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AN ALGORITHM FOR THE SYNTACTIC ANALYSIS IN THE R2 INFORMATION SYSTEM

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Abstract

This paper presents a pure syntax parsing algorithm for the R2 question answering system. The parsing is a necessary part in the processing of information for the retrieval of answers by giving the syntactic structure of both questions and statements of fact. The syntactic analysis is performed on individual statements by using grammatical rules and various grammatical transformation. The parser has been implemented in LISP 1.5 on an IBM 360/75 computer. Experimental results from the system include examples of the analysis of some compound and complex sentences, as well as simple sentences.

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INTRODUCTION

During the last decade there has been significant activity in the area of syntactic analysis [2,4,5]. Of particular interest have been the development of parsers for automatic translation [7,8,9,12,13,14] and question answering systems [1,3,11,18,19,20]. A number of automated parsers have also been described [2,6,10,15,16,17].

Unlike Simmons and Cocke[†], the algorithm described here is capable of handling complex sentences including relative phrases. In addition, the approach taken here does not have as many rules as found in either Kuno or Cocke, and the rules are less complex than those of Robinson and Friedman and thus can be executed in less time.

The grammar used for the syntactic analysis in this system is a modified context-free immediate constituent phrase-structure grammar. A phrase-structure grammar is a grammar G consisting of four parts: a terminal vocabulary V_t (words such as boy, eats, etc.), a non-terminal vocabulary V_n (parts of speech such as noun, preposition, conjunction, etc.; syntactic categories such as noun phrase, verb phrase, etc.; and types of sentences such as compound, complex, and simple), a set of grammatical rules P, and a starting symbol σ to clarify where the input begins.

An immediate constituent grammar is a grammar that builds or decomposes syntactic categories out of adjacent syntactic categories and syntactic classes. A context-free grammar is a phrase-structure grammar where the rules are of the form $\alpha \rightarrow \beta$ (α is an element of the non-terminal vocabulary

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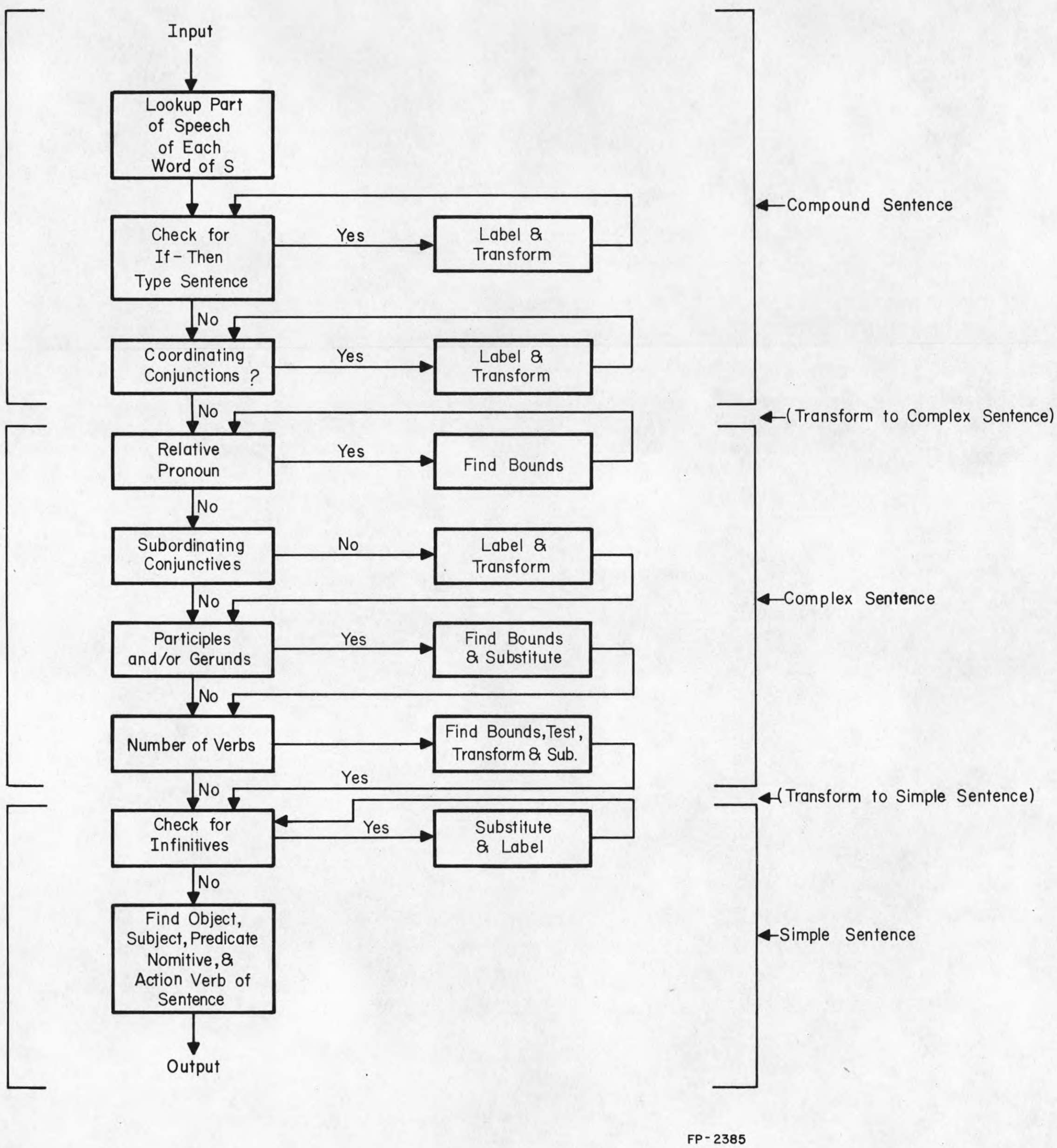
[†] As described in Hayes [7].

and β is any non-empty string), and thus the grammar is independent of the context of the sentence. A grammar is bottom-up when it combines elements of $V_n \cup V_t$ into an element of V_n.

The input to the parser is a sentence. The words are read in one by one and associated with their parts of speech by a dictionary look-up. Grammatical rules and various transformations are then applied to the sentence, and the output is in the following form:

PREDICATE(modifiers)(SUBJECT(modifiers),OBJECT(modifiers))

Thus the subject and the object of the sentence are a function of the predicate. Figure 1 shows the basic parts that the parsing algorithm has.



Input
Lookup Part of Speech of Each Word of S
Check for If- Then Type Sentence
Yes
Label & Transform
No
Coordinating Conjunctions ?
Yes
Label & Transform
No
Relative Pronoun
Yes
Find Bounds
No
Subordinating Conjunctives
No
Label & Transform
No
Participles and/or Gerunds
Yes
Find Bounds & Substitute
No
Number of Verbs
Find Bounds, Test, Transform & Sub.
Yes
No
Check for Infinitives
Yes
Substitute & Label
No
Find Object, Subject, Predicate Nomitive, & Action Verb of Sentence
Output
Compound Sentence
(Transform to Complex Sentence)
Complex Sentence
(Transform to Simple Sentence)
Simple Sentence
FP-2385

Figure 1.

THE ALGORITHM

Associated with the parser is a dictionary containing the words of the sentences to be parsed along with their parts of speech. There is also a set of hierarchial immediate-constituent rules, a set of transformational rules, and a set of phrase-markers defined in another dictionary.

