WORKING PAPER 73

ANOTHER APPROACH TO ENGLISH

by

MARTIN BROOKS

Massachusetts Institute of Technology

Artificial Intelligence Laboratory

June 1974

Abstract

A new approach to building descriptions of English is outlined and programs implementing the ideas for sentence-sized fragments are demonstrated.

Work reported herein was conducted at the Artificial Intelligence Laboratory, a Massachusetts Institute of Technology research program supported in part by the Advance Research Projects Agency of the Department of Defense and monitored by the office of Naval Research under Contract Number N00014-70-A-0362-0005.

This is a progress report on the natural language system I have been building during the last few months. I now have almost-debugged LISP programs that build descriptions of English inputs over a small vocabulary. All examples are taken from the programs' output.

The principal strategy behind my programs is that one should teach the computer about concepts in a frame-like manner and this knowledge should include information about communicating the concept in English. (I have only worked on understanding, not generation.) This is similar to recent vision theories where one teaches concepts including how they are to be parsed out of a visual scene. This approach indicates that grammar consists of analogies over the similarities of linguistic presentations of different concepts. As such, it must be built upon many specific instances and constructing some of these instances is my concern now.

I have written frame-program-definitions of ten concepts: three actions, four entities and three descriptive concepts.

For the most part they are limited to the world of text-editing. My image of the semantics of this world is that there are entities of two types: places (e.g. pages, lines, spaces) and text (e.g. paragraphs, diagrams, sentences, words, letters, punctuation). Each type admits relationships within, e.g. is-part-of and is-part*of, the transitive closure of is-part-of, and there are relationships between the classes, e.g. containment; paragraphs usually occupy a portion of a page, sentences are contained in several lines, letters are contained in spaces, etc. One can structure them via a geometry that is between one and two dimensional, not too complex but not trivial. There are actions which a person (another type of entity) may perform on and/or with these entities, e.g. inserting, deleting, moving, underlining, making-room-for, etc.

For the purposes of perceiving and communicating aspects of the actions and entities one builds descriptive systems such as size and the geometry already mentioned. One might also include a system for indicating identifications between concepts referred to in sentence or extended discourse.

Of the concepts mentioned I have programmed insert (F8-INSERT), delete (F1-DELETE), move (F5-MOVE), sentence (F3-SENTENCE paragraph (F4-PARAGRAPH), page (F6-PAGE), size (F7-SIZE), Martin (F2-MARTIN), and Barbara (F2*5-BARBARA), (two people distinguishable only by name). I have also programmed two STATIVE-DESCRIPTORS, have (F9-HAVE) and be (F10-BE), devices for attaching properties and descriptions to actions and entities.

I will now discuss some aspects of my implementation of frame-like structures. A frame has two distinguished parts, a control section and a slot section. The control section is a program that receives messages and responds to them, perhaps by binding one of its slots to another structure. The slot section is the data structure with those slot bindings. When one talks about a specific frame-description of a concept one must talk about an instance of that frame description. In my scheme different instances of (what has been decided for now to be) the same concept share the control section but have different slot structures. This is done by making the control section be a program of two inputs: a message and an atom. The atom's property list has all the slot bindings for that instance of the frame-description. The pair of the control section and the slot section together make an instantiated frame, which is given a name.

My frames each have several parts, also inplemented as frames. The basic structure is that all messages sent to an instantiated frame that come from outside the frame pass through a clearinghouse. Depending on the kind of message (to find out - ask it) it is relayed to one or another of the frame's parts. There are three important kinds of messages:

INFO-MSG, MOD-MSG, RSVP-MSG.

An important part of a frame-system is a language internal to the system describing the frames themselves. For instance, F3-SENTENCE and F4-PARAGRAPH are ENTITIES and TEXT, F2-MARTIN is an ENTITY and a PERSON, F10-BE is a STATIVE-DESCRIPTOR, F8-INSERT is an ACTION. Often a frame will want to know whether another frame referred to in a message is a PLACE, or whatever. It does this by asking the frame itself whether it is a PLACE. It asks this with an INFO-MSG. Thus when a frame receives an INFO-MSG it sends it off to the part of itself that knows these sorts of things.

When a string of words is read it is converted to a list of lists of morphemically decomposed words each of which is then replaced with whatever the DICTIONARY says it should be replaced with. For prepositions and conjunctions (and eventually determiners) this is the token itself. For others, a newly instantiated frame for the concept the word stands for will replace the word. This newly instantiated frame will also contain information about the affixes or irregular presentation (e.g. is) of the concept's word. I call this list of instantiated frames and tokens a CONTEXT. Now that we have this CONTEXT the problem is to interconnect the frames with the relationships indicated (to a reader of English) by the string. The knowledge needed for determining these relationships is in the frames. The top level interpreter in my system sets up "conversations" between adjacent frames to see if they should be interconnected. (This interconnection is entirely controlled by the frames, the possibility of the connection is controlled by the interpreter, it recognizes the frames to be adjacent, furthermore it does not set up these conversations in random order (see below)). When two adjacent frames do become interconnected the pair is removed from the CONTEXT (along with any prepositions, conjunctions, etc., that the frames want) and a new CONTEXT with the interconnected structure or whatever the frames designate, as the result of their conversation (see discussion of F10-BE and F9-HAVE below) replacing the pair is made (i.e. given a name). Further processing proceeds on this new CONTEXT. When there is only one structure in the context, processing is successfully completed.

