On-Site at Your Location

COURSE 447 (2.4 CEUs)

Applied Kalman Filtering with Emphasis on GPS-Aided Systems

	DAY 1	DAY 2	DAY 3	DAY 4
	Mr. Michael Vaujin, Aerospace, Navigation & Defense Consultant (25+ Years)			
8:30	**Random Process Review** • Random variables, probability densities, Gaussian and multivariate • Expectation, covariance matrix, random process, autocorrelation, power spectral density, stationary and nonstationary • Linear response, shaping filters **State Space Modeling** • Models derived from differential equations, PSDs and block diagrams • Discrete time solution • Mean and covariance response • Markov and integrated Markov examples • Transition and process covariance **Random Process Simulation and Analysis** • Vector random process simulation • Autocorrelation and PSD from data • Markov random process modeling and design • Computer demo	**Linearization and Nonlinearity in KFs** • Taylor series *vs.* perturbation • Linearized and extended KF • KF combined with reference • Linearization examples • Simplest integration **GPS Orbit Determination** • Linearization for GPS orbit determination • Inverse GPS nav perspective • Computer demo • **More on GPS Navigation** • Use of Doppler measurements, • delayed states vs integrated velocity states • Carrier smoothing of range measurements	**Smoothing & Prediction** • Prediction recursive equations • Smoothing, fixed point, fixed lag, fixed interval derivations • Computer demo **Square Root Filtering** • Motivation • Square root filtering (SRCF) • Square root smoothing (SRCS) • UD filtering • Computer demo **Adaptive Filtering** • Residual analysis, on-line, off-line • Advanced residual analysis (iterative) • Residual tuning for Q & R • Multiple model adaptive estimation • Computer demo	**Information and Square Root Information Filters** • Motivation and theoretical development • Information summing • Computer demo **Practical KF implementation** • Psi angle ECEF error state form for navigation • Computing PHI in real time • Sensor error model and random walk • Care and feeding of **P** **Aided Navigation System Software Demo** • 17 state KF • Computer demo
	LUNCH IS ON YOUR OWN 12:00-1:30 PM			
5:00	**KF System Integration** • Integration with complementary filtering • Integration examples • State space modeling • Simplified KF derivation **The Kalman Filter** • Simplified algorithm description • Bias, random walk and Markov examples • Off-line error (covariance) analysis **Alternate Kalman Algorithms** • State augmentation • Sequential processing • Known control inputs • Generalized KFs for correlated noises • LU decorrelation • Matrix partitioning for efficiency	**GPS Aided Inertial Design** • Basis for inertial navigation • Inertial system error models • Computer demo **Building Extended KF** • Radar tracking of vertical body motion (non-linear dynamics) • Sled tracking of horizontal motion (non-linear measurements) • Computer demo **Advanced Suboptimal Analysis and KF Design** • Effects of mis-modeling • "Dual State" covariance analysis • "Two Pass" error budget design analysis for aided inertial navigation design • Computer demo	**Nonlinear Estimation Perspective** • Nonlinear waveform estimation, MAP estimator, and estimation bounds • GPS waveform mapping and correlator observation model • GPS line-of-sight dynamics innovation model **Extended KF Mechanizations** • Integration hiearchy • Sub-components and interfaces • Filter formulations • Latency clock effects • Jamming adaptation **Case Studies** • Modeling and simulation techniques stand-alone high-accuracy applications • High-accuracy tactical applications, including landing guidance • Anti-jamming applications	**Unscented Kalman Filters** • Unscented transforms and sigma points • Augmented & non-augmented filters • Application to navigation • Performance vs EKF • Computer demo **Radar Tracking of a Ballistic Body** • Nonlinear dynamics and error model • Linearized, extended and unscented filter comparisons • 2nd order EKF • Computer demo **Particle Filters** • Bootstrap, extended particle filter, unscented particle filter • Curse of dimensionality, particle degeneracy • Resampling • Computer demo

Course Objectives

This is a highly intensive, 4-day short course on Kalman filtering theory and Kalman filtering applications. The student will receive a thorough understanding of linear, extended, unscented, and square root Kalman filters and their practical applications to real time strapdown navigation and target tracking. The student will also be exposed to Information filters, 2nd and 3rd order extended Kalman filters, particle filters, integrity monitoring, and methods of smoothing.

Emphasis is on practical applications, but sufficient supporting theory is provided to give attendees the necessary tools for meaningful research and development work in the field. Considerable time is devoted to modeling, the most difficult aspect of Kalman filtering, in an application setting.

There will be a high level of instructor/attendee interaction, designed to provide hands-on problem solving and solution discussions.

Who Should Attend?

Engineers who need a working knowledge of Kalman filtering or who work in the fields of either navigation or target tracking.

Equipment Recommendation

- A laptop (PC or Mac) with full version of MATLAB® 5.0 (or later) installed. This will allow you to work the problems in class and do the practice "homework" problems each evening. All of the problems will also be worked in class by the instructor, so this equipment is *not required*, but is ***recommended***.
- These course notes are searchable and you can take electronic notes with the Adobe® Acrobat®9 Reader we will provide you.

Prerequisites

- A basic understanding of linear systems
- A basic understanding of probability, random variables, and stochastic processes
- A thorough familiarity with matrix algebra principles.

Materials You Will Keep

- A color electronic copy of all course notes will be provided on a USB Drive or CD-ROM. Bringing a laptop to this class is highly recommended; power access will be provided.
- A black and white hard copy of the course notes will also be provided.
- Public Venue Attendees: *Introduction to Random Signals and Applied Kalman Filtering, 3rd edition,* by R. Grover Brown and Patrick Hwang, John Wiley & Sons, Inc., 1996. ((Note: This arrangement does not apply to on-site contracts. Any books for on-site group contracts are negotiated on a case by case basis.)

Instructor

Mr. Michael Vaujin,
Aerospace, Navigation
and Defense Consultant