Defeasible Temporal Reasoning

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Abstract

This work is involved with the confluence of two areas of artificial intelligence (AI) called "defeasible reasoning" and "temporal reasoning". The work can be briefly described as the extension of a particular kind of defeasible reasoning systems, called "argumentative systems", to allow them to use temporal references.

The importance of this study is given by the intensive usefulness of temporal concepts in computer sience. At the same time there are several areas in AI where time plays a fundamental role. Since the goal is to capture human abilities in solving problems, to consider temporal concepts is unavoidable. An intelligent agent makes a decisive use of temporal references in its communication and its deductive processes. For example, in natural language written text comprehension, medical diagnosis elaboration, faults detection and in planning systems for industrial applications or robots.

Getting a deep understanding of temporal concepts had worried philosophers since centuries ago. In recent decades also AI researchers had tried to define means to automatize its use. Such a work historically involved the search for a language that allows temporal knowledge representation and reasoning. In this work we start by considering this previous work, by both philosophers and AI researchers. We start from these works selecting, improving and building over them to obtain an improved proposal.

Another research interest in AI was to pursue a detailed study and formal-

izations of "defeasible reasoning", a special kind of "non monotonic reasoning". In particular, "argumentative systems" are a kind of systems providing adequate defeasibility features. These systems caracterize the skill that allow us to reason about a changing world where available information is incomplete or little reliable. When new information is available, new reasons to obtain further conclusions or better reasons to sustain previous conclusions can be considered. But it could happen that some conclusions loose support. Through this inference dynamic, argumentative systems provides the ability to change conclusions according to the new information that arrives to the system.

The conclusions obtained by the system are "justified" through "arguments" supporting their consideration. In addition, an argument could be seen as a "defeasible proof" for a conclusion. The knowledge of new facts can lead to prefer a conclusion instead of a previous one, or to consider that a previous inference is no longer correct. In particular it could exist an argument for a conclusion C and a "counter-argument", contradicting in some way the argument for C. An argument is a justification for a conclusion C if it is better than any other counter-argument for C. To establish the preference of an argument over the others the definition of preference criteria is required. Altough several preference methods are possible, one that is widely used is "specificity": more specific information, i.e., better informed arguments, are preferred. It is important to highligth that argumentative systems emphasize the role of justification of inferences and the dialectical process related to reasoning activities. In our work the underlying argumentative system is used as defined in [Simari,Loui 92]. Unfortunately, the language used on [Simari,Loui 92] is not prepared for temporal notions. This is why the starting point for the work developed in this thesis is to embed temporal reasoning in defeasible reasoning.

Recently, some proposals for a definition of an argumentative system capable of handling temporal references have been done. In [Ferguson,Allen 94] it was proposed an argumentative system based on the notion of *interval* and in [Augusto,Simari 94] one based on *instants*. The thesis defended in this work is that it is useful to have a temporal extension of the argumentative system and that this could be done enhancing the aforementioned attempts with respect to ontology, language, and other related notions to the representation and use of temporal concepts.

This work is organized as follows. First an introduction of the development of the research, followed by a review of the use of other temporal logics and other ways to represent temporal knowledge in the philosophy and AI related literature (chapter 2 and 3 respectively). A review of the main proposals for non monotonic temporal reasoning is given as part of the background on the main topic (chapter 4). This includes also a review of argumentative systems without temporal references given the close relation between them and the new argumentative system proposed here. After that, the definition of a temporal argumentative system is accomplished in two steps. First (chapter 5), a proposal based on instants including an explanation about its use to solve planning problems is considered Then (chapter 6), the extension allowing interval-like temporal references as well as instants is detailed. The motivation for this progressive presentation is that if the instant-based system fits the user's needs, it wouldbe preferable to the interval based version because of its simplicty of definition, implementation and use. It may be also better at implementation-time to develop first the instant-based system and later to extend it considering the ontology that adds intervals.

The most general proposal is then offered in chapter 6. In a few words, it includes the proposal of a temporal logic, an extension to the argumentative sytem using this language and the consideration of problems arising from their interaction. Regarding the logic, a many-sorted language with types and equality is proposed. Because of the specific interest on providing means to solve temporal reasoning problems this language has pre-established sorts. They allow the consideration of entites like properties, events, actions and temporal references. An interval and instant based ontology was considered, whose temporal structure corresponds with an unbounded and discrete time line. In this way, and as a difference with previous works, a conciling ontology between concepts usually regarded as antagonic to define a temporal ontology is offered. As pointed before by [Galton 90] this is needed to solve certain kinds of problems not considered in [Allen,Ferguson 94], for example when the theory is suplemented with axioms for modeling continuous time. Using reification, problems related to the lack of precise knowledge could be solved with this language. Because events, properties and actions can be referred to as individuals, it is possible to split their modifiers, allowing to store partial information. This also allows us to complete such knowledge gradually in a more flexible and economic way regarding storing. Also the logic makes possible event-based reasoning, i.e. without the need of having precise knowledge about when the events occurred, or combine it with reasoning based on explicit time. It is worth to highlight that as a difference with previous argumentative systems, syntax and semantics of the temporal language used to build the arguments are made explicit as well as the inference rules, defined in a Gentzen-style system. An explicit equality theory is defined on the entities considered in the ontology. Our system improves upon the time-related causality notion as provided in [Allen84]. Also we provide means to deal with the "persistency problem". This problem is about predicting for how long the truth value of a literal will remain so during the time when we do not have explicit information about it. A way to cope with this is proposed here. We use a combination of two previous proposals, that together with the reification possibility over properties, events and actions brings us the possibility of reducing the knowledge needed in the closure axioms technique. After having specified the basic temporal language the definitions of the argumentative system of [Simari,Loui 92] are adapted to consider the new language. Solutions to problems specifically introduced in the argumentative process by the consideration of the new ontology are proposed. Finally the behaviour of the system is illustrated by showing how benchmark problems widely known in the literature can be solved using the temporal argumentative system.

References

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