

NATURAL LANGUAGE INPUT FOR SCENE GENERATION *

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ABSTRACT

In this paper a system which understands and conceptualizes scenes descriptions in natural language is presented. Specifically, the following components of the system are described: the syntactic analyzer, based on a Procedural Systemic Grammar, the semantic analyzer relying on the Conceptual Dependency Theory, and the dictionary.

I INTRODUCTION

In this paper a system is presented, which understands and conceptualizes scenes descriptions in natural language (Italian) and produces simple static images of the scenes. It is part of a larger project that aims at understanding the description of static scenes, reasoning (in case of incompleteness or inconsistency) and dialoguing about them, and finally generating and displaying them.

The Input Analyzer (IA) of the system is the most stable end experimented component and it is the topic of this paper. It consists of a Syntactic Analyzer, a Cognitive Data Base (CDB) and a Semantic Interpreter.

II SYNTACTIC ANALYZER

The syntactic analysis is performed by means of a Procedural Systemic Grammar (PSG) (McCord,77). The main characteristics of the PSG parser is that the operation flow is highly structured, since different levels of the analysis are associated to the syntactic units of the sentence. Five processes can be activated (CLAUSE, COMPL.GR, NOUN.GR, ADJ.GR and VERB.GR) devoted to recognize respectively:

- (i) the sentences, (ii) the propositional phrases, comparatives, quantification and noun phrases,
- (iii) the components of the noun phrases, (iv) the adjectives and their modifiers, (v) the verb and its modifiers.

Fig.1 shows how these processes can interact in our parser: double arrows indicate message passing and

single arrows indicate reading from input. Each

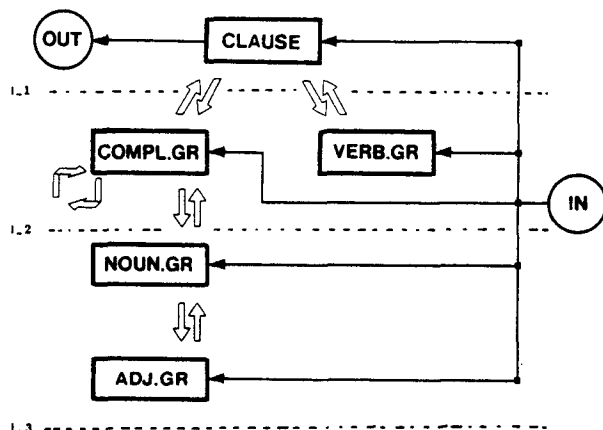


Fig.1 - Levels of Syntactic Analysis

level is activated by the superior one, as shown in Fig.1, and returns to its caller the results of its computation as a message. A feature network is associated to each process, which is activated together with its corresponding processes.

In a PASCAL-like language the feature network can be defined as follows:

```

type FEATURE= ...(.LIST_OF_FEATURES.)...;
LINK=^NODE;
NODE=record
    NAME:FEATURE;
    VALUE:boolean;
    FATHER,NEXT_BROTHER:LINK;
    FIRST_SON,ALTERNAT:LINK;
end;
FEATURE_NETWORK:array(FEATURE) of LINK;
    
```

Each NODE represents a feature identified by its NAME; the ALTERNATE pointer allows the connection in a circular list of mutually exclusive features as in SHRLDU (Winograd,72). Each process gives as output a fragment of the FEATURE_NETWORK manipulated to describe the input; this is performed by means of a set of functions which test the presence

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of a feature in the FEATURE_NETWORK, add and erase features, as described in McCord ('77). The process is divided into a set of sequential routines, called SLOTS, analyzing the functional components of a Syntactic Unit. In the function:

```
function FILLER(ARG1:PROCESS,
                ARG2:SET_OF_FEATURES):boolean;
```

ARG1 activates the appropriate process to fill the caller slot; the second argument of the function selects the set of features to which the called process must be initialized.

This last features-passing mechanism is absent in the original PSG; from our experience, we found it useful in all the cases in which a choice in a syntactic level is determined by the superior level or by a more larger context.

