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DESIGN AND CONTROL OF A Y-4 TILT-ROTOR VTOL AEROBOT FOR FLIGHT ON MARS

Abstract

Surrey Space Centre has been working on an autonomous fixed-wing all-electric vertical take-off and landing (VTOL) aerobot for the exploration of Mars for several years. The current design is a novel "Y-4" configured tilt-rotor, comprising two large fixed co-axial lift rotors embedded in a blended wing/body, with a pair of smaller tractor tilt-rotors mounted just forward of the wing. Thus, there are 4 rotors configured in a "Y" shape. During take-off and landing, all four rotors operate in the vertical direction, with the bulk of the lifting force being provided by the thrust of the co-axial lift rotors. During transition to horizontal flight, the pair of tilt-rotors rotate to the horizontal position and the co-axial rotors are slowed as the wings begin to provide aerodynamic lift. Once sufficient speed has been built up, these rotors are stopped, and a set of clam-shell doors close to enclose them to provide a smooth lifting surface over the body. Thus, in forward flight, only the pair of tractor tilt-rotors operate, thereby considerably reducing the electrical power demands of the aircraft compared to, for example, a conventional quad-copter or helicopter design. The baseline mission of the aerobot is to investigate the Isidis Planitia region on Mars over a month long period using optical sensors during flight and a surface science package when landed. During flight operations the aerobot will take off and land vertically, transitioning to and from horizontal flight. The flight time is around an hour, with the flights taking place close to local noon to maximize the power production of the wing/body mounted solar cells. A nonlinear six degree of freedom (6DoF) dynamic model incorporating aerodynamic models of the aerobot's body and rotors has been developed to model the vertical, transition, and horizontal phases of flight. A nonlinear State-Dependent Riccati Equation (SDRE) controller has been developed for each of these flight phases. The nonlinear dynamic model was transformed into a pseudo-linear form based on the states and implemented in the SDRE controller. During transition flight the aerobot is over actuated and the weighted least squares (WLS) method is used for allocation of control effectors. Simulations of the aerobot flying in different configurations were performed to verify the performance of the SDRE controllers, including hover, transition, horizontal flight, altitude changes, and landing scenarios. Results from the simulations show the SDRE controller is a viable option for controlling this novel Martian Aerobot.