REPRESENTATION OP TEMPORAL KNOWLEDGE

Kandrashina E.Yu.

AI Laboratory, Computing Center, Siberian Branch of the USSR Academy of Sciences, Novosibirsk 630090, USSR

Abstract

The paper describes a system of notions (a T-model) developed for representing temporal information on the semantics-pragmatics level in a natural language understanding system.

The choice of the notions to be considered has been relied upon a necessity of special facilities for describing situations with various degrees of detailing according to an inexact character of temporal information in natural language texts.

Time is modelled as a straight directed line, and four main objects: point, interval, quantity and chain together with four groups of notions associated with them are included into the model.

A structure of the T-model and its base notions are briefly outlined in the first section of the paper. The representation of temporal information by means of T-model objects is then considered by examples.

1. Introduction

1.1. A problem of representing and understanding temporal information is of great importance in the process of developing and implementing AI systems intended for dynamic object domains, i.e. those dealing with situations varying in time. In this paper a formal model of time (T-model) is outlined which provides a method for dealing with temporal information in NL-understanding systems.

These problems are now considered in a great number of works on knowledge representation and automatic text comprehension, see, for example, Goldstein, 1977; Dembovskaya, 1980; Litvinceva, 1980; Allen, 1981; Hirshman, 1981.

Our T-model contains several notions similar to those considered in the papers mentioned above, but on the whole it provides far more general facilities of representing temporal information. It also includes a number of new components forming developed system of notions for defining dates, time range measures, repetitive events etc. An accurate distinction between the proper formal means and their interpretation is made in the model.

1.2. Our T-model may be used as a standard component of a knowledge representation system providing temporal data processing. It consists of a set of notions (objects, relations) and a r.et of productions describing their semantics.

The notions of the model are represented by means of rather simple frame-structures (due to the simplicity of the object domain).

This paper is a continuation of (Kandrashina, 1978), in which a first version of the T-model and its implementation in the frameworks of the VOSTOK system has been described.

There are two parts in the paper. First part (Section 2) gives characteristic of the T-model notions, second one (Section 3) considers some variants of using the base T-model objects for representing temporal components of knowledge.

2. Basic notions of T-model

Time is modelled as a straight directed line. Four objects: point, interval, chain and quantity considered below in detail are the basic notions of the T-model.

2.1. Since such objects as point and/or interval have been studied in almost all the works on temporal aspects of knowledge representation, a set of notions connected with them is only outlined here.

Order relations $\leq$, $<$, $=$, $\neq$ and a distance function $R\{x_1, x_2\}$ are defined over the points $(x, x_1, x_2, \ldots)$. The quantity is a value of the distance function. The noti'on of the quantity plays an auxiliary role and allows denotatum of "quantity of time" (time range measure) to be separated from representation of its number value. This notion is also sketched in the paper. It should be noted that special types of structures for indicating its number value by means of units of measurement are defined for the quantity (10 years; 5 hours; and 5 months; 2 hours, 15 minutes and 40 seconds, and a special set of productions describes number value transformations (3 years and 5 months ⟺ 41 months).

The interval $(t, t_1, t_2, \dots)$ is defined as a pair of points $t=(x_1 x_2)$ connected by the relation $x_1 < x_2$ where x_1 is a beginning of t, x_2 is an end of t:

$$x_1 = \underline{begin}(t);$$
$$x_2 = \underline{end}(t).$$

Besides, a length as a distance between boundary points is associated with the interval ($\underline{length}\ (t) = R\ \{x_1, x_2\}$). Some relations defined over the intervals are considered below ($x_i = \underline{begin}(t_i)$, $y_i = \underline{end}\ (t_i)$):

$$\text{BEFORE}(t_1,t_2) \Leftrightarrow y_1 \leq x_2;$$
$$\text{DURING}(t_1,t_2) \Leftrightarrow (x_2 \leq x_1) \& (y_1 \leq y_2);$$
$$\text{OVERLAPS}(t_1,t_2) \Leftrightarrow (x_1 < x_2) \& (x_2 < y_1) \& \& (y_1 < y_2);$$
$$\text{SEPARATELY}\ \{t_1,t_2\} \Leftrightarrow \text{BEFORE}(t_1,t_2) \vee \vee\ \text{BEFORE}(t_2,t_1).$$

2.2. A chain being a sequence of intervals such that each is BEFORE the next is introduced on the basis of the above considered notions, that essentially increases T-model possibilities of representing temporal information in comparison with the systems of notions presented in the other works on temporal semantics known to the author.