The input sentence must be grammatically correct. The object of the parsing is to transform the input sentence, which is assumed to be compound, to a kernel sentence with its modifiers or to a set of kernel sentences and its modifiers. A compound sentence contains two or more independent sentences. Each statement in a compound sentence is a main clause and is coordinate with the other statements. Clauses in a compound sentence are joined in one of three ways: (1) by coordinating conjunctions - and, but, or, for, either...or, neither...nor, (2) by semicolons, or (3) by conjunctive adverbs - accordingly, however, also, consequently, therefore, etc. Kernel sentences are the sets of elementary sentences and combiners, such that all sentences of the English language are obtained from one or more kernel sentences by means of one or more transformations. Each kernel sentence is a construction of classes. The kernel constructions of English are the following:

Noun Phrase Verb ....

Noun Phrase-Verb Phrase-Noun Phrase

Noun Phrase-Verb (to be)-Noun Phrase

Noun Phrase-Verb (to be)-Adjective Phrase

Noun Phrase-Verb (to be)-Adverb.

The intermediate step between a compound and a simple sentence is a complex sentence. Thus, if a sentence is not a compound sentence, we assume it to be a complex sentence. A complex sentence consists of one main clause and one or more subordinating clauses. The main clause expresses the principle statement, the subordinate clause the secondary statement.

Complex sentences offer more variety than simple sentences and are generally more exact than compound sentences because the subordinating conjunctions are more numerous and more precise in meaning than coordinating conjunctions. Most parsing programs can only handle simple sentences; however, in the design of this algorithm compound and complex sentences are considered for the simple reason that it is desirable to accept the full range of sentences.

Compound Sentences

Assuming the sentence is a compound sentence; a check to see if it is an if-then type of sentence. This is a simple test to see if one of the four conditions exist:

if....,then....; or ....., if.....; or if....., ...; or ...., then ......

If one of these conditions occur, the program is sent into a transformation routine. The transformations are the following:

T1. if....., then..... = if-then(S_1,S_2)

T2. ...., if..... = if-then(S_2,S_1)

T3. if..........,...... = if-then(S_1,S_2)

T4. ....,then.... = if-then(S_1,S_2)

If none of the four structures occur, then the program continues and checks for coordinating conjunctions.

In this part of the program each coordinating conjunction is looked at to see if it is the connective of two independent sentences. This is done for each coordinating conjunction until it either works or we are finished in checking all the coordinating conjunctions. The procedure is the following:

1. Look at the first coordinating conjunction and see if there is a comma (phrase-marker) immediately following the coordinating conjunction. Do this for all coordinating conjunctions. If this does not produce a transformation into two independent sentences, check the environment of each coordinating conjunction. This is done by first looking at the left side and comparing its structure to the right side, since it is a coordinating conjunction and the structure at the left side must equal the structure of the right side. If the structure is a sentence, then the necessary transformations are made. If not, the structure is stored for later reference. (In the checking of the environment of the coordinating conjunction, first go to the left most boundary which is either another conjunction or a series of blanks which means the beginning of the sentence. The same is done on the right-hand side, if it is going to be transformed.) Continue this checking until the number of coordinating conjunctions has been exhausted. Some examples of if-then sentences and sentences that have coordinating conjunctions follow:

1. If a car fails to stop at a red light, it is breaking a law. This sentence would be handled the following way:

if-then(a car fails to stop at a red light, it is breaking a law)

2. Cars must obey all traffic laws, and pedestrians must do the same. This sentence would be handled the following way: A search is made for coordinating conjunctions. The word 'and' is found preceded by a comma. Left environment is a sentence, thus we have the following: and(Cars must obey all traffic laws, pedestrians must do the same). One can see the form of the transformation of the compound sentence to a coordinating conjunction and its two variables 'complex sentence one' and 'complex sentence two'.

3. Cars and buses are vehicles.

This sentence would be handled the following way: Again a search is made for the coordinating conjunction. The word 'and' is found. Check the left environment of the conjunction and find it is a Noun phrase; again, the same must be true for the right environment. Thus, both the left and the right environment are functions of the conjunction 'and', and the sentence is now considered a complex sentence with a compound subject.

Complex Sentences

If the input sentence S cannot be transformed into compound sentences S_1 and S_2, then a transformation of S into the complex sentence S' is performed and a check for subordinating conjunctions continues.

If there is a subordinating conjunction in the complex sentence, the following transformations are made:

$$\ldots\ldots\ldots\ldots, \ SC\ldots\ldots\ldots \rightarrow SC(S_1', S_2') \qquad (1)$$

$$SC \ \ldots\ldots\ldots\ldots, \ldots\ldots\ldots\ldots \rightarrow SC(S_2', S_1') \qquad (2)$$

In case (1) S_1' is the main clause and in case (2) S_2' is the main clause of the sentence.

The transformation is made by finding the subordinating conjunctions and looking to the right of the conjunction until a series of blanks is found, if the SC is not the first word of the sentence. The SC's right environment is labeled S_2 and the words to the left of the SC are labeled S_1 and the necessary transformation is performed. If the subordinating conjunction is at the beginning of the sentence, its environment is found by a complex sentence test and an immediate constituent analysis. When its environment is found, the necessary transformation is performed. After this a test for relative pronouns (adverbial and adjectivial phrases) occurs. The list of subordinating conjunctions are: although, though, that, because, since, so that, in order that, as, unless, before, where, when.

Two examples of sentences that contain a subordinating conjunction are the following:

1. We study the "Rules of the Road" booklet, because we want to pass our driver's test.

2. Unless we take the driving test, we will never get a driver's license.

The sentences are handled the following way. In sentence 1, the word 'because' is found and the sentence is transformed into a main clause - 'We study the "Rules of the Road" booklet, and a subclause - 'we want to pass the driver's test' as a function of the subordinating conjunction.

because(We study the Rules of the Road, we want to pass the driver's test)

In sentence 2, the word 'unless' is found and the sentence is transformed into a main clause - 'we will never get a driver's license' and a subclause - 'we take the driving test' as a function of the subordinating conjunction 'unless'.

unless(we will never get a driver's license, we take the driving test.)

Relative Pronouns

The next check is for relative pronouns. The pronouns in the relative pronoun dictionary are used as an adverb, adjective, or a noun, if the phrase-marker '?' does not appear in the input string.

A check of the input string to see if there is a relative pronoun is performed. If one exists its environment is found and the necessary transformations are made. The environment of a relative pronoun is almost always a simple sentence. The environment is found by looking to the right of the relate pronoun, and by immediate constituent analysis finding the simple sentence. After it is found the structure is labeled RP and it is substituted into the original sentence. Now look at what type of syntactic category RP can be. It can either be used as a noun or as a modifier. This can be handled by a simple test to see if an NP is needed to make the complex sentence have syntactic sense. It can either be subject, object, or object of a preposition if it is an NP. If there already is an object of a sentence, or a subject of a sentence, or no hanging prepositions, then the relative pronoun and its environment will be used as a modifier. It will modify either the subject or the object (or predicate nominative) or the predicate of the sentence. It will usually modify an NP (object or subject), and the one it modifies can be determined by which syntactic category it is nearest to. When it is decided what the relative pronoun and its environment's use is RP is given its equivalent value, either NP, Adj, or Adv (rare). The list of relative pronouns are: who, which, what, that, whoever, whatever, whichever, whom, whomever.

Three examples of sentences that contain relative pronouns are the following:

1. The driver, who was found drunk, will be prosecuted.

In this sentence, the relative pronoun 'who' is found. The environment of 'who' is also found easily, since it is surrounded by commas. The relative pronoun and the environment is a simple sentence with 'who' as the subject, 'was found' as the predicate, and 'drunk' as the adjective phrase. The relative phrase is used as an adjective here since it modifies the subject of the main sentence 'driver'.

