Adaptive Electromechanical Stability Control for Model Aircraft

Introduction

Model aircraft may look convincingly like their larger real-world counterparts, but their flight characteristics are very different. The world they fly in does not scale down with them, so small gusts have profound effects on stability and thus the realism of flight. This work addresses an experimental system to mitigate some of the shortcomings through the following objectives:

- 1. Outfit a model airplane with sensors to acquire flight performance data
- 2. Fabricate a hexapod test platform for controlled, repeatable experiments on the plane in the lab
- 3. Collect data from the plane in the lab and in the field under various conditions
- 4. Retrofit and configure the plane with prototype stability systems
- 5. Test and refine the systems manually in the lab and in the field
- 6. Investigate machine learning for automated refinement so the systems optimize themselves

Background

The plane is an electric-powered Piper Super Cub with a nine-foot wingspan. The large size is necessary to accommodate on-board hardware.



Flight involves controlling the yaw, pitch, and roll angles in three dimensions as the plane moves forward. Any disruption to them causes the flight path to deviate abruptly.



Accelerometers, gyroscopes, an attitude-heading reference system, altimeter, and GPS receiver measure the state of the plane.



Stability Processing

The sensors feed data to a tiny BeagleBone Black single-board computer. It determines the expected and actual states of the plane and any corrections to apply.



Two systems can apply the corrections. The first involves the standard flight control surfaces (green arrows) that are already part of the plane. The computer can react faster and better than the human pilot on the ground to compensate for deviations.

The second system is novel. It uses compressedair jets on each axis (orange arrows) to rapidly adjust the angles. Stability control can use either system separately or both together.



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Sensor Input

Actuator Output

Hexapod Test Platform

Testing both stability systems in the air is very difficult because there is no way to control the environment: wind does whatever it does. The second part of this work involves a large test platform that can reproduce all the motions and deviations that occur in real flight under full computer control. The plane is not actually flying, but the systems do not know this.



Zero-G Experiments

A secondary goal of this work is to investigate how well the systems operate under common conditions when the sensors do not function properly, namely during zero-gravity maneuvers.



Flying a parabolic arc results in weightlessness at the peak, as demonstrated by the author in a full-sized NASA test plane.





Results

The computer records all data for later analysis, correction, and refinement. Interactive animated visualizations recreate the flight paths to help understand how the systems performed.



The data also export to numerical and graph forms for mathematical and statistical analysis.



Machine Learning

All these steps require a human to design, program, debug, and tune them manually. Machine learning allows the systems to change their configurations automatically to optimize performance. Experiments on the test platform teach the computer how to react to various inputs. Then the plane performs the same maneuvers in the air for comparison. Many experiments are necessary for this part, which is still under development.