

Mechanical Engineering Master's Defense

A Variational Approach to Planning, Allocation and Mapping in Robot Swarms using Infinite Dimensional Models

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abstract

This thesis considers two problems in the control of robotic swarms. Firstly, it addresses a trajectory planning and task allocation problem for a swarm of resource-constrained robots that cannot localize or communicate with each other and that exhibit stochasticity in their motion and task-switching policies. We model the population dynamics of the robotic swarm as a set of advection-diffusion-reaction (ADR) partial differential equations (PDEs). Specifically, we consider a linear parabolic PDE model that is bilinear in the robots' velocity and task-switching rates. These parameters constitute a set of time-dependent control variables that can be optimized and transmitted to the robots prior to their deployment or broadcasted in real time. The planning and allocation problem can then be formulated as a PDE-constrained optimization problem, which we solve using techniques from optimal control. Simulations of a commercial pollination scenario validate the ability of our control approach to drive a robotic swarm to achieve predefined spatial distributions of activity over a closed domain, which may contain obstacles. Secondly, we consider a mapping problem wherein a robotic swarm is deployed over a closed domain and it is necessary to reconstruct the unknown spatial distribution of a feature of interest. The ADR-based primitives result in a coefficient identification problem for the corresponding system of PDEs. To deal with the inherent ill-posedness of the problem, we frame it as an optimization problem. We validate our approach through simulations and show that reconstruction of the spatially-dependent coefficient can be achieved with considerable accuracy using temporal information alone.

