



Search and rescue, Environmental monitoring, Infrastructure inspection

Development of a new control algorithm that enables cyborg insects to move as a swarm

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<https://researchmap.jp/wakamiya?lang=en>

Abstract

Cyborg insects are real insects equipped with tiny electronic devices on their backs, consisting of various sensors like optical and infrared cameras, a battery, an antenna for communication, and wires for electrical stimulation. Cyborg insects are envisioned to be helpful in search and rescue missions, infrastructure inspection, and environmental monitoring, where narrow spaces and unpredictable conditions render conventional robots ineffective. Prof. Wakamiya, in cooperation with Prof. Ogura (Hiroshima University) and Prof. Sato (Nanyang Technological University), have developed an advanced swarm navigation algorithm for cyborg insects that prevents them from becoming stuck while navigating challenging terrain. Experiments demonstrated that 20 cyborg insects could successfully reach a target area as a swarm in unknown obstructed soft terrain.

borg insects to perform tasks cooperatively as a swarm without requiring detailed and complex control on each individual as in conventional approaches.

The algorithm uses a leader-follower dynamic, where one cyborg insect acts as a group leader guiding the others to a target area. Each cyborg insect is not fully controlled like a robot; rather, it generally moves freely, while being occasionally controlled to adjust its heading direction not to stray away from the others. In addition, the algorithm operates based on local environmental conditions and thus does not require the centralized management.

Experiments using Madagascar hissing cockroaches demonstrated that they moved toward a target area in formation. By allowing cyborg insects to move freely 50% of time, they could navigate over obstacles, and more interestingly they helped free nearby cyborg insects stuck or flipped over without control from a backpack.

The developed algorithm leverages the insects' innate natural behaviors, enabling the formation of cyborg insect swarms with high flexibility and efficiency.

Background & Results

Conventional robots are ineffective in performing complex tasks in narrow spaces and unpredictable conditions for their large size, limited mobility, and high energy consumption. Cyborg insects are expected to make significant contributions to those application fields. Our cooperative research group has developed a novel, simple, and flexible control algorithm that enables a group of cy-

Significance of the research and Future perspective

The results establish a foundation for cyborg insect swarms to support humans and contribute to society. In the future, cyborg insects are expected to work collaboratively with humans in various fields, enhancing the safety and security of our daily lives.



Illustration of cyborg insects moving as a swarm under the guidance of a leader cyborg insect



Photo of the actual experiment. The cyborg insect in front is a leader

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Bai, Yang; Tran, Ngoc Phuoc Thanh; Nguyen, Huu Duoc et al. Swarm navigation of cyborg insects in unknown obstructed soft terrain. *Nature Communications*. 2025, 16, 221. doi: 10.1038/s41467-024-55197-8

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cyborg insect, swarm, control, algorithm