Hybrid Control and Estimation for Space Missions

Classical and advanced control techniques have played a major role in achieving objectives in autonomous space missions, particularly in formation flying, rendezvous and docking. Previous control techniques switch between various controllers based on the mission plan. Such switching techniques are not stable or efficient in the presence of measurement noise, actuator disturbances, time delay and other uncertainties. In particular, the presence of sensor-actuator disturbances combined with switching often results in chattering, i.e., an undesirable series of fast changes between controllers. Advanced techniques such as hybrid control and estimation strategies may be employed, however, to mitigate these effects and achieve the desired objectives in the presence of limited measurement data, uncertainties, and time delay.

The concepts of hybrid system theory, which include both continuous and discrete dynamics, formulate a hysteresis region to switch between various controllers, thus overcoming the issue of chattering. In the current research, we consider the problem of rendezvous, proximity operations and docking of an autonomous spacecraft. The problem can be divided into four phases: 1) rendezvous with angle-only measurements, 2) rendezvous with range and angle measurements, 3) docking phase, and 4) docked phase. A control algorithm is presented with mathematical rigor in formulating the necessary conditions for controller switching in the presence of sensor-actuator limitations. Next, as an extension to this research on safe and reliable spacecraft control, a general proof for a robust hybrid Kalman filter is presented which estimates the states (position and velocity) of a nonlinear spacecraft model from limited sensor data. Because of the advantages of using hybrid system theory in addressing the chattering issues, this research is extended to spacecraft rigid body control, where dual quaternions are used to present both translational and rotational dynamics. Due to the stringent mission requirements for each of the problems above, the solution requires hybrid controllers and estimators that induce convergence, invariance, or asymptotic stability properties. Such properties are designed using recent techniques in the literature of hybrid systems.

Bio

Malladi received her BS degree in mechanical engineering from Jawaharlal Nehru Technological University in Hyderabad, India, and her MS in aerospace engineering from the University of Arizona, in 2004 and 2007, respectively. From 2008 to 2010, she worked as an application engineer for LMS North America Inc. and as a research fellow at National Aerospace Laboratories in India. She then started her PhD program at UA in 2010 under the supervision of Ricardo G. Sanfelice and Eric A. Butcher.

AME Lecture Hall, Room S212
Thursday, April 27, 2017
4 p.m.
Refreshments and socializing 3:45 p.m. at the east end of the AME Courtyard