Nature Inspired Neuroengineering: Using Animal Flight to Inspire New Sensing Technologies

(Talk #4)

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Flying animals propel themselves with compliant wings that bend of deform in response to inertial and elastic dynamics as well as aerodynamic loading. That deformation has profound consequences to the magnitude of lift forces and thus the control of the flight path [1]. Moreover, in insects the instantaneous forces on their wings are neutrally encoded by a multitude of specialized mechanosensory structures (campaniform sensilla) that respond with extraordinarily high precision [2]. And most importantly, wing flapping accompanied by body rotations leads to Coriolis forces that act on the wings. Thus, like halteres, the gyroscopic sensory organ of flies, wings could be serving a similar sensory function; one that has not been previously considered. Indeed, halteres are evolutionarily derived from hind wings and share many of the same sensory structures. Unlike halteres, however, wings also clearly serve as actuators. We raise the possibility that wings provide a novel dual role of both sensing and actuation.

To explore this issue we combine theoretical, experimental, robotic, and behavioral studies to examine the bending dynamics of wings and their role in flight control in the hawkmoth *Manduca sexta*. First, using both intra- and extracellular recording techniques we show that the strain sensing campaniform sensilla on wings neutrally encode deformation in a manner nearly identical to those of halteres. We further show that animals produce a steering response that can be initiated by a visual pitch stimulus, a mechanical pitch rotation to the whole body and, importantly, a mechanical pitch stimulus produced only on the wings (via tiny magnets and a rotating Helmholtz coil). Using a combination of simulations and robotic experiments, we also show that flapping wings subject to rotation in an axis orthogonal to the flapping axis experience a Coriolis force that is manifest as a torsional wave on the wing surface. Finally, we show that torsional strain of flapping wings provides a signal that can discriminate Coriolis forces from other inertial elastic forces.

We then combine concepts from both computational neuroscience and from compressive sensing to predict optimal sensor placement for discrimination of Coriolis forces on flapping wings [3]

References:

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