Thus, for instance, the set of features characterizing a prepositional phrase is determined at the corresponding syntactic level by the preposition and the features of the nominal phrase; but further and not less important selection criteria can be imposed by the verb which is found in the upper level. The output of a simple analysis is shown in Fig.2; it gives an idea of the syntactic representation.

```
INPUT: IL MIO GATTO STA MANGIANDO {my cat is eating}
RESULT_OF_THE_ANALYSIS:
TIPO          DICHIARATIVA_ATTIVA {declarative active}
IL MIO GATTO  SOGGETTO             {subject}
STA MANGIANDO VERB.GR
FEATURE_NETWORK:
-CLAUSE-!-PROPOSIZIONE-!-PRINC-!-DICHIARATIVA--
!-VERB.GR-----!-PEPS-!-TERZA--
!
!          !-NUM---!-SINGOLARE--
!          !-MODO---!-ESPLICITO-!-INDICATIVO--
!          !-TEMPO-!-PRESENTE--
!          !-ACT---!-TRANSITIVA--
!          !-FORMA-!-STARE--
!          !-GENERICO--
!-COMPL.GR-----!-PERS-!-TERZA--
!          !-GEN---!-MASCILE--
!          !-NUM---!-SINGOLARE--
!          !-NOUN.GR-!-NOME--
!          !-TIPO-!-COMUNE_PERS--
```

FIG.2 - Result of a Sentence Analysis

The choice of PSG is mainly motivated by the possibility of parallel computation. A control structure allowing the parallel computation is:

```
cobegin ... coend;
```

It is a single input-output structure, very useful to handle alternative choices for the same computational level. In the case of mutually exclusive alternatives only one of the "n" processes activated by a cobegin control structure can end successfully. In the case of not mutually exclusive alternatives, it is still possible to use the cobegin control structure, but it is necessary to define a strategy for the selection of the most suitable alternative when the coend occurs.

An experimental implementation in terms of parallel computation has been made on a multiprocessor system (Adorni et al., '79). Another version of this

parser has been implemented in PASCAL (DiManzo et al., '79) and a version in FranzLisp is in progress.

III STRUCTURE OF THE COGNITIVE DATA BASE

The organization of knowledge, in this system, is based on a set of THOUGHTS. A THOUGHT is a frame like structure within which new data are interpreted in terms of concepts acquired through previous experience (Minsky, '75), (Schank, Abelson, '77).

Every THOUGHT has a TYPE which determines a set of operations applicable to it. The following predefined types are allowed (Adorni, DiManzo, '83):

- DESCRIPTIVE, that defines the complete description of a physical, abstract, animate or not, object.
- PROTOTYPE, that defines the structural part of a physical object in terms of generalized cones (Marr, Nishihara, '78). An example of definition of simple prototype object is given in Fig.3.

- JOINT, that defines the element of connection between physical objects, in order to build more complex objects or scenes (Fig.4).

- SPATIALREL, that defines spatial relationships like "on, near, on the left of, ..." between objects. All the linguistic relationships like "above, under, behind", and so on, are reduced into quantitative geometrical relationships between the coordinates of some points of the involved objects; this choice is motivated by the possibility of deriving a set of very general inference rules from analytic geometry (Adorni et al., '82), (Bogges, '79), (Bogges, Waltz, '79). The coordinates of an indefinite point P are given in the form:

$$\text{COORD K OF P (REFERREL_TO A)}=H$$

where K is a group of possible coordinates, H a set of values for these coordinates and A is the THOUGHT of the object to which the reference system used is connected. Fig.5 shows the THOUGHT for an use of the preposition "on".

A spatialrel type THOUGHT can contain conceptualizations and prototype THOUGHTS; a joint type can contain only its description; a prototype type can contain joint or prototype THOUGHTS or descriptions in terms of generalized cones; all these types can be enclosed in a descriptive type which can contain conceptualizations and all the types of THOUGHTS, previously introduced. A descriptive type can include the following fields (Adorni, DiManzo, '83), (see Fig.6):

- DESCR, contains all the basic not specialized knowledge about the object;
- LEVELS, contains a description of the shape of the object (in terms of prototype THOUGHTS) divided in different levels of detail hierarchically organized;
- USE, contains the descriptions of the most common activities involving the use of the object, in terms of spatialrel between prototype THOUGHTS;

