TOWARDS A COMBINED REPRESENTATION FOR SPATIAL AND TEMPORAL REFERENCE

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Temporal and spatial references have been treated as unrelated issues in semantic representation. What must be represented are the spatial and temporal situations to which the speaker alludes. For example, with "John threw a ball through a window", It must be shown that the event occurred some time in the past and that the ball followed a trajectory that took it through a window. Many theories that mention one topic discuss the other, but only separately, e.g., Fillmore (1968), Schank (1973), and Schubert (1976).

This paper proposes a simultaneous resolution of an important part of both problems. It is proposed that spatial and temporal references be shown as predicating a single type of entity showing the spatiotemporal locations of the events or states of affairs to which the speaker refers. These entities are called "space/time zones". We present this analysis in a. semantic net formalism resembling those of Brachman (1976) and Schubert (1976).

The proposal will be sketched out in the remainder of the paper. First temporal, then spatial reference, and finally the combined analysis will be considered. The final presentation will constitute a revision of the two earlier ones.

Temporal Reference

Our proposal is to show temporal references predicating the times in which events occured or states of affairs held. In doing this, we follow a tradition in semantics, exemplified recently by Schubert (1976). In a semantic net, what is shown is a node representing a temporal entity, or time, being linked to a node representing an event or state. The temporal reference is then repsented by relating this time to others. One of the many arguments for this analysis is the straightforward connection between syntax and semantics. Syntactically, temporal references generally involve the verb. Since verbs also identify the type of event or state we reflect that here. Similarly, when temporal reference is associated with nouns they are verbal and event nouns, as in "the swimming this afternoon" and "the game at three". Some constructions do not show this simple relationship between verb and event. In "John mailed the package to Mary this afternoon.", the time of the mailing was this afternoon but the time when the package is to get to Mary is not identified by this afternoon. These constructions do, however, fit in naturally with analyses where single clauses are shown by several events or states, such as in Schank (197$. Here temporal references can be associated with the time of some or all of the events or states involved.

Spatial Reference

Intuitions based on phrases such as "the boy in the car" do not lead to an event-and-state analysis. Schubert (1976), for example, shows spatial references applying to participants in events. However, there are phrases such as "kissing in the park" and the word "where", as in "Where is the game being played?". These can easily be seen as locating events. This section sketches an analysis based on such insights. A more complete presentation of the work is found in Sondheimer (1977).

The semantic-net analysis of space parallels in its simplest form the proposed analysis of time. Event or state nodes are linked to a spatial reference, as in Figure I. The event type is "Sleeping", the physical objects are shown in ovals, and the space through a square. The spatial reference is shown through a preposition-based concept, "IN", which references the space through its F-arc, for "figure", and the related object through its G-arc, for "ground". The T-arc and time in the example follows the earlier description.

This type of analysis allows directly for the examples that lead to it, but it is also proposed for the apparent counterexamples. In these examples, an abstract state of affairs, "BEING-AT", is used to show the existence of objects in space and time. Therefore "the boy in the car (assuming past)" and also "The boy was in the car.", would be shown as in Figure I except with BEING-AT replacing Sleeping. Note that on this point our analyses are isomorphic to those of Schubert (1976).

The above does not allow for one important connection between event or state locations and object location. For example from "The boy slept in the car.", that the boy was in the car is evident. To fit this in with our analysis, we propose the use of inference. As is usual with semantic nets, what we have been using is an abbreviation of a complete notation. Importantly the distinction between concepts and instances, or types and tokens, is missing here, see Brachman (1976). Our examples only show instances. With the complete system, a conceptual level is available to supply interpretative structure including appropriate inference rules. What we propose is that these inference rules supply the connection between event and state location and object location. For example it would be appropriate to use a rule like "if something is sleeping some place then infer that that thing is at that place".