2. Whoever drives the car must fill the car with gas.

In this sentence, the relative pronoun 'whoever' is found. The environment of 'whoever' is 'drives the car'. The relative phrase is a simple sentence with 'whoever' as the subject, 'drives' as the predicate, and 'the car' as the direct object. The relative phrase in this sentence is used as a noun phrase which is the subject of the sentence.

3. Who lost my hat?

In this sentence the relative pronoun 'who' is found, but the phrase marker '?' is also found. Therefore, a relative phrase does not exist.

Participles and Gerunds

The next check is for participles and gerunds. V_{ing} (a verb with an ing ending) and V_{ed} (a verb with an ed ending) can either be a participle, a verb form used as an adjective; or it can be a gerund, a verb form used as a noun; or it can be the main verb of the sentence, if it is used with another verb.

The first test is to see if it is used with another verb, in which case it must directly follow another verb (V_{ing} can only follow the verb to be). This is done first because it is the most simple form of the V_{ed} and the V_{ing} forms. If it does not follow a verb then it is assumed that the form is a gerund. This implies that it must be the object of the sentence, subject of the sentence, or object of a dangling preposition. If it fits into one of these categories there is no further analysis necessary in this part. The V_{ing} of V_{ed} is labeled G and substituted into the complex sentence. If it is neither a verb nor a gerund it is called a participle, and since participles are usually used as adjectives it will modify a noun, which will follow immediately after or two words after the participle. Participles and gerunds also have environments. These are words (or a word) immediately following the participle or gerund. The word (word and modifiers) is the object, predicate nominative, or predicate adjective of the V_{ing} or V_{ed} form. (This happens because a participle of a gerund still has properties of being a verb). Therefore, the participle and gerund will have a syntactic analysis also. Three examples of sentences that contain either a participle, gerund, or a verb of the specified type are the following:

1. Driving a bus is very hard to do.

'Driving' is a V_{ing} verb and is used as a noun; therefore, it is a gerund. 'Driving a bus' is the gerund phrase with 'a bus' being the object of the word 'driving.'

2. The speeding car received a ticket.

'speeding' is a V_{ing} verb and is used as an adjective; therefore, it is a participle.

3. He has played very hard.

'played' is a V_{ed} verb, and with the auxiliary verb 'has', is used as the predicate of this sentence.

Multiple Verbs

The next check is to see if there is more than one verb. This is done, because if there is more than one verb in the sentence (V+V construction means one verb) implies that S' is still a complex sentence. Verbs taken care of in coordinating conjunctions, if-then sentences, subordinating conjunctions, and relative pronoun phrases are not counted. Having more than one verb in the sentence usually occurs when a relative pronoun is left out. If this occurs, the appropriate relative pronoun is placed in front of the first verb, (second, third,..... if necessary) to see if it makes syntactic sense and thus eliminate the problem of extra verbs. An example of more than one verb in the sentence is the following:

1. I hope he comes.

In this sentence the relative pronoun 'that' is deleted. The two verbs are 'hope' and 'comes'. The sentence is transformed to the sentence - I hope that he comes.

Simple Sentences

What now remains are simple type sentences with a variety of possible substitutions if the sentences were processed as either compound or complex types.

Infinitives

There may be an infinitive in the simple sentence. The form of an infinitive is the following: to+verb. An infinitive may be used as a noun, adjective, or an adverb.

The testing procedure is to first check to see if it is a noun, the same way a relative pronoun phrase is checked to see if it is a noun. If it is not a noun and it follows directly after a noun or an adjective, it then modifies the noun or adjective it follows and Adj can be substituted for the infinitive. If it is not a noun and it follows directly after a verb, then it modifies the verb and is labeled an adverb. Three examples of sentences that contain infinitives are the following:

1. To be asked to the party makes any girl proud.

In this sentence 'to be asked' is the infinitive with 'to be asked to the party' as the infinitive clause. The infinitive is used as a subject, thus it is a noun phrase.

2. I have plenty of work to do.

In this sentence the words 'to do' are used as an infinitive. Since 'to do' modifies work, it is used as an adjective.

3. The students came to learn.

In this sentence the words 'to learn' are used as an infinitive. Since 'to learn' shows purpose, cause, etc., it is an adverb modifier.

Immediate Constituent Analysis

The simple sentence is easily handled by immediate constituent analysis and simple transformations. The immediate constituent rewrite rules are in hierarchial levels. Table 1 lists the symbols used in the rules.

Symbol	Meaning
N	noun
V	verb
Pro	pronoun
adv	adverb
det	determiner
adj	adjective
prep	preposition
NP	noun phrase
VP	verb phrase
PP	prepositional phrase
RP	relative phrase
AP	adjectivial phrase
S	sentence
∅	no construction possible
aux	auxiliary verb

The following seven stages of rules perform the immediate constituent analysis:

Rule	Meaning
<u>Stage 0</u>:	
Pro-------N	Pronouns such as he, they, me, etc. are rewritten as nouns.
Adverb shift	Any adverb in the sentence is shifted to the immediate right of the verb it modifies*
<u>Stage 1</u>:	
Det+N-----NP	N(Det)
Adj+N-----NP	N(Adj)
Prep+N----PP	Prep(N)
N_1+N_2-----NP	N_2(N_1)
V+adv-----VP	V(Adv)
N+∅-------N	N( )
V+∅-------V	V( )
aux+aux---aux	aux aux
etc.	

*will be discussed on page 22.

<u>Stage 2</u>:

NP+∅------NP'	N( )
NP+N------NP'	N(NP)
VP+∅------VP	VP( )
V+V-------VP	V+V ( )
V+∅-------VP	V( )
∅+N-------NP'	N( )
Adj+∅-----Adj	Adj( )
Det+NP----NP'	NP(Det)
aux+V-----VP	aux V

<u>Stage 3</u>:

$\left\{\begin{matrix}V_{ing}\\V_{ed}\end{matrix}\right\}$+NP'--NP'	NP'$\left(\left\{\begin{matrix}V_{ed}\\V_{ing}\end{matrix}\right\}\right)$
$\left\{\begin{matrix}V_{ed}\\V_{ing}\end{matrix}\right\}$+∅----NP'	$\left\{\begin{matrix}V_{ed}\\V_{ing}\end{matrix}\right\}(\quad)$

<u>Stage 4</u>:

NP'+RP----NP"	NP'(RP)
NP'+Adj---NP"	NP'(Adj)
Prep+NP'--PP	Prep(NP')
∅+RP------NP"	RP( )
RP+∅------NP"	RP( )

Adjective shift,adjective shifted immediately in front of subject**

VP+RP-----VP'	VP(RP)
VP+∅------VP'	VP( )
PP+∅------PP	PP( )

<u>Stage 5</u>:

NP"+PP----NP"	NP"(PP)
VP'+PP----VP'	VP'(PP)
PP+NP"----NP"	NP"(PP)

<u>Stage 6</u>:

NP"+VP"+∅-S	VP'(NP",∅)
NP_1"+VP'+NP_2"----S	VP'(NP_1",NP_2")
∅+VP'+NP"--------S	VP'(∅,NP")

** Will be discussed on page 21.

Several examples will now be given of how the algorithm parses sentences.

Example 1:

If a driver breaks too many driving laws, he may lose his driving license.

This sentence would be parsed:

S_1=a driver breaks too many driving laws,

S_2=he may lose his driving license.

if-then (S_1, S_2)

S_1 = breaks(too many) (driver(a),laws(driving))

S_2 = may lose (he, license(driving))

if-then(breaks(too many)(driver(a),laws(driving)),may lose(he, license(driving)))

After the words are given a parts of speech, the input would be like the following:

if Det N V Adv Adv V_{ing} N, Pro aux V adj V_{ing} N.

