

A Geometric Dynamic Temporal Reasoning Method with Tags for Cognitive Systems

Rui Xu, Key Laboratory of Autonomous Navigation and Control for Deep Space Exploration, Ministry of Industry and Information Technology & School of Aerospace Engineering, Beijing Institute of Technology, Beijing, China

Zhaoyu Li, Key Laboratory of Autonomous Navigation and Control for Deep Space Exploration, Ministry of Industry and Information Technology & School of Aerospace Engineering, Beijing Institute of Technology, Beijing, China

Pingyuan Cui, Key Laboratory of Autonomous Navigation and Control for Deep Space Exploration, Ministry of Industry and Information Technology & School of Aerospace Engineering, Beijing Institute of Technology, Beijing, China

Shengying Zhu, Key Laboratory of Autonomous Navigation and Control for Deep Space Exploration, Ministry of Industry and Information Technology & School of Aerospace Engineering, Beijing Institute of Technology, Beijing, China

Ai Gao, Key Laboratory of Autonomous Navigation and Control for Deep Space Exploration, Ministry of Industry and Information Technology & School of Aerospace Engineering, Beijing Institute of Technology, Beijing, China

ABSTRACT

Temporal reasoning is one of the cognitive capabilities humans involve in communicating with others and everything appears related because of temporal reference. Therefore, in this paper a geometric dynamic temporal reasoning algorithm is proposed to solve the temporal reasoning problem, especially in autonomous planning and scheduling. This method is based on the representation of actions in a two dimensional coordination system. The main advantage of this method over others is that it uses tags to mark new constraints added into the constraint network, which leads the algorithm to deal with pending constraints rather than all constraints. This characteristic makes the algorithm suitable for temporal reasoning, where variables and constraints are always added dynamically. This algorithm can be used not only in intelligent planning, but also computational intelligence, real-time systems, and etc. The results show the efficiency of our algorithm from four cases simulating the planning and scheduling process.

KEYWORDS

Autonomous Planning and Scheduling, Cognitive Systems, Constraint Propagation, Dynamic Temporal Reasoning, Geometric Method

1. INTRODUCTION

The notion of time is obvious in any activity that requires intelligence (Pani & Bhattacharjee, 2001; Wang, 2014). The temporal reasoning is one of the cognitive capabilities humans involve in communicating with others (Stock, 1998). Everything appears related because of temporal reference (Pani & Bhattacharjee, 2001). Therefore, cognitive models or intelligent systems have to be developed to mode this capability of representing time and reasoning about temporal relationship (Stracuzzi, Li, Cleveland, & Langley, 2009; Wang & Patel, 2009). Certainly, it is also important many possible application of computer-based systems, for instance planning actions in the real world which is one of high cognitive abilities, scheduling within a complex system (Cervantes, Rodríguez, López, Ramos, & Robles, 2013; Stock, 1998).

This paper takes the application of temporal representation and reasoning in autonomous planning and scheduling as an example to specify our work, because concepts about time are very important when people are talking about actions or events. In real world, actions are not instantaneous but have start times, end times and durations. An important challenge in current planning and scheduling research is time dimension management to allow for the simultaneous execution of non-instantaneous actions (M. C. Cooper, Maris, & Régnier, 2013). The sequential nature of classical plans is often too restrictive to cope with a temporal plan that consists of a set of instances of durative actions (M. Cooper, Maris, & Régnier, 2014). Therefore, time and temporal constraints must be considered in planning and scheduling methods.

Plan-space planning is well suited to temporal planning problems (Cushing, 2012). In plan-space planning, temporal reasoning is needed to check whether a simple temporal problem (STP) instance is consistent once a flaw and conflict is solved (Barták, Morris, & Venable, 2014). It means the temporal reasoning algorithm is called for many times. So improving the efficiency of temporal reasoning in dynamic environment can make the performance of the planning and scheduling method better. Therefore, the authors are interested in dynamic reasoning, namely whenever a new constraint or variable is asserted, this paper wants to maintain a solution of the STP rather than recomputing it using a “static” algorithm (Gerevini, 2005). The static algorithm, such as the Floyd-Warshall algorithm (Aini & Salehipour, 2012), leads to computation cost, because when the value of local variables changes or a variable/constraint is added to an STN, the whole network needs to be propagated again (Xu, 2004).

