A MODEL OF NATURAL LANGUAGE PROCESSING OF TIME-RELATED EXPRESSIONS

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This paper proposes a model of automatic processing of time-related expressions by introducing the notion of focus in the cognition level. The linguistic categories of time are determined on the basis of the relationships among the time of an extra-linguistic situation, the focused time and the time of utterance.

INTRODUCTION

It is generally understood that there is no one-to-one correspondence between the extra-linguistic (real world) time of situations and the grammatical expressions of time in sentences of natural languages. If there is no correspondence of the extra-linguistic situation to the linguistic expressions, it is impossible to simulate this process by a computer model.

This paper proposes a model of automatic processing of time-related expressions by introducing the notion of focus in the cognition level between the extra-linguistic time of situations and the linguistic expressions of time. As well, it points the way toward the computer-realization of the model. The computer programming language used for this model is SNOBOL.

Failure of correspondence between an extra-linguistic situation and linguistic expressions of the time concept can easily be demonstrated in most languages, if not all. For example, suppose the extra-linguistic situation is the speaker's writing during a certain period in the past (say, between two and three o'clock yesterday). In reference to it, we can use any of the following sentences.

(1) I wrote a letter.
(2) I was writing a letter.
(3) I have written a letter.
(4) I had written a letter (when John came).

The differences among sentences (1) through (4) are attributed to the speaker's different point of view. Comrie[1] mentions that 'aspects are different ways of viewing the internal temporal constituency of situations.' The speaker's way of viewing, however, affects not only his choice of aspects but also his choice of tenses. Note the following examples from Japanese.

(5) ah sokoni aru.
'There it is!'
(6) ah sokoni atta.
'There it was (all the time)!'

There is no difference in the denotative meaning of sentences (5) and (6). Both sentences can be used when someone has found something he has been looking for. Whether the speaker uses sentence (5) or sentence (6) depends, again, on his view point.

FOCUS

The difference in the speaker's view-point, or that of cognition, cannot be ignored, as seen in the above examples, when we consider the time-related expressions of natural language. Physical events in the extra-linguistic world present themselves as sense data, and are perceived not passively, but actively by an intervention of mind, and are subsequently stored in the momory as experiences. The experiences represent the material that can be formulated and articulated as the linguistic forms.

We believe that unless we incorporate cognition into the process of generating linguistic expressions we cannot explain the relationship between the extra-linguistic situations and the linguistic expressions. And we consider the notion of focus the most important cognitive element in connection with time-related expressions. 'Focus' is defined as the period along the extra-linguistic time line upon which the speaker directs his attention.

MODEL

By incorporating the speaker's focus into a model we can generate the time-related expressions rather

automatically, that is, by one-to-one correspondence, and therefore it is possible to implement this model as a computer model to generate linguistic expressions.

For the model we consider three levels; that is,

1. the extra-linguistic (real world) level,
2. the cognition level, and
3. the linguistic level.

Information on extra-linguistic situations observed by the speaker is stored in the extra-linguistic level in the form of the situation and its existing period of time. The speaker's focus in the cognition level is matched against the situation(s) in the extra-linguistic level and the way they match or do not match determines the selection of linguistic items such as verbs, adjectives, negation, aspect and tense.

The linguistic level forms the sentences by syntactic, morphological and phonological rules.

EXTRA-LINGUISTIC LEVEL

The computer model under consideration simulates this process by our creating three levels here also. The extra-linguistic level stores information on situations in the following form (Nos. 2-9 of the appended program).

```
SITUATION START-DS  END-DS    END-SS

SPEAK(I)  10030930 10031000
READ(I,A-BOOK)
          10021400 10021630
COME(JOHN,HERE)
          10021130 10021200 10021400
GO-ON(A-LIGHT)
          10021900 10021900 10022359
CALM(IT,HERE)
          10012000 10012000 10030500
```

The information includes situation in the form of verbal expressions and their arguments, the starting time of dynamic situations, the ending time of dynamic situations, and the ending time of static situations. In the number for the time, the first two digits stand for the month, the next two for the day, the next two for the hour, and the last two for the minute. This number system may be expanded to include the year, the second, etc.

