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Time-informed task planning in multi-agent collaboration

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Abstract

Human-robot collaboration requires the two sides to coordinate their actions in order to better accomplish common goals. In such setups, the timing of actions may significantly affect collaborative performance. The present work proposes a new framework for planning multi-agent interaction that is based on the representation of tasks sharing a common starting and ending point, as petals in a composite daisy graph. Coordination is accomplished through temporal constraints linking the execution of tasks. The planner distributes tasks to the involved parties sequentially. In particular, by considering the properties of the available options at the given moment, the planner accomplishes locally optimal task assignments to agents. Optimality is supported by a fuzzy theoretic representation of time intervals which enables fusing temporal information with other quantitative HRI aspects, therefore accomplishing a ranking of the available options. The current work aims at a systematic experimental assessment of the proposed framework is pursued, verifying that it can successfully cope with a wide range of HRI scenarios.

Keywords: Multi-criteria planning; Time-informed planning; Daisy planner; Multi-agent collaboration; Human-robot interaction

1. Introduction

Efficient and realistic human-robot collaboration encompasses crucial temporal and synchronization aspects which are typically overlooked in contemporary robot planning literature. In recent years though, there is a steadily increasing interest to explore the role of time in multi-agent collaboration setups (Chao, 2012; Effinger, Williams, Kelly, & Sheehy, 2009; Hoffman, 2013; Maniadakis & Trahanias, 2014). Multi-agent synchrony is typically achieved by introducing constraints that aim to maximize coincidence in the parallel activities of independent robots (Morris, 2014; Morris, Muscettola, & Vidal, 2001; Shah, Stedl, Williams, & Robertson, 2007; Smith, Gallagher, Zimmerman, Barbulescu, & Rubinstein, 2007).

Simple Temporal Networks (*STNs*) provide the basis to deal with temporal constraints in planning problems. To manage temporal constraints, *STNs* are typically mapped to the equivalent Distance Graphs (*DGs*) to check the existence of no negative cycles and thus prove the consistency and dispatchability of the plan (Dechter, Meiri, & Pearl, 1991). Along this line, recent works have considered back propagation rules to dynamically preserve dispatchability of plans (Morris, 2014; Shah et al., 2007), address temporal problems with choice (Shah & Williams, 2008), or reason between interacting agents (Boerkoel & Durfee, 2013).

Despite the effectiveness of relevant approaches, *STNs* exhibit an inherent limitation to deal with event sequences where start and end points coincide; such behaviors are termed "*daisy behaviors*" in the current work, as will be explained in Section 4 of the paper. The coincidence of start and end points creates *STN* loops which enable the

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