The most commonly used method is based on a simple temporal network (STN) and there is a list of algorithms. Xu et al. (2004) has proposed a dynamic algorithm which only computes the partial network influenced by the new introduced constraint rather than the whole network with the worst time complexity of the algorithm. Mouhoub and Yip (2002) presented a comparative study of dynamic arc-consistent algorithms in the case of temporal constraint problems and shown the efficiency of AC-3.1IDC algorithm. Planken et al. (2010) presented a brief survey of existing incremental algorithms and proposed a new algorithm that incrementally enforces partial path consistency. Gerevini (2005) proposed a collection of new polynomial algorithms to incrementally decide satisfiability, to maintain a solution, or to update the minimal representation of the CSP. This approach based on STN also has been used in several planning and scheduling systems in order to solve real-world problems, such as the Heuristic Scheduling Testbed System of Deep Space 1 (Muscettola, 1994), the EUROPA system (Barreiro et al., 2012; Bresina, 2015; Iwig et al., 2015), IxTeT (Lemai, 2004) and VHPOP (Younes & Simmons, 2003).

The authors aim to propose an efficient dynamic temporal reasoning algorithm to determine the consistency of the STP and to eliminate possible values to variables in planning and scheduling problems. In order to verify the efficiency of our algorithm, the authors compare it with the temporal reasoning algorithm in EUROPA. It provides incremental algorithms e. g. adaptive Bellman-Ford algorithm to detect a negative cycle which is sufficient for backtrack-free search (Chandrachoodan, Bhattacharyya, & Liu, 2001). On the one hand, the authors want to solve planning and scheduling problems in the future, so it is more suitable and convenient to select a reasoning algorithm having used in planning and scheduling system. On the other hand, the algorithm in EUROPA is actually efficient in temporal reasoning.

Durative actions are 2-dimensional (2-D) in nature, making their 1-dimensional (1-D) representation ambiguous (Rit, 1986). Therefore, in order to solve problems above and take advantage of the 2-D nature, this paper introduces a geometric method to represent durative actions based on our prior work (Li, Xu, Cui, Xu, & He, 2016) and proposes a dynamic algorithm using tags on constraints to propagate temporal constraints.

This paper is organized as follows. First, the authors introduce related work to help readers understand our method, including defining the planning and scheduling problems and the basic representation of actions in the 2-D space. Then, details of the geometry-based dynamic temporal constraint reasoning algorithm are described. In the fourth section, the authors present experiments to verify the performance of our method compared with that of the algorithm in the EUROPA system.

15 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: www.igi-global.com/article/a-geometric-dynamic-temporal-reasoning-method-with-tags-for-cognitive-systems/174448

Related Content

Designing Light Weight Intrusion Detection Systems: Non-negative Matrix Factorization Approach

Václav Snášel, Jan Platoš, Pavel Krömer and Ajith Abraham (2012). *Machine Learning: Concepts, Methodologies, Tools and Applications* (pp. 304-317). www.irma-international.org/chapter/designing-light-weight-intrusion-detection/56148

Hierarchical Function Approximation with a Neural Network Model

Luis F. de Mingo, Nuria Gómez, Fernando Arroyo and Juan Castellanos (2012). *Software and Intelligent Sciences: New Transdisciplinary Findings* (pp. 466-479). www.irma-international.org/chapter/hierarchical-function-approximation-neural-network/65145

Sustainable Stock Market Prediction Framework Using Machine Learning Models

Francisco José García Peñalvo, Tamanna Maan, Sunil K. Singh, Sudhakar Kumar, Varsha Arya, Kwok Tai Chui and Gaurav Pratap Singh (2022). *International Journal of Software Science and Computational Intelligence* (pp. 1-15). www.irma-international.org/article/sustainable-stock-market-prediction-framework-using-machine-learning-models/313593

Multi-Objective Adaptive Manta-Ray Foraging Optimization for Workflow Scheduling with Selected Virtual Machines Using Time-Series-Based Prediction

Sweta Singh, Rakesh Kumar and Udai Pratap Rao (2022). *International Journal of Software Science and Computational Intelligence* (pp. 1-25). www.irma-international.org/article/multi-objective-adaptive-manta-ray-foraging-optimization-for-workflow-scheduling-with-selected-virtual-machines-using-time-series-based-prediction/312559

Feature Engineering for Credit Risk Evaluation in Online P2P Lending

Shuxia Wang, Bin Fu, Hongzhi Liu, Zhengshen Jiang, Zhonghai Wu and D. Frank Hsu (2017). *International Journal of Software Science and Computational Intelligence* (pp. 1-13). www.irma-international.org/article/feature-engineering-for-credit-risk-evaluation-in-online-p2p-lending/181045