Autopilot for Small Unmanned Aerial Vehicles

Small unmanned aerial vehicles (UAVs) have numerous applications in civilian sectors. These include terrain monitoring for agriculture, assessment of damage caused by natural or manmade hazards, archaeological discovery, and exploration of remote and inaccessible areas.

In all these applications, stable, controllable flight of the vehicle is essential. The UAV must be able to follow a commanded trajectory and maintain its attitude so as to ensure high-quality sensor data. The small size and low weight of the craft make it susceptible even to low-level wind disturbances, plus small UAVs exhibit significant nonlinearities in their dynamics—presenting challenges for flight control and autopilot design.

Autopilots

The controllable flight of aircraft requires the precise manipulation of aerodynamic surfaces such as elevators, ailerons, and rudders. Pilots do not affect these actuators directly. Instead, a flight computer, the "autopilot," translates higher-level commands (e.g., heading and altitude changes) into appropriate commands to the surfaces.

In many cases, and especially for small UAVs, automated and systematic approaches for autopilot design are lacking. Autopilots are based on simple single-variable PID controllers. Extensive manual tuning is required for adequate performance.

New "robust control" techniques have been developed that automate much of the autopilot design process for UAVs and also allow accurate flight in a substantially broader range of environmental conditions.

Robust Design of Multiloop Autopilots

- Robust control theory suggests a rigorous, holistic approach to designing flight controllers. The interactions of different sensors and actuators are directly and elegantly handled by these mathematical techniques.
- The protracted manual and heuristic trial-and-error process of tuning PID controllers is replaced by a model- and tool-based framework. Autopilots can be designed in hours instead of weeks, and UAV performance is significantly improved!
- Several sources of variation related to manufacturing and operation must be addressed. These include wind gusts, changes in payload for different missions, and the lack of repeatability of low-volume manufacturing.
- A probabilistic robust controller has been developed that takes into account model and environmental parametric uncertainties for small UAVs.
- The controller is implemented as an open-source autopilot that can be reprogrammed in flight if required.

The MicroHawk UAV family has been developed at Politecnico di Torino (Italy) to promote innovative scientific techniques for Antarctic exploration, as well as archaeological and other applications of societal interest within project ITHACA (Information Technology for Humanitarian Assistance and Cooperation Actions—in cooperation with the UN World Food Program). Robust multivariable autopilots have been designed and implemented for the MicroHawks, with demonstrated improvements in both controller design time and UAV performance.

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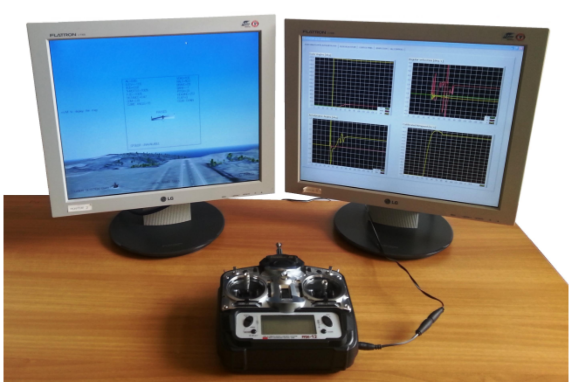
MicroHawk flights have been completed in urban and rural areas. Missions have been flown successfully in various weather conditions.

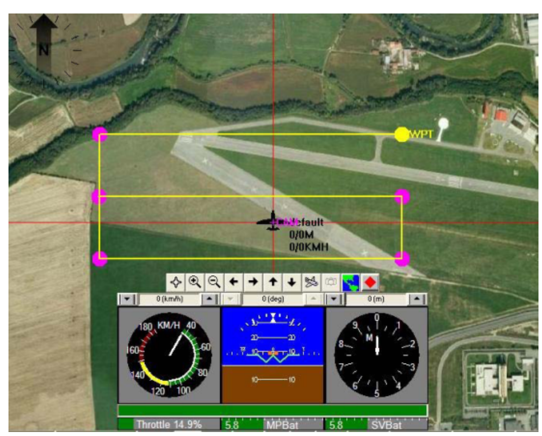
UAV operators can provide high-level commands such as waypoints to which the vehicle should fly and customized trajectories the vehicle should take.

The adoption of the model-based framework also allows the development of operator training systems and simulators.

Archaeological site monitoring with a MicroHawk 2000. The photos were taken from an onboard camera during UAV flight. In the top photo, the aircraft's shadow can be seen over the Roman Amphitheatre of Bene Vagienna, Italy.



MicroHawk educational and training flight simulator



Waypoint assignment via the operator interface during a flight test at the airport Aeritalia, Torino, Italy