Extra-linguistic situations are divided into two categories; dynamic and static. For the distinction, let us quote Lyons[5](p. 483) .

> A static situation (or state-of-affairs, or state) is one that is conceived of as existing, rather than happening, and as being homogeneous, continuous and unchanging throughout its duration. A dynamic situation, on the other hand, is something that happens (or occurs, or takes place): it may be momentary or enduring; it is not necessarily either homogeneous or continuous, but may have any of several temporal contours;...

Dynamic situations are in turn divided into two types. Those such as 'reading' are situations occurring for a certain period of time. Therefore situations of this type have a starting time and an ending time. The second type of dynamic situation, like '(a light) going on', is momentary, and therefore it is understood that the starting time and the ending time are identical.

Static situations, on the other hand, continue for a certain period of time. But they may be results of dynamic situations and they may also change into other situations again by dynamic situations. The starting time of a static situation is usually the ending time of a dynamic situation and its ending time, if any, is the starting time of another dynamic situation.

It is worth mentioning here that what are stored in this level are not linguistic expressions but situations. Therefore, the time period of an existing situation is not influenced by the type of particular linguistic expressions of a particular natural language. Taking an English expression for example, '(a light) goes on' is considered to be momentary event. Therefore, we cannot say '*a light is going on.' However, 'lights are going on' is possible, in which case we can identify a different starting time and ending time. Further, if we could observe the period of duration of a light going on by a high-speed film for instance, the different starting and ending times could be recorded in the data by expanding time digits to second or millisecond.

However, there are some phenomena peculiar to individual languages. For instance, the situation of 'coming' is

considered to have a time duration in English. Therefore, 'John is coming' is a paraphrase of 'John is on the way.' But in Japanese it is considered to be momentary, that is, 'coming' is a sort of switch from 'is not here' to 'is here'. Therefore there is not Japanese expression equivalent to English 'John is coming.' Theoretically, this kind of difference among individual languages should be taken care of by elaborating the structure of situations in the data of this level, but in the current model it is taken care of by the linguistic level.

COGNITION LEVEL

Now in the cognition level, the focused situation and the period of focus as well as the time of utterance are inserted into the program (Program Nos. 10-27). The focused situation is in the form of verbal expression and its arguments. The period of focus is in the form of either a time adverbial such as 'now', 'this morning', 'yesterday' and 'last month', or numbers for chronological time points similar to those of extra-linguistic situation time. When the input is a time adverbial, the program calculates it against the time of utterance and translates it into chronological numbers (Program Nos. 28-40).

So far, data stored in the program are:

1. Extra-linguistic situations, each comprising:
   a. the starting time-point of a dynamic situation(A),
   b. the ending time-point of a dynamic situation(B),
   c. the ending time-point of a static situation(C);
2. Time of utterance(O):
3. Focused situation, comprising:
   a. the starting time-point of focus(S), and
   b. the ending time-point of focus(E).

Here it is checked whether a particular extra-linguistic situation exists within the focused period or moment and, if so, how it is focused. On the basis of the relationship among the three kinds of time-points of an extra-linguistic situation (A,B and C), and the two kinds of focus time-points of the same focused situation (S and E), the cagegories of aspects are determined (Program Nos. 41-62).

The categories of aspects are determined in the following way:

I. If the focus is on the Static Situation(SS);
   1. and if the focus is on the point,
      a. and if the focus is completely inside the SS, then: STATIVE,
      b. otherwise, the Dynamic Situation(DS) is checked.
   2. If it is otherwise,
      a. and if the SS overlaps the focus completely, then: STATIVE,
      b. otherwise, the DS is checked.

II. If the focus is completely outside the DS, then: NEGATIVE.

III. If the focus is on a point,
   1. and if the DS is on a point, then: PERFECTIVE.
   2. If it is otherwise, and
      a. if the focus is on the beginning of the DS, then: PERFECTIVE (INGRESSIVE),
      b. if the focus is on the ending of the DS, then: PERFECTIVE (COMPLETED),
      c. if neither of the above, then: IMPERFECTIVE.

