allow many choices of cases.

A noun group can also take several of the same cases as the clause, such as time and location. An analysis of the prepositions and the cases or secondary events they flag is given below. Where two case names are given, the first is for the noun and the second for the object of the preposition, when they are used in a secondary event. VALUE and AGENT-OF-HAVE are not cases, but special indicators. VALUE means that the noun is the modifier rather then vice-versa in the relation that follows. AGENT-OF-HAVE gives the case and the verb. Note that the same ambiguities about time, etc. will hold as held for adjectives.

For Secondary Subject

a) OBJECT-OF AGENT-OF

I bought some books for girls. (to read [redacted])

[redacted] ([redacted])

b) [redacted] [redacted] OF
SPECIFIC-LOCATION-OF OBJECT-OF

A grave for a dead body should be six feet deep. (to be in [redacted].)

This is good land for cotton. (to grow on [redacted].)

This is a home for water plants. (to be at)

[redacted] OBJECT-OF

We need more roads for cars. (to run on [redacted].)

[redacted] (Put dead body in [redacted].)

d) PREREQUISITE-USED-OF OBJECT-OF

That is good wood for arrows. (to be made with [redacted].)

e) INSTRUMENT-OF ING-SC

We use lamps for killing germs. (Kill germs with lamps.)

f) OBJECT-OF ING-SC

These are good apples for eating. (Eat apples.)

g) [redacted]

These are factories for making tools. (Make tools at the factory.)

h) PREREQUISITE-USED-OF ING-SC

This is good wood for making arrows (Make arrows with wood.)

PREREQUISITE-USED-OF
i) [redacted] OBJECT-OF

The performance for the king was a flop. (to be entertained by [redacted].)

That is the German word for dog. (Word have-value dog.)

j) INSTRUMENT-OF OBJECT-OF

We need a knife for butter. (to be cut with [redacted].)

PREREQUISITE-USED-OF
k) [redacted] ING-SC

Dogs for hunting rabbits are still common. (We [redacted] hunt rabbits with dogs.)

From

SOURCE-OF

[redacted]

He was born five miles from here.

SOURCE-OF

I prefer milk from a cow to milk from a goat.

In

SPECIFIC-LOCATION-OF

He eyed the fish in the school.

[redacted] LOCATION-OF

He purchased a house in Florida.

On WITH-RESPECT-TO
A difficulty in mathematics is that there are too many professors.

SPECIFIC-LOCATION-OF

The leaves on the tree were yellow.

LOCATION-OF
About The block on the table is red.

OBJECT-DESCRIBED

I found a good story about a bear.
The story about his adventures was exciting.

To He got the idea about copying birds.

~~OBJECT-OF~~ [redacted]

~~The lands to the east are unknown.~~ [redacted]

OBJECT-OF DESTINATION-OF

The path to John's house was wide. (Travel the path to John's house.)
The lands to the east are unknown.

OBJECT-OF RECIPIENT-OF

A toast to the married couple is always in order. (Give a toast to the married couple.)

With

~~AGENT-OF-HAVE~~ OBJECT-OF

Animals with backbones have more backbone. (Animals ~~have~~ backbones.)

Of

a) OBJECT-OF AGENT-OF-HAVE

The branch of a tree fell down.

b) VALUE FRACTION-OF

Half of the apples were rotten.

c) VALUE COUNT-OF

A number of the apples were rotten.

Five of the apples were rotten.

d) VALUE RELATIVE-COUNT-OF

A few of the apples were rotten.

e) VALUE SUPERLATIVE-OF

The biggest of the cakes was too small.

f) OBJECT-DESCRIBED

The story of his adventures was exciting.

He got the idea of copying birds.

The painting of Salisbury Cathedral was pretty.

[redacted].

g) CONTENTS-OF

He bought a carton of milk and a flock of sheep.

I burned a cord of wood.

h) A-K-O

That is a kind of chemical.

I have a way of finding out.

i) VALUE A-K-O

The state of Texas is very big.

j) [redacted]

He was born south of here.

k) AGENT-OF

The growling of the lion kept me awake.

l) OBJECT-OF

The making of the stew takes three hours.

~~b)~~ VALUE VALUE-OF

MEASURE-OF
VALUE-OF
NUMBER-OF
COUNT-OF
FRACTION-OF
STORY-OF
IDEA-OF
characteristic OF
measure OF
KIND-OF
WAY-OF
alteration OF
state of confusion
US-state of Texas

Lees (7) gives a discussion of how classifiers and compound nouns can be derived by the same process we have used for prepositional modifiers of the noun group. However, although we say pine cone we don't say apple fruit. It is clear how apple fruit should be interpreted and we have our option as to how to proceed. Since a great many relationships could exist between the two nouns, we will insist that classifier noun pairs be treated as noun idioms and listed explicitly, with the exception of the sequences

noun, ordinal number; as in item 5

proper-noun, noun; as in A and T store.

These both will be turned into proper nouns.

Operation of the Parser

The parser recognizes the following aggregates of words and phrases:

TOP-LEVEL-CONJUNCTION

MAJOR-CLAUSE

SECONDARY-CLAUSE

NOUN-GROUP

ADJECTIVE-GROUP

ADVERB-GROUP

QUESTION-GROUP

PREPOSITION-GROUP

VERB-GROUP

A state transition network has been written for each phrase. Each state can have three kinds of arcs leading out of it, next-unit, try-branches-of (indicated by -----→ in the word order charts below), and no-success. When building a phrase, the parser tries each of the next-unit arcs out of the current state, if none of these applies it looks for the try-branches-of arc, (of which there is at most one) and tries the arcs of the state indicated by it. If none of these leads to success it looks for a no-success arc, which indicates under what conditions the phrase can be complete without further constituents added. Each arc gives the syntactic type of the word or phrase which must be found next and a function which must be successfully applied to the MAPL expression built up so far, and the MAPL expression for the phrase just found. If the function is successful it returns the new partial MAPL expression for the part of the phrase found so far.

For example, a fragment of the noun group network currently implemented looks like

```
(NOUN-GROUP    DET=NUM=ADJ=NOUN=PRONOUN
 (WE=YOU       ADD-PRONOUN-TO-NG
    (NOUN-GROUP    NUM=ADJ=NOUN=ALL
         (NO-SUCCESS     DO-NOTHING1  SUCCEED)))
 (TRY-BRANCHES-OF  DO-NOTHING1    ORDINAL-SUBTREE))
```

The first line says that we have a NOUN-GROUP going and we are currently looking for something which is a kind of DET=NUM=ADJ=NOUN=PRONOUN. The second line says that if we in fact find something which is a kind of WE=YOU then we attempt to apply the function ADD-PRONOUN-TO-NG to the MAPL form of the noun group, and the MAPL form of WE=YOU. If this function returns NIL the parse can't proceed. The only alternative then is given by the fifth line, which says that if the function DO-NOTHING1 can be applied to the NOUN-GROUP MAPL form with a non-NIL result, we advance to state ORDINAL-SUBTREE. If ADD-PRONOUN-TO-NG gives a non-null result the third line tells us that we then have a noun-group going and are looking for a NUM=ADJ=NOUN=ALL. If we don't find one, the fourth line says that if DO-NOTHING1 applied to the NOUN-GROUP MAPL form is non-NIL, then that result is the completed noun group, which can then be added to a superior group or clause.

