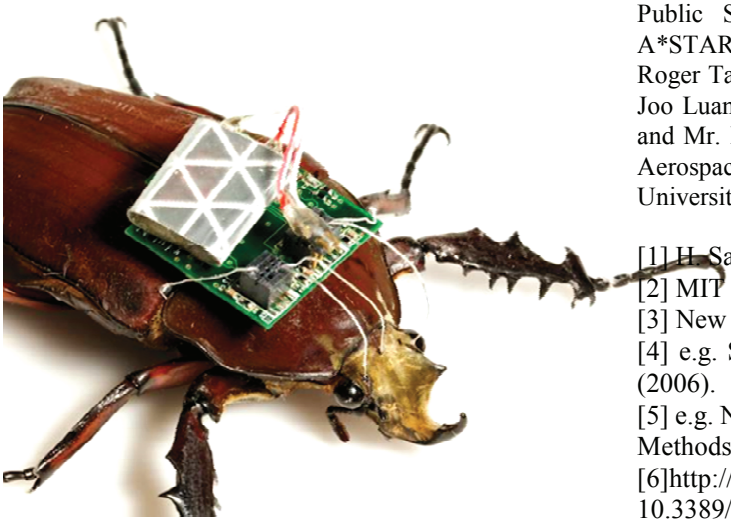
Cyborg Beetle: remote radio control of insect flight

Vo Doan Tat Thang[1], Svetoslav Kolev[2], Huynh Ngoc Anh[3], Zhang Chao[1], Travis L. Massey[2], Pieter Abbeel[2], Michel M. Maharbiz[2], Hirotaka Sato[1]

1. School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore
2. Department of Electrical Engineering and Computer Science, University of California, Berkeley, USA
3. School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore

***Abstract*— We demonstrated the remote control of insects in free flight via an implantable radio-equipped miniature neural stimulating system. The system consisted of neural stimulators, muscular stimulators, a radio transceiver-equipped microcontroller and a microbattery. Flight initiation, cessation and elevation control were accomplished through neural stimulus of the brain which elicited, suppressed or modulated wing oscillation. Turns were triggered through the direct muscular stimulus of either of the basalar muscles. This paper summarizes the work in [1-3].**

Micro air vehicles (MAV's) or tiny air planes have been a hot research topic for decades. Despite major advances, MAV's still present significant trade-offs between payload mass, flight range, and speed. Insect has flight performance unmatched by man-made craft of similar size [4]. Moreover, both the flight dynamics and the neurophysiology of insects are increasingly well understood [5]. Our attempt was producing an MAV with a live insect platform whose flight behaviors were under control via a man-made tiny stimulator.



Our stimulator (~1.3 g in total mass) consisted of a custom PCB, an off-the-shelf microcontroller, a foldable dipole antenna, a rechargeable micro battery and six wire electrodes. We employed Mecynorhina torquata beetle as the insect platform (10 g, 6 cm, 3 g payload capacity for free flight). The stimulator assembly was mounted on the beetle's pronotum (see the figure) and the terminals of wire electrodes were inserted into the optic lobes, brain, basilar flight muscles and dorsal thorax (counter electrode).

Flight initiation was triggered by applying 2-4 V, 100 Hz, 20 % duty cycle, biphasic square pulse trains between the two electrodes implanted into the optic lobes. Cessation was triggered by a single DC pulse applied to the same sites as the initiation. The wing power was decreased (and thus throttle down) when the same 100 Hz pulse trains were applied to the brain. Turnings were elicited by applying the same pulse trains to either the left or right basilar flight muscle. The beetle turned in opposite direction to stimulated side: left turn was, for example, conducted by the right side stimulation. All the flight control demonstration movies are available at [6]

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