IV. If the focus is on a period,
   1. and if the DS is on a point, then: PERFECTIVE.
   2. If it is otherwise, and
      a. the DS overlaps the focus completely, then: IMPERFECTIVE,
      b. if the DS overlaps the focus partially, and
         i. the beginning of the DS is on or before the ending of the focus, then: PERFECTIVE (INGRESSIVE),
         ii. the ending of the DS is on or before the ending of the focus, then: PERFECTIVE (COMPLETED),
         iii. it is neither of the above, then: PERFECTIVE.

This aspect assignment is illustrated in the diagrams in the Appendix I.

The categories of tenses are in turn determined on the basis of the relationship between the focused time and the time of utterance (Program Nos. 63-69). If the focus is on the time of utterance, the PRESENT is assigned. If the focus is before the time of utterance, the PAST is assigned; if the reverse, the FUTURE. Japanese and Russian, for example, work in this way. In English one more

category of tense is needed. That is, if the focus is on a period and the end of the focus coincides with the time of utterance, the PAST-PRESENT is assigned. This category will later cover expressions like 'I have been studying linguistics.'

FINAL REMARKS

In the linguistic level time-related morphemes are assigned on the basis of the categories of time-related expressions sent from the cognition level. Here the peculiarities of individual natural languages are involved. Therefore a unique program is required for each natural language. After the morpheme assignments, syntactic and morphological rules together with phonological rules determine the forms in the sentences.

We shall omit detailed discussion on this level, since this process involving word categories closely related to the distinction between dynamic and static situations is complicated. For simplicaity of explanation, we have omitted the discussion and the programming of expressions of habit, experience and atemporal expressions. We have also omitted the discussion of relative tenses.

In summary, we have discussed an automatic process of time-expression generation in natural language. We believe that this is only possible by the introduction of the speaker's time focus and an examination of the relationship between the extra-linguistic situational time and focused time. By further examining the manner of morpheme assignments in as many natural languages as possible, we believe, we can expand the number of universal rules common to all languages and minimize the number of rules peculiar to individual languages.

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2. Forsyth, J. (1970). A Grammar of Aspect. Cambridge: Cambridge University Press.

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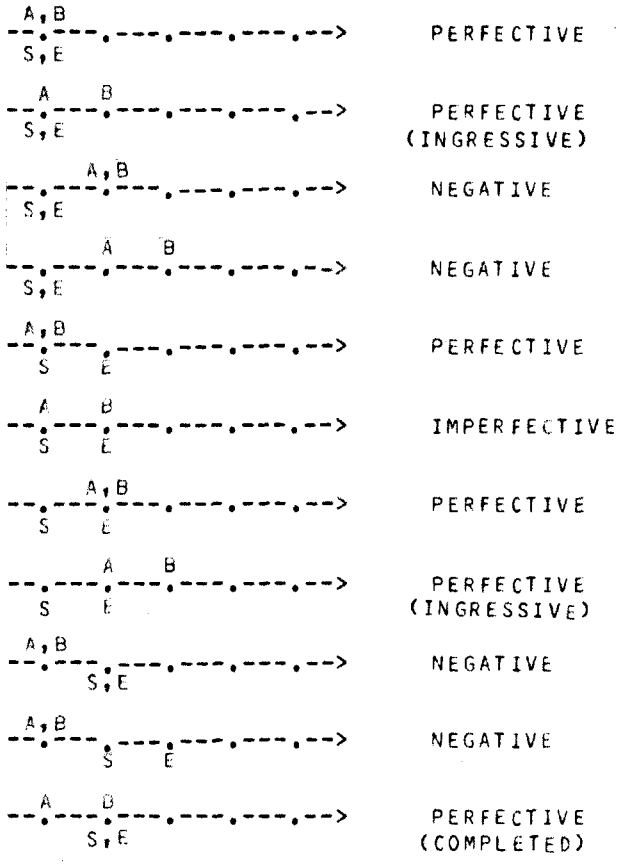
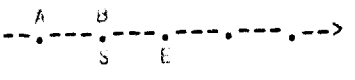
5. Lyons, J. (1977). Semantic II. Cambridge: Cambridge University Press.