The order in which the interpreter sets up the conversasations between frames is determined so as to make a nondeterministic version of the control structure Vaughan Pratt espouses in CGOL (Reference: Vaughan Pratt, [1973]) with operator precedence replaced by the conversation. This guarantees (assuming certain restrictions on the frames' behavior) that all modifications among frames are nested and that no frame gets taken as a modifier to another until it has received all of its modifiers.

Even though all relationships between frames are done via two way links (i.e. if an instance of F3-SENTENCE knows it is BEFORE an instance of F4-PARAGRAPH then the F4-PARAGRAPH knows it is AFTER the F3-SENTENCE) the acquisition of this relationship is asymetric. When a conversation between FRAME 1 and FRAME 2 is set up (either by the interpreter or an instance of F10-BE or F9-HAVE, see below) it may typically proceed as follows:

> A message is sent to FRAME 1 asking it if it is interested in taking FRAME 2 as a modifier. This is a MOD-MSG, and being a MOD-MSG tells FRAME 1 what the situation is. If FRAME 1 does not want FRAME 2 then the conversation is restarted by asking FRAME 2 if it would like FRAME 1 as a modifier. If FRAME 1 does want FRAME 2 (perhaps along with some tokens in the CONTEXT (prepositions, conjunctions, etc.) it sends a message to FRAME 2 saying that it wants it and in what capacity it will be used. This is done with an RSVP-MSG and being an RSVP-MSG is what clues FRAME 2 in to what is happening. FRAME 2 may now reject the whole idea, in which case FRAME 1 is not allowed to take FRAME 2, or if FRAME 2 approves the suggestion, it will record the relationship in its slot structure and send a message of approval back to FRAME 1 which will then record the relationship in its slot structure

and decide what structure should replace the two in the CONTEXT. Very often this is simply itself, although in the cases of subordinate clauses and most usages of F10-BE and F9-HAVE this will not be the case.

I should mention that the interpreter is a small recursive algorithm (less than one page of LISP). All the work is done by the frames since they have the knowledge to do it. This also results in there being no concept of sentence.

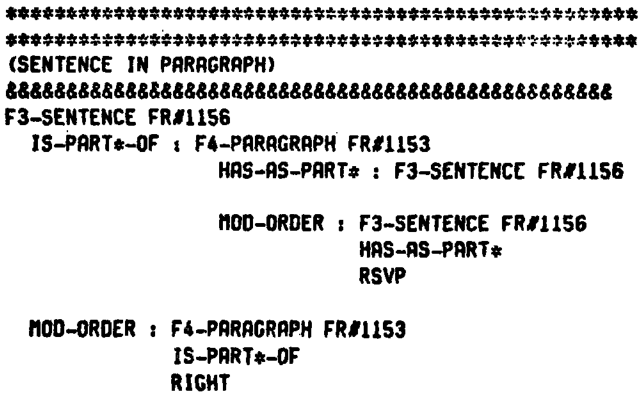
What kinds of knowledge do frames use in responding to a MOD-MSG? A MOD-MSG has two slots, called BODY and LEX. BODY contains the frame which is the proposed modifier. LEX says where the proposed modifier is coming from. This might be LEFT, RIGHT, FIO-BE, or F9-HAVE. LEFT and RIGHT indicate that the proposed modifier was lying in the CONTEXT (immediately) to the frame's left or right. The frames F10-BE and F9-HAVE each take two frames as slot-fillers, upon receiving the second one it sends a MOD-MSG to one asking if it would like the other as a possible modifier. In this case LEX of this MOD-MSG would be F10-BE or F9-HAVE. (F9-HAVE and F10-BE perform some other functions, discussed below).

Where the proposed modifier comes from (i.e. what LEX is) is very important. Other important things are the way the proposed modifier responds to certain questions about itself and what prepositions and conjunctions (i.e. tokens, in general) appear in various places in the CONTEXT.

In Example 1, F3-SENTENCE uses the fact that LEX = RIGHT, that the proposed modifier (F4-PARAGRAPH) is TEXT and something it could be PART* of (transitive closure of PART) (F3-SENTENCE knew that itself), and that there was a CONTAINMENT-PREP (i.e. one of { in, on, of }) in between them (see Example 1)(I have not done determiners yet, read them in as you please).

