Insect Cyborgs: A New Frontier in Flight Control Systems

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Abstract

The development of a micro-UAV via a cybernetic organism, primarily the Manduca sexta moth, is presented. An observer to gather output data of the system response of the moth is given by means of an image following system. The visual tracking was implemented to gather the required information about the time history of the moth's six degrees of freedom. This was performed with three cameras tracking a white line as a marker on the moth's thorax to maximize contrast between the moth and the marker. Evaluation of the implemented six degree of freedom visual tracking system finds precision greater than 0.1 mm within three standard deviations and accuracy on the order of 1 mm. Acoustic and visual response systems are presented to lay the groundwork for creating a stochastic response catalog of the organisms to varied stimuli.

Keywords: autonomous flight, controls, MEMS, cybernetics, cybernetic organisms, cyborgs, visual tracking

1. INTRODUCTION

Biologically-inspired flight has been the catalyst of nearly all designs in the aerospace industry since its inception. Various classical research of the 20th and 21st century has been invested into two main types of aircraft platforms, flapping-wing structures [1,2] and fixed-wing structures, the latter being the most widely used commercially. Some hybrid compromises have also emerged between the two mainstreams, mostly referring to them as adaptive or morphing aircraft [3]. Regardless of the platform, each system approach lends to different capabilities with respect to their missions and flight envelopes. In control systems, the main drive for new designs lies in the development of unmanned autonomous vehicles (UAVs). With all the advancements in these types of aircraft, the base issue still remains with scaling of these systems to ever smaller platforms. Main causes for the lack of success of these micro-UAVs lay with the weight of the structure with respect to its lift, energy available for sustained flight missions, and reliability of the functioning actuators. A novel solution to advancing these small-scale flight vehicles is to use nature itself as the platform, specifically insects, to which the flight control system is based. This concept has been typically referred to as "cybernetics," the use of organisms with electromechanical controls attached, compactly coined as cyborgs from the combination of the terms cybernetic organisms. While this concept is not a new one, only with the latest developments in micro- and nanotechnology have these robotic systems moved from the realm of science fiction to become attainable at the micro-UAV scale.

As a reference, a more detailed explanation of cybernetics is "the science of communication and control theory that is concerned especially with the comparative study of automatic control systems, as the nervous system and brain and mechanical-electrical communication systems." [4] It is derived from the Greek word Κυβερνήτης, pronounced kybernetes, meaning governor or steersman. Using a more broad interpretation of the field, it involves topics ranging from artificial intelligence to decision support systems to learning organizations, to name a few.

2. OUR APPROACH

Like previously stated, nature has historically been the inspiration to which much of the evolutionary design process has had its beginnings. With the advances in methods for power generation and the miniaturization of electronics, bio-inspired robotics have transformed into near "life-like representations" with respect to some of their mannerisms as compared with their biological counterparts. The vast complexity of "Mother Nature" is still incapable of being truly

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