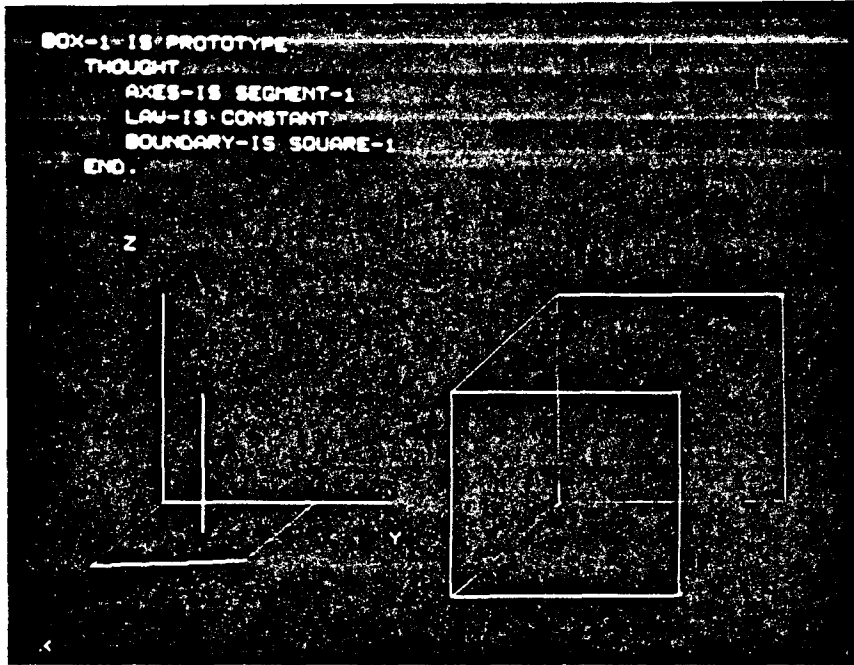


FIG.3 - Example of Definition of a Simple Prototype

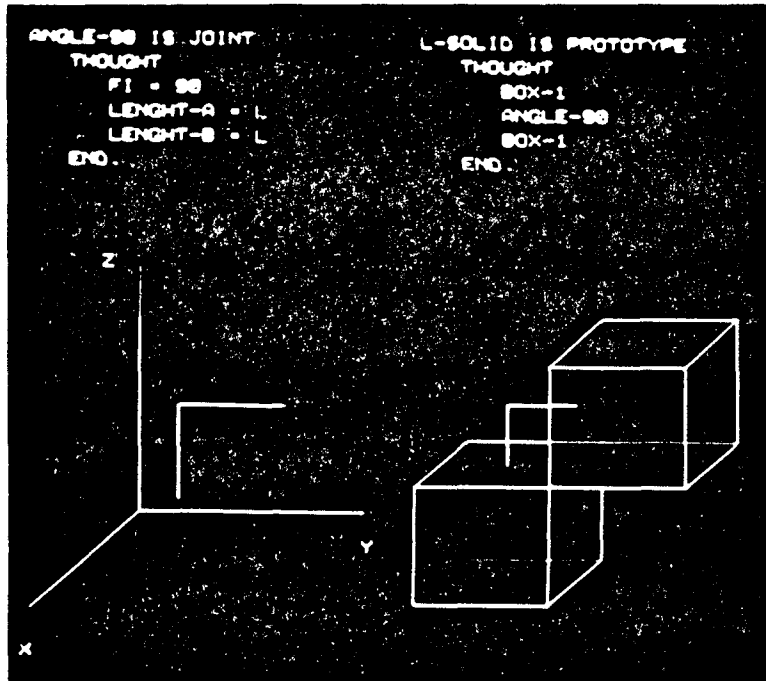


FIG.4 - Definition of a Simple Jointing Element and Use of this Element to build a More Complex Object

- POSITION, gives the most common spatial relations between the described object and other objects in standard scenes, in terms of a spatialrel between prototype THOUGHTS;
- SUPPORT, contains the indication, in terms of descriptive THOUGHTS, of the objects which are supported in standard situations;
- COLOR and MADE, describe the possible set of colors and materials, while WEIGHT contains information about the range of possible weights;
- CONTENT, says, in terms of descriptive THOUGHTS, that the normal use of the object is a container for other objects;
- DYNAMIC, contains the current expectations about the boundaries of the dimensions of the objects; it can be dynamically updated every time a new object of the same class enters the system's CDB.

IV SEMANTIC INTERPRETER

The Semantic Interpreter of the IA interacts with the Syntactic Analyzer and operates on a set of rules in order to build the concepts a sentence was intended to mean. The output of this module is a Conceptual Dependency Network (Schank, '75), in which every nominal is substituted by a complex descriptive THOUGHT instantiated from the CDB.