During the parse, the parser maintains a stack of pairs: a current state in a phrase and a partial MAPL expression. The stack is started off with one pair; the first state of MAIN-CLAUSE and a null MAPL expression. The parser then looks at the next word of the input string and takes a number of actions which are dependent on our view of the structure of English. First, it checks to see if the word starts a noun idiom and builds it if it does. Failing this, it tries to add the word to the current phrase. Failing this, it checks to see if the word would begin one of the other phrases. If it will, it starts that phrase. It then checks to see if this new phrase could possibly be fitted onto the current one when the new one is finished. It does this by comparing what we have going in the new phrase with what we are looking for in the current one.

If the new phrase can yield a constituent we are looking for, it adds the new phrase to the stack. When a phrase is finished the parser removes it from the stack and tries to add it to the one immediately above. If this fails, it checks to see if the one above can be considered complete without additional constituents being added.- For example, consider

I rode down the street in the car.

At some point we will in effect have

I rode →

down →

the street →

in the car.

The parser will try to form

I rode →

down →

the street in the car

but the MAPL world will block this. The parser will then form

I rode →

down the street

in the car.

and then it will form

I rode down the street →

in the car.

and it will then be successful in attaching <u>in the car</u> to the main clause.

In starting a new group the parser must also consider the possibility that it begins a secondary clause. For example, consider

We celebrated the day the rain came.

The parser will get

We celebrated →

the day →

and it will then see that the next word starts another noun group. A noun group cannot post-modify a noun group, but it can start a secondary clause. The parser forms

We celebrated →

the day →

→

the →

and continues as normal. All parsings are found. Negation, surface-objective-case, and person-number are not used to stop a phrase until it is time to add it to the one above. Such features didn't seem to block many false parses. That is, these features are checked by the features which combine MAPL forms rather than to describe what we are looking for and what we have going. In parsing the determiner structure a number of properties are found. The properties of the noun group and major clause are listed below, along with the word order charts for our phrases. Following the word order charts are lists of words and phrase categories used in them. In the word order charts, a "0" means that the network has been completed.

MAJOR-CLAUSE

SLOT-FLAG
OBJECT-OF, LOCATION-OF, SECONDARY-SUBJECT-OF

UNUSED-SUBJECT-NG-OF
(NG CANDIDATE-CASE-LIST)
UNUSED-FIRST-NG-OF
(NG CANDIDATE-CASE-LIST)
UNUSED-SECOND-NG-OF -
(NG CANDIDATE-CASE-LIST)
UNUSED-AUXILIARY-VG-OF
SUBJECT-OF
RELATION-QUESTIONED-OF
TYPE-OF
A-K-O
TENSE-OF
VOICE-OF
NEGATION-OF
PERSON-NUMBER-OF
AGENT-OF
DEGREE-OF-COMPLETION-OF
BENEFICIARY-OF
OBJECT-OF
[redacted]
SOURCE-OF
DESTINATION-OF
[redacted]LOCATION-OF
CHARACTERISTIC-OF
INSTRUMENT-OF
[redacted]TIME-OF
PREREQUISITE-USED-OF
[redacted]
DURATION-OF
[redacted]
[redacted]
METHOD-OF
QUANTITY-OF
[redacted]
GOAL [redacted]-OF
CONTEXT-OF
[redacted]
COMPLEMENT-OF
COMPARISON-OF
AS-IF-OF
MANNER-OF
RECIPIENT-OF
EXCHANGE-OF
WITH-RESPECT-TO-OF
ORDINAL-OF
[redacted]
EDITORIAL-COMMENT-OF

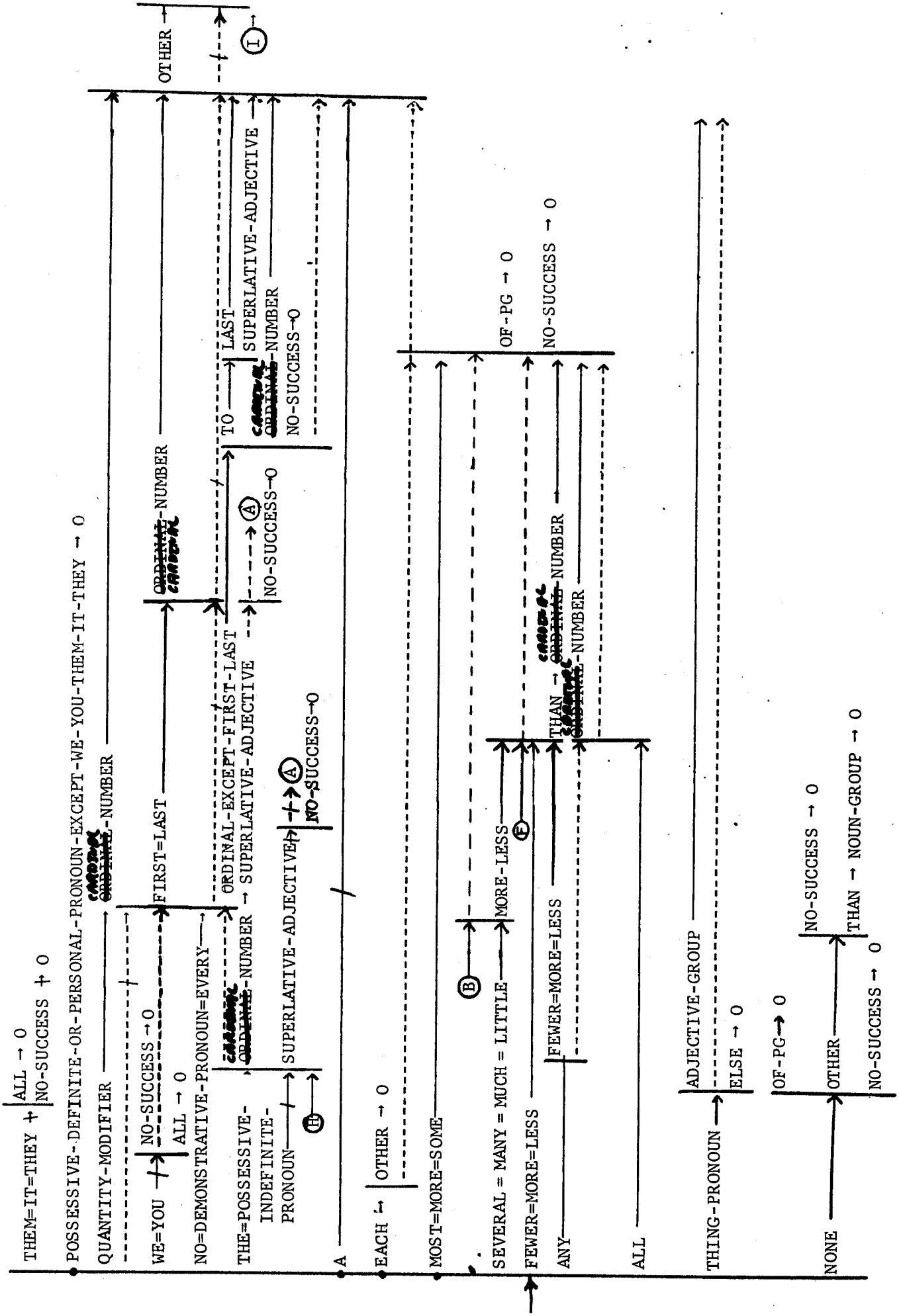
SPECIFIC-LOCATION-OF
TRAJECTORY-OF
[redacted]
DEMONSTRATIVE-OF
REFLEXIVE-OF

