Theoretical and Experimental Studies of Temporal Constraint Satisfaction Problem

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Reasoning with time is embedded in many application domains than we are often aware of. For example, understanding a parallel program involves how each unit of the program is temporally related to the other unit through dependency. There is a growing awareness about the importance of understanding *time* in any dynamic or evolving situation. Within last twenty years different dimensions of reasoning have been identified, such as, qualitative reasoning versus quantitative reasoning, point-based representation versus interval-based representation, propositional expression versus first order expression. My work concentrates on interval-based qualitative propositional reasoning. The representation scheme and a polynomial approximate algorithm were proposed by James Allen. The problem of detecting global consistency has been subsequently proved to be NP-complete. Practical reasoning systems have been developed based on Allen's 3-consistency algorithm. This algorithm checks for consistency over constraints between each subset of 3 temporal entities of the full set of temporal assertions in the system (rather than checking for complete consistency between all constraints, which is called global-consistency). There has been very little systematic study on either the 3-consistency problem, or the global-consistency problem.

We have hypothesized that the hardness of the problem, measured by the average-case time-complexity of 3-consistency algorithm, is a well-behaved function of the initially generated constraints, parameterized with two distributional coefficients (average, and second moment) of (1) initially constrained arcs (with a constraint network representation) for each node (temporal entities), and (2) the degree of constraints on each initially constrained arc. We are doing rigorous statistical analyses to find a predictable behavior of the time-complexity with respect to those structural parameters of the input problem. Our work is in line with the current experimental research on NP-complete problems. But a richer problem structure in TCSP demands a more rigorous data analyses technique than have been attempted so far. We have developed a statistical regression model for predicting time-complexity of the algorithm. The model can be used for the purpose of theoretical explanation of empirical results, thus providing with a better insight into the problem of temporal consistency. We have also identified easy-hard zones of the problem[1].

I have also developed a heuristic-based global-consistency algorithm to find all consistent temporal scenarios. Ladkin et al has recently shown that the problem of detecting global-consistency is not as hard, on an average, as is suggested by its property of being NP-complete. Our algorithm has been implemented. Current experiments with the implementation is producing promising results from the point of view of efficiency. One of our results shows that, on randomly generated network, the growth rate of the number of temporally consistent models is not as explosive as intuition suggests. The algorithm has some importance from application points of view, specially in temporal data base[1]. However, apart from having its applied significance, we hope to do some fundamental experimental studies on global-consistency problem with this algorithm in future. This result, along with the statistical studies of 3-consistency algorithm, is likely to produce a better understanding of the temporal constraint satisfaction problem. Hopefully, this study will also lead to a better insight in relating NP-complete problems and P-class problems. Such a study involving approximate algorithms for temporal reasoning are also part of the project.

References

[1] Debasis Mitra and Rasiah Loganantharaj. Some experimental works with 3-consistent temporal constraint propagation algorithm. In *IJCAI-93 Workshop on Spatial and Temporal Reasoning*, 1993.

[1] Our implementation is in C++. We hope to extend it to a practical reasoning system in future.