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Nonlinear coordination control for a group of mobile robots using a virtual structure

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ABSTRACT

This paper considers the problem of creating a coordination algorithm for a team of mobile robots. The goal for coordinating a group of mobile robots is to create an efficient architecture and control algorithm that enables them to work both individually and in meaningful robot formations. This is achieved by employing coordination and trajectory following techniques, and the knowledge derived by the localization of the robots from their environments.

The model use a combination of the Lyapunov technique and graph theory embedded in the virtual structure. In this way, the knowledge derived by the localization of the robots in the group allows for efficient coordination and trajectory following, which can then create useful robot formations.

The results obtained from experiments, using three mobile robots in differing formations, show the performance of the controller and the coordination algorithm. They also demonstrate the ability of the algorithm to recover from position sensor measurement errors and temporary delays or failures in the communication, which may cause the robots to momentarily abandon their place in the group formation.

1. Introduction

The various ways to control and coordinate a team of mobile robots have been studied over recent years. When comparing the mission outcome of a group of multi-mobile robots (MMR) to that of a single robot, it is easy to see that the overall performance of the MMR group can improve task allocation, performance, time duration required and the system effectiveness to achieve the outcome [3–6]. Instead of building a powerful single robot, a MMR group provides the flexibility in performing the task required, as well as making the system more tolerant to possible individual robot faults. MMR's have a variety of applications including grounded mobile robots [13,14], underwater autonomous vehicles [15,16], aerial vehicles [17–19] and a fleet of marines [20,21]. For a MMR group where individual robots communicate with each other via inbuilt sensors, there can be issues with sensor crosstalk [6,7]. In practice, there is a limited communication range that restricts the abilities of the robots to talk with each other. Some research work has been done using variable phase communication to minimize these errors [25–27].

In this paper, we consider the problem of controlling a team of mobile robots which have inbuilt sensors to move along designated trajectories in a group formation to reach desired target points. By attaching wheeled encoder sensors to a group of mobile robots, information about the local environment can be input and interpolated to create the trajectory following and coordination by the group. The strategies that have been developed to control and coordinate the MMR group are an important consideration when creating the control architecture to compliment the sensor network. These include whether to have a centralized or decentralized system, and what behaviors the robots must exhibit to complete their tasks.

Theoretical views of MMR behavior are divided between centralized and decentralized systems. In a centralized system, a powerful core unit makes decisions and communicates with the robots in the team. This core unit can optimize robot coordination, accommodate individual robots faults and monitor the accomplishment of the mission. However, it is possible that any faults in the core can facilitate a failure of the whole system.

In the decentralized approach, each robot can communicate and share information, but can only achieve part of the global mission by being given specific task allocations. Decentralized systems optimize the allocation of resources and robot faults can also be overlooked by this system, but can result in a less efficient mission outcome. This allocation of resources in the decentralized approach is considered the most efficient way to process the algorithm required to control the robot's behavior.

Different architectures and strategies have been developed in order to control and coordinate a MMR group. These include: behavior based [2,11,12], virtual structure [9,10,28] and leader

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