Cyborg-Insect Networks for Mapping of Unknown Environments

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1 Motivation

Cyborg-insect networks are systems that take advantage of existing biological platforms such as cockroaches [2] by attaching small instrumented payloads for sensing and motion control. These agents can be used in applications such as mapping and exploration of environment for emergency response (e.g., search and rescue operations after earthquakes, tsunamis, hurricanes, etc.) These agents can gain access to locations that may not be reachable otherwise by moving underground through smaller locations. The power limitations of such platforms place restrictions on sensing, communication, and motion control. Hence, traditional mapping and exploration techniques may not perform well under these adverse conditions.

We propose a robust approach to obtain a topological map of an unknown environment using the coordinate free sensory data obtained from these cyborg-insect networks. This approach was first introduced in [1]. In order to minimize control input, we take advantage of the natural behavior of insects in order to estimate a topological model of the environment based only on neighbor-to-neighbor interactions.

2 Proposed Framework

We think of the cyborg-insect network as a collection of stochastic agents only capable of identifying other agents in their vicinity and record their IDs and the time of their encounter. This coordinate-free proximity information is recorded as so called encounter events, and is used to build a metric for representation of a combinatorial map in terms of simplicial complexes. Topological data analysis (TDA), persistent homology in particular, is used to extract topological features, such as connected components holes in the environment from the point cloud constructed using the encounter metric. To improve robustness characteristics of the data with respect to noise, density based subsampling techniques have been employed. We also propose a classification technique to provide a robust quantitative representation of topological features in the data.

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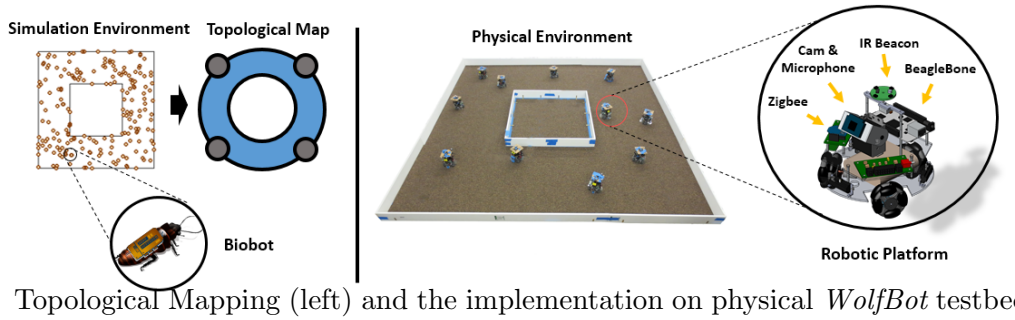

Figure 1: Topological Mapping (left) and the implementation on physical *WolfBot* testbed platform (right).

Besides testing our approach on simulations, we have implemented our algorithms on a swarm robotic platform designed by us for research and educational purposes called the *WolfBot*. This platform is open-source and open-hardware with an accessible software interface. The robots are programmed to mimic the probabilistic motion model of the cyborg-insect agents and collect the encounter data to construct a map of the environment in a distributed manner and relying only on local interactions. In the future, we plan to implement our algorithms in actual cyborg-insects.

3 Impact on CPS

The synergy of computational resources onboard each cyber-insect together with the natural locomotive capabilities of the insects makes these networks a complex CPS to study. For our research, we assume that we have control over the stochastic behavior of the agents (e.g., switching between random walk and wall following behaviors), which can be thought of as a discrete input control for this system.

Our goal is to develop robust algorithms to map unstructured environments using sensory information provided by the agents, and to use the control on the agents behavior as a means for strategies that maximize reachability and minimizes exploration time. So far, we have constructed the building blocks for mapping of these unknown environments using cyborg-insect networks via topological mapping as our core estimation technique for this system. The proposed methodology can have impact in several application areas including security and monitoring, and mapping for emergency response.

References

[1] A. Dirafzoon and E. Lobaton, " *Topological Mapping of Unknown Environments using an Unlocalized Robotic Swarm* ", in IROS, 2013.

[2] Bozkurt A. (2013) *"Latest Advances in Biobotic Agents for Environmental Sensor Networks"*. Proceedings of 35th International Conference of the IEEE Engineering in Medicine and Biology Society(EMBC13).