NOUN GROUP

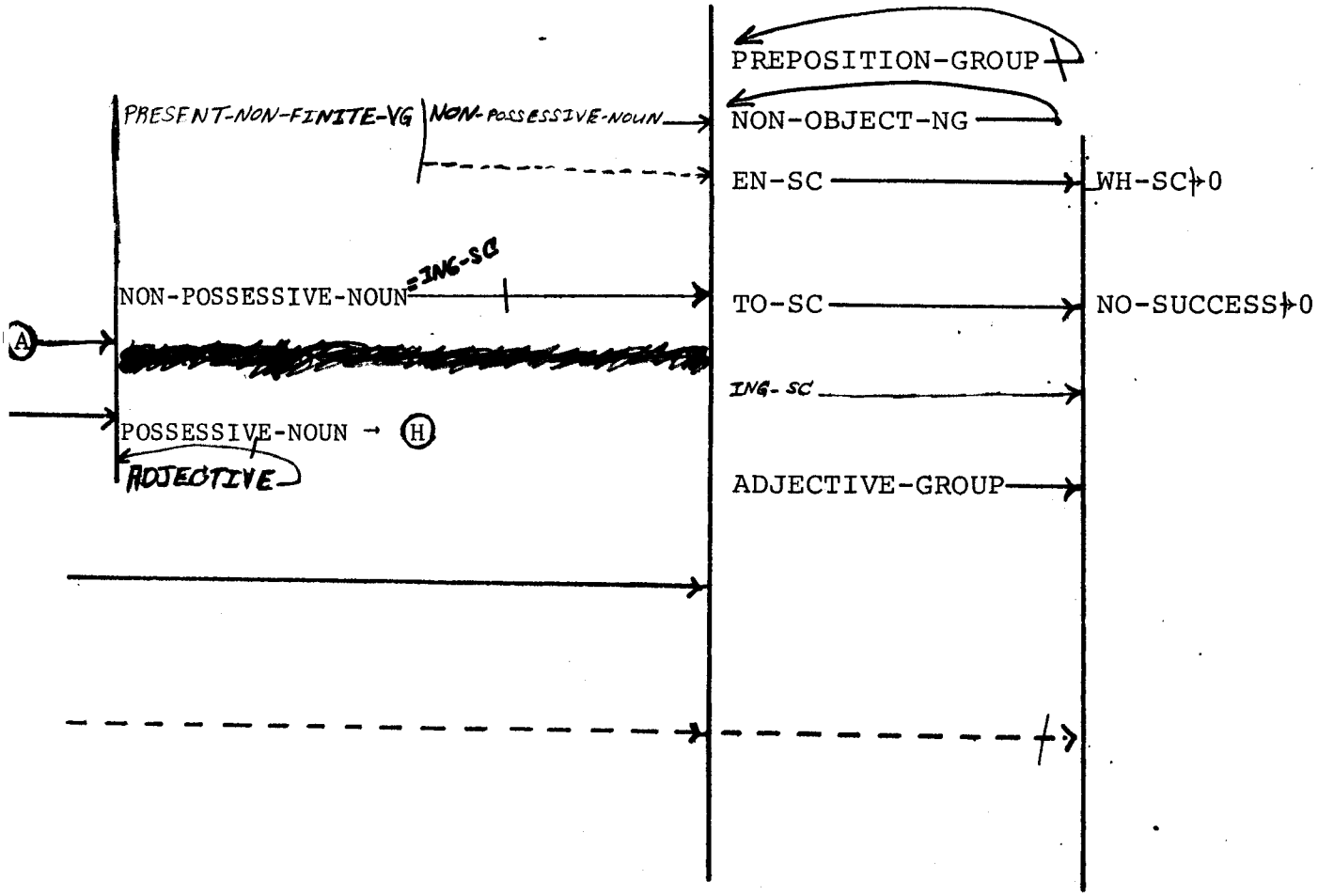
UNUSED-MODIFIER-OF
(TYPE MODIFIER)
RELATION-QUESTIONED-OF
A-K-O
PERSON
FIRST
SECOND
THIRD
NUMBER-OF
SINGULAR
PLURAL
GENDER
MASCULINE
FEMININE
NEUTER
SYNTACTIC-CASE
SUBJECT
OBJECT
POSSESSIVE
DEFINITE
INDEFINITE
DEMONSTRATIVE
HERE
THERE
THE
SELECTIVITY
ALL
ANY ONLY
NO
ORDINAL
EXPRESSION
ORDINAL
NEXT
LAST
REFLEXIVE
REFLEXIVE
TYPE-OF
VALUE-OF

