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Temporal Logic

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Preface

Time is a very exciting subject. It is one of the few subjects on which everyone is an expert. We move through time continuously and in order to survive and manage ourselves sensibly we constantly have to make temporal decisions. Philosophy, since the days of Aristotle, has been trying to analyse the way we make these decisions. With the rise of computer science, where ideally one wants the machine to do the job for or of the human, there is a new urgency in the precise logical analysis of human temporal activity.

Human (and hence computer) time related activity can be divided into several main areas, all very familiar to us. One of the simplest, and the most important area, is our handling of time dependent data. In computing this is the area of databases. To us ordinary people, it is just time dependent information, involving questions like when to go to the dentist, when to pick up the child from school, until when can one delay in not filing one's tax return and so on. There is another temporal dimension involved in the area of time dependent data besides direct dependency on time. This is the dimension of when a data item is presented to us. For example, if we get a bill to pay our tax on January 1st 1990, it is important when the bill was sent or received, e.g. received September 1989 for January 1990. In database terms there are two times involved: the time dependency of the data and the time when it was introduced into the database. Surprisingly, computing is only now beginning to cope with such things.

Another important area in both human activity and computing is planning. If I have to do the shopping and take my child to visit a friend and cook supper, I have to organise the sequence properly. Going shopping is a simple planning problem but to organise an airport is a more complex planning problem. To be able to let the computer solve it for us we need to develop a logical theory and correctly analyse the steps involved.

Everybody knows the term "time sharing"; what it means in practice is that if neither of us can afford something (e.g. a car or a flat in Spain) then we buy it together and time share. (Computers are more humble, they share things like memory or a printer in order to be more efficient.) We can formulate some intuitive principles on how to share (in computing this is called the *specification*) but there is always the question of exactly how we are going to manage it (what dates am I going to be in the flat and what dates are you, who is going to do the garden and collect the garbage etc.). This is the *implementation* of the principles. Given such an implementation, we have the problem of how to show that it is fair and square and satisfies the specification. One way of doing it is to formulate the procedures in "temporal" logic and then formally prove that it satisfies the specification. In computing the official name is program *specification and verification.*

The main present day research areas of temporal logic are:

1. Philosophical applications. Temporal logic is used in philosophy to clarify various concepts which have been studied since the time of Aristotle. Some examples are causality, historical necessity, identity through time, the notions of events and actions, etc.
2. Applications in computer science as described above.
3. Natural language. Logical analysis of the use of tense and aspect in natural languages. Logical time models for natural language.
4. Pure logical study of temporal logic within the framework of logic itself. Special topics here include:
   (a) Axiom systems, theorem proving and proof theory. Decidability. Model theory.
   (b) Expressive power of temporal languages.
   (c) Applications of temporal logic to the pure theory of other logics (e.g. the notion of provability as a modal logic etc.)
   (d) Deductive reasoning involving time.

   To computer science all the above four aspects of the pure logical theory are of great importance.

Temporal logics can be presented in several different ways:

1. Use predicate logic with an additional parameter for time.
2. Use special temporal logics to express temporal phenomena. There are two methods of presentation here.
   (a) Semantic presentation.
   (b) Presentation using axiomatic or other deductive systems for the connectives.
3. The final method is via direct reference to events.

Temporal logic has changed and developed incredibly since its conception as a discipline by Arthur Prior thirty years ago. It is studied by many researchers of numerous and different backgrounds. Different research groups have different conceptions of what temporal logic is and of what it is exactly they themselves do. On many occasions we have heard comments like "that is not logic" referring to a system presented by a colleague. The subject is certainly in a state of accelerated dynamic growth and a new orientation and point of view is currently needed as well as a good coverage of its mathematical and computational aspects. A good understanding, communication and cooperation will enable the subject and the community of researchers to face the challenges of the future.

The conference is the first *international conference* particularly dedicated to temporal logic. It started with four tutorials: *Programming with Temporal Logics* by Michael Fisher, Manchester Metropolitan University, England, *Incorporating Time in Databases* by Vram Kouramajian, Huston, Texas, USA, *Verification of Finite-State Systems* by Orna Grumberg, The Technion, Haifa, Israel and *Reasoning about Action and Change – Temporal Reasoning in AI* by Erik Sandewall, Linköping University, Sweden. The four invited lectures were given by some of

the leading researchers in temporal logic, Johan van Benthem, Hans Kamp, James F. Allen and Amir Pnueli. The presentation of the technical papers included in this volume was accompanied by a workshop with more informal and spontaneous contributions.

We are indebted to the program committee for their effort and thought in organizing the program, to the invited speakers and to the presenters of the tutorials. Our special thanks go to the colleagues and secretaries for their support in organizing this conference: Mark Reynolds, Ruy de Queiroz, Lydia Rivlin, Janice Londsdale, Ellen Fries and Christine Kiesel, and in particular to Christine Harms, who has been an invaluable help ensuring that the event ran smoothly.

April 1994. Dov Gabbay and Hans Jürgen Ohlbach

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