Let us illustrate the procedure of analysis considering the following sentence (the translation is word by word in order to reproduce the problems of Italian):

- (1) "l'uomo dai capelli grigi e' andato a Roma con l'auto di Giuseppe"
 (the man with the grey hair has gone to Rome with the car of Joseph)

The procedure of analysis has several steps:

A. Analysis of Words and Simple Phrases

During this step the entities which take part into the conceptualization are identified. In fact an indexed identifier Xi is associated to each object referred to in the sentence (each nominal), which points to one or more conceptualizations, contained in the field "descr" of each nominal in the CDB. The adjectives contained in the noun phrases are also analyzed during this step. Each of them adds some conceptualizations which contribute to further individuate the nominal. During this step personal pronouns are identified as:

Xi \Leftrightarrow ISA(HUMAN)

Temporal and local adverbials are also analyzed in this phase in order to assign to the sentence conceptualization a time and place identification according to certain rules described in (Adorni et al., '81).

At the end of this step the sentence (1) is represented as follows:

identifier	nominal	conceptualization
X1	uomo (man)	X1 \Leftrightarrow ISA(HUMAN)
X2	capelli (hair)	X2 \Leftrightarrow ISA(HAIR)
X3	Roma (Rome)	X3 \Leftrightarrow ISA(CITY) X3 \Leftrightarrow NAME(ROME)
X4	auto (car)	X4 \Leftrightarrow ISA(CAR)
X5	Giuseppe (Joseph)	X5 \Leftrightarrow ISA(HUMAN) X5 \Leftrightarrow NAME(JOSEPH)

The sentence (1) can then be read:

- (2) "X1 da X2 e' andato a X3 con X4 di X5"
 (X1 from X2 is gone to X3 with X4 of X5)

B. Analysis of Modifiers

The simple phrases of a sentence can either fill conceptual cases of a main conceptualization, thus serving as 'picture producer' (PP), or further indi

```

ON is spatialrel (A_ON_B)
thought
begin
COORD X,Y OF P REFERRED_TO M = COORD X,Y OF Q REFERRED_TO M
and
P PART(A) and P NUM(>0) and Q PART(B)
end
and
begin
COORD Z OF P  $\geq$  COORD Z OF Q and P QUANT(1)
end
and
begin
B  $\Leftrightarrow$  PROPEL  $\leftarrow$  OBJ(FOPCE(N))  $\leftarrow$  DIR((FROM(NIL))(TO(A)))
end
end.

```

{exists, at least, a point P which is part of the THOUGHT(A) and a point Q which is part of the THOUGHT(B) and for any pair of points P and Q is Z(P) \geq Z(Q). More, there is an assertion about the fact that the THOUGHT(B) support the THOUGHT(A).

FIG.5 - Example of Use of a Spatial Relationship in a Case Like "a man is on a chair"

viduate a PP. Therefore they can be classified according to whether they modify:

- a) the nominal that precedes (also not immediately);
 "i libri di Carlo"
 (the books of Charles)
- b) the subject or object independently from their position;
 "Maria e' andata a Roma con Anna"
 (Mary has gone to Rome with Ann)
- c) the action;
 "Maria e' andata a Roma con la macchina"
 (Mary has gone to Rome with the car)

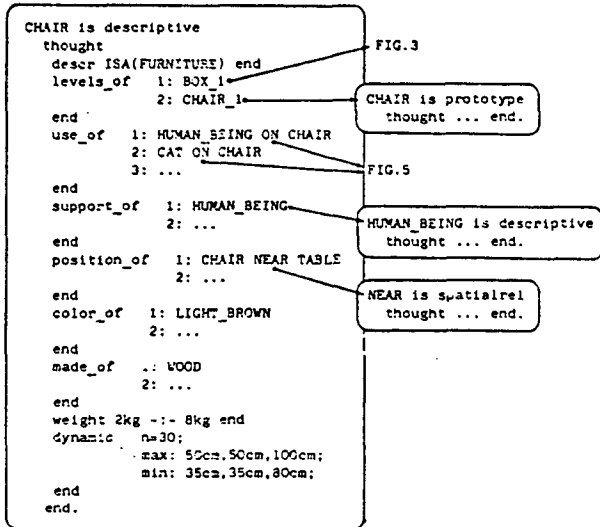


FIG.6 - Definition of the Descriptive THOUGHT of a Chair

The treatment of the modifiers in b) and c) requires that the structure of the sentence is entirely known and cannot, in any case, be performed before the verb has been analyzed (subject and object are considered type c) modifiers). The modifiers in a), on the contrary, have a local role, limited to the PP they are to modify, and their relation to the sentence structure is marginal. They are, therefore, immediately associated to their corresponding nominals. In (2) "da X2" and "di X5" are of this kind and are consequently linked to X1 and X4 producing:

- (3) "X1 e' andato a X3 con X4"
 (X1 has gone to X3 with X4)

In the "descr" field of THOUGHTs X1 and X4 the following information is added:

- X2 <====> PART_OF(X1)
- X5 <====> OWNERSHIP(X4)

The embodying of a modifier creates complex PPs or CLUSTERS. Each CLUSTER has as its HEAD a b) or c) modifier, a conceptual index node modified

by the accessory concepts.

In our example "l'uomo dai capelli neri", "a Roma", and "con l'auto di Giuseppe" are CLUSTERS, in which the head is always the leftmost nominal.

The decision about the embodying of a modifier into its head is related to the classical problem of the placement of PP's. In fact, it is not always the case that a prepositional phrase modifies a conceptual index node; it is often possible that it has to be embodied into another accessory modifier, as in:

"il libro dell'uomo dal cappotto blu"
 (the book of the man with the blue coat)

If it is defined:

- md ----> the current phrase;
- md-1 ----> the immediately preceding phrase;
- md-2 ----> the phrase that immediately precedes md-1;

the solution is obtained by recursively deciding whether md is to be embodied into md-1 or md-2. Recursion is from the lower level.

This decision is made by a set of standard general procedures associated to prepositions (di, da, con, per, ...) and adverbs (sopra, sotto, davanti, dietro, ...). Non-standard specialized alternatives are activated by particular nouns and verbs in order to treat hidiosyncrasies. These procedures are written as three-steps programs, which accomplish the operations of:

1-LOOKING for compatibility of certain features of md, md-1, and md-2. Typical features are superset and part-of relations of md's. A rule may state that "IF md has a part-of relation to md-2 THEN md may be embodied into md-2". Example:

"il libro del bambino dalla copertina rossa"
 /--md-2-----md-1-----md-----/
 (the book of the child with red cover)

2-Deciding whether MERGING can be performed. This is made by imposing further restrictions of the type described above. Also the main conceptualization and other linguistic peculiarities are taken into account.

3-Actual LINKING. In our example, the structure:

```

md <====> PART_OF(md-1 OR md-2)
"l'uomo dai capelli grigi"
/--md-1-----md-----/
HAIR <====> PART_OF(MAN)
  
```

is produced because md "capelli" can be part-of md "uomo".

Should it not have been the case, the following structure would have been produced:

```

(md-1 OR md-2) <====> POSS(md)
"l'uomo dal vestito scuro"
/--md-1-----md-----/
  
```

(the man with the dark dress)
 MAN <====> POSS(DRESS)

```

LAMPADA DA TAVOLO is descriptive
  thought
  descr
    X<COND=>USE<--- OBJ(LAMPADA)
    and
    IMPLICAT(LAMPADA ON TAVOLO)
  end
  ...
end.
  
```

(it is an object such that if x use the lamp in a standard way, then the lamp is on the table)

FIG.7 - THOUGHT of the Table Lamp

C. Construction of the Main Conceptualization

The nucleus of a main conceptualization can be associated in the CDB both to a noun indicating an action, state or change of state and a verb. In our example, we find the THOUGHT of fig. 8. A time identification always related to the present (T0), is taken from the syntactic analysis and connected to this conceptualization, thus resulting into:

```

X <====> PTRANS <--- OBJ(X) <--- DIR((FROM(Z))(TO(Z)))
and
INSTR(CONC)
and
T1 < T0
  
```

If a lexical ambiguity arises, the features assumed by the nominals in the previous steps will help to desambiguate.

```

ANDARE is descriptive
  thought
  descr
    X<====>PTRANS<--- OBJ(X) <--- DIR((FROM(Y))(TO(Z)))
    and
    INSTR(CONC)
  end
end.
  
```

FIG.8 - THOUGHT of the verb "andare" (to go).

