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Robot as Physical Models for the Study of Biomechanics and Control of Small Animals, Robert Wood

The panelist explores the world of biomechanics and control of small animals. The main inspiration of its work is a paper of Michael Dickinson “Wing Rotation and the Aerodynamic Basis of Insect Flights”, a detailed quantitative experimentally validate understanding of the aeromechanics of insect flights. In this experiment Dickinson was able to take the high-speed videography of the flight, reproduce it by quantifying and qualifying the phenomenon. This gave the recipe of how to move wings. The device has two wings with 2 degrees of freedom each, two actuators for wing, finalized to produce the wing motion. The main thesis of the authors’ work is that robots can be considered as a physical model for the study of biomechanics and control of small animals. The lecture focuses on three different categories of small robots: flying robots, terrestrial robots, and jumping-striking robots. Starting with the first researchers tried to create devices that operate like insects to an approximate level. One first attempt was the multi-scale, multi-material, rapid prototyping aimed at creating the devices to try to understand complex problems like design and fluid mechanics. In this context complexity could be defined in different ways: ratios to largest-smallest features size, degrees of freedom, one peculiarity of this methods, is that it does not lose complexity as scaling down. For the design inspiration was taken from flies: within the thorax, flat muscles power the wings, actuation is injected upon the wings to adjust bias. The rotational motions are passive, driven by the dynamic properties of the wings and the thorax structure. As that it was possible to recreate perfect wing motion. One major question was how to shape wings: the main dichotomy was to chose between following nature of improving nature with more complex and efficient shapes made possible by the increased bandwidth of the materials. Trying to follow the second approach there were many studies that tried to denote what were the most important features in flying and how to increase performance through shape. In one noteworthy paper, Kevin Chen was able to implement a solver for the fluid-mechanics in 2D and in 3D and to solve the equations for pressure and iso-vorticity contour for different stiffnesses and shapes. Flipping the wings around creates vortices, as Dickinson firstly realized, through Chen’s work, it became possible to induce the desired wing strikes that lead to the desired vortices. The phase angle between flapping and rotation is critical and is mediated by the choice of dynamic properties of the wings. The next challenge was to understand which sensor to integrate on the surface of those robots. Again, taking inspiration of nature, robots given ocelli and antennae, and to improve nature they were also provided with IMU, magnetometer, pressure, and range finder. It was found that ocelli were very useful in insects to get an altitude estimation for the flying robot: if the light source is a monotonic decreasing function, like in sunsets or sunrises, it was possible to triangulate light and understand the altitude of the robot. Thanks to this coupled with simple control laws it was possible to stabilize altitude. One noteworthy observation was that models consumed similar level of power as metabolic power of flying insects at similar size. The second parenthesis was on terrestrial locomotion. Again, it was possible to notice how robots had comparable energy to other animals and of comparable is mass. Using high bandwidth actuators allowed to operate with slip-like behaviors. In the early days of the microfabrication process development, it was possible to realize a centipede of 20 legs and 40 actuators, and use it as a platform to test microfabrication capability, and also study the open loop dynamics on the presence and absence of compliance between segments. Surface area to volume scaling implied that gravity mattered less, and this enabled robots to walk on water. One major issue in having robots walk on water was understanding the law of surface tension for small animals. As matter of facts, the biggest issue was not sinking of floating, but getting the robot back out of the water: the surface tension outweighed the forces generated by the robot. Lastly, another set of topics, relatively recent, was exploiting the “impulsive mechanism”: load energy slowly and release it very fast, to have jumping robots on water. This is called

“Torque reversal mechanism”: storing a lot of energy in the structure as well as in the actuators, and, as soon as it saturates, reverse the storage in an instantaneous release.

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