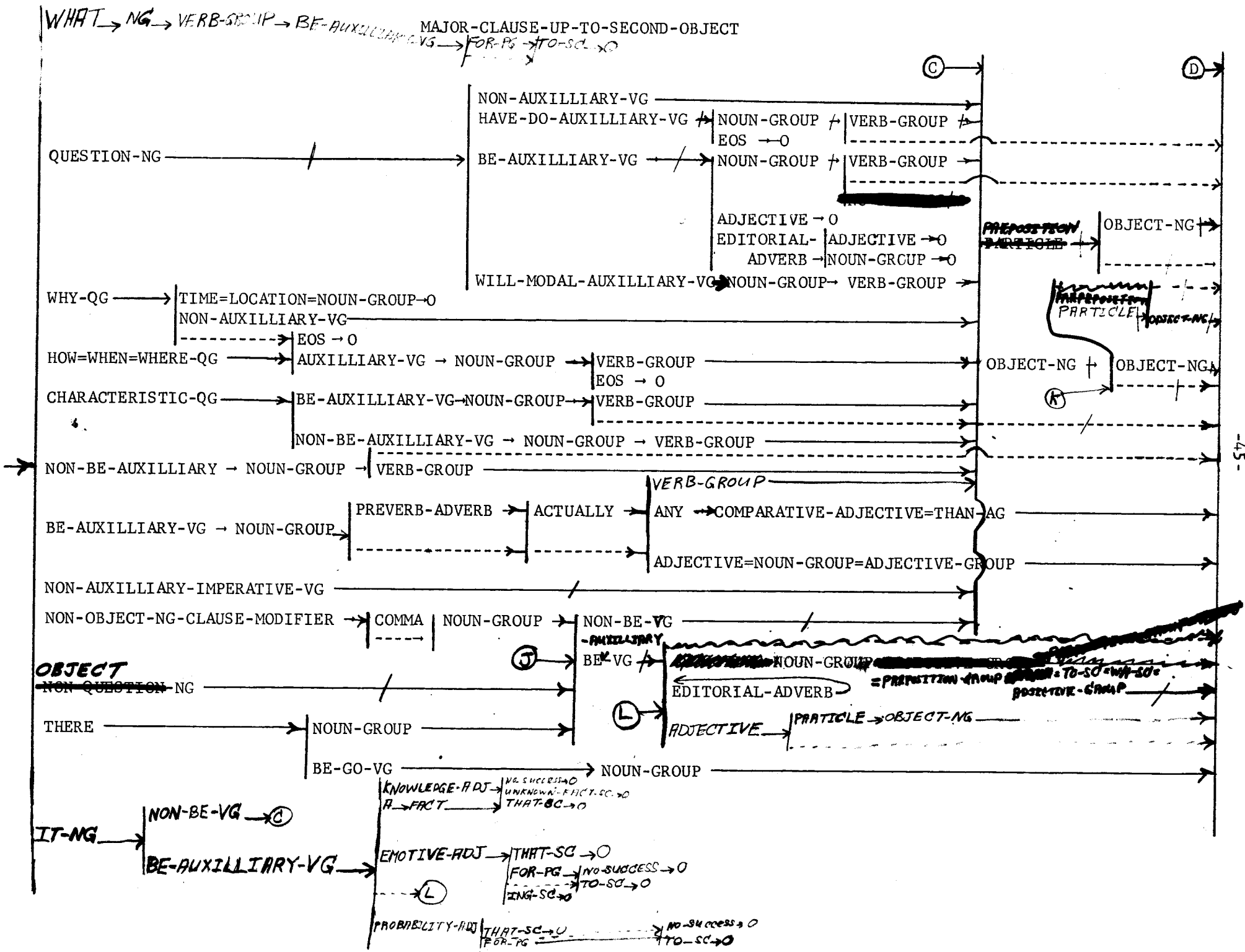
MEASURE
BENEFACTOR
GOAL
HAVE-VALUE
OBJECT-DESCRIBED
[redacted]
SPECIFIC-LOCATION
[redacted]LOCATION
[redacted]
[redacted]TIME
WITH-RESPECT-TO
AGENT
OBJECT
SOURCE
MODIFIER
SECONDARY-SUBJECT
POSSESSOR
FRACTION
FEW
MOST
OTHER-OF
SAME
OTHER
QUANTITY
COUNT-OF
INTEGER
A-FEW
SEVERAL
MANY
EXPRESSION
COUNTABILITY-OF
COUNTABLE
MASS
RELATIVE-COUNT-OF
FEWER
MORE
EXPRESSION
REPETITION-INTERVAL
[redacted]

