Improved Sequential Monte Carlo Filters for Ballistic Target Tracking

The problem of automatic tracking of ballistic targets in the phase of reentry into the atmosphere has received considerable attention in recent years due to the proliferation of ballistic missile technology and the growing threat posed by old satellites and other forms of space debris that fall from their orbits and may crash on the Earth's surface. The inherent nonlinearities in the ballistic motion model and in the radar measurement model preclude however the direct application of optimal linear least-squares estimation techniques such as the Kalman filter to the ballistic target tracking problem. In this talk, we consider an alternative approach using Sequential Monte Carlo (SMC) filters, also known as particle filters.

Assuming a known ballistic coefficient, we design first an improved sampling/importance resampling (ISIR) filter that uses a locally optimized importance function to combat particle degeneracy and also incorporates an additional measurement-driven Metropolis-Hastings (MH) move step to reduce particle impoverishment. In the sequel, we consider the problem where the ballistic coefficient is fixed (time-invariant), but random and unknown. In that scenario, we present two different SMC filters for joint state and parameter estimation. The first filter assumes an artificial random walk evolution model for the unknown ballistic coefficient with data-dependent drift and variance. The second algorithm is in turn a density-assisted particle filter (DAPF) that uses a parametric approximation of the joint posterior probability density function (pdf) of the target state and the ballistic coefficient conditioned on the observations, and, at each iteration, resamples a new set of particles from that approximate pdf. Both designs incorporate the optimized importance function that was previously introduced in the scenario where the ballistic coefficient was perfectly known. We test all proposed algorithms with simulated data and compare their performances, whenever possible, to the theoretical posterior Cramér-Rao lower bound for the mean-square estimation error.

Speaker's Bio: Marcelo G. S. Bruno received the bachelor's and master's degrees in Electrical Engineering from the University of São Paulo, Brazil, and the Ph.D. degree in Electrical and Computer Engineering from Carnegie Mellon University, Pittsburgh PA, U.S.A. Since October 2001, he has been affiliated with the Instituto Tecnológico de Aeronáutica (ITA), São José dos Campos, Brazil, where he is currently an Associate Professor. Dr. Bruno's research interests are in statistical signal processing, particularly Markov random fields (Mrfs), Bayesian networks, probabilistic inference on graphs, hidden Markov models (HMMs), particle filters/sequential Monte Carlo methods, Markov Chain Monte Carlo (MCMC), and their applications in target tracking, image processing, computer vision, mobile robotics, sensor fusion, and telecommunications. Dr. Bruno served as an Associate Editor for the IEEE Signal Processing Letters from January 2002 until December 2004 and now serves as an Associate Editor for the IEEE Transactions on Signal Processing.