The sentence is found to be of the if-then type, and transformed into two complex sentences. The ing verbs are then labeled as participles (RP). The two subsentences are transformed into simple sentences. A pronoun to noun substitution is made and finally the immediate constituent rules are processed.

Example 2:

When entering a street or a highway from a driveway or a private road, drivers must yield to all other traffic, and they must not enter the roadway until it is safe to do so.

This sentence is an example of a compound-complex sentence. (A compound-complex sentence contains two or more main clauses and one or more subordinate clauses). Here 'when' and 'until' are subordinating conjunctions, 'or' and

'and' are coordinating conjunctions ('or' in both cases coordinates two noun phrases, thus it is treated later; 'and' coordinates the two main clauses of the subordinating conjunction 'when').

S_1' = entering a street or a highway from a driveway or a private road

S_2' = drivers must yield to all other traffic, and they must not enter the roadway until it is safe to do so.

S_2' is decomposed into S_1" and S_2". The final parsing is the following.

When(and(must yield(to (all))(other(traffic))(drivers,),(until(must not enter (they,roadway(the)), is (so) (it(safe)(to do),),(entering(from)(or(driveway) (road)((private) a) (,(street)(a)))))

After the words are given their parts of speech, the input would look like:

S.Conj V_{ing} Det N CC Det N Prep Det N CC Det adj N, N Aux V Prep Pro Prep N, CC Pro Aux Aux V Det N S, Conj. Pro V(to be) Adj Inf Adv.

One can see that this is an extremely difficult sentence to parse. Rule ordering plays an important role in the parsing of this sentence. If one looks at the coordinating conjunction 'and', a search to the right of 'and' finds a sentence construction as the right-hand environment. Thus, the two sentences that 'and' coordinates are the main sentences of the subordinate conjunction 'when'. This is the major problem of this sentence's parsing. By the parsing rules this is handled correctly. A second major problem of this sentence is the other subordinating conjunction 'until'. This divides the second main clause into a sub-main-clause and a dependent clause. This is also handled by the parsing rules.

Example 3:

If a policeman is directing traffic, the right-of-way laws do not apply and drivers must do as the officer tells them.

This sentence is another example of a compound-complex sentence, but it is much easier than the last one. This example will be parsed as the computer would parse it. After the words are given a part of speech, the input would look like the following:

if Det N V(to be) V_{ing} N, Det Adj N Aux Aux V CC N Aux V S Conj Det N V Pro

1. The first test is the if-then test. The word 'if' is found without then. The if-then sentence is transformed to the following:

if-then(Det N V(to be) V_{ing} N, Det Adj N Aux Aux V CC N Aux V SC Det N V Pro)

2. The next test is for coordinating conjunctions. A CC is found and the left-hand environment of the CC is:

Det Adj N Aux Aux V

This is parsed by the immediate constituent analysis rules and stored for later use.

Adj+N---NP and Aux+Aux---Aux at level 1, det+Np---NP' and Aux+V---VP at level 2. NP+ϕ---NP" and VP+ϕ---VP' at level 4, and NP"ϕVP'----S at level 5. The parsing would look like:

aux aux V (N(adj)(Det),)

3. Next, the SC is found and the right environment is parsed. This turns out to be the left environment of the coordinating conjunction 'and'.

4. Aux+V---VP at level 1 and N+ϕ----NP" at levels 2 and 4 and VP+ϕ---VP' at level 4 and NP"ϕVP'----S at level 5. The parsing would look like: Aux V (N,). This information is stored and the parsing of the subsentences begins.

5. if-then(is directing(policeman(a), Traffic)), and(do not apply(laws(right-of-way),)),(as(must do (drivers,)(tells (officer(the), them)))

This is equivalent to the part-of speech parsing that is tacked on to each individual word:

if-then(V V_{ing} (N(Det),N)), CC(aux aux V(N(Adj),)),(SC(Aux Aux (N,)(V (N(Det), Pro)

PICKING THE CORRECT PART OF SPEECH FOR THE WORDS IN THE DICTIONARY

Different parts of speech of individual words can be eliminated from the possible parsings by separating the rules that are impossible to have. For example the rule N+N---NP is legitimate, while the rule Adj+Prep----? is impossible. If a word can have two or more parts of speech the impossible rules are needed. This is done in the following way:

Example: The driver did see the speed trap.

This input can have any of the three following parts of speech associated with it:

Det N V V N N (1)

Det N V V V N (2)

Det N V V N V (3)

(1) can be analyzed the following way:

D+N---NP	∅+VP---VP'	NP"+VP'+NP'---S
V+V---VP	NP+∅----NP'	
N+N---NP	NP'+∅---NP"	

(2) cannot be analyzed because:

D+N---NP	NP+∅---NP'
V+V---VP	V+∅----VP
V+N----?	N+∅----NP

It is impossible to combine at levels past 3.

(3) cannot be analyzed because:

D+N---NP	N+∅---NP
V+V---VP	∅+V---VP
N+V----?	

Same as (2).

So, the only possible parsing is (1).

UNIQUE FEATURES OF THE PARSER

Several unique features of the parser are the adjective shift, adverb shift, and the verb-participle-gerund test.

Adjective Shift The car is a mossy green and beatleish.

$$DN, V(to\ be)\ Adj_1\ Adj_2\ C\ Adj_3$$

The first check is for conjunctions and 'and' is found. A test to the right environment of 'and' finds that the part-of-speech adjacent to it is an adjective, which implies the right side has the same part of speech and we would combine them as follows:

$DNV(to\ be)Adj_1C(Adj_2,Adj_3)$.

The next combination would be D+N=NP=N(D).

$NP\ V(to\ be)\ Adj_1\ C(Adj_2,Adj_3)$

The next combination would be $Adj_1 + Adj_2 = Adj_2(Adj_1) = AP$

$NP\ V(to\ be)\ Conj(AP,Adj_3)$

The next combination would be Conj(AP,Adj) = AP'

NP V(to be) AP'

The next combination would be the movement of AP' to left adjacent of NP and we get:

AP' NP V(to be)

The next combination is AP' + NP = NP' - NP(AP')

NP' + V(to be)

V(to be) is transformed into VP and we get

NP' + VP

The final combination is NP' + VP = VP(NP,ϕ) = S

S = is ((car(the))(and(green(mossy)),beatelish),ϕ)

Adverb Shift

He played the game well.

Pro V D N Adv

The adverb would be shifted right adjacent to the verb first, and the pronoun would be transformed to a noun. Thus:

N_1 V Adv D N_2

Next combine D + N_2 = NP = N(D)

N_1 V Adv NP

Combine V + Adv = VP and transform N_1 into NP_1.

Thus we have

NP_1 VP NP_2

Then combining this into VP(N_1,N_2) = S

S = played (well)(he,game(the))

Verb-Participle-Gerund Test.

Stopping at stop signs is necessary.

Stopping is an 'ing-verb' and it is not known if it is used as a verb (with auxiliary helper), a gerund or participle.

V_{ing} Prep Adj_1 N V(to be) Adj_2

Adj_1 + N = NP = N(Adj_1)

V_{ing} Prep NP V(to be) Adj_2

Prep + NP = PP

V_{ing} PP V(to be) Adj

Since there is no subject (NP_1) implies V_{ing} is this NP_1 and must be a gerund. Therefore,

NP PP V(to be) Adj

NP + PP = NP' = NP(PP)

NP' V(to be) Adj

Next the adjective shift and

NP'(Adj) V(to be)

Next, make the transformation to get

V(to be)(NP',ϕ) = S.

