SEMINAR NOTICE

Department of Electrical and Systems Engineering

Nonlinear Filters with Particle Flow

Fred Daum
Raytheon Company
225 Presidential Way
Woburn, MA 01801

Abstract: We present a new particle filter with superior performance compared with the classic particle filter. In particular, we achieve estimation errors that are many orders of magnitude smaller than the classic particle filter. We compute a flow of particles using log-homotopy to implement Bayes' rule. We do not use any proposal density, and we do not resample. This is a radical departure from any other particle filter. We evaluate performance for high dimensional fully-coupled (i.e., non-sparse) but smooth problems (d = 1 to 24). We have tested various nonlinearities in both the measurements and dynamics, including quadratic and cubic, with various signal-to-noise ratio and process noise.

A homotopy does not work, owing to the singularity of the resulting ODE, but a log-homotopy removes the singularity and works extremely well. We do not have to use any proposal density or resampling, because we move the particles to the correct distribution in state space using our particle flow. We completely avoid particle collapse or so-called degeneracy. We avoid the curse of dimensionality for certain problems that enjoy concentration of measure; for example, log-concave probability densities. We never compute the density itself, but rather we represent the unnormalized log-density. Our algorithm is extremely robust, and it requires only a few tuning parameters. A key ingredient is the approximation of the gradient of the log-homotopy; we studied 17 distinct methods for this, and we now use a simple but effective approach borrowed from geology. We show the flow of particles using very interesting movies. In particular, for an important radar application, we show the correct non-Gaussian density using our particles, which were called the "contact lens" for obvious reasons. For this radar problem, our filter has much better velocity estimation accuracy compared with the extended Kalman filter. We also show fascinating movies of particle flow for multimodal densities.

This work was done in collaboration with Jim Huang.

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11:00 a.m.
Bryan Hall, Room 305

Host: Arye Nehorai

Short Bio: Fred Daum is a graduate of Harvard University. Fred is an IEEE Fellow and is a senior principal fellow at Raytheon, which is the highest technical rank at Raytheon. Fred was awarded the Tom Phillips prize for technical excellence, in recognition of his ability to make complex radar systems work in the real world. He developed, analyzed and tested the real time algorithms for essentially all the large long range phased array radars built by the USA in the last four decades. These real time algorithms include: extended Kalman filters, radar waveform scheduling, Bayesian discrimination, data association, track initiation, discrimination of satellites from missiles, calibration of tropospheric and ionospheric refraction, and target object mapping. Fred's nonlinear filter theory has been applied by engineers at Boeing for the boost phase intercept problem, with results that are vastly superior to the extended Kalman filter. Fred's nonlinear filter theory generalizes the Kalman and Bene filters. He has published nearly one hundred technical papers, and he has given invited lectures at MIT, Harvard, Yale, Brown, Georgia Tech., University of Connecticut, Univ. of Minnesota, Melbourne Univ., Univ. of New South Wales, Univ. of Illinois at Chicago and Northeastern University.

Washington University in St. Louis
School of Engineering & Applied Science