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PREFACE: TEMPORAL ASPECT IN INFORMATION SYSTEMS

In the information society, there exists an irresistible need, one may even say a necessity, to acquire and comprehend knowledge. Equipped with a sufficient level of knowledge and defined rules of inference, we are able to undertake specific decisions. In order to attain better representation and exploration of the ever expanding knowledge resources and to undertake appropriate decisions, we create constantly improved means of representing knowledge and enhanced methods of modelling situations for the real world. The language of classical logic is an appropriate tool for the formal description of statistical incidents. Incidents taking place in time require a novel approach. The power of expression, enabling a formal description of the time component, is made possible by the language of temporal logic. When we ask: *What order should the complete information contained in a sentence have?* the answer is simple. The information should have such form as to obtain answers to the questions: *When? Why? How?* and *Where?* in the same order as the questions were asked. The ancient Romans already valued knowledge associated with the time of an event and put the question of the time of the event first. The temporal aspect was therefore not only important (among other aspects) but due to the priority of the question of time, we may say that beginning with ancient times, it was the most significant aspect.

The need for the analysis and investigation of temporal reasoning is noticeable in numerous scientific fields, among others, in computer sciences, geographical information systems, philosophy, psychology, and linguistics. In computer sciences, temporal reasoning is the key object of research in information systems, verification of programs, and artificial intelligence, as well as in numerous areas connected with the modelling processes.

In numerous implementations, the information containing the temporal component of the phenomenon is of significant importance. It takes place, for

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example, when we want to predict the future behaviour of the system, when we want to draft a plan basing it on our knowledge about the future, when we want to discover what is the basis of changes taking place in the system, and when we analyse data based on previous information and attempt to explain why events are as they are.

In recent years, much research related to time has emerged. This research, in principle, has focused on analysing the temporal context in topics associated with artificial intelligence and management of databases. There are, however, significant differences between a temporal approach to the representation of knowledge and the temporal approach to database management. The differences in the implementation of temporal information become clear when we analyse the articles contained in this volume.

Temporal processing of knowledge is connected with the processing of knowledge in general, whereas in the process of forming a system for database processing, efforts are focused mainly on issues connected with storing knowledge, searching for information, maintaining data, and constructing a communication interface with the system user which would allow efficient access to the knowledge contained in the database. Systems of knowledge representation consider one time perspective, whereas database management systems may contain numerous time perspectives and require both linear time models as well as accurate dates. Information in knowledge processing systems is represented by sentences. In database systems, information represented in "classical" form is enriched by the temporal component.

Temporal logic, as an apparatus of formal description, should be employed when we are performing the description of knowledge undergoing a change over time. Time and change are therefore strictly connected with each other. The mutual interdependence of change and time are the basis of two diverse approaches to temporal reasoning:

– An approach based on the concept of change, and
– An approach based on the concept of time.

The approach based on the concept of change has a number of limitations. The limitations of models based on the concept of change are, for example, immediate actions (actions should not be extended in time) or immediate results (results extended in time are not expressible in this approach). Furthermore, implementing this approach, it is not possible to denote continuous processes, simultaneous events or events overlapping each other in time.

In the approach based on the concept of time, time is considered as a separate entity or as a one-dimensional space. Time may have a point structure (where time points are the basic concept) or interval structure (where a interval is the basic concept). The majority of the discussion is based on linear and discrete time.

Point time differs from segment time not only by the type of assumed primary concepts. Differences between these approaches take place on many levels. Consequently, conceptual differences occur. In the interval approach, the completion is assumed only above segments, whereas in the point approach, completion is accepted both in points as well in segments. Structural differences also occur: i.e. in the interval approach, ordered linear time is considered; whereas in the point approach, branching time may be considered. In order to avoid technical difficulties, in the interval approach discrete time is considered. In the point approach it is possible to consider compact time, unlimited time, and real timeline. There are also, among the above mentioned time concepts, differences in logical approaches. In the interval models, logic based on time segments and also first order predicate calculus is implemented. In point models, logic based on modal logic with dissimilar time moments which perform the role of possible worlds is employed.

Classical methods of modelling databases concentrate on the problem of processing static information using database systems. Methods of constructing databases that take into consideration the temporal aspect are, however, in their essence unifying methods, allowing the processing of both static information as well as dynamic information which changes over time.