Thus S = is (Stopping(necessary)(at,(signs(stop))),ϕ)

PROGRAM FOR IMMEDIATE CONSTITUENT ANALYSIS OF SIMPLE SENTENCES

This LISP program is internal to the larger parsing program. The function FTEST applies the seven stages of the immediate constituent rules to a simple sentence.

Abbreviations

The abbreviations for parts of speech vary slightly from the list on page 14 . They are as in Table 2.

TABLE 2.

N	noun
PRO	pronoun
V	verb
VGD	verb ending with "ing" or "ed"
PREP	preposition
D	determiner
AJ	adjective
ADV	adverb
NP	noun phrase
PP	prepositional phrase
VP	verb phrase
RP	relative phrase

Input

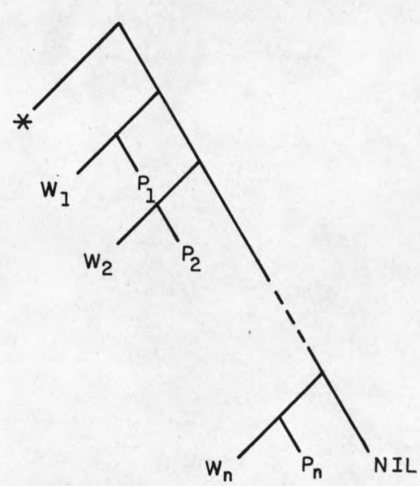
The application of FTEST to a simple sentence is best illustrated by an example. The LISP statement to apply FTEST to the simple sentence "The young boy goes to school." is as follows:

```
FTEST((* *THE•D) (YOUNG•ADJ) (BOY•N) (GOES•V)
     (TO•PREP) (SCHOOL•N)))
```

Thus the argument of FTEST for a simple sentence of n words $w_1 \ldots w_n$ with n parts of speech $p_1 \ldots p_n$ is the following LIST:

$$(* \ (w_1 \cdot p_1) \ (w_2 \cdot p_2) \ \ldots \ (w_n \cdot p_n))$$

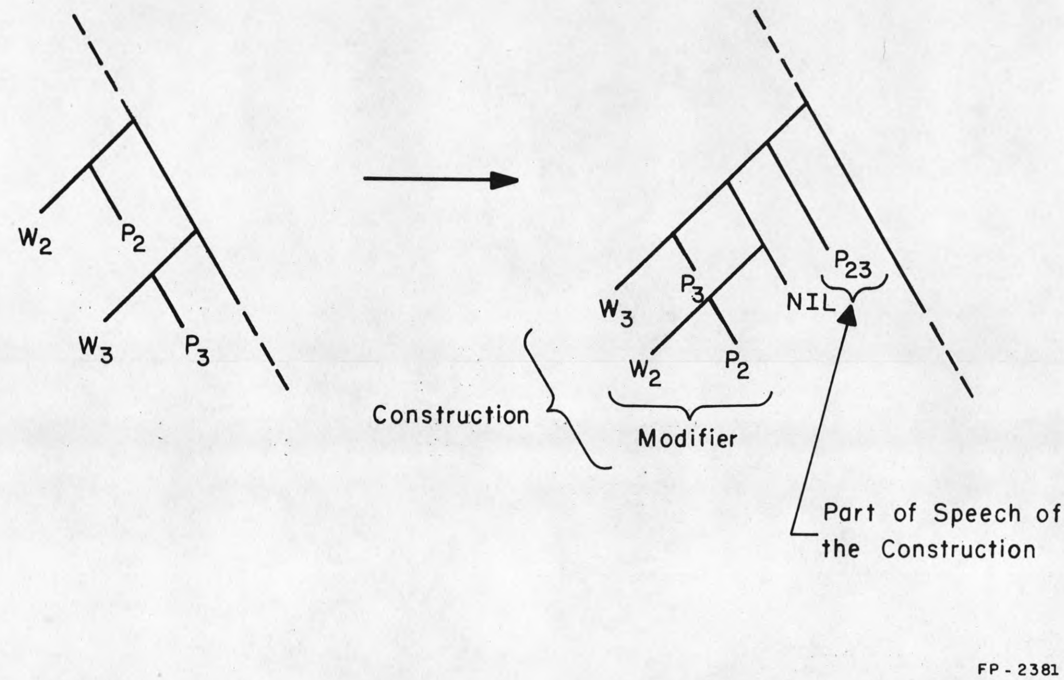
The tree structure of this list is:



FP-2383

Application of the rules to the simple sentence

The LIST is altered as the seven stages are successively applied. When the parts of speech of two adjacent list members satisfy a rule within a stage, the two members are combined into one. If w_2 modifies w_3 the construction is as follows:

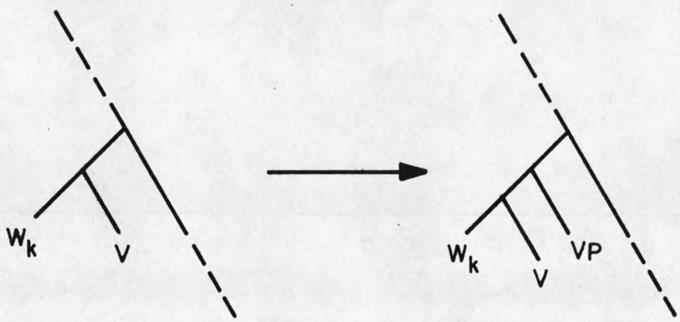


where p_{23} is the part of speech of the combination of w_2 and w_3. Had w_3 modified w_2, their positions would be switched in the transformed LIST member. At any stage, the CAR of any member of the LIST is the part of speech of the construction which is the CDR of that member. Thus at successive stages the parts of speech are compared and further constructions are made.

There are minor differences between the rules applied in the program and those listed in page 14. One is that primed parts of speech (e.g., NP′′) were not needed in the program. Another is that when a rule such as N+∅...N is satisfied where no LIST members are combined, and the part of speech is not changed, no action is taken. Thus these rules are not in the program.

There are several rules where the part of speech of a member of the LIST is changed without forming a new construction with an adjacent member.

In this case, there is no modifier. If the stage 2 rule $V+\phi \ldots VP$ is satisfied by word w_k (a verb), the following construction takes place:



FP-2384

Output

After Stage 5 has been applied by FTEST the LIST that started as a simple sentence now has (not including *) two members, a noun phrase and a verb phrase in either order, or three members, a noun phrase, a verb phrase, and a noun phrase in that order. In Stage 6, FTEST constructs the output of the analyzed simple sentence.