Chain $(S, S_1, S_2, \dots)$ is an original basic notion of the model. A chain, like a point and an interval, may be independently used for semantics representation. Only in special cases the chain is prescribed by explicit enumeration of its elements. A relation "ϵ" ($t \in S$) along with its special forms R(elative)-NUMBER and NUMBER denotes a belonging of an interval to the chain.

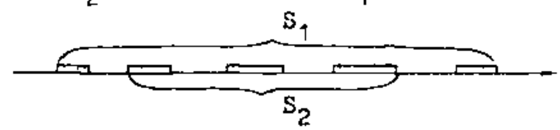
The relation R-NUMBER (S, t_1, t_2, k) assumes the intervals t_1, t_2 to be the members of S ($t_1, t_2 \in S$) and position number of t_2 in S with respect to t_1 to be equal to k. The relation NUMBER $(S, t, 1)$ is defined only for left-bounded chains and it means that $t \in S$ and its number is equal to 1 (when calculating from left to right).

Let us enumerate some slots associated with the chain:

- power (element number);
- determinant containing sufficient conditions of belonging an interval to the chain;
- including-interval being a minimal interval including all the elements of the chain;
- r and d being metric characteristics of the chain (r defines a distance function range for adjacent chain elements and d defines an element length range).

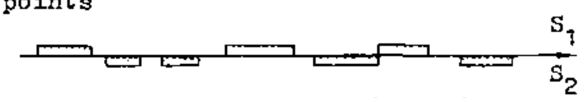
A powerful collection of relations is defined over extended set of objects (point, interval, chain). The introduced relations may be partitioned into three subsets depending on their semantics:

(1) the relations operating with the chain as an ordered set. They are relations "ϵ", R-NUMBER, NUMBER, set operations $\cup$, $\cap$, relations "$\subseteq$" and PIECE(S_1, S_2) being a particular case of "$\subseteq$". The latter cuts out a whole fragment S_2 from the chain S_1, for example:

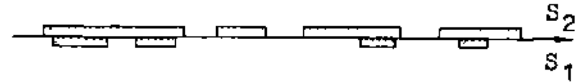


(2) the relations generalizing some interval relations. They are BEFORE, DURING, TOGETHER, SEPARATELY, BETWEEN. Their semantics coincides with that of interval relations having the same names, for example:

- the relation SEPARATELY $\{S_1, S_2\}$ holds, if S_1 and S_2 have no generic points

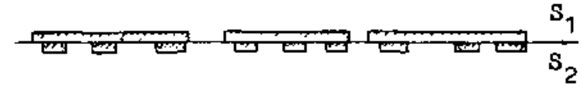


- the relation DURING(S_1,S_2) holds, if for each element $t \in S_1$ there exists the interval $\tau \in S_2$ such as DURING(t, τ)

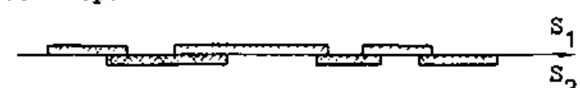


(3) the relations representing correlations between the elements of a pair of chains in more detail. They have no analogy with the interval relations. These relations are MULTIPLE, SYNCHRO-OVERLAPS, ALTERNATION etc.:

- the relation MULTIPLE(S_1, S_2, k) is valid, if DURING(S_2, S_1) and for each interval $\tau \in S_1$ there exists exactly k intervals being members of S_2 and imbedded in τ, for example (when $k = 3$):



- the relation SYNCHRO-OVERLAPS(S_1, S_2) corresponds to the situation:



- the relation ALTERNATION (S_1, S_2) corresponds to the situation:

3. The T-model object interpretation

Let us consider several interpretations of such objects as interval and chain. It should allow us to understand the role of the notions of the T-model in representing temporal knowledge.

