Aerospace and Mechanical Engineering Seminar

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Estimation of Spacecraft Relative Motion: Kalman Filtering, Nonlinear Observability, Ambiguous Orbits and Consensus Strategy

Relative orbit estimation is desirable for many types of spacecraft missions, including close proximity operations such as formation control, rendezvous, and space-based orbit determination in which relative navigation between spacecraft is required. Among different relative orbit estimation strategies, estimation based only on on-board measurements reduces the total operating cost and improves safety against communication interruptions with ground stations. However, for relative orbit estimation, the issue of choosing proper dynamic models and the practicality of using certain measurement types such as angles-only or range-only measurements has received limited attention in the literature.

Therefore, the first goal of this research is to study of the effects of using relative motion models of different nonlinear orders by applying relative angles-only or range-only measurements between two spacecraft. As a standard tool for sequential estimation, Kalman filter is used and a series of numerical examples are obtained which show the improving benefits of using higher-order nonlinear models of relative motion. To study the observability analytically, a nonlinear observability criterion using Lie derivatives is adopted to manifest the improvements on observability conditions when higher order models are used. Same conclusions are drawn by using numerical observability measures such as observability index and condition number.

Since the unobservability issue of using linear dynamics was discovered, the second part of this research was devoted on the analysis of ambiguous orbits under linear dynamic models and range-only measurements. Multiple ambiguous orbits are found, proven to exist and simulated through numerical examples. The transformation of these ambiguous orbits under the variation of the chief orbit's eccentricity is studied and solved via perturbation analysis. Finally, as a solution to avoid these ambiguous orbits, the consensus estimation strategy is introduced to improve the global observability of the system and avoid the possibility of Kalman filter converging on these ambiguous orbits.

Bio

Jingwei Wang received his bachelor's and master's degrees in aerospace engineering from Harbin Institute of Technology in 2007 and 2011 respectively. He joined the University of Arizona as a PhD student in aerospace engineering in 2014 under the supervision of Eric Butcher. His research interests include estimation and control of spacecraft relative motion, astrodynamics, consensus system, and attitude dynamics.

AME Lecture Hall, Room S212
Thursday, April 6, 2017
4 p.m.
Refreshments and socializing 3:45 p.m. at the east end of the AME Courtyard