These structures are printed so that the name (the second name of a frame is the name of the atom with the slot-structure in its property list) appears above a vertical list of its bound slots. (There are no slots bound by default for these purposes). The contents of the bound slot is printed recursively after the colon following the slot's name. To avoid problems with circular pointers any structure to be printed which is already being printed has its name printed only. The slot called MOD-ORDER is a list of the frame's modifiers in the order they were received. (most recent on the top), including the slot the modifier fills and where it comes from. (LEFT, RIGHT, F10-BE, F9-HAVE as before, or RSVP if it was taken as a result of an RSVP-MSG). This is very useful for understanding a frame's history which is in turn useful for debugging and parsing CONTEXTS with conjunctions.

Example 1:



```
*****************************************************
*****************************************************
(SENTENCE IN PARAGRAPH)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F3-SENTENCE FR#1156
  IS-PART*-OF : F4-PARAGRAPH FR#1153
                  HAS-AS-PART* : F3-SENTENCE FR#1156

                  MOD-ORDER : F3-SENTENCE FR#1156
                              HAS-AS-PART*
                              RSVP

  MOD-ORDER : F4-PARAGRAPH FR#1153
              IS-PART*-OF
              RIGHT
```

As well as initiating relationships between the two frames filling their slots F10-BE and F9-HAVE determine the time relationships between these two frames, and in case one is an action, inform it of its VOICE and ASPECT. ASPECT (either COMPLETED or ONGOING) is not important to the action at this point, however VOICE determines which of the two forms of presentation (PASSIVE and ACTIVE) it should use as a first assumption about its presentation in the CONTEXT. This decision relates to what modifiers it expects to receive from where.

When one makes a description of something, it is a description of the something a certain time. Furthermore, a description of X at time T1 may include that at time T2 X will have a certain property. I have observed that English transmits descriptions of this form via the instances of F10-BE and/or F9-HAVE between an entity (or in some cases this will be an action) and an action the entity is involved in, as follows (this is not all these "auxiliary verbs" determine): they determine the relationship (either BEFORE, AT, or AFTER) between TIME-OF-UTTERANCE and the time of the description of the entity and the relationship between the time of the description of the entity and the time of the description of the action. For example, compare the TIME slots in F2-MARTIN and F8-INSERT in examples 2, 3 and 4. There are nine such pairs of relationships and it is easy to figure out how to

Example 2:

```
*****************************************************
*****************************************************
(MARTIN WILL HAVE INSERTED)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F8-INSERT FR#4816
  TIME : BEFORE
         WHO
  VOICE : ACTIVE
  SUFFIX : ED
  ASPECT : COMPLETE
  WHO : F2-MARTIN FR#4817
          TIME : AFTER
                 TIME-OF-UTTERENCE
          ACTIONS-INVOLVED-IN : F8-INSERT FR#4816

          MOD-ORDER : F8-INSERT FR#4816
                      ACTIONS-INVOLVED-IN
                      RSVP

  MOD-ORDER : F2-MARTIN FR#4817
              WHO
              LEFT
```

Example 3:

```
*****************************************************
*****************************************************
(MARTIN HAS INSERTED)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F8-INSERT FR#5066
  TIME : BEFORE
         WHO
  VOICE : ACTIVE
  SUFFIX : ED
  ASPECT : COMPLETE
  WHO : F2-MARTIN FR#5067
          TIME : AT
                 TIME-OF-UTTERENCE
          ACTIONS-INVOLVED-IN : F8-INSERT FR#5066

          MOD-ORDER : F8-INSERT FR#5066
                      ACTIONS-INVOLVED-IN
                      RSVP

  MOD-ORDER : F2-MARTIN FR#5067
              WHO
              LEFT
```

Example 4:

```
*****************************************************
*****************************************************
(MARTIN HAD INSERTED)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F8-INSERT FR#5281
  TIME : BEFORE
         WHO
  VOICE : ACTIVE
  SUFFIX : ED
  ASPECT : COMPLETE
  WHO : F2-MARTIN FR#5282
          TIME : BEFORE
                 TIME-OF-UTTERENCE
          ACTIONS-INVOLVED-IN : F8-INSERT FR#5281

          MOD-ORDER : F8-INSERT FR#5281
                      ACTIONS-INVOLVED-IN
                      RSVP

  MOD-ORDER : F2-MARTIN FR#5282
              WHO
              LEFT
```

say each in almost any voice or aspect
in English, using the "auxiliaries" have, be and going.

This theory can be extended to include the appropriate filler for the TIME slot (i.e. time of description) for every frame in the CONTEXT. It has interesting aspects when considering subordinate clauses. However, I have not yet implemented this extension.

The actions in Examples 5 and 6 use knowledge about the VOICE of their presentation (in 5 deduced by default, in 6 informed by F10-BE), where they receive the proposed modifier from (RIGHT, LEFT or F10-BE), the way the proposed modifier answer their questions and the prepositions occurring in order to fill in the appropriate slots.

