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Design and Implementation of a Fixed-Wing VTOL UAV Utilizing Conventional Control Surfaces for Automatic Vertical Take-Off and Horizontal Transition

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This paper presents the development of a compact fixed-wing unmanned aerial vehicle (UAV) capable of automatic vertical take-off and transition to horizontal flight using only conventional control surfaces, without the need for additional tilt mechanisms or actuators. The design combines the vertical lift advantage of multirotor craft with the aerodynamic efficiency of fixed-wing aircraft, offering a lightweight, low-cost, and mechanically simple solution for constrained operational environments. This solution introduces a complex control problem that, once solved and implemented, greatly enhances the mechanical robustness of the aircraft. The UAV was designed and fabricated using a KT foam airframe with a 0.8 m wingspan and powered by a single BLDC motor. Aerodynamic performance was analyzed using 3D CAD simulations and XFLR5, and the resulting aerodynamic coefficients were used to construct state-space models representing both vertical and horizontal flight dynamics, which were then used to develop the flight controller. A custom flight mode, named FIXED_VTOL, was integrated into the open-source ArduPlane firmware to implement the developed flight controller, simplifying implementation to solving the transition problem of the aircraft. The control architecture employed sensor fusion, attitude stabilization, and gain-scheduled PID control for seamless switching between flight regimes. The system was implemented on a Mateksys F405 Wing V2 flight controller and tested using both Software-In-The-Loop (SITL) simulation and physical flight experiments. Experimental results confirmed vertical take-off, reliable attitude control during take-off, and smooth transition to forward flight at approximately 70% throttle. Minor oscillations observed during transition were mitigated through controller tuning. The study successfully demonstrated the feasibility of achieving fully automatic vertical take-off and horizontal transition functionality using standard aerodynamic surfaces of a simple fixed-wing aircraft, reducing mechanical complexity while maintaining stability and efficiency. Future work will focus on integrating automatic vertical landing, enhancing structural rigidity, and advancing control algorithms for improved flight performance in dynamic environments.

Keywords: Hybrid UAV design, Automatic vertical-to-horizontal transition, Conventional control surface VTOL, State-space flight modelling