Models which are implemented in the temporal representation of knowledge are usually based on certain temporal logic. Prior to the commencement of the construction of temporal logic, a number of significant matters essential for the construction of this logic should be considered and a number of important questions answered. Issues which should be taken into account are as follows:

Conceptual issues, i.e.,

- whether the considered logic will be based on point time or on segment time?
- whether theorems will be recognized in reference only to time points or in reference to segments?
- whether zero measure sections which would be identical with points are permitted?
- whether from the truthfulness of a sentence in reference to a segment may be inferred the truthfulness of this sentence in reference to another segment?

Structural issues should also be considered, i.e. issues connected with mathematical objects used in representing time structures. Is time ordered, is it discreet or compact, limited or limitless, etc.? Finally, the problem of **which** logical formalism will be implemented should be considered. Will it be first-order logic or one of the versions of temporal logic?

An important quality of the language of temporal logic is the possibility of implementing it in the specification of a wide spectrum of information systems. Computer science adopts temporal logic to its own applications. From the point of view of the informational applications of temporal logic, the logic of discrete time is of significant importance. The language of temporal logic employed in computer science omits operators of past time or assigns them a supplementary character. Temporal logic implemented in computer science is, on the one hand, poorer due to the lack of philosophical inspiration, but on the other, it is richer due to the tasks it is to perform in computer science and its applications.

It seems that time is an immanent component of our daily life. Utilizing time, making use of time, or referring to time, usually do not cause problems. It is a different matter when we refer to time in information systems. Implementing temporal data into information systems causes many difficulties. These difficulties are the result of several factors: the lack of precision of certain expressions of the natural language referring to time (for example: "now" may refer to this moment in time, to today, to the current year, the current decade, etc.) or different interpretations of time elements (for example, historians perceive a year as not a large time interval, whereas a second is perceived by engineers designing microprocessors as a very long time.) There are various actions which may differ; for example, the time of the occurrence of the effects of actions, for there exist both actions with immediate effects as well as those whose occurrence will be extended in time. Certain actions may occur simultaneously, others may occur sequentially, still others may start and end in different time moments, but a particular temporal interval may be common to both actions.

The information system should be inspected prior to its use to determine if it is performing the tasks for which it was designed, and if these tasks are being carried out properly. The information system should also be tested. Testing however will not give sufficient certainty as to the infallibility of the system. In the case of reaction systems, methods based on temporal logic turn out to be most appropriate for conducting testing procedures. The are two types of such methods: proof theory and model theory. The basic drawback of model theory methods is however the problem of finding proof. Proof theory, on the other hand, does not give a negative answer: the proof is found when the system is correct, but when it is not correct, we do not find the proof. Lack of proof however, should not be treated as a statement of the faultiness of a system. For the lack of proof may be the result of the inability to find it. The model theory method does not possess the above mentioned flaws, for it allows the finding of errors in a system even when the system is erroneous.

In his article, Kazimierz Trzęsicki considers methods for verifying software as well as implemented information systems supporting 'model theory' verification of software.

The article of F. Samaranche deals with the extension of Knuth's 16 Boolean binary logic operators for the need of fuzzy logic. The author provides Venn diagrams for the introduced operators. The introduced operators are improved versions of the Boolean operators described in 2003.

A. Schumann considers an abstract machine of Belousov-Zhabotinsky and proposes a proof for theoretical interpretation of process calculus within the framework of considered formalism.

A. Krasuski, T. Maciak, and K. Kreński describe a national project for a decision support system for the fire service based on a distributed database.

S. Zadrozny presents a construction of a logical system which, in the intent of the author, may serve as a means for formal description of a mental process. The author supplies and analyses a collection of specific sentence conjunctions and considers the advantages of supplied formalism in reference to modelling of human intelligence by utilising information techniques.

M. Giero describes the application of bi–temporal databases for the representation and exploration of medical data. The article describes the semantics of the system, gives preferable qualities of semantic time, and presents examples of queries conducted utilizing temporal operators.

In another article, M. Giero and R. Milewski describe the application of the formalism of temporal logic and bi-temporal databases for storing and retrieving information containing medical data on the treatment of infertility.

In the last article, R. Milewski, J. Jamiołkowski, A. Milewska, J. Domitrz and S. Wołczyński describe a unique case of representation and exploration of knowledge on the basis of an implemented application assisting electronic registration of patients treated for infertility.

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