To be precise F10-BE and F9-HAVE expect one modifier from the LEFT and another either also from the LEFT or from the RIGHT. In the latter case it sends a MOD-MSG to the one from the LEFT asking if it would like the one from the RIGHT as a modifier. If the one from the RIGHT is an action and the one from the LEFT an entity then the entity will know (since the message it receives in from F10-BE or F9-HAVE) that it should send a MOD-MSG to the action proposing itself as a possible modifier. If the one from the RIGHT is not an action then the one from the

Example 5:

```
*****************************************************
*****************************************************
(TO PAGE MARTIN MOVED LONG PARAGRAPH)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F5-MOVE FR#5722
  WHAT : F4-PARAGRAPH FR#5706
           ACTIONS-INVOLVED-IN : F5-MOVE FR#5722

           SIZE : F7-SIZE FR#5707
                    PARTICULAR-VALUE : LONG
                    WHAT : F4-PARAGRAPH FR#5706

                    MOD-ORDER : F4-PARAGRAPH FR#5706
                                WHAT
                                RSVP

           MOD-ORDER : F5-MOVE FR#5722
                       ACTIONS-INVOLVED-IN
                       RSVP
                       F7-SIZE FR#5707
                       SIZE
                       LEFT

  TIME : AT
         WHO
  VOICE : ACTIVE
  SUFFIX : ED
  ASPECT : COMPLETED
  WHO : F2-MARTIN FR#5735
          TIME : BEFORE
                 TIME-OF-UTTERENCE
          ACTIONS-INVOLVED-IN : F5-MOVE FR#5722

          MOD-ORDER : F5-MOVE FR#5722
                      ACTIONS-INVOLVED-IN
                      RSVP

  TO-WHERE : F6-PAGE FR#5723
               ACTIONS-INVOLVED-IN : F5-MOVE FR#5722

               MOD-ORDER : F5-MOVE FR#5722
                           ACTIONS-INVOLVED-IN
                           RSVP

  MOD-ORDER : F4-PARAGRAPH FR#5706
              WHAT
              RIGHT
              F6-PAGE FR#5723
              TO-WHERE
              LEFT
              F2-MARTIN FR#5735
              WHO
              LEFT
```

Example 6:

```
******************************************************
******************************************************
(SENTENCE WAS INSERTED IN PARAGRAPH ON PAGE BY MARTIN)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F8-INSERT FR#691
  WHO : F2-MARTIN FR#688
          ACTIONS-INVOLVED-IN : F8-INSERT FR#691

          MOD-ORDER : F8-INSERT FR#691
                      ACTIONS-INVOLVED-IN
                      RSVP

  TIME : AT
         WHAT
  ASPECT : COMPLETE
  SUFFIX : ED
  VOICE : PASSIVE
  WHAT : F3-SENTENCE FR#719
           TIME : BEFORE
                  TIME-OF-UTTERENCE
           ACTIONS-INVOLVED-IN : F8-INSERT FR#691

           MOD-ORDER : F8-INSERT FR#691
                       ACTIONS-INVOLVED-IN
                       RSVP

  WHERE : IN F4-PARAGRAPH FR#692
               CONTAINED-IN : F6-PAGE FR#696
                              CONTAINS : F4-PARAGRAPH FR#692

                              MOD-ORDER : F4-PARAGRAPH FR#692
                                          CONTAINS
                                          RSVP

               ACTIONS-INVOLVED-IN : F8-INSERT FR#691

               MOD-ORDER : F8-INSERT FR#691
                           ACTIONS-INVOLVED-IN
                           RSVP
                           F6-PAGE FR#696
                           CONTAINED-IN
                           RIGHT

  MOD-ORDER : F2-MARTIN FR#688
              WHO
              RIGHT
              IN F4-PARAGRAPH FR#692
              WHERE
              RIGHT
              F3-SENTENCE FR#719
              WHAT
              LEFT
```

left will consider it as a possible modifier, (see Examples 7, 8, 9 and 10. One might also wish to communicate the relationship in 10 but with more emphasis on F4-PARAGRAPH (perhaps for the purpose of further modification). This is done as in Example 11. In this example F10-BE receives both of its modifiers on the LEFT, which is what distinguishes it from Example 10.

When it is presented in the ACTIVE voice F8-INSERT "expects" to fill its WHAT slot with some TEXT from its RIGHT as in Example 12. However, if it receives some TEXT from the LEFT it will use it as WHAT but also take it as an indication that it should not return itself as a replacement for the pair in the CONTEXT, but rather it should return the TEXT, as in Example 13. This is the general idea behind how I do subordinate clauses, having "expectations" that are broken. (See Examples 14, 15, and 16).

More complex constructions are easily recognized by looking for a preposition in the right place. Compare Examples 17 and 18. Example 17 involves a change, in F8-INSERT, F4-PARAGRAPH is taken as WHAT until F3-SENTENCE is considered as a possible modifier. Then, since the preposition comes after the occurrence of F3-SENTENCE, a switch is made, IN F4-PARAGRAPH becomes WHERE and F3-SENTENCE becomes WHAT.

