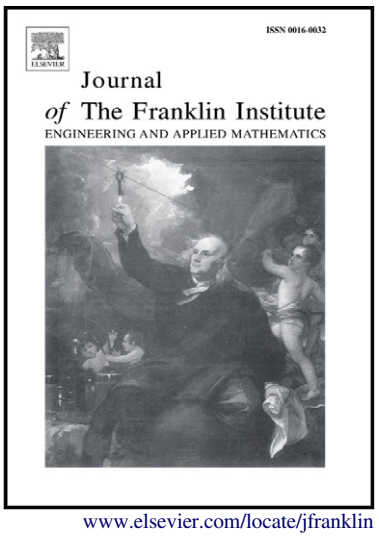

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Y.-C. Liu

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Task-Space Coordination Control of Bilateral Human-Swarm Systems

Yen-Chen Liu

Abstract

This paper proposes a system framework and control algorithms that enable a human operator to simultaneously interact with a group of swarm robot in a remote environment. In order to cope with kinematic dissimilarity and spatial discrepancy between human and swarm systems, a task-oriented control framework is developed. Based on the proposed control system, the human operator is able to convey action commands to the swarm, and the swarm robot can provide feedback information for the human operator. Additionally, the cognitive limitation of the human operator due to lack of entire information about the remote environment can be mitigated by utilizing the null-space of the swarm robot. Stability and performance of the proposed control system are investigated when the communication channels are subject to time delays and the system is influenced by non-passive external forces. The control algorithms are validated via numerical simulations on a 3-DOF robotic manipulator with a group of mobile swarm robot.

Index Terms

Human-swarm interaction, communication delay, swarm robot, bilateral teleoperation, networked robot system.

I. Introduction

The study of multi-robot control systems has attracted extensive attention from the control and robotics communities in the past decades. Recently, the applications of this research topic has been focused on the aspects of keeping formation, avoiding obstacles, maintaining connectivity, and monitoring the environment [1]–[10]. By utilizing graph theory to control the relative position and orientation between the followers and the leader(s), the formation control of a group of mobile robots was presented in [1], [6]. The technique of potential functions has been exploited to the study of connectivity control for multi-agent system [8], [11], and formation control for a group of swarm robot [12]. An interesting work has been proposed recently [9], [10] to control a swarm by positioning robots inside a desired region while maintaining a minimum inter-robot distance without having specific identities or requiring a leader. Without explicitly directing the relative position and orientation for multi-robot formation, the idea of controlling a group of robots through the abstraction was presented in [13]–[15]. However, the development of the aforementioned systems in executing a predefined tasks would decrease flexibility and limit potential for applications.

Enduing a swarm with the intelligence of human operators can benefit multi-robot systems in cooperative manipulation [16], data estimation [17], and environmental exploration [18]. In order to endow swarm robot with the ability to perform various and complicated missions, several researchers have explored using a single human operator to remotely interact with a group of mobile robots [19]–[23]. A semi-autonomous teleoperation control framework was presented in [19] where the group of robots can maintain a rigid formation while following the trajectory specified by the human operator. Based on passivity techniques, [21] addressed the stability problem of controlling groups of mobile robots by only one master

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Y.-C. Liu is with the Department of Mechanical Engineering, National Cheng Kung University, Tainan 70101, Taiwan, e-mail:(yliu@mail.ncku.edu.tw)