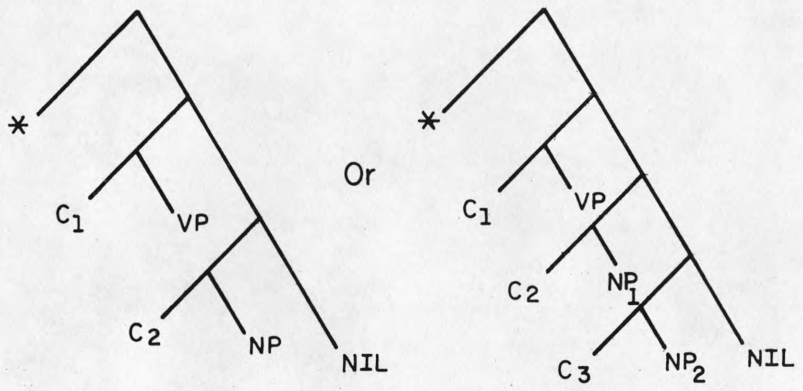
The Stage 6 rules are:

$$NP + VP + \phi \text{ ---- } S \quad VP(NP,\phi)$$

$$NP_1 + VP + NP_2 \text{ --- } S \quad VP(NP_1,NP_2)$$

$$\phi + VP + NP \text{ --- } S \quad VP(\phi,NP)$$

The final LIST returned by FTEST has the following structure:



FP-2382

where c_1, c_2, and c_3 are constructions like those noted above. In LISP notation:

