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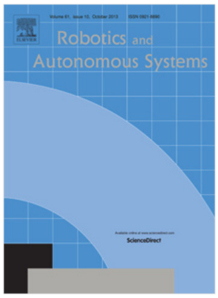

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A two stage approach for distributed cooperative manipulation of unknown object without explicit communication and unknown number of robots

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Abstract

This paper proposes a distributed algorithm for cooperatively manipulating an object rigidly grasped by a team of mobile manipulators. In order to increase the flexibility of the multi-robot cell and differently from other approaches, it is assumed that the object is completely unknown and there is not information exchange between robots. The devised strategy includes two stages: at the first stage, each robot estimates the object kinematic and dynamic parameters by applying specific contact wrenches, while, in the second stage, the estimated parameters are exploited within a distributed cooperative control framework that can be adopted, for instance, to control the interaction wrench exerted by the environment on the object or to implement a zero-force control algorithm. In addition to the total absence of communication and differently from existing solutions, the proposed technique assumes that each robot has not knowledge of the number of cooperative agents in the team and, remarkably, it is devised in the 3-dimensional space with the aim of handling both the position and the orientation of the object. Finally, the feasibility of the approach is proven via numerical simulations.

Keywords: Distributed estimation; Distributed cooperative manipulation.

1. INTRODUCTION

Teams of mobile manipulators can be adopted to perform complex tasks such as moving or assembling large and/or heavy objects that cannot be handled by a single robot. To the aim, different objectives can be pursued as, for example: i) ensuring the tracking by the object of a desired trajectory; ii) controlling the wrenches exerted by the manipulators on the object in order to ensure an efficient distribution of the load; iii) controlling the wrenches exerted by the environment on the object.

First approaches on cooperative manipulation were based on object-level control schemes where manipulators and grasped object are considered as a whole system to be controlled in a *centralized* manner [1]. An example of such an approach is the augmented object model control, devised in [2], where cooperative systems are modeled to pave the way for control strategies that are consistent with the operational space formulation.
An object impedance control strategy is designed in [3] for limiting the internal wrenches that are applied by robots on the manipulated object and, whilst do not contribute to its motion, can damage the object or the robot. In [4] two impedance loops are designed in order to both limit the interaction wrenches between the object and the environment and to avoid large internal wrenches. The same scheme was recently extended to aerial manipulators moving a rigid object [5].

As an extension of the object impedance methods, the multiple impedance control (MIC) was proposed in [6]. Such a paradigm is aimed at enforcing an equivalent impedance relationship both at the manipulator end-effectors and at the grasped object level. Furthermore, the MIC approach is extended to the cooperative manipulation of flexible objects in [7] and [8].

The case of unilateral exchanged forces between the object and the robots in cooperative manipulation is tackled in [9]. This work faces the problem of positioning thrusters on the boundary of the object so as to ensure the small-time local controllability (STLC) condition.

All the works cited above make use of centralized; however, when a strict-rigid formation motion is not required, decentralized solution can be adopted [10]. Centralized approaches are very effective in terms of performance but they require a central unit and/or complete communication among all robots. This feature might be difficult to meet in practical scenarios or might be undesirable when mobile robots are involved. Therefore, in the last decade many decentralized approaches to the cooperative manipulation have been proposed. Among the main advantages of decentralized solutions there are the major flexibility and robustness to faults, while main disadvantages are the reduced performance and the more complex control design.

Nowadays, the effort of the research community is aimed to get, as much as possible, the performance of centralized solutions within a decentralized framework in order to combine the advantages of both the approaches. Moreover, this trend to-