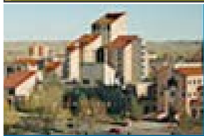
University of Colorado at Boulder



AEROSPACE ENGINEERING SCIENCES

Seminar

Mark L. Psiaki, Professor

Sibley School of Mechanical
and Aerospace Engineering

Cornell University

The Blind Tricyclist Problem and a Comparative Study of Nonlinear Filters

A blind tricyclist problem, an example nonlinear Kalman filtering problem, has been developed and used to compare several nonlinear estimation methods, including a new Gaussian mixture filter. This comparison illustrates potential weaknesses of algorithms that are claimed suitable for most nonlinear/non-Gaussian problems. It also highlights the strength of two newer algorithms, the Moving Horizon Estimator (MHE) and a new version of the Gaussian Mixture Filter (GMF). The blind tricyclist problem has nonlinear dynamics and measurement models. The kinematic state of the tricyclist is comprised of the two-dimensional Cartesian position in the horizontal plane and the heading. The tricyclist navigates based on relative-bearing measurements to moving targets that have parametric location uncertainties. Thus, the full filter state includes the tricyclist's position and heading along with the unknown parameters of the moving reference points. The extended Kalman filter (EKF), the unscented sigma-points Kalman filter (UKF), the particle filter (PF), a batch least-squares filter (BLSF), a MHE, and the new GMF are all tested on this problem. For moderate levels of initial uncertainty, all of the filters show reasonable performance. For larger initial uncertainties, however, the EKF performs poorly, as does the UKF and the PF. The BLSF has degraded accuracy, but it does not diverge. The MHE performs the second best, and the GMF the best. The MHE achieves its good performance by using explicit retrospective nonlinear smoothing calculations. The GMF exploits a new mixture re-approximation scheme that has similarities to importance re-sampling in a particle filter (PF). The resulting GMF might properly be termed a “Blob Filter” because it generelizes a PF’s probably density approximation from a weighted sum of Dirac delta functions to a weighted sum of functions with a finite, rather than an infinitesmal, covariance. The MHE and the GMF are very expensive computationally, but the PF is even more expensive because it uses a large number of particles, and the PF fails to yield good performance despite using the most computational resources. Additional tests of some of the filters are performed using an alternate, 1-dimensional problem that has a bi-model prior distribution. These tests counter-balance the results on the blind tricyclist problem; they show that the PF has advantages in certain situations.

Friday, February 6, 2015
2:00 – 3:00 pm
DLC Bechtel Collaboratory

SHORT BIO OF MARK L. PSIAKI

Mark Psiaki holds a B.A. in Physics (1979) and an M.A. (1984) and Ph.D. (1987) in Mechanical and Aerospace Engineering, all from Princeton University. He has been on the faculty of the Sibley School of Mechanical and Aerospace Engineering at Cornell University since 1986 and currently holds the rank of professor. He has conducted research in the areas of estimation and filtering, GPS/GNSS receivers, navigation and remote sensing using GNSS signals, GNSS security and integrity, spacecraft attitude and orbit determination, aerospace vehicle guidance, numerical trajectory optimization, and dynamic modeling of satellites, aircraft, and wheeled vehicles. He has authored or co-authored over 60 refereed journal articles and 60 additional conference or trade magazine papers. He holds 5 patents. He is a fellow of the Institute of Navigation. He has received 6 best paper awards for AIAA conferences along with the Institute of Navigation's Tycho Brahe award and its Burka award for the best paper in a volume of *Navigation*. He has spent 2 sabbatical leaves at the Aerospace Engineering Faculty of the Technion in Haifa, Israel, where he held appointments as a Lady Davis visiting associate professor. He is currently on sabbatical leave as an NRC Senior Research Associate at the Air Force Research Lab at Kirtland AFB, NM.