$$(*\ (c_1 \cdot VP)\ (c_2 \cdot NP))$$

or

$$(*\ (c_1 \cdot VP)\ (c_2 \cdot NP_1)\ (c_3 \cdot NP_2))$$

The Program

```
//JOBLIB DD DSN=USER.P1923.LISP151,VOL=SER=UIUSR4,                  *
// UNIT=2314,DISP=OLD
// EXEC PGM=LISP151,TIME=4,REGION=348K
//LISPOUT DD SYSOUT=A
//LISPIN DD *
   CSET (N N)
   CSET (PRO PRO)
   CSET (V V)
   CSET (VGD VGD)
   CSET (PREP PREP)
   CSET (D D)
   CSET (AJ AJ)
   CSET (ADV ADV)
   CSET (NP NP)
   CSET (PP PP)
   CSET (VP VP)
   CSET (RP RP)
   CSET (PHI PHI)


  DEFINE((   (CADDDR (LAMBDA (A) (CAR (CDR (CDDR A  )))))))

  DEFINE((
        (STAGE01 (LAMBDA (X)
                    (COND ((EQ (CDR X) PRO) (CONS (CAR X) N))
                          (T X))))

        (GTEST01 (LAMBDA (X Y)
                    (COND ((NULL X) Y)
                          (T (APPEND Y (GTEST01 (CDR X)
                                      (LIST (STAGE01 (CAR X)))))))))

        (FTEST01 (LAMBDA (A)
                    (GTEST01 (CDR A) (LIST STAR))))


   (STAGE1 (LAMBDA (X Y)
     (COND ((EQ (CDR Y) N) (COND ((EQ (CDR X) D)
                                      (LIST (CONS (LIST Y X) NP)))
                                 ((EQ (CDR X) AJ)
                                      (LIST (CONS (LIST Y X) NP)))
                                 ((EQ (CDR X) PREP)
                                      (LIST (CONS (LIST X Y) PP)))
                                 ((EQ (CDR X) N)
                                      (LIST (CONS (LIST Y X) NP)))))
           ((EQ (CDR Y) ADV) (COND ((EQ (CDR X) V)
                                      (LIST (CONS (LIST X Y) VP))))))))

   (COMB1 (LAMBDA (X Y)
      (COND ((EQ Y N) (COND ((EQ X D) T)
                            ((EQ X AJ) T)
                            ((EQ X PREP) T)
                            ((EQ X N) T)
                            (T F)))





            ((EQ Y ADV) (COND ((EQ X V) T)
                              (T F)))
            (T F))))

   (GTEST1 (LAMBDA (X Y)
      (COND ((NULL X) Y)
            ((NULL (CDR X)) (APPEND Y (LIST (CAR X))))
            ((COMB1 (CDAR X) (CDADR X))
               (APPEND Y (GTEST1 (CDDR X)
                                    (STAGE1 (CAR X) (CADR X)))))
            (T (APPEND Y (GTEST1 (CDR X) (LIST (CAR X))))))))

   (FTEST1 (LAMBDA (A)
      (GTEST1 (CDR A) (LIST STAR))))
```

```
DEFINE ((
  (ADVT (LAMBDA (X)
     (COND ((NULL X) F)
           ((EQ (CDAR X) ADV) T)
           (T (ADVT (CDR X))))))

  (VFIRST (LAMBDA (X)
     (COND ((EQ (CDAR X) ADV) F)
           ((EQ (CDAR X) V) T)
           (T (VFIRST (CDR X))))))

  (SRCHA (LAMBDA (X)
     (COND ((EQ (CDAR X) ADV) (CONS (CAR X) NIL ))
           (T (CONS (CAR X) (SRCHA (CDR X)))))))

  (SRCHV (LAMBDA (X)
     (COND ((EQ (CDAR X) V) (COND ((EQ (CDADR X) V)
                                   (CONS (CAR X)
                                      (CONS (CADR X) NIL)))
                                 (T (CONS (CAR X) NIL))))
           (T (CONS  (CAR X) (SRCHV (CDR X)))))))
 ))

DEFINE ((
  (SRCHVA (LAMBDA (X)
     (COND ((EQ (CDAR X) V)
                 (COND ((EQ (CDADR X) V)
                        (SRCHA (CDR X)))
                     (T (SRCHA X))))
           (T (SRCHVA (CDR X))))))

  (SRCHAV (LAMBDA (X)
     (COND ((EQ (CDAR X) ADV) (SRCHV X))
           (T (SRCHAV (CDR X))))))
))




DEFINE ((
  (SRCHV1 (LAMBDA (X)
     (COND ((EQ (CDADR X) V)
                 (COND ((EQ (CDADR (CDR X)) V)
                        (CONS (CAR X)
                          (CONS (CADR X) NIL)))
                     (T (CONS (CAR X) NIL))))
           (T (CONS (CAR X) (SRCHV1 (CDR X)))))))

  (SRCHA1 (LAMBDA (X)
     (COND ((EQ (CDADR X) ADV)
                 (CONS (CAR X) NIL))
           (T (CONS (CAR X)
                (SRCHA1 (CDR X)))))))
))

DEFINE ((
  (SRCHA2 (LAMBDA (X)
     (COND ((EQ (CDAR X) ADV) (CDR X))
           (T (SRCHA2 (CDR X))))))

  (SRCHV2 (LAMBDA (X)
     (COND ((EQ (CDAR X) V)
                 (COND ((EQ (CDADR X) V)
                        (CDDR X))
                     (T (CDR X))))
           (T (SRCHV2 (CDR X)))))))
))
```

```
  DEFINE((
    (LAST1 (LAMBDA (X)
        (COND ((NULL (CDR X)) X) (T (LAST1 (CDR X))))))
    ))
DEFINE ((
  (OMITA (LAMBDA (X)
     (COND ((EQ (CDAR X) ADV) NIL)
           (T (CONS (CAR X) (OMITA (CDR X)))))))

  (TRANVA (LAMBDA (X)
     (COND ((EQ (CDDR X) NIL) X)
           (T (APPEND (LIST (CAR X)) (APPEND (LAST1 X)
                   (OMITA (CDR X))))))))

  (TRANAV (LAMBDA (X)
  (APPEND (CDR X) (LIST (CAR X)))))
))

DEFINE((
 (FTEST02 (LAMBDA (A)
  (COND ((ADVT (CDR A))
         (COND ((VFIRST (CDR A))
                   (APPEND (SRCHV1 A)
                    (APPEND
                     (TRANVA
                      (SRCHVA (CDR A)))
                      (SRCHA2 A))))
               (T (APPEND (SRCHA1 A)



                     (APPEND
                      (TRANAV
                       (SRCHAV (CDR A)))
                       (SRCHV2 A))))))
        (T A))))
))


 DEFINE((
 (STAGE20 (LAMBDA (X Y)
   (COND ((EQ (CDR Y) N)  (COND ((EQ (CDR X) NP)
                                 (LIST (CONS (LIST Y X) NP)))))
         ((EQ (CDR Y) NP) (COND ((EQ (CDR X) AJ)
                                 (LIST (CONS (LIST Y X) NP)))
                                ((EQ (CDR X) D)
                                 (LIST (CONS (LIST Y X) NP)))))
         ((EQ (CDR X) V)  (COND ((EQ (CDR Y) V)
                                 (LIST (CONS (CONS X Y) VP))))))))

 (COMB20 (LAMBDA (X Y)
   (COND ((EQ Y N)  (COND ((EQ X NP) T)
                          (T F)))
         ((EQ Y NP) (COND ((EQ X AJ) T)
                          ((EQ X D) T)
                          (T F)))
         ((EQ X V)  (COND ((EQ Y V) T)
                          (T F)))
         (T F))))

 (GTEST20 (LAMBDA (X Y)
   (COND ((NULL X) Y)
         ((NULL (CDR X)) (APPEND Y (LIST (CAR X))))
         ((COMB20 (CDAR X) (CDADR X))
          (APPEND Y (GTEST20 (CDDR X)
                              (STAGE20 (CAR X) (CADR X)))))
         (T (APPEND Y (GTEST20 (CDR X) (LIST (CAR X))))))))

 (FTEST20 (LAMBDA (A)
   (GTEST20 (CDR A) (LIST STAR))))
```

```
    ))
DEFINE((
(STAGE21 (LAMBDA (X)
  (COND ((EQ (CDR X) N) (LIST (CONS X NP)))
        ((EQ (CDR X) V) (LIST (CONS X VP))))))

(COMB21 (LAMBDA (X)
  (COND ((EQ X N) T)
        ((EQ X V) T)
        (T F))))

(GTEST21 (LAMBDA (X Y)
  (COND ((NULL X) Y)
        ((COMB21 (CDAR X))




          (APPEND Y (GTEST21 (CDR X) (STAGE21 (CAR X)))))
        (T (APPEND Y (GTEST21 (CDR X) (LIST (CAR X))))))))

(FTEST21 (LAMBDA (A)
  (GTEST21 (CDR A) (LIST STAR))))


    ))
DEFINE((
(STAGE30 (LAMBDA (X Y)
  (LIST (CONS (LIST Y X) NP))))

(COMB30 (LAMBDA (X Y)
  (COND ((EQ X VGD) (COND ((EQ Y NP) T)
                          (T F)))
        (T F))))

(GTEST30 (LAMBDA (X Y)
  (COND ((NULL X) Y)
        ((NULL (CDR X)) (APPEND Y (LIST (CAR X))))
        ((COMB30 (CDAR X) (CDADR X))
          (APPEND Y (GTEST30 (CDDR X)
                             (STAGE30 (CAR X) (CADR X)))))
        (T (APPEND Y (GTEST30 (CDR X) (LIST (CAR X))))))))

(FTEST30 (LAMBDA (A)
  (GTEST30 (CDR A) (LIST STAR))))


    ))
DEFINE((
(STAGE31 (LAMBDA (X)
  (LIST (CONS X NP))))

(COMB31 (LAMBDA (X)
  (COND ((EQ X VGD) T)    (T F))))

(GTEST31 (LAMBDA (X Y)
  (COND ((NULL X) Y)
        ((COMB31 (CDAR X))
          (APPEND Y (GTEST31 (CDR X) (STAGE31 (CAR X)))))
        (T (APPEND Y (GTEST31 (CDR X) (LIST (CAR X))))))))

(FTEST31 (LAMBDA (A)
  (GTEST31 (CDR A) (LIST STAR))))
      )).
```

```
DEFINE((
 (STAGE401 (LAMBDA (X Y)
      (LIST (CONS (LIST X Y) RP))))

 (COMB401 (LAMBDA (X Y)
         (COND ((EQ X NP) (COND ((EQ Y RP) T)









                                    (T F)))
                (T F))))

 (GTEST401 (LAMBDA (X Y)
    (COND ((NULL X) Y)
          ((NULL (CDR X)) (APPEND Y (LIST (CAR X))))
          ((COMB401 (CDAR X) (CDADR X))
             (APPEND Y (GTEST401 (CDDR X)
                              (STAGE401 (CAR X) (CADR X)))))
          (T (APPEND Y (GTEST401 (CDR X) (LIST (CAR X))))))))

 (FTEST401 (LAMBDA (A)
   (GTEST401 (CDR A) (LIST STAR))))
   ))


DEFINE((
 (STAGE41 (LAMBDA (X Y)
      (COND ((EQ (CDR X) PREP) (LIST (CONS (LIST X Y) PP)))
            ((EQ (CDR X) VP)   (LIST (CONS (LIST X Y) VP))))))

 (COMB41 (LAMBDA (X Y)
      (COND ((EQ X PREP) (COND ((EQ Y NP) T)
                               (T F)))
            ((EQ X VP)   (COND ((EQ Y RP) T)
                               (T F)))
            (T F))))

 (GTEST41 (LAMBDA (X Y)
    (COND ((NULL X) Y)
          ((NULL (CDR X)) (APPEND Y (LIST (CAR X))))
          ((COMB41  (CDAR X) (CDADR X))
             (APPEND Y (GTEST41  (CDDR X)
                              (STAGE41  (CAR X) (CADR X)))))
          (T (APPEND Y (GTEST41  (CDR X) (LIST (CAR X))))))))

 (FTEST41  (LAMBDA (A)
   (GTEST41  (CDR A) (LIST STAR))))
   ))


DEFINE((
 (STAGE43 (LAMBDA (X)
      (COND ((EQ (CDR X) RP) (LIST (CONS X NP)))
            (T X))))

 (GTEST43 (LAMBDA (X Y)
    (COND ((NULL X) Y)
          (T (APPEND Y (GTEST43  (CDR X) (LIST (CAR X))))))))

 (FTEST43  (LAMBDA (A)
   (GTEST43  (CDR A) (LIST STAR))))
   ))
```

```
DEFINE((
 (STAGE5 (LAMBDA (X Y)
      (COND ((EQ (CDR X) NP) (COND ((EQ (CDR Y) PP)
                                    (LIST (CONS (LIST X Y) NP)))))
            ((EQ (CDR X) VP) (COND ((EQ (CDR Y) PP)
                                    (LIST (CONS (LIST X Y) VP)))))
            ((EQ (CDR X) PP) (COND ((EQ (CDR Y) NP)
                                    (LIST (CONS (LIST Y X) NP)))))
                                                            )))

 (COMB5 (LAMBDA (X Y)
      (COND ((EQ X NP) (COND ((EQ Y PP) T)
                             (T F)))
            ((EQ X VP) (COND ((EQ Y PP) T)
                             (T F)))
            ((EQ X PP) (COND ((EQ Y NP) T)
                             (T F)))
            (T F))))

 (GTEST5 (LAMBDA (X Y)
    (COND ((NULL X) Y)
          ((NULL (CDR X)) (APPEND Y (LIST (CAR X))))
          ((COMB5   (CDAR X) (CDADR X))
             (APPEND Y (GTEST5   (CDDR X)
                         (STAGE5   (CAR X) (CADR X)))))
          (T (APPEND Y (GTEST5   (CDR X) (LIST (CAR X))))))))

 (FTEST5   (LAMBDA (A)
    (GTEST5   (CDR A) (LIST STAR))))
   ))


DEFINE((
 (FTEST6   (LAMBDA (A)
      (COND ((EQ (CDADR A) NP) (COND ((NULL (CDDDR A))
                                      (LIST STAR
                                         (CADDR A)
                                        (CADR A)))
                                    (T (LIST STAR
                                     (CADDR A)
                                       (CADR A)
                                         (CADDDR A)))))
            (T A))))

 (FTEST (LAMBDA (A)
    (FTEST6 (FTEST5 (FTEST43 (FTEST41 (FTEST401
          (FTEST31 (FTEST30 (FTEST21 (FTEST20
                    (FTEST1 (FTEST02 (FTEST01 A)))))))))))))
   ))
```

```
 ARGUMENTS FOR EVALQUOTE ...
   FTEST
   ((STAR (THE . D) (YOUNG . AJ) (BOY . N) (GOES . V) (TO . PREP) (SCHOOL . N)))

***  (ARGUMENTS OF FTEST
   ((STAR (THE . D) (YOUNG . AJ) (BOY . N) (GOES . V) (TO . PREP) (SCHOOL . N)))

***  VALUE OF FTEST
   (* ((((GOES . V) . VP) (((TO . PREP) (SCHOOL . N)) . PP)) . VP) (((((BOY . N) (YOUNG . AJ)) . NP)
    (THE . D)) . NP))
  TIME      99MS,  VALUE IS ...
   (* ((((GOES . V) . VP) (((TO . PREP) (SCHOOL . N)) . PP)) . VP) (((((BOY . N) (YOUNG . AJ)) . NP)
    (THE . D)) . NP))


 ARGUMENTS FOR EVALQUOTE ...
   FTEST
   ((STAR (THE . D) (BOY . N) (SWALLOWS . V) (QUICKLY . ADV) (AN . D) (ORANGE . AJ) (TANGERINE . N)
   ))

***  VALUE OF FTEST
   (* (((SWALLOWS . V) (QUICKLY . ADV)) . VP) (((BOY . N) (THE . D)) . NP) (((((TANGERINE . N) (ORANGE .
   AJ)) . NP) (AN . D)) . NP))
  TIME     116MS,  VALUE IS ...
   (* (((SWALLOWS . V) (QUICKLY . ADV)) . VP) (((BOY . N) (THE . D)) . NP) (((((TANGERINE . N) (ORANGE .
   AJ)) . NP) (AN . D)) . NP))


***  ARGUMENTS OF FTEST
   ((* (A . D) (CAR . N) (GOES . V) (EAST . ADV)))

***  VALUE OF FTEST
   (* (((GOES . V) (EAST . ADV)) . VP) (((CAR . N) (A . D)) . NP))


***  ARGUMENTS OF FTEST
   ((* (IT . PRO) (TURNS . V) (LEFT . ADV)))

***  VALUE OF FTEST
   (* (((TURNS . V) (LEFT . ADV)) . VP) ((IT . N) . NP))
```

```
*** ARGUMENTS OF FTEST
    ((* (HE . PRO) (MAY . ADV) (LOSE . V) (HIS . PRO) (LICENSE . N)))
*** VALUE OF FTEST
    (* (((LOSE . V) (MAY . ADV)) . VP) ((HE . N) . NP) (((LICENSE . N) (HIS . N)) . NP))


*** ARGUMENTS OF FTEST
    ((* (SSEING . VGD) (IS . V) (BELIEVING . VGD)))
*** VALUE OF FTEST
    (* ((IS . V) . VP) ((SEEING . VGD) . NP) ((BELIEVING . VGD) . NP))


*** ARGUMENTS OF FTEST
    ((* (A . AJ) (CAR . N) (GOES . V) (EAST . ADV)))
*** VALUE OF FTEST
    (* (((GOES . V) (EAST . ADV)) . VP) (((CAR . N) (A . AJ)) . NP))


*** ARGUMENTS OF FTEST
    ((* (THIS . AJ) (CAR . N) (TURNS . V) (RIGHT . ADV)))
*** VALUE OF FTEST
    (* (((TURNS . V) (RIGHT . ADV)) . VP) (((CAR . N) (THIS . AJ)) . NP))


*** ARGUMENTS OF FTEST
    ((* (WHAT . RP) (IS . V) (THE . D) (FINAL . AJ) (DIRECTION . N)))
*** VALUE OF FTEST
    (* *WHAT . RP) ((IS . V) . VP) (((((DIRECTION . N) (FINAL . AJ)) . NP) (THE . D)) . NP))
```

