Representing Incomplete and Uncertain Temporal Knowledge

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Generally speaking, time plays a fundamental and important role in modelling natural phenomena and human activities concerning both the static and dynamic aspects of the world under consideration. However, complete and absolute temporal knowledge is usually not always available for many knowledge based systems. Based on a time theory that takes both points and intervals as primitive, this talk presents a graphical representation for uncertain and incomplete temporal knowledge, which allows logical expressions of both absolute and relative temporal relations, including both logical conjunctions and disjunctions. The consistency of any given collection of uncertain and incomplete temporal knowledge depends on if there is at one temporal scenario that is temporal consistent, where a visualised consistency checker for temporal scenarios is provided.

1 - Introduction

One of the simplest and the most important, human temporal enterprise is to handle time dependent knowledge. Generally speaking, time seems to play the role of a common universal reference - everything appears to be related by its temporal reference, although temporal references may have different forms:

- *Absolute temporal entities,* e.g., "15:30 on the 23rd of August 2010" and "from 9am to 5pm", which refer to explicit time elements with absolute values;
- *Relative temporal entities* , e.g., "after the Civil War" and "during the time when the second speaker was talking after the first speaker ", which refer to time elements that are known only by their relative temporal relations to other time elements, which again, may be absolute or relative;
- *Absolute temporal durations*, e.g., "3 hours" and "8 days", which refer to some certain amount of temporal granularity;
- *Relative temporal durations*, e.g., "less than 3 hours" and "more than 8 days but less than 12 days", which refer to some uncertain amount of temporal granularity.

Bibliographic References

[1] Allen, J.: Towards a General Theory of Action and Time, *Artificial Intelligence*, 23, 123-154, 1984.

[2] Ma, J. and Knight, B.: A General Temporal Theory, *the Computer Journal*, 37(2), 114-123, 1994.

[3] Ma, J. and Knight, B.: A Reified Temporal Logic, *the Computer Journal*, 39(9), 800-807, 1996.

[4] Ma, J. and Knight, B.: Representing The Dividing Instant, *the Computer Journal*, 46(2), 213-222, 2003.

[5] Ma, J. and Hayes, P.: Primitive Intervals Vs Point-Based Intervals: Rivals Or Allies? *the Computer Journal*, 49(1), 32-41, 2006.

[6] Ma J.: Ontological Considerations of Time, Meta-Predicates and Temporal Propositions, *Applied Ontology,* Vol.2(1), 37-66, 2007.

- *Certain relative orders*, e.g.: event e_1 occurred "before" event e_2, where the precise starting and finishing time of events may be not specified.
- *Uncertain relative orders*, e.g.: event e_1 occurred "*before*", or "*over the same time*", or "*during*" event e_2, etc.

The problem of representing and reasoning with uncertain and incomplete temporal information in the mixture of these forms is two folds:

- How to represent various kinds of uncertain and incomplete temporal knowledge?
- How to construct a reliable method of inference, based on this representation?

Allen's interval-based temporal logic [1] is a representative example of temporal systems addressing relative temporal relations. It has been claimed in the literature that time intervals are more suited for expression of common sense temporal knowledge. In addition, approaches like that of Allen [1] that treat intervals as primitive temporal elements can successfully overcome/bypass puzzles like the *Dividing Instant Problem* [1, 4], which is in fact an ancient historical puzzle encountered when attempting to represent what happens at the boundary point that divides two successive intervals. However, a theory of time based only on intervals is not adequate for reasoning correctly about continuous change. In fact, many common sense situations suggest the need for including time points in the temporal ontology as an entity different from intervals. For instance, it is intuitive and convenient to say that instantaneous events such as "The database was updated at 00:00am", "The light was automatically switched on at 10:00pm", and so on, occur at time points rather than intervals, no matter how small they are.

In what follows in this lecture, we shall introduce a time theory which takes both points and intervals as primitive. A graphical representation for uncertain and incomplete temporal knowledge, allowing logical expressions of relative temporal relations including both logical conjunctions and disjunctions, is presented. In terms of a necessary and sufficient condition, a consistency checker is provided for any given collection of uncertain and incomplete temporal knowledge.

Note 1. Allen, J.: Towards a General Theory of Action and Time, Artificial Intelligence, 23, 123-154, 1984.

2 - Links to external web content

<http://staffweb.cms.gre.ac.uk/~j.ma>