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THE ROBOTICS INSTITUTE

Thesis Proposal

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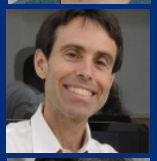

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Behavior Composition in Human Interaction with Robotic Swarms

Thursday, April 27, 2017
GHC 4405
1:00 p.m.

Abstract

Robotic swarms are multi-robot systems whose global behavior emerges from local interactions between individual robots and spatially proximal neighboring robots. Each robot can be programmed with several local control laws that can be activated depending on an operator's choice of global swarm behavior (e.g. flocking, aggregation, formation control, area coverage). In contrast to other multi-robot systems, robotic swarms are inherently scalable since they are robust to addition and removal of members with minimal system reconfiguration. This makes them ideal for applications such as search and rescue, environmental exploration and surveillance.

For practical missions, which may require a combination of swarm behaviors and have dynamically changing mission goals, human interaction with the robotic swarm is necessary. However, human-swarm interaction is complicated by the fact that a robotic swarm is a complex distributed dynamical system, so its state evolution depends on the sequence as well as timing of the supervisory inputs. Thus, it is difficult to predict the effects of an input on the state evolution of the swarm. More specifically, after becoming aware of a change in mission goals, it is unclear at what point the operator must convey this information to the swarm or which combination of behaviors to use to accomplish the new goals.

The main challenges we seek to address in this thesis are characterizing the effects of input timing on swarm performance and using this theory to inform automated composition of swarm behaviors to accomplish updated mission goals.

We begin by formalizing the notion of Neglect Benevolence --- the idea that delaying the application of an input can sometimes be beneficial to overall swarm performance --- and using the developed theory to demonstrate experimentally that humans can learn to approximate optimal input timing. By restricting our behavior library to consensus-based swarm behaviors, we then apply results from control theory to present an algorithm for automated scheduling of swarm behaviors to time-optimally accomplish multiple unordered goals. We also present an algorithm that solves the swarm behavior composition problem when our library contains general swarm behaviors, but the switch times are known.

In our completed work, we have made significant progress towards the swarm behavior composition problem from the perspective of scheduling. In our proposed future work, we plan to (1) extend our work on behavior scheduling by simultaneously relaxing assumptions on switch times and the types of behaviors in the library and (2) study behavior composition from the perspective of synthesis. In this context, synthesis describes the act of appropriately instantiating from a set of swarm meta-behaviors, the necessary concrete swarm behaviors to complete a desired task.