REFERENCES

1. Biss, K., Syntactic Analysis for the R2 System, Report R-399, Coordinated Science Lab., University of Illinois, Dec. 1968.

2. Bobrow, D. G., Syntactic Analysis of English by Computer - A Survey, AFIPS Conf. Proc., Spartan, Baltimore, Vol. 24, pp. 265-387 (1963).

3. Bobrow, D. G., "Syntactic Theories in Computer Implementations," in Borko, ed., Automated Language Processing, New York, Wiley, 1967.

4. Chomsky, N., "Syntactic Structures," The Hague: Mouton and Co., 1957.

5. Fodor, Jerry A. and Katz, Jerrold, The Structure of Language: Readings in the Philosophy of Language Prentice Hall. 1964.

6. Friedman, J. A., "A Computer System for Transformational Grammar," CACM, 11, 2, Feb. 1968, pp. 77-113.

7. Hays, D. G., "Automatic Language-Data Processing," in Borko, ed., Computer Applications in the Behavioral Sciences, Englewood Cliffs, N. J.: Prentice-Hall, 1962.

8. ___________, "Grouping and Dependency Theories," RM-2646. The Rand Corp., Santa Monica, California, September, 1960.

9. ___________, "Dependency Theory: A Formalism and Some Observations," RM-4087-PR. The Rand Corp., Santa Monica, California, July, 1964.

10. Kay, M., "A Parsing Program for Computational Grammars," RM-4283-PR, Rand Corp., Santa Monica, Calif., 1964.

11. Kellogg, C. H., "On Line Translation of Natural Language Questions into Artificial Language Queries," S.D.C. Document SP-2927. Apr. 28, 1967.

12. Kuno, S., "The Predictive Analyzer and a Path Elimination Technique," Comm. of ACM, V. 8 (July, 1965), 453-461.

13. ___________, "The Augmented Predictive Analyzer for Context-Free Languages--Its Relative Efficiency," Comm. of ACM, V. 9 (November, 1966), 810-823.

14. ___________, "Computer Analysis of Natural Languages," presented at the Symposia in Applied Mathematics, 1967.

15. McConlogue, K. and Simmons, R. F., "Analyzing English Syntax with a Pattern-Learning Parser," Comm. of ACM, V. 11 (November, 1965) 687-698.

16. Robinson, J., "Preliminary Codes and Rules for Automatic Analysis of English," RM-3339-PR, Rand Corp., Santa Monica, Calif. 1962.

17. Robinson, J., "PARSE: A System for Automatic Syntactic Analysis of English Text, Part I," RM-4654-PR, Rand Corp., Santa Monica, Calif. 1965.

18. Simmons, R. F., "Automated Language Processing," in Cuadra, ed., Annual Review of Information Science and Technology, 1965, New York, Interscience Publishers, 1966.

19. Simmons, R. F., Burger, J. F., and Schwarez, R. M., "A Computational Model for Verbal Understanding," Fall Joint Computer Conference, 1968, pp. 441-456.

20. Simmons, R. F., and Burger, J. F., "A Semantic Analyzer for English Sentences, Systems Development Corp. Report, January 10, 1968.

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13. ABSTRACT

This paper presents a pure syntax parsing algorithm for the R2 question answering system. The parsing is a necessary part in the processing of information for the retrieval of answers by giving the syntactic structure of both questions and statements of fact. The syntactic analysis is performed on individual statements by using grammatical rules and various grammatical transformation. The parser has been implemented in LISP 1.5 on an IBM 360/75 computer. Experimental results from the system include examples of the analysis of some compound and complex sentences, as well as simple sentences.

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