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Multi-Robot Systems Implementing Complex Behaviors Under Time-Varying Topologies

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Abstract

In this paper we address the problem of obtaining complex dynamic behaviors in multi-robot systems. In particular, those complex behaviors are modeled in terms of cooperative tracking of periodic setpoint trajectories. The proposed solution considers a heterogeneous group of robots: a few independent robots are used as a control input for the system, with the aim of controlling the position of the remaining robots, namely the dependent ones. The proposed control strategy explicitly considers changes in the communication topology among the robots, that lead to the definition of a switched system. In particular, these changes happen as the system evolves, since robots are equipped with finite range communication devices. A methodology is introduced for defining the system parameters in order to guarantee asymptotic stability of the switched system, thus guaranteeing the desired tracking performance, assuming that independent robots are able to measure or estimate the global state of the multi-robot system.

Keywords: Multi-Robot Systems; Decentralized Control; Switched Systems

1. Introduction

This paper deals with the problem of coordinating the motion of a multi-robot system, with the purpose of obtaining a desired coordinated dynamic behavior.

Multi-robot systems and decentralized control strategies have been extensively studied in the last few years. Typically, decentralized control strategies define local interaction rules that aim at obtaining a global objective with the multi-robot system. In particular, most of the decentralized control strategies that can be found in the literature aim at solving a *regulation problem*: namely, the objective is that of regulating the overall state of the multi-robot system to some desired configuration, thus obtaining coordinated behaviors such as aggregation, swarming, formation control, coverage and synchronization [1, 2, 3, 4, 5].

While these basic regulation control strategies defined the basis for the decentralized control of multi-robot systems, they do not provide solutions to typical real world problems, that require additional developments. As a motivating example, consider the idea of having a group of mobile robots, cooperating for the production of an object, in a similar way as a group of humans would do. For instance, each robot could be equipped with a general purpose tool (e.g. a drill, a hammer, a solder, a screwdriver, ...), and the sequence of operations to be performed depends on the *production cycle* of the particular object to be produced, generally composed of *periodic* operations. As a result, the production cycle of the object defines a set of *periodic trajectories* to be tracked by the mobile robots. This idea appears appealing for modern small size factories, often required to produce small batches of rapidly changing products: for this purpose, considering mobile robots, the sequence of operations can be constantly changed, as tools are not constrained on a fixed

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