Army looks to improve quadrotor drone performance

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Credit: The Army Research Laboratory

When an aircraft veers upwards too much, the decrease in lift and increase in drag may cause the vehicle to suddenly plummet. Known as a stall, this phenomenon has prompted many drone manufacturers to err on the side of extreme caution when they plan their vehicles' autonomous flight movements.

For vertical takeoff and landing tail-sitter drones, most manufacturers program the aircraft so that the vehicle body turns very slowly whenever it transitions from hover to forward flight and vice versa.

The U.S. Army Combat Capabilities Development Command's, now referred to as DEVCOM, Army Research Laboratory collaborated with researchers at Rensselaer Polytechnic Institute to create a trajectory planner that significantly shortens the time it takes for VTOL tail-sitter drones to make this crucial transition.

The team designed the trajectory planner specifically for the Army's Common Research Configuration platform, a quadrotor biplane tail-sitter used to test new design features and study fundamental aerodynamics.

"The goal of this work was to use a model-based trajectory planner that could capture the quadrotor's dynamic characteristics sufficiently while executing quickly enough to provide trajectories in-flight," said Dr. Jean-Paul Reddinger, Army aerospace engineer at the laboratory's Vehicle Technology Directorate. "We're essentially building in a kinesthetic model of the aircraft's own dynamics that it can reference."

According to Reddinger, VTOL tail-sitters typically rely on a heuristic-based approach whenever they transition between hover and forward flight, where they follow a very slow but very safe predetermined set of actions. In contrast, the trajectory planner can find the optimum sequence of flight movements for these transitions that tailor to each situation.

Researchers discovered the availability of these more agile maneuvers when they modeled the unique interaction between the wake of the vehicle's rotors and the aerodynamics of its wings.

"If this vehicle is hovering, the wings are pointed upwards and the rotors are spinning above it constantly; if you wanted to start moving it forward, you would be dragging this wing effectively flat against the air," Reddinger said. "You would think that this causes a lot of drag, but in reality, because of the air being blown down onto the wing, it's actually not seeing a whole lot of drag."

As a result of this extra downwash from the rotors, VTOL tail-sitters can handle a more aggressive transition between hover and forward flight than one would have assumed, Reddinger said.

Through simulation, the researchers found that the incorporation of rotor on wind wake interference into the trajectory planner enabled the CRC to transition into hover and land in half as much time as compared to the conventional approach.

The team believes that the trajectory planner may eventually allow the CRC to intelligently switch between hover and forward flight as it navigates across dense or urban areas.

"Right now, it's at a state where you give it the initial state that you want—maybe you have a specific altitude or velocity that you're starting at—and it will plot a path that gets you from that initial state to the desired final state as efficiently as possible," Reddinger said. "The direction we're trying to take this in is to incorporate obstacles and additional kinds of constraints on its maneuverability."

Reddinger compared the autonomous behavior of the CRC to that of humans and how the knowledge of our own capabilities allows us to move efficiently from one location to another.

Similarly, the incorporation of more sophisticated flight models in the trajectory planner will provide the CRC with a better understanding of the complex aerodynamic environment as it moves.

"For instance, if there was a building in the way, does it make more sense to fly over the building or around the building?" Reddinger asked. "Do you want to transition to build up speed and then transition back or do you just stay in hover mode? There's a range of possibilities, and the idea is to always be picking the best one."

Once the trajectory planner undergoes more simulation trials, the researchers plan to hook the software up to hardware models to ensure a high level of robustness before they commence flight tests.

Reddinger believes that a faster, more efficient transition between hover and forward flight will eventually help the Army develop new vehicles for intelligence, surveillance and reconnaissance missions as well as aerial resupply operations.

"In order to capitalize on the flight capabilities of the emergence of novel configurations, we need autonomous pilots that are capable of making the most of the agility and performance that these aircraft are designed to allow," Reddinger said. "This method of model-based trajectory planning is a step in the direction of integrating high level autonomy with platform-specific dynamics."

Provided by The Army Research Laboratory

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