

Swarm-Based Planning and Control of Robotic Formations

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Abstract

Basic issues with a robotic task that requires multiple mobile robots moving in formations are to assemble at an initial point in the work space for establishing a desired formation, to maintain the formation while moving, to avoid obstacles by occasionally splitting/deforming and then re-establishing the formation, and to change the shape of the formation upon requests to accommodate new tasks or safety conditions. In the literature, those issues have been often addressed separately. This research proposes a generic framework that allows for tackling these issues in an integrated manner in the optimal formation planning and control context.

Within this proposed framework, a leader robot will be assigned and the path for the leader is obtained by utilising a modified A* search together with a vector approach, and then smoothed out to reduce the number of turns and to satisfy the dynamic and kinematic constraints of mobile robots. Next, a reference trajectory is generated for the leader robot. Based on the formation configuration and the workspace environment, desired trajectories for follower robots in the group are obtained. At the lowest level, each robot tracks its own trajectory using a unified tracking controller.

The problem of formation initialisation, in which a group of robots, initially scattering in the workspace, is deployed to get into a desired formation shape, is dealt with by using a Discrete Particle Swarm Optimisation (DPSO) technique incorporated with a behaviour-based strategy. The proposed technique aims to optimally assign desired positions for each robot in the formation by minimisation of a cost function associated with the predefined formation shape. Once each robot has been assigned with a desired position, a search scheme is implemented to obtain a collision free trajectory for each robot to establish the formation.

Towards optimal maintenance of the motion patterns, the path that has been obtained for robots in the group by using the modified A* search, is further adjusted. For this, the Particle Swarm Optimisation (PSO) technique is proposed to minimise a cost function involving global motion of the formation, with the main objective of

preventing unnecessary changes in the follower robot trajectories when avoiding obstacles.

A PSO formation motion planning algorithm is proposed to search for motion commands for each robot. This algorithm can be used to initialise the formation or to navigate the formation to its target. The proposed PSO motion planning method is able to maintain the formation subject to the kinematic and velocity constraints.

Analytical work of the thesis is validated by extensive simulation of multiple differential drive wheeled mobile robots based on their kinematic models. The techniques proposed in this thesis are also experimentally tested, in part, on two Amigo mobile robots.