Name: M.S.Siva
Degree Registered: PhD (ERP)
SR No: 5711-123-091-06568
Department: Aerospace Engineering
Affiliation: Indian Institute of Science, Bangalore 560012, India
Title of the Thesis: Integrated Relative Position and Attitude Control of Distributed Spacecraft Formation for High Resolution Imaging
Thesis Supervisors: Debasish Ghose and M. Seetharama Bhat (IISc), R. Pandiyan (ISRO)

Abstract

One of the major challenges in space technology is to achieve high resolution imaging of the intended area on demand to meet civilian and military applications. Spacecraft formation flying with coordinated control of smaller satellites offers improvement in image resolution using distribution of payloads across the formation group. Quick revisit and stereo coverage, as well as provision of modularity and redundancy, are other benefits achieved by formation flying.

The thesis addresses spacecraft formation flying with coordinated control of smaller satellites in realizing this high resolution system without compromising agility. The work focuses on coordination and control realization which is achieved through a distributed control strategy that leads to consensus agreement among formation members. To begin with, the problem of formation control for a two spacecraft leader-follower (L-F) system is formulated and is subsequently extended to a fleet of multiple satellites. Synchronized relative position and attitude control forms a major role in achieving the stereo-imaging requirement. Navigation information is obtained by fusion of Inertial Navigation System (INS) and Carrier phase Differential GPS (CDGPS) measurements. Mono-propellant thrusters and micro-reaction wheels are used as control actuators for the position and attitude control, respectively. For a two satellite leader-follower formation, the control system has been designed using Proportional-Derivative (PD) control as well as Linear Quadratic Regulator (LQR) based optimal control techniques. While extending to more than two satellites, graph theory based consensus agreement concepts are applied to achieve desired formation goal. In this case, control system is designed using distributed formation control based on Linear Matrix Inequalities (LMI). The use of LMI-based control methods help in achieving global stability of formation groups while satisfying the consensus property among members.

Detailed simulations are performed and analysis of the results assure that the designed system is capable of meeting the task of formation flying with micro-satellites. A brief analysis of the collision avoidance concept using eccentricity-inclination vector separation for passive orbits has been made. Null Space based Behavioral (NSB) approach, which determines the guidance trajectory based on priority among the tasks, namely, collision avoidance, plume avoidance and tracking error reduction, has also been presented. The distributed control system for a group of six satellite formation in Projected Circular Orbit (PCO) configuration has been demonstrated using LMI based controller together with consensus observer. The collision avoidance between the formation members has been demonstrated by assessing the inter-satellite distance between the formation members. The formation stability has also been proved through simulations and analysis. The proposed control design is expected to improve the revisit capabilities of the mission in addition to improving the spatial and spectral resolution of the remote sensing satellite systems by aperture distribution and baseline enhancement.