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TIME-DELAY FLIGHT CONTROL OF SMALL-SCALE VERTICAL TAKE-OFF AND VERTICAL LANDING DEMONSTRATOR USING A MINI GAS TURBINE ENGINE

Abstract

Recently, many countries have developed small scale Vertical Take-off and Vertical Landing (VTVL) demonstrators to verify the technologies used before applying to a full-scale launch vehicle, e.g., the Frog-T designed by the CNES to test GNC algorithms for an Ariane launch vehicle. In this paper, by benchmarking the Frog-T, we construct a small scale VTVL demonstrator, which is composed of three actuator systems, roll control system, thrust vector control system, and thrust system. Each system consists of four BLDC motors, two linear servo motors and a 170N-class gas turbine engine.

Many studies, including Frog-T, have designed the flight control system of the VTVL demonstrators using PID controller. Due to uncertainties of the VTVL flight environment resulting from differences in atmospheric and gravity conditions between space and Earth, we design a time-delay flight control system for an attitude and position control system of the VTVL demonstrator. The Time-Delay Control (TDC) method is known to be robust to unknown dynamics and disturbances and has an efficient structure that does not require real-time calculation of the nonlinear dynamics model. The TDC method controls outputs while following a reference model by compensating the unknown with the immediate previous estimated states. Since the reference model is set as a second-order system, the TDC method requires estimated acceleration to derive a control output. To estimate the attitude and position, several sensors are used such as onboard IMU, 1D-LiDAR, and GPS.

We use an open-source flight control platform such as PX4 to apply the TDC method. Since PX4 provides various functions for flight from sensor calibration and parameter setting to mission planning and failsafe system which are complex and take a long time to implement, users can construct a small scale VTVL demonstrator with low cost and easy accessibility.

Since customizing and modifying controllers require a high level of software knowledge using PX4, we use UAV Toolbox Supports Package for PX4 Autopilots of MATLAB. It provides an intuitive implementation method of the flight control system to users by designing control system as block diagrams. Using this approach, we verified the TDC performance of the VTVL demonstrator through waypoint following simulations and tethered flight tests. These procedures can provide educational opportunities to design and verify the various control methods of lunar landers and reusable launch vehicles as well as the TDC method for many engineers.