APPENDIX I

Diagrams of Aspect Assignment

A -- starting time of a dynamic stuation
B -- ending time of a dynamic stuation
C -- ending time of a static stuation
S -- starting time of focus
E -- ending time of focus





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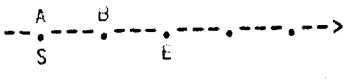

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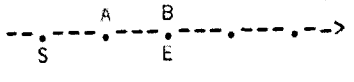

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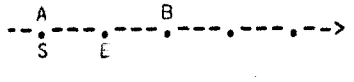

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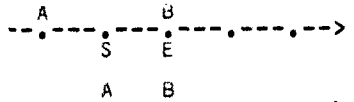

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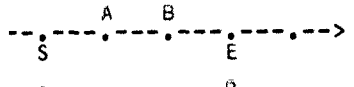

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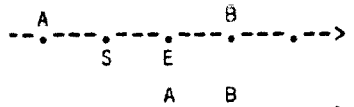

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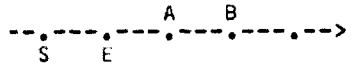

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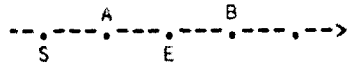

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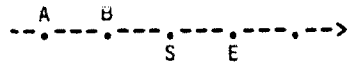

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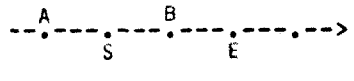

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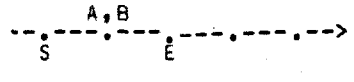

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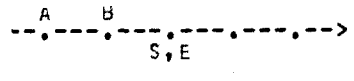

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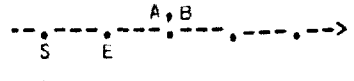

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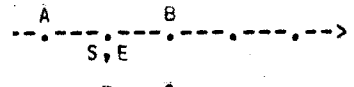

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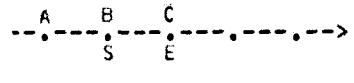

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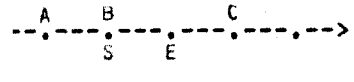

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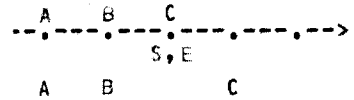

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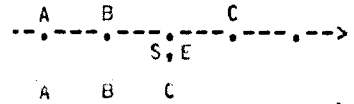

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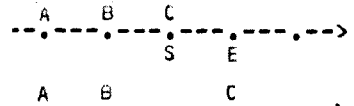

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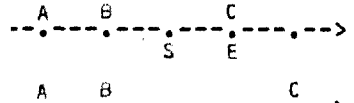

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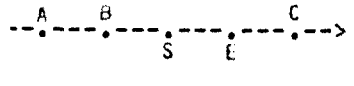

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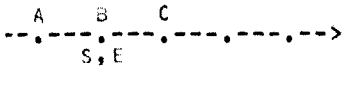

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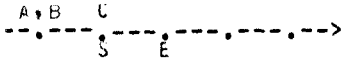

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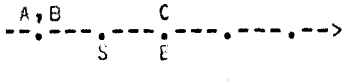

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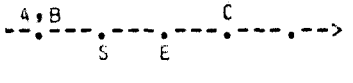

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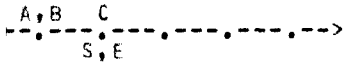

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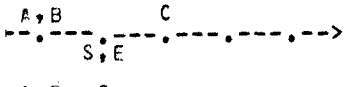

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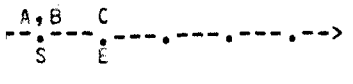

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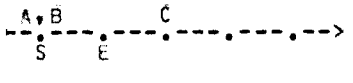

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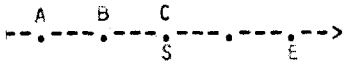

