Students capture the flight of birds on very high-speed video

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Graduate student Eirik Ravnan works with a parrotlet that he is training to fly from perch to perch in order to be filmed by a high-speed camera. Credit: L.A. Cicero

Stanford mechanical engineering professor David Lentink and his students capture slow-motion video from the fastest wings in the bird world, with an eye toward building flying robots that take design cues from Mother Nature.

"The best way to prevent a small drone from spying on you in your office is to turn on the air-conditioning," said David Lentink, an assistant professor of mechanical engineering at Stanford. That little blast of air, he explained, creates enough turbulence to knock a hand-size UAV off balance, and possibly send it crashing to the floor.

A pigeon, on the other hand, can swoop down busy city streets, navigate around pedestrians, sign posts and other birds, keep its path in all sorts of windy conditions, and deftly land on the tiniest of hard-to-reach perches.

"Wouldn't it be remarkable if a robot could do that?" Lentink wondered.

If robots are to become a bigger presence in urban environments, they will need to.

In order to build a robot that can fly as nimbly as a bird, Lentink began looking to nature. Using an ultra-high-speed Phantom camera that can shoot upwards of 3,300 frames per second at full resolution, and an amazing 650,000 at a tiny resolution, Lentink can visualize the biomechanical wonders of bird flight on an incredibly fine scale.

Anna's hummingbirds, often spotted darting from flower to flower on the Stanford campus, beat their wings about 50 times per second, nothing but a green blur to human eyes.

"Our camera shoots 100 times faster than humans' vision refresh rate," Lentink said. "We can spread a single wing beat across 40 frames, and see incredible things."

First flight

Every time Lentink's students take the camera into the field, they have the potential to make a groundbreaking discovery. Thousands of birds have never been filmed with a high-speed camera, their secret flight mechanics never exposed.

Students Andreas Peña Doll and Rivers Ingersoll filmed hummingbirds performing a never-before-seen "shaking" behavior: As the bird dived off a branch, it wiggled and twisted its body along its spine, the same way a wet dog would try to dry off. At 55 times per second, hummingbirds have the fastest body shake among vertebrates on the planet – almost twice as fast as a mouse.

The shake lasted only a fraction of a second, and would never have been seen without the aid of the high-speed video.

"We're actually in a position where we can quantitatively analyze this video, and some of the results are the first results of their kind," said Ingersoll, an engineering graduate student who specializes in hummingbird flight. "It is kind of cool to know that potentially other researchers in the future will look at the data we've got in this class and [it will] help them with their research."

Though Lentink's lab has amassed hours of short clips of bird flight, it's difficult to frame up a perfect shot in the wild, so his students supplement this footage with carefully orchestrated laboratory-based experiments.

"In the field, you can observe social interactions near other birds, how they fly through the wind or through clutter," Lentink said. "This is very valuable. But the conditions aren't always ideal for examining discrete motions."

Eirik Ravnan, a mechanical engineering graduate student, trains small birds called parrotlets to fly from perch to perch, or to fly through narrow passageways. In exchange for their flight displays, the birds receive their favorite seeds as a reward.

Repeating and videotaping these actions in controlled conditions, he said, makes it possible to look more carefully at, for example, exactly how a bird tilts its wings to slow itself when landing, or how birds corner. The lab just acquired an advanced flow measurement system that can help elucidate how the birds manipulate the airflow with their wings during such maneuvers.

"I've never even had a pet," Ravnan said. "But working with birds and investigating their flight mechanics and thinking about how to apply those abilities to robots has been a really interesting way to apply my studies in fluid dynamics."

A better bird 'bot

Search-and-rescue is one of the more attractive applications for robotic planes, particularly scanning a wide urban area for survivors after a natural disaster. The unpredictable environment will demand robots that can better deal with changing conditions.

Mini-copters and planes often stall at steep angles, or when they get caught in a gust of wind. They have difficulty avoiding other airborne objects, and fly clumsily near buildings.

Lentink and his students have already begun applying the lessons they've learned from birds to various robotic designs.

"Hummingbirds are amazing at hovering, but it's not a very efficient form of flight," said Waylon Chen, a graduate student in Lentink's lab. "A swift flies a lot, so it has a very efficient wing platform, but its legs are too short to land. As we lay out the goal of our robotic design, we can pick and choose which natural mechanisms will be useful, and incorporate only those."

This summer Lentink is making his camera and students available to local birders. (To apply, fill out this questionnaire. Email questions to birderquestionnaire@gmail.com)

"We'd like to pair the camera with some bird enthusiasts who might know the natural history of these birds better than us," Lentink said. "We want to give people outside of Stanford the magical experience of using this camera, and hopefully learn something more about birds in the process."

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