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UA engineers study hybrid systems to design robust unmanned vehicles

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Mechanical engineering senior (and beekeeper) Sean Phillips prepares bees for tracking of their flight patterns in the UA College of Engineering's Hybrid Dynamics and Control Laboratory in Tucson, Ariz. Credit: University of Arizona College of Engineering

The UA College of Engineering's Hybrid Dynamics and Control Laboratory is developing mathematical analysis and design methods that could radically advance the capabilities of unmanned aircraft and ground vehicles, as well as many other systems that rely on autonomous decision making.

Researchers in the lab design computer control systems that may one day allow robotic surveillance aircraft to stay aloft indefinitely. These systems also might be used to safely guide aircraft and automobiles through small openings as they enter buildings. Or they could help airplanes and ground vehicles navigate in cluttered environments without colliding.

In addition, the research can be applied to multiple programmable devices aboard vehicles or in stationary locations, allowing them to communicate in the presence of adversaries.

The lab's research focuses on mathematical analysis and design of control systems that have applications in robotics, biology and aerospace engineering.

"What we do here in our lab is mainly theory," said Ricardo Sanfelice, an assistant professor of aerospace and mechanical engineering, who directs the lab. "We model dynamical systems, analyze them mathematically, devise ways to control them, test them in simulations and, when possible, validate them in our test bed.

"But, because of the complexity of movement in some systems that can include sudden transitions in speed or direction, we have to be very careful to be sure computer simulations reflect the real world, and that's where the experimental lab provides a place for us to check our results."

The lab, which is located in UA's Aerospace and Mechanical Engineering building, consists of a computer room, where Sanfelice and his students devise the computer control systems, and a cavernous test lab, topped with eight motion-capture cameras.

The cameras, which were originally designed to create animated figures from the recorded movements of humans and animals, sit on a rail 20 feet off the floor and track the movements of radio-controlled model airplanes, helicopters and automobiles that are flown or driven by computers. The cameras take the place of satellites in this indoor GPS system.

"We can test our theories 24/7 in this test lab without the weather constraints involved in outdoor testing," Sanfelice, said. "We mathematically model the systems we want to control and design a set of computer instructions to accomplish a particular task, such as hovering."

Testing outdoors is more time consuming and costly, and conditions are more difficult to control, he explained. Testing indoors allows the computing brains to stay safely on the ground making decisions based on data coming from the motion-capture cameras. The cameras continuously record the vehicle's position, orientation, and velocity.

"When we transition to outdoor testing, the computer has to be onboard, like a traditional airplane autopilot, receiving information from satellite-based GPS systems, whereas in the lab, the cameras function as the GPS," he said.
"After extensive testing indoors, we're in a better position to use our resources more efficiently when we transfer to outdoor, real-world experiments to validate and fine tune our controllers."

Sanfelice and his students currently are studying ways to extract energy from wind gusts and thermals to gain altitude without using power, just like birds do when soaring to greater altitudes. "This is very different from traditional control system design, where you want to nullify the effects of perturbations. Here, we're exploiting them," he said.

Sanfelice noted that hybrid control system theory is a relatively new field, having evolved during the past 20 years or so. As a result, theoretical tools for analysis, design, and simulation of hybrid control systems are in the early stages of development. "We are developing a toolbox for such systems, to make them more designer- and user-friendly," he explained. "We hope that our simulation software for these systems will eventually become part of a commercial simulation product."

Provided by University of Arizona

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