Bio-Inspired Tail in Miniature Robots

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Engineers often turn to nature for inspiration when constructing robots. Despite all their efforts, natural creatures are still superior to their mechanical counterparts.

In the past several years, robotics research groups started looking into tails as a versatile mechanism that can significantly improve performance of the existing robots. In this talk, I will address some aspects of using inertial tails in miniature ground and aerial robots.

Inertial tails (or appendages) have been previously demonstrated in ground robotics for retaining stability after an impact [1], maintaining orientation during jumps and falls [2-4], for fast turns and increased maneuverability [5,6]. Here, I will discuss implementation of tails on miniature robots where the traditional control/steering is not applicable due to the size limitations. An off-the-shelf legged robot (Figure 1) with a symmetric tail was used for experimentation. An analytical model was used to study the impact of tail inertia, friction properties, and other system parameters on turning performance. Experimental results showed good matching to the model, and the robot exhibited turn rates up to 700 °/s with near zero turn radius. Closed loop control using on-board MEMS gyroscope demonstrated programmed trajectory following including traversing surfaces with different coefficients of friction.

In aerial robotics, inertial tails have been mostly neglected due to overwhelming benefits of aerodynamic control using large surfaces. However, this changes dramatically at the small scale where large surfaces increase susceptibility to air gusts and decrease maneuverability. Also, recent studies in biology have revealed that insects (such as the hawkmoth *Manduca Sexta*) use their abdomens in hover as inertial appendages in synergy with wings [7-9].

Here I will describe our attempt to make the first step towards developing a multifunction bio-inspired inertial tail that supplements control and performance of flapping wing NAVs in hover. The theoretical analysis and experimental tests were performed for the problem of stabilizing an inverted pendulum-like mass using an active tail (Figure 2). This considerably simplifies the original problem but preserves the instability dynamics of NAVs and operation principle of the active tail. The additional challenge of stabilizing an NAV stems from the problem constraints: the actuated inertial tail needs to be lightweight and low power, and the control algorithm needs to be computationally inexpensive for implementation on a small microcontroller.

Our work studies the effect of actuator parameters on the performance metrics like critical tilt angle and energy efficiency. The successful stabilizing of the inverted mass is demonstrated in a series of impact and vibration tests.

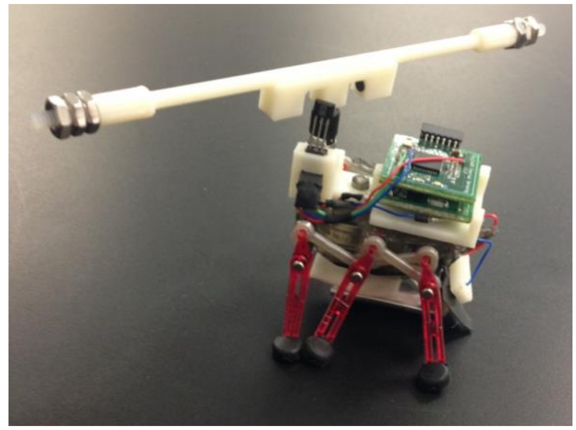

Figure 1. Underactuated hexapod with mounted tail

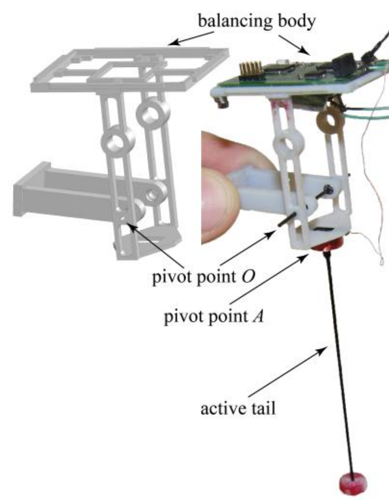

Figure 2. Inverted pendulum-like mass with active tail

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