NOUN-GROUP-UP-TO-ADJECTIVE

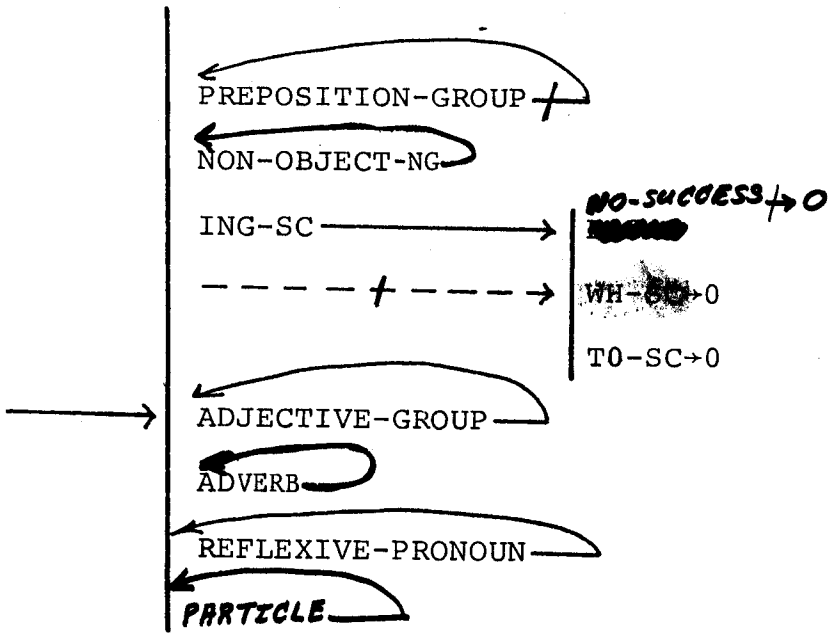


NOUN-GROUP-FROM-ADJECTIVE

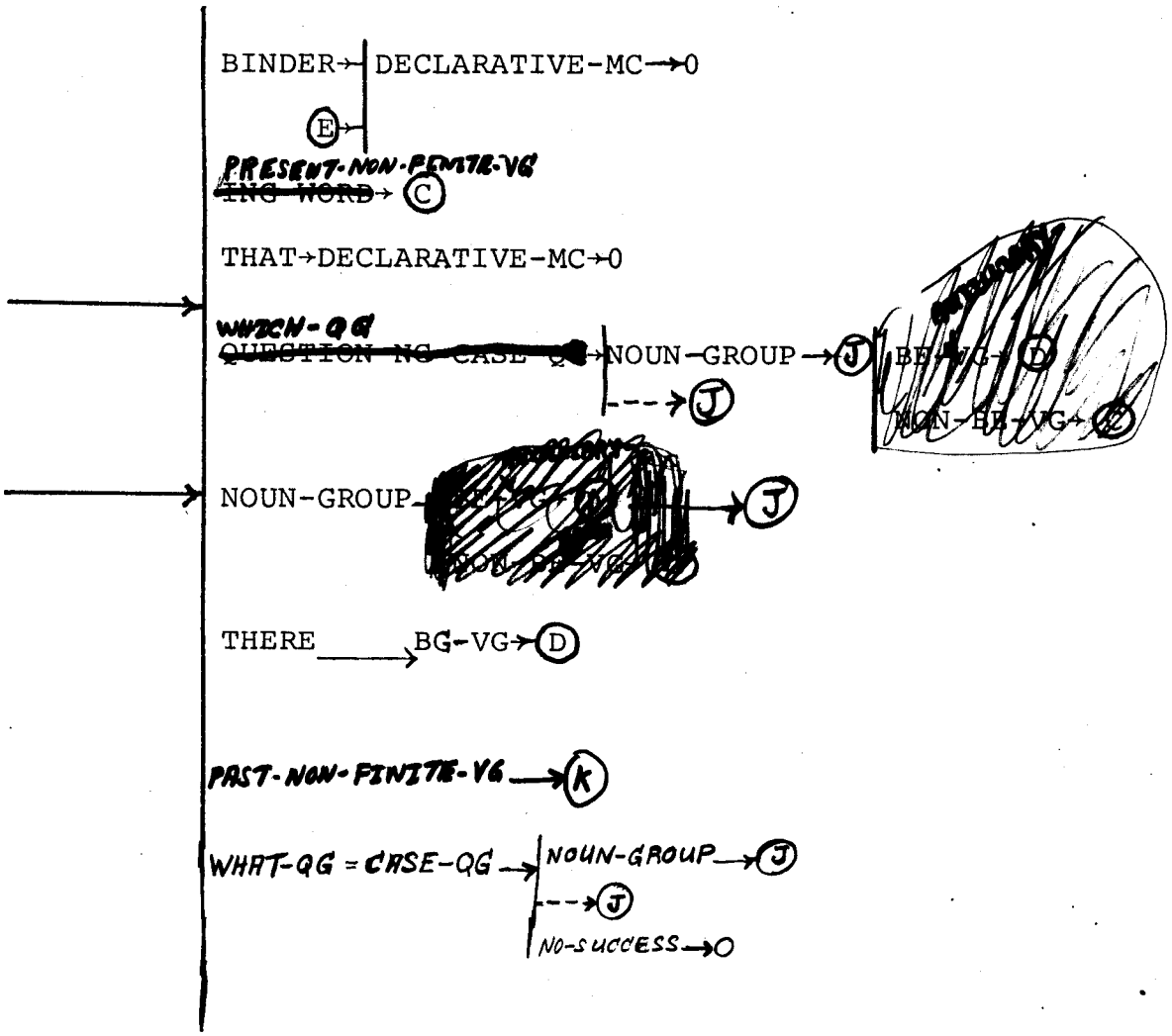



WHAT → NG → VERB-GROUP → BE-AUXILLIARY-VG → FOR-PG → TO-SC → O
MAJOR-CLAUSE-UP-TO-SECOND-OBJECT
C
D
NON-AUXILLIARY-VG
HAVE-DO-AUXILLIARY-VG
NOUN-GROUP
VERB-GROUP
EOS → O
QUESTION-NG
BE-AUXILLIARY-VG
NOUN-GROUP
VERB-GROUP
ADJECTIVE → O
EDITORIAL-ADVERB → O
ADJECTIVE → O
NOUN-GROUP → O
PREPOSITION
PARTICLE
OBJECT-NG
WILL-MODAL-AUXILLIARY-VG
NOUN-GROUP
VERB-GROUP
WHY-QG
TIME=LOCATION=NOUN-GROUP → O
NON-AUXILLIARY-VG
EOS → O
HOW=WHEN=WHERE-QG
AUXILLIARY-VG → NOUN-GROUP
VERB-GROUP
EOS → O
OBJECT-NG
OBJECT-NG
K
CHARACTERISTIC-QG
BE-AUXILLIARY-VG → NOUN-GROUP
VERB-GROUP
NON-BE-AUXILLIARY-VG → NOUN-GROUP → VERB-GROUP
NON-BE-AUXILLIARY → NOUN-GROUP → VERB-GROUP
VERB-GROUP
BE-AUXILLIARY-VG → NOUN-GROUP
PREVERB-ADVERB
ACTUALLY
ANY → COMPARATIVE-ADJECTIVE=THAN-AG
ADJECTIVE=NOUN-GROUP=ADJECTIVE-GROUP
NON-AUXILLIARY-IMPERATIVE-VG
NON-OBJECT-NG-CLAUSE-MODIFIER
COMMA
NOUN-GROUP
NON-BE-VG
J
BE-VG
NOUN-GROUP
EDITORIAL-ADVERB
L
ADJECTIVE
PARTICLE → OBJECT-NG
OBJECT
NON-QUESTION-NG
THERE
NOUN-GROUP
BE-GO-VG
NOUN-GROUP
IT-NG
NON-BE-VG
C
BE-AUXILLIARY-VG
KNOWLEDGE-ADJ
A → FACT
NO SUCCESS → O
UNKNOWN-FACT-SC → O
THAT-SC → O
EMOTIVE-ADJ
L
THAT-SC → O
FOR-PG → NO-SUCCESS → O
TO-SC → O
ING-SC → O
PROBABILITY-ADJ
THAT-SC → O
FOR-PG
NO-SUCCESS → O
TO-SC → O

