Machinery/Automation

Development of Biomorphic Flyers

Autonomous flight control and navigation in small size is offered for planetary and terrestrial exploration applications.

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Biomorphic flyers have recently been demonstrated that utilize the approach described earlier in "Bio-Inspired Engineering of Exploration Systems" (NPO-21142), *NASA Tech Briefs*, Vol. 27, No. 5 (May 2003), page 54, to distill the principles found in successful, nature-tested mechanisms of flight control. Two types of flyers are being built, corresponding to the imaging and shepherding flyers for a biomorphic mission described earlier in "Cooperative Lander-Surface/Aerial Microflyer Missions for Mars Exploration" (NPO-30286), *NASA Tech Briefs*, Vol. 28, No. 5 (May 2004), page 36. The common features of these two types of flyers are that both are delta-wing airplanes incorporating bio-inspired capabilities of control, navigation, and visual search for exploration. The delta-wing design is robust to ~40 G axial load and offers ease of stowing and packaging.

The prototype that we have built recently is shown in the figure. Such levels of miniaturization and autonomous navigation are essential to enable biomorphic microflyers (<1 kg) that can be deployed in large numbers for distributed measurements and exploration of difficult terrain while avoiding hazards. Individual bio-inspired sensors that will be incorporated in a biomorphic flyer have been demonstrated recently. These sensors include a robust, lightweight (~6 g), and low-power (~40 mW) horizon sensor for flight stabilization. It integrates successfully the principles of the dragonfly ocelli. The ocelli are small eyes on the dorsal and forward regions of the heads of many insects. The ocelli are distinct from the compound eyes that are most commonly associated with insect vision. In many insects, the ocelli are little more than single-point detectors of short-wavelength light and behavioral responses to ocelli stimuli are hard to observe. The notable exception is found in dragonflies, where flight control is notably degraded by any interference with the ocellar system. Our team has discovered recently that the ocelli are a dedicated horizon sensor, with substantial optical processing and multiple spectral sensitivity. To our knowledge, this is the world's first demonstrated use of a "biomorphic ocellus" as a flight-stabilization system.

The advantage of the ocelli over a similarly sized system of rate gyroscopes is that both attitude control and rate damping can be realized in one device. A full inertial unit and significant processing would otherwise be required to achieve the same effect. As a prelude to full autonomy, substantial stability augmentation is provided to the pilot at very low cost in terms of space, power, and mass. The sensor is about 40 times lighter than a comparable inertial attitude reference system. Other significant features of the biomorphic flyer shown in the figure include its ability to fly at high angles of attack ~30° and a deep wing chord which allows scaling to small size and low Reynold's number situations. Furthermore, the placement of the propulsion system near the center of gravity allows continued control authority at low speeds. These attributes make such biomorphic flyers uniquely suited to planetary and terrestrial exploration where small size and autonomous airborne operation are required.

Photograph shows the **Biomorphic Flyer Platform**. The platform was successfully demonstrated in 2001.

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NPO-30554

Second-Generation Six-Limbed Experimental Robot

This robot is designed to be more agile and dexterous than its predecessor.

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The figure shows the LEMUR II — the second generation of the Limbed Excursion Mechanical Utility Robot (LEMUR), which was described in "Six-Legged Experimental Robot" (NPO-20897), *NASA Tech Briefs*, Vol. 25, No. 12 (December 2001), page 58. The LEMUR II incorporates a number of improvements, including new features, that extend its capabilities beyond those of its predecessor, which is now denoted the LEMUR I.

To recapitulate: the LEMUR I was a six-limbed robot for demonstrating robotic capabilities for assembly, maintenance, and inspection. The LEMUR I was designed to be capable of walking autonomously along a truss structure toward a mechanical assembly at a prescribed location and to perform other operations. The LEMUR I was equipped with stereoscopic video cameras and image-data-processing circuitry for navigation and mechanical operations. It was also equipped with a wireless modem, through which it could be commanded remotely. Upon arrival at a mechanical assembly, the LEMUR I would perform