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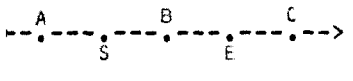
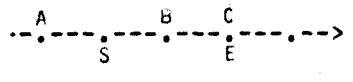
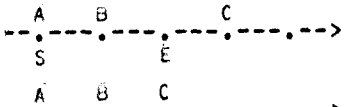


PERFECTIVE (COMPLETED)



PERFECTIVE (COMPLETED)



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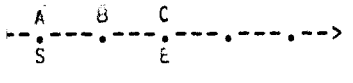

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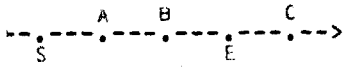
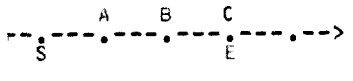
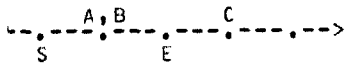


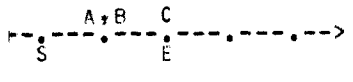
PERFECTIVE



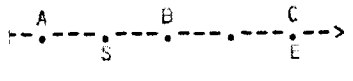
PERFECTIVE



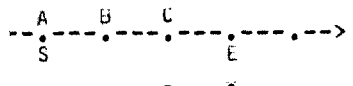
PERFECTIVE



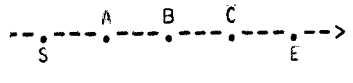
PERFECTIVE



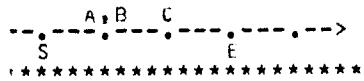
PERFECTIVE (COMPLETED)



PERFECTIVE (COMPLETED)