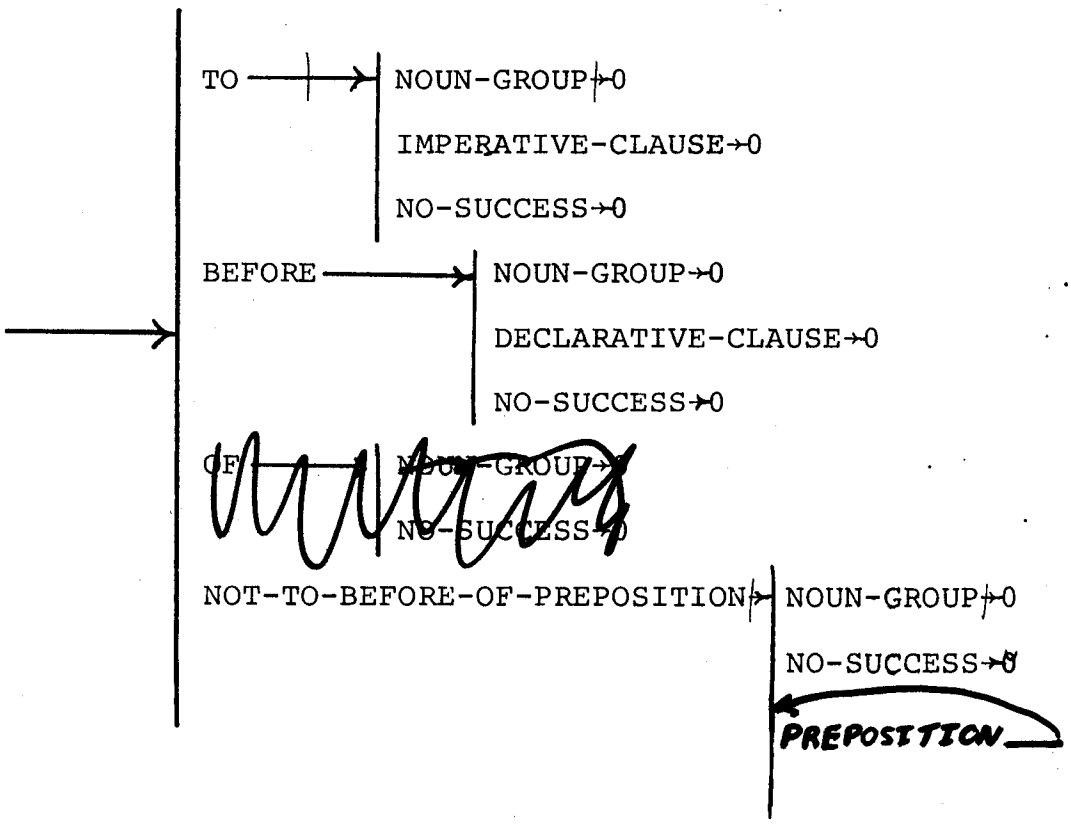
MAJOR-CLAUSE-PAST-SECOND-OBJECT



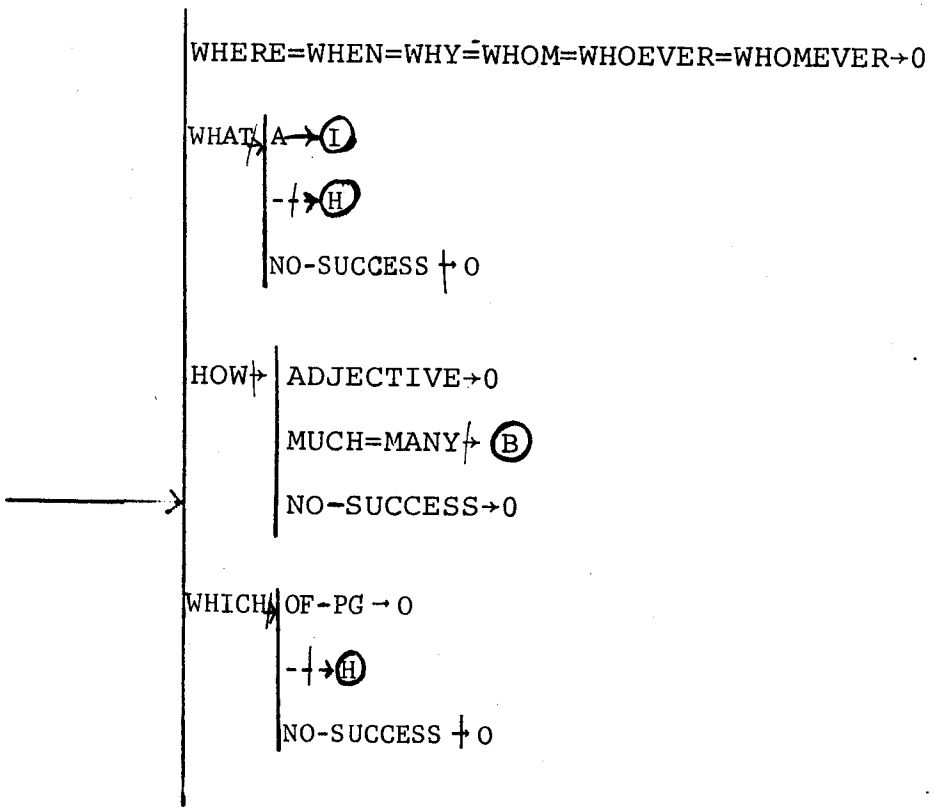
SECONDARY-CLAUSE



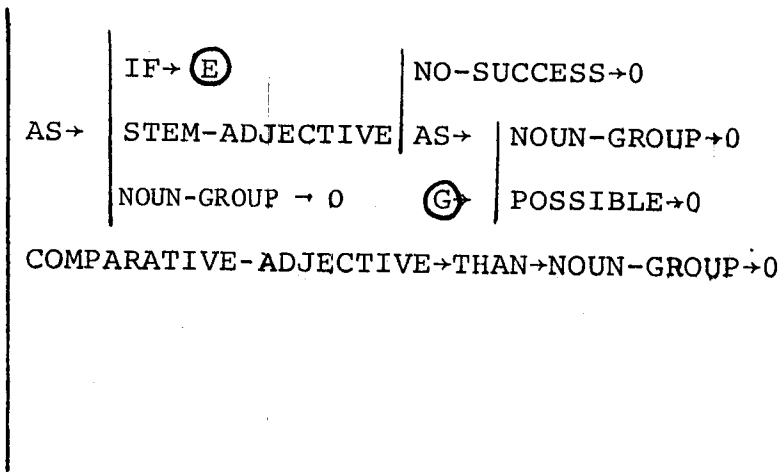
PREPOSITION-GROUP



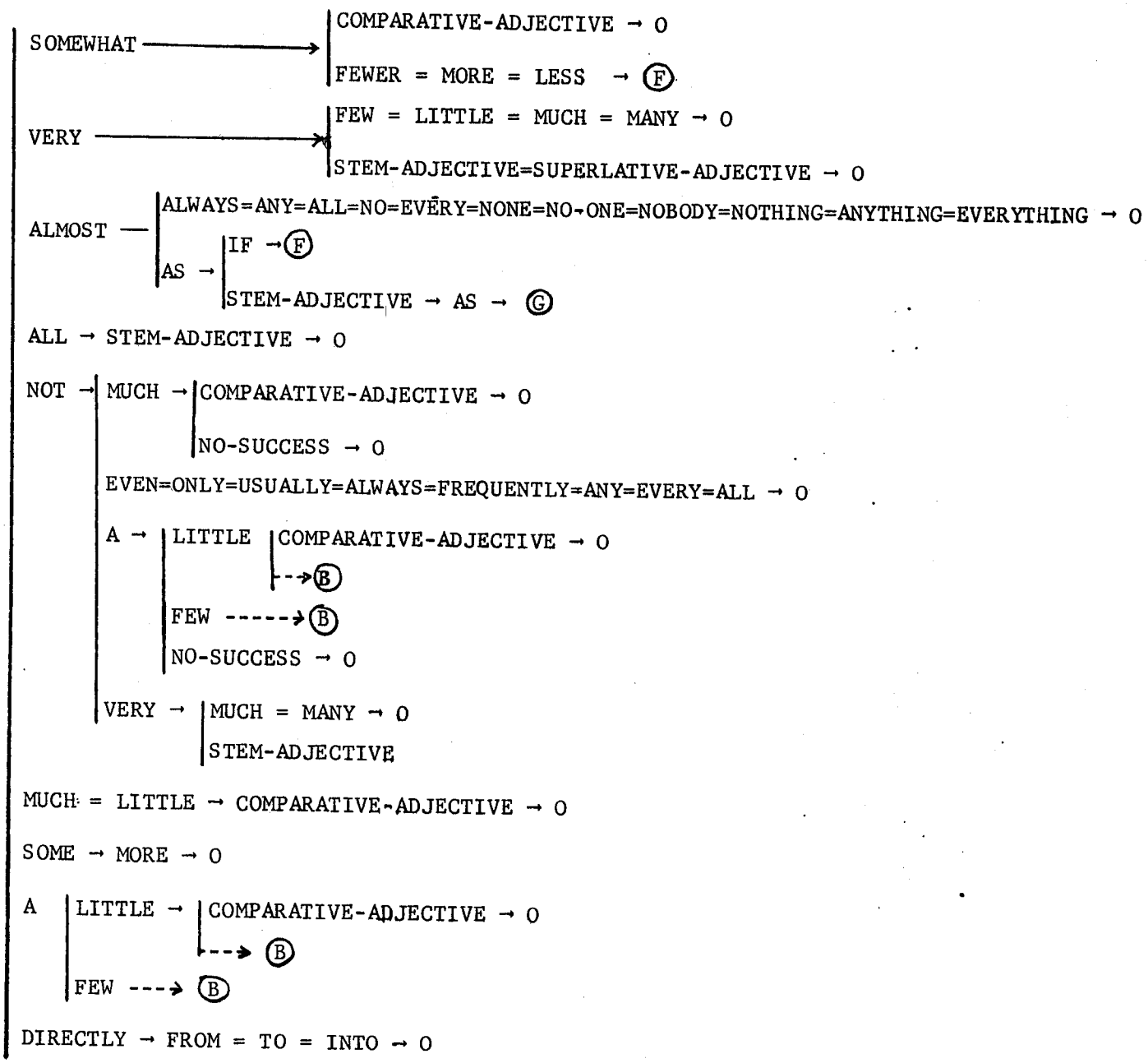
QUESTION-GROUP



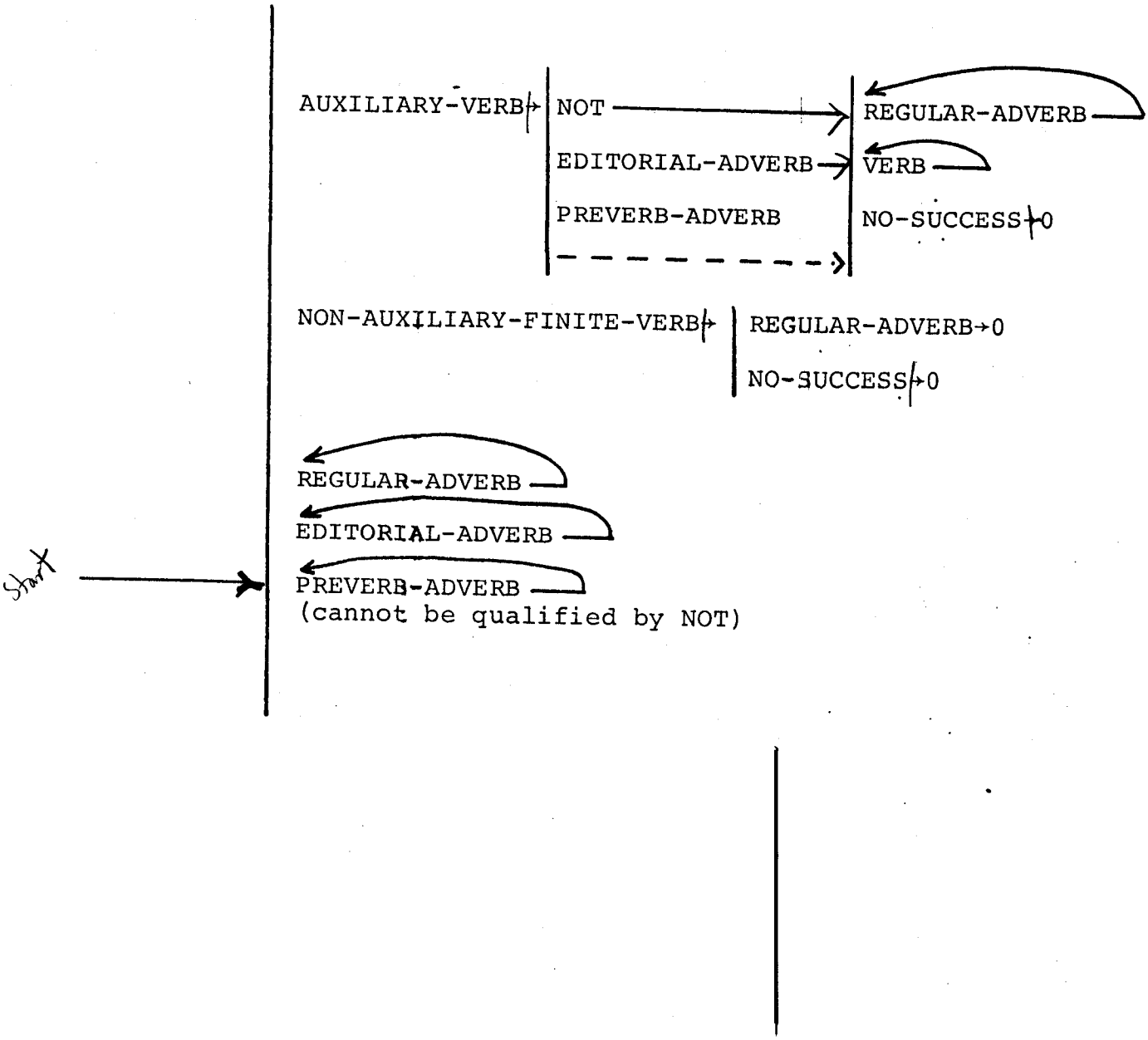
ADJECTIVE GROUP



ADVERB-GROUP



VERB GROUP


AUXILIARY-VERB
NOT
REGULAR-ADVERB
EDITORIAL-ADVERB
VERB
PREVERB-ADVERB
NO-SUCCESS→0
NON-AUXILIARY-FINITE-VERB
REGULAR-ADVERB→0
NO-SUCCESS→0
REGULAR-ADVERB
EDITORIAL-ADVERB
Start
PREVERB-ADVERB
(cannot be qualified by NOT)

PRONOUNS

THING-PRONOUN	PERSONAL-PRONOUN-EXCEPT-WE-YOU-THEN-IT-THEY		WE=YOU
SOMETHING	I	MYSELF	WE
ANYTHING	HE	YOURSELF	YOU
NOTHING	SHE	HIMSELF	
EVERYTHING	ME	HERSELF	
NO-ONE	HIM	ITSELF	
NOBODY	HER	OURSELVES	
SOMEONE	US	YOURSELVES	
ANYONE		THEIRSELVES	
EVERYONE			