Example 7:

```
*****************************************************
*****************************************************
(PARAGRAPH HAD SHORT SENTENCE)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F4-PARAGRAPH FR#5542
  HAS-AS-PART* : F3-SENTENCE FR#5526
                   IS-PART*-OF : F4-PARAGRAPH FR#5542

                   SIZE : F7-SIZE FR#5527
                            PARTICULAR-VALUE : SHORT
                            WHAT : F3-SENTENCE FR#5526

                            MOD-ORDER : F3-SENTENCE FR#5526
                                        WHAT
                                        RSVP

                   MOD-ORDER : F4-PARAGRAPH FR#5542
                               IS-PART*-OF
                               RSVP
                               F7-SIZE FR#5527
                               SIZE
                               LEFT


  TIME : BEFORE
         TIME-OF-UTTERENCE
  MOD-ORDER : F3-SENTENCE FR#5526
              HAS-AS-PART*
              F9-HAVE
```

Example 8:

```
*****************************************************
*****************************************************
(PARAGRAPH IS SHORT)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F4-PARAGRAPH FR#4474
  SIZE : F7-SIZE FR#4471
           WHAT : F4-PARAGRAPH FR#4474

           PARTICULAR-VALUE : SHORT
           MOD-ORDER : F4-PARAGRAPH FR#4474
                       WHAT
                       RSVP

  TIME : AT
         TIME-OF-UTTERENCE
  MOD-ORDER : F7-SIZE FR#4471
              SIZE
              F10-BE
```

Example 9:

```
*****************************************************
*****************************************************
(PARAGRAPH IS ON PAGE)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F4-PARAGRAPH FR#4573
  CONTAINED-IN : F6-PAGE FR#4570
                   CONTAINS : F4-PARAGRAPH FR#4573

                   MOD-ORDER : F4-PARAGRAPH FR#4573
                               CONTAINS
                               RSVP

  TIME : AT
         TIME-OF-UTTERENCE
  MOD-ORDER : F6-PAGE FR#4570
              CONTAINED-IN
              F10-BE
```

Example 10:

```
***************************************************
***************************************************
(SENTENCE WAS BEFORE PARAGRAPH)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F3-SENTENCE FR#92
  LOCALE : BEFORE F4-PARAGRAPH FR#88
                    LOCALE : AFTER F3-SENTENCE FR#92

                    MOD-ORDER : AFTER F3-SENTENCE FR#92
                                LOCALE
                                RSVP

  TIME : BEFORE
         TIME-OF-UTTERENCE
  MOD-ORDER : BEFORE F4-PARAGRAPH FR#88
              LOCALE
              F10-BE
```

Example 11:

```
***************************************************
***************************************************
(SENTENCE PARAGRAPH WAS BEFORE)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F3-SENTENCE FR#4686
  LOCALE : AFTER F4-PARAGRAPH FR#4682
                    LOCALE : BEFORE F3-SENTENCE FR#4686

                    MOD-ORDER : BEFORE F3-SENTENCE FR#4686
                                LOCALE
                                RSVP

  TIME : BEFORE
         TIME-OF-UTTERENCE
  MOD-ORDER : AFTER F4-PARAGRAPH FR#4682
              LOCALE
              F10-BE
```

Example 12:

```
*****************************************************
*****************************************************
(BARBARA HAS BEEN INSERTING SENTENCE)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F8-INSERT FR#604
  WHAT : F3-SENTENCE FR#601
           ACTIONS-INVOLVED-IN : F8-INSERT FR#604

           MOD-ORDER : F8-INSERT FR#604
                       ACTIONS-INVOLVED-IN
                       RSVP

  WHO : F2*5-BARBARA FR#606
          ACTIONS-INVOLVED-IN : F8-INSERT FR#604

          TIME : AT
                 TIME-OF-UTTERENCE
          MOD-ORDER : F8-INSERT FR#604
                      ACTIONS-INVOLVED-IN
                      RSVP

  ASPECT : ONGOING
  SUFFIX : ING
  VOICE : ACTIVE
  TIME : BEFORE
         WHO
  MOD-ORDER : F3-SENTENCE FR#601
              WHAT
              RIGHT
              F2*5-BARBARA FR#606
              WHO
              LEFT
```

Example 13:

```
*****************************************************
*****************************************************
(SENTENCE BARBARA HAS BEEN INSERTING)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F3-SENTENCE FR#1109
  ACTIONS-INVOLVED-IN : F8-INSERT FR#1108
                          SUBORDINATE : WHAT
                          TIME : BEFORE
                                 WHO
                          VOICE : ACTIVE
                          SUFFIX : ING
                          ASPECT : ONGOING
                          WHO : F2*5-BARBARA FR#1121
                                  TIME : AT
                                         TIME-OF-UTTERENCE
                                  ACTIONS-INVOLVED-IN : F8-INSERT FR#1108

                                  MOD-ORDER : F8-INSERT FR#1108
                                              ACTIONS-INVOLVED-IN
                                              RSVP

                          WHAT : F3-SENTENCE FR#1109
                          MOD-ORDER : F3-SENTENCE FR#1109
                                      WHAT
                                      LEFT
                                      F2*5-BARBARA FR#1121
                                      WHO
                                      LEFT


   MOD-ORDER : F8-INSERT FR#1108
               ACTIONS-INVOLVED-IN
               RSVP
```