3.1. There are several possibilities of using the notion interval in knowledge representation:

(1) as "existence" time of elements of a real-world situation (occurence of events, life-time of objects, duration of states). In such a case the relations defined over the intervals allow temporal correlations between the situation elements to be established (for example, the event P_1 occured before/during the event P_2, B was here before A, object X has existed in XIX century etc.);

(2) as a means for defining a temporal component of abstract knowledge:

- a typical location and/or duration of the objects/events (snowdrops are blooming in spring, lesson goes 45 minutes on etc.);
- temporal conditions of existence of slots, for example, such slots as employment, husband/wife are connected with a man only in some periods of his life;
- different phases of object/event occurence, for example, building may have the following phases of existence: design, construction, exploitation, destruction.

3.2. Let us consider now chain. This object may, for example,

(1) represent a total time of occurences (existence time) of a set of real-world events (he has visited Moscow three times, she has read a paper twice);

(2) reflect time of occurence of discontinuous events (the rain now stopped, now began again; he has a headache nearly all the day; he has read the paper in two steps, - compare with the similar example given above);

(3) define various calendars and dates: thus, years may be represented as an infinite chain with a zero distance function ($r = 0$) and equal length elements; just the same representation is possible for such notions as week, day, month, hour etc. The T-model relations allow relationships between these notions to be described. In the frameworks of the established calendar the chain relations permit the dates of various degrees of definiteness (i.e., second sunday of May, last week of the month, 3-rd of August, next week, current month etc.) to be represented.

4. Conclusion

A fragment of the model including the notion interval, a subset of the interval relations, a fixed calendar (year —→ month —→ day —→ hour) and set of measures for evaluating quantity has been implemented in the question-answering system VOSTOK-0 (Kandrashina,1978). The T-model notions have been employed in (Narin'yani, 1982) for modelling space relations. At present, the implementation of a rather representative fragment of the model including all the basic notions (point, interval, chain) has been started on the BESM-6 computer.

Acknowledgements

I would like to thank Dr.A.S.Narin'yani for influential discussions and critical reading and N.A.Cheremnykh for her invaluable help in preparing the english version of this paper.

References

Allen, 1981 - Allen James F., An Interval-Based Representation of Temporal Knowledge. Proc.7th IJCAI, Vancouver, Canada, August 1981, p.221-226.

Dembovskaya, 1980 - Dembovskaya V.N., Temporal logic for coherent text structuring. (in Russian). - Вопросы кибернетики,М.,1980,вып.61, с. 144-158.

Goldstein, 1977 - Goldstein Ira P., Roberts R., NUDGE, A Knowledge-Based Scheduling Program, MIT Artificial Intelligence Laboratory, Memo 405, February 1977, 23 p.

Hirschman, 1981 - Hirschman L., Story G., Representing implicit and explicit time relations in narrative. Proc. 7th IJCAI, Vancouver, Canada, August 1981, p. 289-295.

Kandrashina, 1978 - Kandrashina E.Yu., Ochakovskaya O.N., Golubeva L.A., An experimental Q/A system including a simple model of time with elementary logic inference.- In: Natural language communication with computers (in Russian). -Новосибирск,1978, с.207-222.

Litvinceva, 1980 - Litvinceva L.V., Pospelov D.A., Time in robots and dialogue systems (in Russian). - Вопросы кибернетики,М.,1980,вып. 61, с.61-70.

Narin'yani, 1982 - Narin'yani A.S.,Kandrashina E.Yu., A sketch of a model of space in the system of knowledge about reality (in Russian). -Новосибирск,1982, 35 с. (Препринт ВЦ СО АН СССР, 368).