Cyborg MAVs Using Power Harvesting and Behavioral Control Schemes

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Abstract. The focus of this research is to use flying insects, coupled with lightweight electronics, to develop cyborg MAVs, or CMAVs. The premise isn't simply to build telemetry devices on the insects, but to embed controls and power systems within the insects to create MAVs that are alive yet manipulated in their actions. The model insect implemented is the *Manduca sexta* moth, which has a wingspan up to 10cm, a body mass up to 2 grams, and can withstand payloads up to 1 gram. The technique used to create these CMAVs is an integration of MEMS and CMOS devices onto a single silicon device that is surgically inserted into the moth. The control and sensor systems are powered by harvesting energy from the vibration of the insect flight by means of piezoelectric material and inductor-coils. Methods for controlling the insect flight include reactionary responses to visual and direct stimulation. Guidance is achieved through an ultra-wideband communication system and a micro GPS system. The primary discussion topics of this paper are the power harvesting devices employed and the control schemes used to manipulate the flight of the CMAVs.

Introduction.

Micro air vehicles, or MAVs, have shown significant improvements using bio-mimetic techniques in order to scale down the size of these flying robots. As scales decrease, many researchers are transitioning to ornithoptic, or flapping, flight to create sufficient lift [1]. This trend is one that is commonly found in nature, as animals decrease in size, they tend to use flapping over fixed wing glide, for example the difference in flight behavior of larger birds compared to insects. While these bio-mimetic approaches have led to MAVs with multiple joint mechanisms and multiple degrees of freedom, the power necessary for this actuation has left many researchers from being able to achieve autonomous flight at the insect scale [1]. The problem that exists is the highest energy density batteries today are incapable of being scaled to the sizes that these MAVs are capable of withstanding during flights of longer than a few minutes [1,2]. Thus, the battery technology available for such MAVs at the insect level simply will not converge to meet MAV endurance requirements without a new approach.

This breakthrough we believe can be achieved by using insects as the flight vehicle instead of trying to engineer mechanical MAVs. By coupling sensors, controllers, and communication systems onto an adult insect, the system can harness the ability of an insect to fly without providing the main power for that flight and will consume consequently lower levels of power to run the onboard systems. Some initial studies with varies insects have shown certain species to have high payload to weight capabilities, carrying nearly half of their original mass while in flight, undisturbed by its effect [3]. Researchers have also found biocompatible methods in which to implant these systems while the insects are in their pupa state, so that tissue healing can occur before the insects emerge as adults [4,5]. These approaches to create cyborg MAVs, or CMAVs, have introduced a new class of MAVs [6]. As far as the viability of such CMAVs coming into existence, with the maturity of MEMS technology, CMOS techniques, and recent advances in methodologies to manipulate the directions in which insects will navigate, CMAVs have moved from the realm of science fiction to that of current day research.