Example 14:

```
******************************************************
(MARTIN DELETED LONG SENTENCE FROM PARAGRAPH BARBARA INSERTED)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F1-DELETE FR#1264
  FROM-WHERE : F4-PARAGRAPH FR#1233
                  ACTIONS-INVOLVED-IN : F1-DELETE FR#1264
                                        F8-INSERT FR#1234
                                          WHAT : F4-PARAGRAPH FR#1233
                                          WHO : F2÷5-BARBARA FR#1236
                                                  ACTIONS-INVOLVED-IN : F8-INSERT FR#1234
                                                  TIME : BEFORE
                                                         TIME-OF-UTTERENCE
                                                  MOD-ORDER : F8-INSERT FR#1234
                                                              ACTIONS-INVOLVED-IN
                                                              RSVP
                                          ASPECT : COMPLETED
                                          SUFFIX : ED
                                          VOICE : ACTIVE
                                          TIME : AT
                                                 WHO
                                          SUBORDINATE : WHAT
                                          MOD-ORDER : F4-PARAGRAPH FR#1233
                                                      WHAT
                                                      LEFT
                                                      F2÷5-BARBARA FR#1236
                                                      WHO
                                                      LEFT
                    MOD-ORDER : F1-DELETE FR#1264
                              ACTIONS-INVOLVED-IN
                              RSVP
                              F8-INSERT FR#1234
                              ACTIONS-INVOLVED-IN
                              RSVP
  TIME : AT
         WHO
  VOICE : ACTIVE
  SUFFIX : ED
  ASPECT : COMPLETED
  WHO : F2-MARTIN FR#1298
           TIME : BEFORE
                  TIME-OF-UTTERENCE
           ACTIONS-INVOLVED-IN : F1-DELETE FR#1264

           MOD-ORDER : F1-DELETE FR#1264
                       ACTIONS-INVOLVED-IN
                       RSVP
  WHAT : F3-SENTENCE FR#1265
            SIZE : F7-SIZE FR#1269
                     WHAT : F3-SENTENCE FR#1265
                     PARTICULAR-VALUE : LONG
                     MOD-ORDER : F3-SENTENCE FR#1265
                                 WHAT
                                 RSVP
            ACTIONS-INVOLVED-IN : F1-DELETE FR#1264
            MOD-ORDER : F1-DELETE FR#1264
                        ACTIONS-INVOLVED-IN
                        RSVP
                        F7-SIZE FR#1269
                        SIZE
                        LEFT
  MOD-ORDER : F4-PARAGRAPH FR#1233
              FROM-WHERE
              RIGHT
              F3-SENTENCE FR#1265
              WHAT
              RIGHT
              F2-MARTIN FR#1298
              WHO
              LEFT
```

Example 15:

```
*************************************************
*************************************************
(SENTENCE WAS INSERTED ON PAGE PARAGRAPH WAS MOVED TO)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F8-INSERT FR#2459
  WHERE : ON F6-PAGE FR#2427
               ACTIONS-INVOLVED-IN : F8-INSERT FR#2459
                                     F5-MOVE FR#2428
                                       TO-WHERE : F6-PAGE FR#2427
                                       WHAT : F4-PARAGRAPH FR#2430
                                                ACTIONS-INVOLVED-IN : F5-MOVE FR#2428

                                                TIME : BEFORE
                                                       TIME-OF-UTTERENCE
                                                MOD-ORDER : F5-MOVE FR#2428
                                                            ACTIONS-INVOLVED-IN
                                                            RSVP

                                       VOICE : PASSIVE
                                       SUFFIX : ED
                                       ASPECT : COMPLETE
                                       TIME : AT
                                              WHAT
                                       SUBORDINATE : TO-WHERE
                                       MOD-ORDER : F6-PAGE FR#2427
                                                   TO-WHERE
                                                   LEFT
                                                   F4-PARAGRAPH FR#2430
                                                   WHAT
                                                   LEFT


               MOD-ORDER : F8-INSERT FR#2459
                           ACTIONS-INVOLVED-IN
                           RSVP
                           F5-MOVE FR#2428
                           ACTIONS-INVOLVED-IN
                           RSVP

  WHAT : F3-SENTENCE FR#2461
            ACTIONS-INVOLVED-IN : F8-INSERT FR#2459

            TIME : BEFORE
                   TIME-OF-UTTERENCE
            MOD-ORDER : F8-INSERT FR#2459
                        ACTIONS-INVOLVED-IN
                        RSVP

  VOICE : PASSIVE
  SUFFIX : ED
  ASPECT : COMPLETE
  TIME : AT
         WHAT
  MOD-ORDER : ON F6-PAGE FR#2427
              WHERE
              RIGHT
              F3-SENTENCE FR#2461
              WHAT
              LEFT
```

