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BY GRACE V. JEAN

Landing Gear Prototypes for Robotic Birds Take Off

The Defense Department is pursuing the development of bird-like and insect-sized flying robots to give troops more overhead surveillance options in future conflicts. By 2015, the Air Force intends to field an avian robot that can operate semi-autonomously for a week to detect harmful chemicals and explosives. It will have a two-foot wingspan and the ability to perch to collect video data and recharge onboard batteries.

Scientists have figured out how to make small aircraft fly and even hover by using flapping wings. But enabling those drones and their fixed-wing counterparts to alight safely on rooftops and phone wires remains one of the toughest technical hurdles.

"The important part is the landing gear," said Bhargav Gajjar, president of Vishwa Robotics and Automation LLC, a firm based in Brighton, Mass. Under a contract with the Air Force Research Laboratory, he has developed bird-like feet and claws to do the job.

Drawing inspiration from Leonardo da Vinci's study of birds and flight, Gajjar investigated the muscles and tendons in avian feet.

"It's all about muscles," he said. "How do birds' muscles grab this quickly? How do they stay perched?"

Gajjar began copying the structures into robotic mechanisms composed of gears, springs and levers that could operate without electrical motors.

"The entire idea is to use mechanical systems instead of electrical systems to perch, but use electrical systems to unperch and walk around," he said.

Bird-sized aircraft will perch on wires and rooftops using foot-and-claw landing gear inspired by nature. VISHWA ROBOTICS

Mimicking how birds land has proven difficult.

"Ever seen a bird perch? They do these high-stall maneuvers, where they lift their heads up with their wings out, and they gently perch," Gajjar said.

"It's easy to perch when you fly very slowly," he pointed out. The trick is landing when the robotic bird swoops in at high speeds.

"The control involved is very non-linear and it's very fast, even too fast for a small microprocessor," so the only option is to crash land the robot, he said. Gajjar tackled the challenge of making lightweight landing gear strong enough to withstand the crash and also allow the vehicle to "stick."

Over a period of six to eight months, he built 20 different foot-and-claw prototypes, many as long as the palm of the human hand. He incorporated everything from small hooks to sticky pads that would allow a bird-sized air vehicle to decelerate and stop in a given area.

"If you use hooks, you cannot grab onto circular objects very well. You could hook onto it, but you wouldn't sit like a bird. You'd be flopping more like a bat," he said.

To test out the concepts, Gajjar flew remotely controlled fixed-wing aircraft as robotic bird surrogates. Through a trial-and-error process, he was able to narrow down the landing gear until he attained a design that could perch properly.

The landing would be accomplished automatically when the aircraft nears a rooftop or wire so that the operator does not have to physically control the movements. Once the "bird" perches, its toes can turn into "legs" that rotate in a rolling motion, which allows the robot to waddle like a wind-up toy. It also can spin around in place.

"A real bird has lots of muscles and tendons so it can actually walk around on its two feet. But that's a coordinated, multimodal process in locomotion," said Gajjar. It also consumes a lot of energy. "Waddling is passive dynamic locomotion. You're not using any actuators," or mechanical devices that convert energy into motion, he said.

If a robotic bird in the future needs to run and jump in the air to take off, a leg-like structure might be more appropriate, he added.

"Jumping is included in my landing gear already, but it's not functional right now," he said. Gajjar is maturing the system to enable those advanced movements.

AFRL last fall awarded a two-year contract to the firm to continue its efforts on the prototype. Gajjar is building a fuselage modeled after the American kestrel — the smallest hawk in the falcon family. The next step in the project is to shrink the feet to true hawk-like dimensions and then commence flight-testing the entire micro-air vehicle system.

A team of Franklin W. Olin College of Engineering students in Needham, Mass., is helping to miniaturize the landing gear. The undergraduates are incorporating into the prototype tougher materials such as carbon fiber and tiny steel balls to maintain its strength while cutting the size and weight in half, said Gajjar. The ultimate goal is to replicate how biological muscles work in avian feet.

There are still many challenges in building tiny muscle-like actuators, said Thomas McKenna, a program manager who oversees Office of Naval Research projects involving bio-inspired autonomous systems.

"We still don't have the right material," he said.

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