Another aspect of the spatial reference problem is that like temporal reference a multiple-event-and-state analysis is sometimes called for. For example in "He held her on his lap in the tunnel.", only she must be shown on his lap with both of them in the tunnel. A typical multiple-event-and-state representation would allow for this by having one entity showing him holding her causing another entity to be true,namely,that she remained somewhere. The "one his lap" can predicate this last state. The "in the tunnel" can apply to the highest form, with inference

rules associating the predication with the participants.

Sentences about motion are among those that require multiple-event-and-state analysis. However the predication of the location of motion presents new difficulties. It is possible to predicate points in motion, as in "He walked into the house.". It is also possible to predicate segments of motion, as in "He walked across the lawn", The sense of "across" here parrellelIng that in "the path across the lawn is made of bark.". Further in motional events, multiple predications can show ordering as in "He walked across the lawn up the stairs into the house.". To allow for these phenomena our proposal takes the location of the movement as a history of the moving objects and uses two functions to produce from that history segments of the journey. Figure II gives an example. The function "SEGMENT" has the movement as its parameter, P-arc, and a segment, shown by " Q] ", as its value, V-arc. These segments are predicated by spatial references. The function "UNIT" produces another type of segment, shown by " [T) ". When a [] is predicated the assertion is that the relation held at the end but not before. The segments themselves are compared by relinks to show ordering.

This is the gist of our spatial reference proposal. But as will be seen there are problems.

Relating Spatial and Temporal Reference

At this point two separate analyses have been related to events and states of affairs. It is claimed that they can and should be combined into one. There are good reasons to do this conjoining. These can begin to be seen through a problem with Figure II in interpreting the less-than comparisons. These must have a scale for comparison. However being between segments of a journey, the only spatial scale available is the ad hoc one based on the journey itself. The way out of the dilemma is to associate the time of the journey with the segments and to compare these times. The location of the motion can be thought of as existing in four-dimensional space, we can call it a "space/time zone" (following a suggestion of Lemmon (1967). The UNIT and SEGMENT function can produce parts of zones on the basis of parameters showing final time and intial and final time, respectively. The times appearing there can then be used for ordering. But now that time is a part of motion, at least here a separate temporal entity is redundant.

This is only half the battle. What of non-motional events and states of affairs? Apparently a space/time zone analysis is not out of order. First, in apparently all durational events and states, it is possible to make motional references. So with "He sat on the books from New York to Boston.", the motional problems reappear. Second, times must be found in order to locate objects used in ground roles in spatial references, e.g., the car in Figure I. Tf the entity in the figure role is a space/time zone, then the appropriate time is immediately available.

From this we conclude that space/time zones can be and should be used for both spatial and temporal reference. We propose a style of analysis exemplified by Figure III. There would be a Space/Time-arc identifying a zone, " gj ". This zone could then be predicated by both spatial and temporal references. Hence we have what we set out to find a simultaneous analysis of spatial and temporal reference.

References

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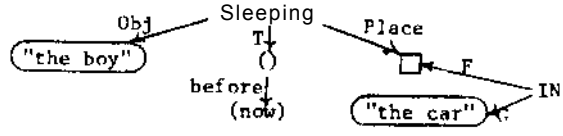

Figure I. "The boy slept in the car."

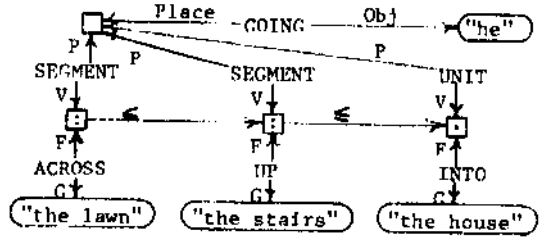

Figure II. The motional component of "He walked across the lawn up the stairs into the house."

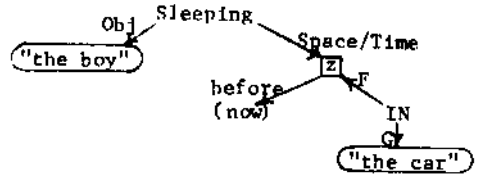

Figure III. A revised "The boy slept in the car."