A Temporal Datalog Primer: Talk Abstract

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1. Talk Abstract

In this talk[1] we present a review of the literature on temporal reasoning, with particular focus on DatalogMTL, an extension of the Datalog language with Metric Temporal Logic operators. We show how temporal reasoning can prove to be a crucial tool for financial data dealing with time.

Financial and economics applications have temporal data deeply ingrained in their nature, and nowadays it is more important than ever to be able to reason over such data. For example, we may be interested in understanding the trend of the price of the stock for a certain company, or in being able to derive conclusions about the likeliness of change of ownership of a company depending on how many of their shares have been bought over time by a shareholder.

Temporal reasoning is one of the key approaches that allow for such and similar reasoning tasks, as it allows to consider complex data structures (e.g. Knowledge Graphs or KGs) not just as a snapshot fixed in time (as it would be for non temporal automated reasoning), but in the evolution of the entities represented in the data, so as to provide a much needed additional dimension to the scope of the domain at hand.

In particular, we are interested in temporal operators that allow to reason on the validity of data for specific periods of time in the past or in the future w.r.t. the current moment.

In order to show how some of these operators work and their usefulness in reasoning, we present, as an example, the scenario of a company concerned with future acquisitions and investments.

$$\boxminus_{[0,3]} \mathit{EstimatedValueIncrease}(startup), \\ \rightarrow \mathit{Buy}(startup) \qquad (1)$$

The box minus $\boxminus_\varrho$ operator assesses whether a fact is always valid in the past relative interval ϱ. In this case, we assume the time unit is in months. Thus, Rule 1 tells the company to buy $startup$ if it has shown an $EstimatedValueIncrease$ continually in the interval that goes from 0 to 3 months in the past.

We present now another example in the same scenario that uses the diamond minus $\diamondminus$ operator and recursion.

$$\diamondminus_{[0,2]} \mathit{InvestInSector}(sector, investment), \\ \diamondminus_{[0,1]} \mathit{ReturnFromInvestment}(sector, return) \\ return > investment, \\ \rightarrow \mathit{SuccessfulInvestment}(sector, investment) \qquad (2)$$

$$\mathit{SuccessfulInvestment}(sector, investment), \\ newInvestement = investment * \beta \\ \rightarrow \mathit{InvestInSector}(sector, newInvestment) \qquad (3)$$

The diamond minus $\diamondminus_\varrho$ operator assesses whether a fact has been valid at least once in the past relative interval ϱ. In this case we will consider the time unit being in years.

Rule 2 states that if an investment in $sector$ in the last 2 years had a $return$, in the last year, greater than the original $investment$, then it is considered a *SuccessfulInvestment*. In Rule 3, then, for each *SuccessfulInvestment* we compute a $newInvestment$ that will be used to invest in the same sector.

Languages. While proposals of a temporal reasoning language and in extension to Datalog have been presented already starting from the 1980s, it is only thanks to a recent resurgence of interest in temporal logic, and in particular in extending Datalog with Metric Temporal Logic (MTL), that led to several studies on various fragments of the proposed language DatalogMTL. These studies attest to the feasibility and the potential of its possible applications, and in recent years we have seen many of them [1, 2, 3, 4, 5, 6, 7, 8, 9]. However, even considering a limited volume of published literature, it is a challenge to understand the expressive power of the involved languages, especially in the context of current ones, and even more than that what is the path to take this research into the future.

In particular, we are interested in understanding what it means to reason in a certain DatalogMTL fragment, and what kind of applications can make use of such a reasoning space.

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While several surveys have been conducted on temporal logic and reasoning over time [10], in fact, to our knowledge most of them are now either outdated [11] or are not focused on covering the topic in terms of practical applications, hence ignoring the latest finds on DatalogMTL and the dense timeline [12, 13, 14, 15].

Contribution. In this talk, we present the following contributions:

- We present a short introduction on temporal reasoning, with a focus on DatalogMTL, which extends the Datalog language with Metric Temporal Logic operators, and which has been deemed to be very promising in terms of practical applications.
- We present some of the recent results of the research on DatalogMTL in terms of complexity and integration with other Datalog languages.
- We propose a number of scenarios in financial applications which deal with temporal data, and we show how problems can be solved through the use of temporal reasoning.
- We list some desiderata for future development of temporal Datalog that would allow us to integrate powerful temporal reasoning into the VADALOG system [16] a reasoning system for Knowledge Graphs.

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