51st IAF STUDENT CONFERENCE (E2)
Student Conference - Part 2 (2)

Author: Mr. Ankit M Patel
Indian Institute of Technology Kanpur, India, ankitmpatelaero@gmail.com

Dr. Dipak Kumar Giri
Indian Institute of Technology Kanpur, India, judipakkumar@gmail.com

RENDEZVOUS AND DOCKING OF AN OVER-ACTUATED SPACECRAFT WITH A DUAL-AXIS GIMBALED ELECTRIC THRUSTER

Abstract

Autonomous rendezvous and docking (RVD) operations for spacecraft are among the most critical and complex aspects of contemporary space missions, such as space structure assembly, on-orbit servicing of spacecraft, etc. These scenarios mandate impulsive orbital manoeuvres and attitude adjustments to effectively regulate the relative position and attitude of the spacecraft. The selection of actuator configuration for control is crucial, especially for space missions with tight constraints on the total mass. Generic impulsive thrusters use liquid propellant nozzles, which undesirably increase spacecraft mass. The solar-powered electric thruster is a promising technology that reduces the total propellant mass required for the mission. Thrust-vectoring spacecraft are ideally suited for the next generation of spacecraft due to their enhanced manoeuvrability. Nevertheless, the modest thrust delivered by electric thrusters renders attitude control by thruster vectoring. Thus, a dual-axis gimbaled electric thruster is employed for thrust vector control. This research aims to implement a near-range RVD problem where a target spacecraft moves in a known elliptic Keplerian orbit. Relative orbital motion is modelled using modified Clohessy-Wiltshire-Hill's equations. The proposed actuator configuration includes a single electric thruster placed on a dual-axis gimbal mechanism that enables thrust vectoring control. A set of two auxiliary body-fixed cold gas thrusters is added to slow down the vehicle during the docking phase, owing to the mechanical constraints of the gimbaled thruster. Reaction Wheels (RWs) along each body axes are mounted for attitude control. The attitude dynamics is over-actuated since the thrust vectoring of the main electric thruster also provides net torque about the centre of gravity of the vehicle. Hence, control allocation methods are employed to optimally use this over-actuated system. This study employs multidimensional Newton-Raphson, fixed-point iteration, and nonlinear least squares methods, considering attitude manoeuvres with and without using auxiliary thrusters separately; this addresses the problem of the nonlinear relationship between forces and moments on spacecraft. This research will provide a comparative study between the six different control allocation methods along with the nonlinear control algorithms through numerical simulation and simulation results obtained during the implementations.