Example 16:

```
**?***************************************************
******************************************************
(PARAGRAPH BEING DELETED HAS SHORT SENTENCE)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F4-PARAGRAPH FR#4334
  HAS-AS-PART* : F3-SENTENCE FR#4318
                   IS-PART*-OF : F4-PARAGRAPH FR#4334

                   SIZE : F7-SIZE FR#4319
                            PARTICULAR-VALUE : SHORT
                            WHAT : F3-SENTENCE FR#4318

                            MOD-ORDER : F3-SENTENCE FR#4318
                                        WHAT
                                        RSVP

                   MOD-ORDER : F4-PARAGRAPH FR#4334
                               IS-PART*-OF
                               RSVP
                               F7-SIZE FR#4319
                               SIZE
                               LEFT


  ACTIONS-INVOLVED-IN : F1-DELETE FR#4336
                          WHAT : F4-PARAGRAPH FR#4334
                          TIME : AT
                                 WHAT
                          VOICE : PASSIVE
                          SUFFIX : ED
                          ASPECT : ONGOING
                          SUBORDINATE : WHAT
                          MOD-ORDER : F4-PARAGRAPH FR#4334
                                      WHAT
                                      LEFT


  TIME : AT
         TIME-OF-UTTERENCE
  MOD-ORDER : F3-SENTENCE FR#4318
              HAS-AS-PART*
              F9-HAVE
             F1-DELETE FR#4336
              ACTIONS-INVOLVED-IN
              RSVP
```

Example 17:

```
******************************************************
******************************************************
(PARAGRAPH BARBARA INSERTED SENTENCE IN)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F4-PARAGRAPH FR#328
  ACTIONS-INVOLVED-IN : F8-INSERT FR#296
                          WHERE : IN F4-PARAGRAPH FR#328
                          WHO : F2*5-BARBARA FR#387
                                  ACTIONS-INVOLVED-IN : F8-INSERT FR#296

                                  TIME : BEFORE
                                         TIME-OF-UTTERENCE
                                  MOD-ORDER : F8-INSERT FR#296
                                              ACTIONS-INVOLVED-IN
                                              RSVP

                          ASPECT : COMPLETED
                          SUFFIX : ED
                          VOICE : ACTIVE
                          TIME : AT
                                 WHO
                          SUBORDINATE : WHERE
                          WHAT : F3-SENTENCE FR#297
                                   ACTIONS-INVOLVED-IN : F8-INSERT FR#296

                                   MOD-ORDER : F8-INSERT FR#296
                                               ACTIONS-INVOLVED-IN
                                               RSVP

                          MOD-ORDER : F3-SENTENCE FR#297
                                      WHAT
                                      RIGHT
                                      IN F4-PARAGRAPH FR#328
                                      CHANGED-TO
                                      WHERE
                                      F4-PARAGRAPH FR#328
                                      WHAT
                                      LEFT
                                      F2*5-BARBARA FR#387
                                      WHO
                                      LEFT


  MOD-ORDER : F8-INSERT FR#296
              ACTIONS-INVOLVED-IN
              RSVP
```

```
***************************************
(PARAGRAPH MARTIN INSERTED ON PAGE)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F4-PARAGRAPH FR#552
  CONTAINED-IN : F6-PAGE FR#549
                   CONTAINS : F4-PARAGRAPH FR#552

                   MOD-ORDER : F4-"ARAGRAPH FR#552
                               CONTAINS
                               RSVP
  ACTIONS-INVOLVED-IN : F8-INSERT FR#553
                          WHAT : F4-PARAGRAPH FR#552
                          WHO : F2-MARTIN FR#555
                                ACTIONS-INVOLVED-IN : F8-INSERT FR#553

                                TIME : BEFORE
                                       TIME-OF-UTTERENCE
                                MOD-ORDER : F8-INSERT FR#553
                                            ACTIONS-INVOLVED-IN
                                            RSVP
                          ASPECT : COMPLETED
                          SUFFIX : ED
                          VOICE : ACTIVE
                          TIME : AT
                                 WHO
                          SUBORDINATE : WHAT
                          MOD-ORDER : F4-PARAGRAPH FR#552
                                      WHAT
                                      LEFT
                                      F2-MARTIN FR#555
                                      WHO
                                      LEFT
  MOD-ORDER : F6-PAGE FR#549
              CONTAINED-IN
              RIGHT
              F8-INSERT FR#553
              ACTIONS-INVOLVED-IN
              RSVP

&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F4-PARAGRAPH FR#613
  ACTIONS-INVOLVED-IN : F8-INSERT FR#601
                          WHERE : ON F6-PAGE FR#597
                                     ACTIONS-INVOLVED-IN : F8-INSERT FR#601

                                     MOD-ORDER : F8-INSERT FR#601
                                                 ACTIONS-INVOLVED-IN
                                                 RSVP

                          WHAT : F4-PARAGRAPH FR#613
                          WHO : F2-MARTIN FR#603
                                ACTIONS-INVOLVED-IN : F8-INSERT FR#601

                                TIME : BEFORE
                                       TIME-OF-UTTERENCE
                                MOD-ORDER : F8-INSERT FR#601
                                            ACTIONS-INVOLVED-IN
                                            RSVP
                          ASPECT : COMPLETED
                          SUFFIX : ED
                          VOICE : ACTIVE
                          TIME : AT
                                 WHJ
                          SUBORDINATE : WHAT
                          MOD-ORDER : ON F6-PAGE FR#597
                                      WHERE
                                      RIGHT
                                      F4-PARAGRAPH FR#613
                                      WHAT
                                      LEFT
                                      F2-MARTIN FR#603
                                      WHO
                                      LEFT
  MOD-ORDER : F8-INSERT FR#601
              ACTIONS-INVOLVED-IN
              RSVP
```

