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Cooperative Minimum Expected Length Planning for Robot Formations in Stochastic Maps

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Abstract

This paper addresses a tightly integrated multi-robot planning, localization and navigation system in stochastic scenarios. We present a novel motion planning technique for robot formations in such kinds of environments, which computes the most likely global path in terms of a defined minimum expected length (EL). EL evaluates the expected cost of a path considering the probability of finding a non traversable zone and the cost of using an alternative traversable path. A local real time re-planning technique based on the probabilistic model is also developed for the formation when the scenario changes. The formation adapts its configuration to the shape of the free room. The partial views of all the robots are integrated to update the multi-robot localization using a modified EKF based on the measurement differencing technique which improves estimation consistency. As a result, a lower uncertainty map of the local navigation area is obtained for re-planning purposes. Experimental results, both in simulation and in real office-like settings, illustrate the performance of the described approach where a hybrid, centralized-distributed, architecture with wireless communication capabilities is used.

Keywords: Planning under uncertainty, Stochastic maps, Cooperative formations localization and navigation, Hybrid architecture

1. Introduction

The interest in the design, development and implementation of multi-vehicle systems has grown tremendously both in the fields of robotics and control systems technology due to their enhanced reliability and robustness over single-vehicle systems.

Key applications such as factory automation, surveillance, exploration or rescue missions may benefit from the use of geometrically constrained multi-robot systems, known as *robot formations* where close cooperation and coordination among the, possibly heterogeneous, vehicles of the team is mandatory for the successful joint mission completion. For instance, the formation can be used to escort a group of people to the exit of a building in an emergency situation where the robots in the formation structure delimit a safe area for them and are spatially arranged to provide a broader field of view to the system.

During the execution of the mission, formation control, either centralized or distributed, keeps the team members on rigid predefined relative positions whilst moving towards the goal. A well-known approach to multi-robot coordination [1] is the leader-following approach where the robot followers navigate coordinately as commanded by the robot leader to reach the mission objectives, whilst maintaining a certain geometric shape (e.g., equilateral triangle, regular pentagon, etc), previously imposed to the formation. However, realistic scenarios with cluttered and dynamic obstacles prevent the formation from moving in the predefined shape along all its trajectory to the goal and thus the shape of the formation must be temporarily adapted to the environment.

The adaptability in the formation shape required to overcome the cluttered zones can be achieved by modeling the links between the robots as virtual spring-damper systems [2, 3]. Furthermore, this approach offers an important advantage when addressing the formation path planning problem, solved only by the robot

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