PERFECTIVE



PERFECTIVE

APPENDIX II

```
@ASNOB,E
ASCII SNOBOL 74R1.1 06/06/80 09:33:56
EXPERIMENTAL VERSION 2, 200531
1               DATE = 'TODAY' ! 'YESTERDAY' ! 'TOMORROW'
2       DCHK1   CHECK = TRIM(INPUT)
3               CHECK '*E'                                              :F(DCHK2)
4       ELDATA  DATA = TRIM(INPUT)
5               DATA '*'                                                :S(DCHK2)
6               N = N + 1
7               DATA ARB . $('ELST' N) ' ' ARB . $('A' N) ' ' REM . RE
8               RE ARB . $('B' N) ' ' REM . $('C' N)                    :S(ELDATA)
9               $('B' N) = RE                                           :(ELDATA)
10      DCHK2   CHECK '*S'                                              :S(SDATA)
11      SDATA   DATA = TRIM(INPUT)
12              DATA '*'                                                :S(FDATA)
13              SPTIME = DATA
14              Q = SPTIME
15              SPTIME LEN(2) . MO LEN(2) . DAY LEN(2) . HR LEN(2) . MNT
16      FDATA   DATA = TRIM(INPUT)                                      :F(END)
17              DATA '*'                                                :S(FDATA)
18              DATA ARB . FST ' ' REM . TADV
19              K = 0
20      KADD    K = K + 1
21              FST ')' =
22              $('ELST' K) FST                                         :S(ABC)
23              EQ(N,K)                                 :F(KADD)S(FDATA)
24      ABC     A = $('A' K)
25              ST = $('ELST' K)
26              B = $('B' K)
27              C = $('C' K)
28      DATE    TADV DATE                                               :F(MO)
29              TADV 'TODAY'                                            :F(D1)
30              ADAY = DAY + 00                                         :(ADJST)
31      D1      TADV 'YESTERDAY'                                        :F(D2)
32              ADAY = DAY - 01                                         :(ADJST)
33      D2      TADV 'TOMORROW'
34              ADAY = DAY + 01                                         :(ADJST)
35      MO      TADV 'MONTH'                                            :F(SE)
36      SE      TADV LEN(8) . S ' ' LEN(8) . E                          :S(SO)
37      ADJST   LT(ADAY,10)                                             :F(AGO)
38              ADAY = '0' ADAY
39      AGO     S = MO ADAY '0000'
40              E = MO ADAY '2359'
41      SO      C LEN(1)                                                :F(C1)
42      S1      GE(S,C)                                                 :S(NEG)
43      S2      LT(S,B)                                                 :S(C1)
44      S3      EQ(S,B)                                                 :F(S5)
45      S4      EQ(E,B)                                                 :S(C1)
46      S5      LE(E,C)                                                 :S(ST1)F(ST2)
47      C1      LT(E,A)                                                 :S(NEG)
48      C2      GT(S,B)                                                 :S(NEG)
49      C3      EQ(E,A)                                                 :F(C5)
50      C4      EQ(A,B)                                                 :S(PEF)F(PEF2)
51      C5      EQ(B,S)                                                 :F(C7)
52      C6      EQ(A,S)                                                 :S(PEF)F(PEF1)
53      C7      LE(A,S)                                                 :F(C9)
54      C8      GT(E,B)                                                 :S(PEF1)F(IMP)
55      C9      GE(E,B)                                                 :S(PEF)F(PEF2)
56      NEG     ASP = 'NEGATIVE'                                        :(TN)
57      IMP     ASP = 'IMPERFECTIVE'                                    :(TN)
58      PEF1    ASP = 'PEFECTIVE (COMPLETED)'                           :(TN)
59      PEF     ASP = 'PERFECTIVE'                                      :(TN)
60      PEF2    ASP = 'PERFECTIVE (INGRESSIVE)'                         :(TN)
61      ST1     ASP = 'STATIVE'                                         :(TN)
62      ST2     ASP = 'STATIVE (COMPLETED)'                             :(TN)
        *
        *** JAPANESE TENSE ASSIGNMENT   ***
63      TN      EQ(S,E)                                                 :F(T2)
64      T1      EQ(S,0)                                                 :S(PRE)
65      T2      LT(E,0)                                                 :S(PST)
66      T3      GT(S,0)                                                 :S(FUT)F(PRE)
67      PRE     TEN = 'PRESENT'                                         :(TA)
68      PST     TEN = 'PAST'                                            :(TA)
69      FUT     TEN = 'FUTURE'                                          :(TA)
        *
70      TA      FST = FST ')'
71              OUTPUT = 'FOCUS  ON  ' FST '  FROM  ' S '  TO  ' E
72              OUTPUT = 'EX-L STUATION  '
73              OUTPUT = '     ' ST
74              OUTPUT = '      A    ' A
75              OUTPUT = '      B    ' B
76              OUTPUT = '      C    ' C
77              OUTPUT = 'EXPRESSION    (ASPECT)   ' ASP
77      +               '     (TENSE)    ' TEN
78              OUTPUT = '     **********************************'       :(FDATA)
79      END
```

```
NO ERRORS WERE DETECTED IN SOURCE PROGRAM.
**********************************************************************************
FOCUS ON SPEAK(I) FROM 10030940 TO 10030940
EX-L STUATION
   SPEAK(I)
     A   10030930
     B   10031000
     C
EXPRESSION    (ASPECT)   IMPERFECTIVE    (TENSE)   PRESENT
     ***********************************
FOCUS ON READ(I) FROM 10020000 TO 10022359
EX-L STUATION
   READ(I,A-BOOK)
     A   10021400
     B   10021630
     C
EXPRESSION    (ASPECT)   PERFECTIVE    (TENSE)   PAST
     ***************************************
FOCUS ON COME(JOHN) FROM 10020000 TO 10022359
EX-L STUATION
   COME(JOHN,HERE)
     A   10021130
     B   10021200
     C   10021400
EXPRESSION    (ASPECT)   PERFECTIVE    (TENSE)   PAST
     ***************************************
FOCUS ON CALM) FROM 10020000 TO 10022359
EX-L STUATION
   CALM(IT,HERE)
     A   10012000
     B   10012000
     C   10030500
EXPRESSION    (ASPECT)   STATIVE    (TENSE)   PAST
     ***********************************
FOCUS ON GO-ON(A-LIGHT) FROM 10022000 TO 10022359
EX-L STUATION
   GO-ON(A-LIGHT)
     A   10021900
     B   10021900
     C   10022359
EXPRESSION    (ASPECT)   STATIVE    (TENSE)   PAST
     ***********************************
```