DEMONSTRATION-PRONOUN	POSSESSIVE-PRONOUN	THEM=IT=THEY
THIS	MY	THEY
THAT	YOUR	IT
THESE	HIS	THEM
THOSE	HER	
	ITS	
	OUR	
	THEIR	
	MINE	
	YOURS	
	HIS	
	HERS	
	ITS	
	OURS	
	THEIRS	

BINDER

BINDER

WHILE

BECAUSE

IF

SO

UNLESS

WHEN
AFTER
BEFORE

THUS
CONSEQUENTLY
HENCE
ACCORDINGLY
RATHER
CONVERSELY
SIMILARLY
SINCE

MEANWHILE
THEN
THEREFORE
NEVERTHELESS
YET
THOUGH
ALTHOUGH
DESPITE
HOWEVER
WHETHER-OR-NOT

ADVERBS

QUANTITY-MODIFIER

EXACTLY

ROUGHLY

APPROXIMATELY

(not used)
QUANTITY-ADVERB

A-FEW

A-LITTLE

SEVERAL

SOME

MANY

MORE

EDITORIAL-ADVERB

ONLY

JUST

~~PROBABLY~~

HOPEFULLY

ACTUALLY

EVEN

~~SURELY~~

~~CERTAINLY~~

(not used)
CHANGE-MODIFYING-ADVERBS

SOMEWHAT

NO

PREVERB-ADVERB

~~EVER~~

USUALLY

~~NEVER~~

~~ALWAYS~~

ALMOST

~~FREQUENTLY~~

ORDINALS

FIRST-LAST	ORDINAL-EXCEPT-FIRST-LAST	ORDINAL-NUMBER
FIRST	SECOND	1
LAST	THIRD	2
	NEXT	ONE
	NTH	TWO

PROBABILITY-ADJ EMOTIVE-ADJ KNOWLEDGE-ADJ ADJECTIVE

LIKELY FUN PUZZLING
CERTAIN ODD CURIOUS
HARD

SUPERLATIVE-ADJECTIVE COMPARATIVE-ADJECTIVE STEM-ADJECTIVE

FEWER=MORE=LESS	ADJECTIVE
FEWER	STEM-ADJECTIVE
MORE	COMPARATIVE-ADJECTIVE
LESS	SUPERLATIVE-ADJECTIVE

SECONDARY-CLAUSE

SECONDARY CLAUSE
EN-SC
TO-SC
WH-SC
ING-SC
UNKNOWN-FACT-SC

NOUN-GROUP

NOUN-GROUP	NON-OBJECT-NG
QUESTION-NG	TIME-NG
NON-QUESTION-NG	LOCATION-NG
NON-OBJECT-NG	
OBJECTIVE-NG	

QUESTION-GROUP

QUESTION-GROUP	CASE-QG
QUESTION-GROUP	WHY-QG
WHY-QG	HOW-WHEN-WHERE-QG
HOW-WHEN-WHERE-QG	any case
CHARACTERISTIC-QG	
CASE-QG	

PREPOSITION GROUP

PREPOSITION GROUP
OF-PG

TIME

TIME
TIME-NG

LOCATION

LOCATION

LOCATION-NG

CLAUSE-MODIFIER

NON-OBJECTIVE-CLAUSE-MODIFIER

NON-OBJECT-NG

PREPOSITION-GROUP

ING-SC

ADJECTIVE-GROUP

ADJECTIVE

TO-SC

VERB GROUP

VERB-GROUP

NON-AUXILIARY-VG

HAVE-DO-AUXILIARY-VG

BE-AUXILIARY-VG

NON-BE-AUXILIARY-VG

WILL-MODAL-AUXILIARY-VG

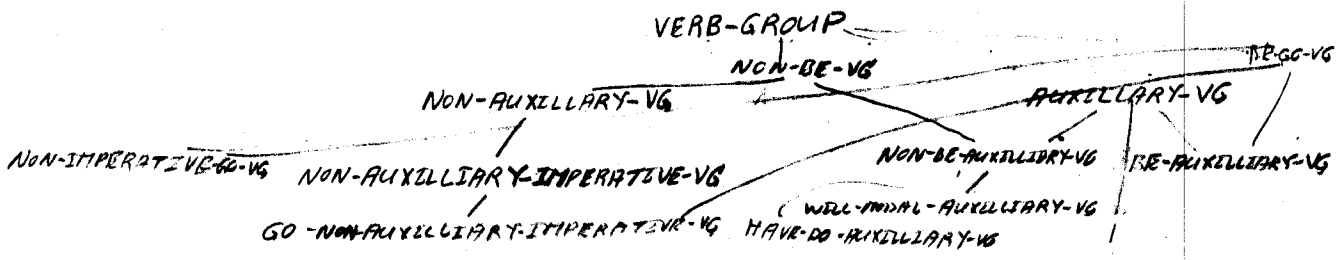
AUXILIARY-VG

NON-AUXILIARY-IMPERATIVE-VG

BE-GO-VG

[redacted]

NON-BE-VG



Construction of the MAPL Form

This is most interesting at the clause level. As the parser finds the noun groups of the clause from left to right it is not always able to assign them to the proper case immediately, therefore it holds them until enough is known. For example, consider the sentence

How much did we sell to Sears in '72?

The parser attempts to move through the sentence putting constituents aside (but remembering their position) until it finds the surface object. First it finds "how much" and remembers this as the first noun group. Then it finds "did" and remembers this as a possible auxilliary. Next it finds "we" and remembers this as the second noun group. Then it finds sell. It now knows that we is the surface subject and did sell is the verb. Next it finds "to Sears". Since this is a preposition group it knows there are no surface objects. It now considers each meaning of "sell". For each meaning it looks up the possible cases for the surface subject and discovers that "we" could be either the agent or the object. Currently it does not attempt to discover that we is Globe Union Battery Company; but that would not change what follows. It discovers that "we" passes both the agent and object predicates for sell, so it remembers that these two possibilities remain, and proceeds with the parse. It finds "to Sears". It finds that to flags the recipient for "sell" and that the recipient does not take a prepositional phrase in fact, but only the object. "Sears" passes the predicate for recipient and is assigned. The parser finds "in '72." "In" flags time, which does take the whole prepositional phrase. "In '72" passes the predicate for time and is stored as

(TIME-REFERENT-OF IN Major clause YEAR-1972).

Now the sentence is finished and "How much" has not been needed by a dangling preposition. "How much" must thus be either the object or recipient. The recipient has already been found, so this makes "How much" the object,

and "we" the agent. Apparently, the interplay between the agent, object, instrument, and recipient does not extend to the other cases. At least, people are annoyed at sentences where cases bump one another like the ones below.

I traded seeds for vegetables for gold.

I fought with my husband against a wall.

I shot the rabbit at the house at the door.

Conclusions

There is no doubt that the current grammar is far from complete. Yet, the basic structure of word order and the interaction of various syntactic and semantic features is very general and can surely be extended. The important test is whether cases and words can be defined in English by a world modeller. It is to this question that we turn our attention.

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