Example 18. Notice the ambiguity. The paragraph could be the one that Martin inserted which is on the page, or it could be the one Martin inserted on the page.

When filling certain of its slots, a frame will make sure that the proposed modifier has certain properties as I have been describing and then, before binding it to the appropriate slot, will look in that slot and make sure that it is empty.
If not it does two things. It looks for a conjunction immediately before or after (depending on whether the proposed modifier comes from the RIGHT or the LEFT) the proposed modifier in the CONTEXT and it looks at its MOD-ORDER slot to see if the most recent modification was the modifier already in the slot in question.
If both conditions hold, the conjunction is removed from the CONTEXT and a new structure which indicates the conjunction is put in the slot. (See Example 19). Simple conditions like these can also be used to parse more complex conjunctions involving deletions, etc., however, I have not implemented this.

The only serious problem I have encountered in my approach is that my programs run terribly slowly. Their time basically increases exponentially with the number of frames in the original CONTEXT. For a medium length sentence, e.g. Example 6, the running-time is about thirty seconds, not counting time spent garbage collecting, with most of my programs compiled. This is a result of some inefficient programming on my part and the non-determinism of the control structure. If other procedures intervened at the branch points within the non-deterministic

Example 19:

```
*****************************************************
*****************************************************
(MARTIN OR BARBARA MOVED PARAGRAPH)
&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
F5-MOVE FR#3267
  WHAT : F4-PARAGRAPH FR#3264
           ACTIONS-INVOLVED-IN : F5-MOVE FR#3267

           MOD-ORDER : F5-MOVE FR#3267
                       ACTIONS-INVOLVED-IN
                       RSVP

  WHO : OR
          F2-MARTIN FR#3278
            ACTIONS-INVOLVED-IN : F5-MOVE FR#3267

            MOD-ORDER : F5-MOVE FR#3267
                        ACTIONS-INVOLVED-IN
                        RSVP

          F2*5-BARBARA FR#3279
            ACTIONS-INVOLVED-IN : F5-MOVE FR#3267

            TIME : BEFORE
                   TIME-OF-UTTERENCE
            MOD-ORDER : F5-MOVE FR#3267
                        ACTIONS-INVOLVED-IN
                        RSVP

  ASPECT : COMPLETED
  SUFFIX : ED
  VOICE : ACTIVE
  TIME : AT
         WHO
         WHO
  MOD-ORDER : F4-PARAGRAPH FR#3264
              WHAT
              RIGHT
              OR
                F2-MARTIN FR#3278
                F2*5-BARBARA FR#3279
              WHO
              LEFT
```

structure and made decisions based on expectations, preferences, and perhaps a global concept of grammar I suspect the slowness would be relieved.

The first logical continuation at this point is a larger vocabulary of concepts, some expansion of linguistic presentations of concepts including more complicated conjoined structures, negation, etc. Introduction of means for specifying identifications between concepts, i.e. determiners, numbers, and ordinals, and implementation of my extended time-reference theory would also be easy; all these things should be straightforward constructions within the structure I have already built.

A more important continuations is to build a mechanism for integrating new information into a body of information already received in d scourse. Aside from deductions, etc., that are specific to the reader's purposes, a most important function of such a mechanism is to make identifications between actions or entities in the information being integrated and those already processed. Such a mechanism will also be very useful for determining pronoun references, opaque references, and the like. Beyond that, generation of English is a good goal.

BIBLIOGRAPHY

Pratt, Vaughan R., Top Down Operator Precedence, published in: ACM Symposium on Principles of Programming Languages, October, 1973.

Minsky, Marvin, Frames: A Framework for Representing Knowledge forthcoming.