At this step "splitting" of a conceptualization often occurs. In the sentence:

"Giovanni dà un colpo a Maria"
 (lit. John gives a blow to Mary)

although two nuclei are present (dà & colpo), nevertheless the correct interpretation is "Giovanni colpisce Maria" (John hits Mary), instead of "Giovanni trasferisce il possesso dell'oggetto colpo a Maria" (John transfers the ownership of the object 'blow' to Mary)!!!

We have observed that this phenomenon involves conceptualizations based on the primitives of "state", "action", and "spatial relationship" and relies only on the pairs ACTION-STATE, ACTION-SPATIAL RE-

LATIONSHIP, and ACTION-ACTION. The regularities ruling the formation of these pairs have been found to depend only upon those conceptual primitives. This keeps the number of rules to be evaluated reasonably small, if compared with the number of CDB entries (~600 entries in the present implementation (Adorni et al., '81)):

An example will illustrate the mechanism of reduction of the conceptual "splitting" as well as of disambiguation.

The pair ACTION-SPATIAL_RELATIONSHIP may be represented by:

```

"tirare su il braccio"
ACTION^ SPATIAL_RELATIONSHIP
(lift the arm)
  
```

The compound "tirare su" has the two meanings:

- innalzare, alzare,...(lift,raise,...);
- confortare, dare sollievo psichico,...(encourage, console,...);

which can be conceptualized respectively:

```

X <====> PTRANS <--- OBJ(Y) <--- DIR((FROM(K))(TO(H)))
and
((COORD Z OF H > COORD Z OF K)
and
R(X<====>PROPEL<--- OBJ(Y) <--- DIR((FROM(NIL))
(TO(NIL)))) ) )
X <====> DO
S(Y(CHANGE_STATE((FROM(HAPPINESS(N))
(TO(HAPPINESS(N)))) ) ) )
  
```

The context helps disambiguation.

In our example, the object of the spatial relationship being a physical object, the first alternative is selected. The rule performs a further control, discovering that the physical object is, in this case, PART_OF(HUMAN); the PROPEL primitive is then substituted by the MOVE primitive.

D. Case Filling in the Main Conceptualization

The next step performed by the semantic module is the filling of the conceptual cases of the main conceptualization with the THOUGHTS instantiated during the previous steps. Again, standard rules are associated to prepositions and adverbs and hidiosyncrasies are also treated. These rules make use of messages sent by the syntactic component and look at the conceptual syntax of the main conceptualization. Through these rules the cluster "con X4" turns out to be 'instrumental' and the following conceptualization is then produced:

(4) X1 <====> USE <--- OBJ(X4)

Since the filler of the instrumental case of the main conceptualization has to be a conceptualization, the rule activated by the "con" modifier fills the instrumental case with (4).

In (3), 'a X3' is placed in the destination of the directive case of the main conceptualization, because preposition 'a' is stated to indicate the

'destination' if the main conceptualization contains a PTRANS, PROPEL or MOVE, with empty directive case; otherwise it indicates 'state'. "Andare a Roma" is thus distinguished from "essere a Roma" (to be in Rome). The result, for our example, is:

```
X1 <====> PTRANS <--- OBJ(X1) <--- DIR((FROM(NIL))(TO(IN X3)))
                                     (TO(IN X3)) )
```

The directive case, as shown in the above example is not simply filled with a md; it is filled with a "spatial_relationship-md" pair. This is a general rule for our system, emphasizing the change of coordinates caused by an action. In our example this means that the primitive PTRANS has moved the object to a point whose coordinates are defined with in the city of Rome. The result of the analysis of (1) is given in Fig.9.

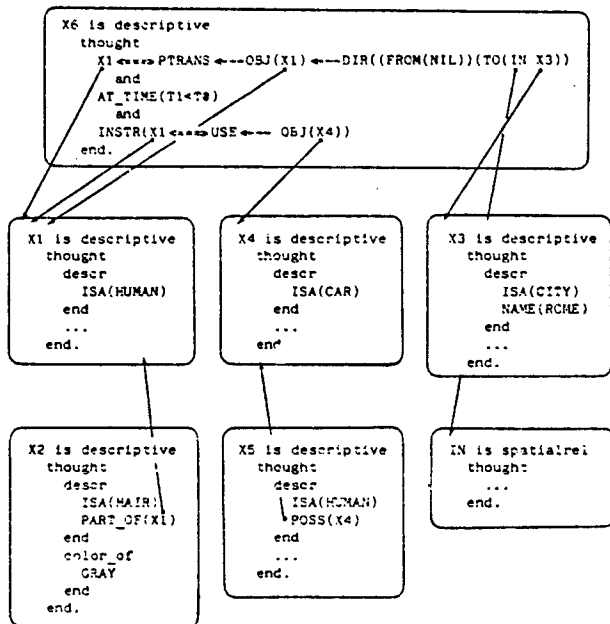


FIG.9 - Result of the Analysis of the Sentence (1)

