Decentralized Estimation and Motion Control for Cooperative Manipulation with a Team of Networked Mobile Manipulators

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Preamble

This report describes the scientific research and the results obtained during the visiting period, from 24 August to 13 September 2015, for the Short Term Mobility program 2015, sponsored by the Italian National Research Council (CNR). The reported research was conducted by Dr. Donato Di Paola (CNR) in collaboration with Dr. Antonio Franchi (LAAS-CNRS) at the Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS) du Centre National de la Recherche Scientifique (CNRS), Toulouse, France.

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Introduction

The research presented in this report, is in the field of multi-robot systems, in particular in the research area of estimation and control for robotic manipulation.
We consider a team of mobile robots that have to control the motion of an unknown load for a manipulation task. We propose two different solutions to solve the aforementioned estimation and control problem when the motion of the load is constrained on a plane. First, a partially decentralized controller is designed, in which each robot computes the control law locally, yet the control is based on the a priori knowledge of the physical parameters of the load (the estimation has been performed in a centralized way).
Then, we propose a fully decentralized strategy based on two parts: the decentralized estimation of the parameters of the object and the extension of the previous partially decentralized control law to perform a robust control of the motion of the load. We prove that both control approaches converge to a desired reference velocity. Moreover, we prove that the fully decentralized controller also converges in presence of estimation errors.
Finally, we corroborate the theoretical results with a simulation campaign that demonstrates the feasibility of the proposed approach using a different number of robots operating in different manipulation settings.

Research results

In this paper we consider the problem of controlling a load whose motion is constrained on a plane and which can be manipulated by a team of networked mobile robots. A conceptual representation of the considered cooperative manipulation scenario is shown in Fig. 1, using five KUKA youBot robots.

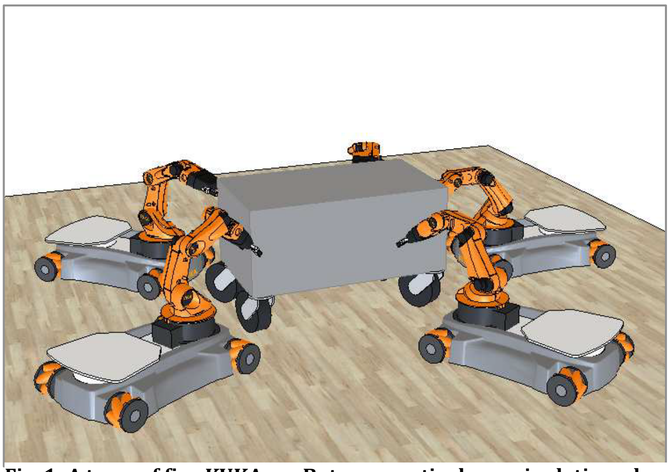

Fig. 1: A team of five KUKA youBot cooperatively manipulating a load which can be moved on a planar surface.

In particular, we present two novel control strategies to solve the cooperative manipulation problem. The first control strategy is partially decentralized, in the sense that each robot computes the control law locally and without the knowledge of the state of all the other robots, but the local control law it is based on the a priori knowledge of the inertial/kinematic parameters of the manipulated load and its state (velocity of the center of mass and angular velocity). This control strategy allows a perfect tracking of the desired linear/angular velocity profile. The second control strategy is instead fully decentralized. This strategy is similar to the first one a part from two crucial aspects. The first is that the parameters and the object state are estimated using the recent results by some of the authors of this paper [1], [2]. The second is a modification of the partially decentralized control law that allows a robust control of the motion of the load also in presence of estimation errors. The price to pay for the full decentralization is a small bounded error in the tracking of the desired linear/angular velocity profile. This is unavoidable due to the intrinsic delays in the multi-hop communication network.
We prove the feasibility of both the approaches via a simulation campaign with different operational scenarios. In particular, the fully decentralized approach is also shown via dynamical simulations in presence of sensor noise, to better evaluate the robustness of the proposed controller.
Furthermore, the results of this research has been prepared as a paper and submitted to the International Conference on Robotics and Automation (ICRA) 2016.

Conclusion

In this report we summarized the research carried out at LAAS-CNRS on cooperative estimation and control for networks of robotic manipulators.
In particular, we have proposed two control schemes: a partially decentralized controller, in which each robot computes the control law locally, but it has an a priori knowledge of the physical parameters of the load, and a fully decentralized approach in which each robot does not know any information about the load. We have proved that the partially decentralized control law converges toward a desired reference signal. Moreover, we have proved that the fully decentralized controller converges up to a small bounded error in the tracking of the desired linear/angular velocity profile. Finally, we have demonstrated the feasibility of the fully decentralized approach via dynamical simulations in different operational scenarios, also in presence of sensor noise.

References

[1] A. Franchi, A. Petitti, and A. Rizzo, "Distributed estimation of the inertial parameters of an unknown load via multi-robot manipulation,"in 53rd IEEE Conf. on Decision and Control, Los Angeles, CA, Dec.2014, pp. 6111–6116.

[2] A. Franchi, A. Petitti, and A. Rizzo, "Decentralized parameter estimation and observation for cooperative mobile manipulation of an unknown load using noisy measurements," in 2015 IEEE Int. Conf. on Robotics and Automation, Seattle, WA, May 2015, pp. 5517–5522.