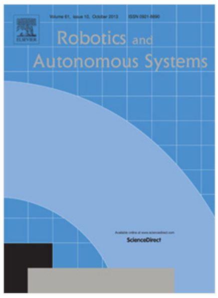

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A Framework for Mapping with Biobotic Insect Networks: From Local to Global Maps[☆]

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Abstract

We present an approach for global exploration and mapping of unknown environments using a swarm of cyborg insects, known as biobots, for emergency response scenarios under minimal sensing and localization constraints. We exploit natural stochastic motion models and controlled locomotion of biobots in conjunction with an aerial leader to explore and map a domain of interest. A sliding window strategy is adopted to construct local maps from coordinate free encounter information of the agents by means of local metric estimation. Robust topological features from these local representations are extracted using topological data analysis and a classification scheme. These maps are then merged into a global map which can be visualized using a graphical representation, that integrates geometric as well as topological features of the environment. Simulation and experimental results with biologically inspired robotic platform are presented to illustrate and verify the correctness of our approach, which provides building blocks for SLAM with biobotic insects.

Keywords: Topological Mapping, Metric Estimation, Manifold Learning, Cyborg Insects, Topological Data Analysis, Emergency Response

1. Introduction

Mapping of unknown environments is an essential and challenging task in search and rescue for emergency response application. In particular, teams of small autonomous agents (e.g. biologically inspired milli-robots [1] or cyborg insects known as *biobots* [2]) have certain advantages over traditional platforms when performing exploration and mapping tasks since larger robotic systems may not be able to reach safely to locations under the rubble of collapsed buildings. Furthermore, biobotic platforms can be particularly versatile at locomotion and navigation in unstructured and dynamic scenes due to their natural ability to crawl through small spaces. Figure 1 shows a realization of a system composed of traditional robotic and biobotic agents. Recent developments in neural engineering and neuromuscular stimulation have enabled us to directly control insect locomotion using wireless neurostimulators to enable remotely controlled biobots [2]. Each agent is equipped with system-on-chip based ZigBee enabled wireless neuro-stimulation backpack system and remote navigational control circuits. In particular, we have been able to control *Gromphadorhina portentosa* (Madagascar hissing) cockroaches in open and mazed environments, and have demonstrated the implementation of fenceless virtual boundaries for such agents [2, 3]. Mapping and localization in under-rubble environments using such platforms becomes extremely challenging due to hardware limitations and the unstructured nature of the environment. Power and computational resource constraints prohibit us from using traditional on-board imaging techniques for their localization (e.g., visual SLAM [4, 5]). Furthermore, traditional signal propagation based localization (e.g., GPS, or computing signal strength or time of flight [6, 7]) may be unreliable for indoor or

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