E. Conceptual Analysis of Complex Sentences

The process of semantic interpretation is applied to every clause in the sentence, identified by a verb or a noun indicating an action. Segmentation into such clauses or nominalized clauses is obviously performed by the syntactic component, which has also non-standard rules for specific classes of (modal) verbs like: dovere (must), volere (to want), potere (can), incominciare (to start), ... These verbs constitute a single main conceptualization together with the embedded infinitive. Simple composition rules have been defined to combine the meaning of clauses (sentences).

Thus for conjunction, as in

"si alzo', si mise il cappello e apri' la porta"

(he stood up, put on its hat and opened the door) the main conceptualizations associated to every proposition are connected by an 'and' relationship.

```
(si alzo')----- T1
and
(si mise il cappello)----- T2 > T1
and
(apri' la porta)----- T3 > T2
```

A time indication is also associated to every main conceptualization to emphasize the execution order of every action.

Conceptual analysis of each single clause (sentence) is activated by this top level structure and at the end the resulting conceptualizations are linked one to the other.

V CONCLUSIONS

In this paper a system for understanding a natural language input to a scene generator has been described. It makes use of a conceptual dependency semantic model, substantially modified in as much as syntax is kept apart from semantic interpretation and a fully formalized dictionary is used, much more complex than the one embodied in Schank's theory. The dictionary is particularly oriented to the generation of scenes, and the stress is on the representation of the structure of objects. The awareness of the structure of the objects is often intimately related to our capability of understanding the meaning of spatial relationships and other complex linguistic expressions. For instance, the meaning "the cat is under the car" is clear, even if it may depend on the state of the car, moving or parked; on the contrary, the sentence "the cat is under the wall" is not clear, unless the wall is crashed or it has a very particular shape. Our model tries to account this understanding activity by means of the following features:

- an object is described at several levels of details; in some cases, only a rough definition of the object dimensions can be sufficient, while in other cases a more sophisticated knowledge about the structure of the object itself is required;
- the characteristic features of an object are emphasized; the recognition of a feature allows the activation of particular rules and the generation of hypotheses about the presence of an object;
- the typical relationships among objects are described.

The interaction between syntactic and semantic analyzers seems rather complex, but it provides some valuable solutions to certain crucial points of computational linguistics, like PP's placement, conceptual splitting, idioms and preassembled

The syntactic analyzer, working top-down, yields a representation of the input sentence in which information about gender, number, person and tense are recorded and for each function such as subj, obj, time, etc... the corresponding filler is identified, or a list of fillers is given in case of ambiguity. These two kinds of information are exactly what is useful for semantic interpretation and are picked up in various steps of the interaction by the semantic analyzer in order to build the main conceptualization and to fill its role. Also MARGIE(Schank, '75) makes some use of syntactic knowledge distributed among lexical definitions of words. This solution gives the entire control to the semantic interpreter and no syntactic functional representation is used. It seems, however, that an intermediate step, keeping the syntactic output separate from the semantic one, has the advantage of avoiding the multiplication of single pieces of syntactic knowledge. It also provides a simpler way of dealing with syntactic variants of the same sentence and a help in identifying coreferences.

The semantic interpreter works fundamentally bottom-up and, although much is still to be attempted, it seems that it can usefully cooperate with a top-down parser to find the correct interpretation. These practical advantages will be taken into account also in the future development of the system. In fact it seems that, although no definite solution has been given to many linguistic problems, the interaction between two fully developed mechanisms controlling each other can provide an indication and a frame into which a more compact system can be built.

In the present version of the system the interaction between the two modules is strictly sequential. In a more compact analyzer, syntactic specialists, i.e. simplified pieces of grammar specialized in particular syntactic phenomena, will be called by semantic interpreter according to opportunity. This second version is still being designed.

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