Introduction to Recursive Filtering, Estimation and Prediction

This block course is organized over 6 main lectures spread over 3 days (6 half days of 3 hours).

Each lecture is made of a 1.5 hour of class taught by the instructor, a 15 min break follows, and the course resumes with a 1.5 hour exercise session where the students solve written or computer exercises. The instructor provides individual guidance to each student in order to effectively progress in the exercises.

The evaluation of the attendees is made by one home assignment (40% grade) and one final exam (60% final grade). The attendees receive a certificate of attendance and successful completion of the course.

Instructor: Dr. Guillaume Ducard

Dr. Guillaume Ducard received his Master of Science (MSc) in Electrical Engineering from ETH Zurich in 2004. In 2007, he completed his doctoral work (PhD) on the topic: "Fault-tolerant Flight Control and Guidance for a Small Unmanned Aircraft," at the Institute for Dynamics Systems and Control (IDSC), ETH Zurich. Between 2008 and 2010, he worked as a postdoc at the IDSC, ETH Zurich, as a team leader for the project "The Flying Machine Arena," and lectured a number of classes at ETH. Since 2010, he is an assistant Professor at University of Nice Sophia Antipolis, France, where he teaches classes on control theory and signal processing, and he continues fundamental research about unmanned aircraft flight control. He is the author of one book and two book chapters by Springer, and a number of journal and conference papers. He is an IEEE member since 2007.

Course description

Recursive methods for real-time filtering and estimation. Topics covered: basics of probability, state space representation of dynamic systems, Bayes theorem, recursive least-squares, Kalman filtering, probabilistic data fusion, and multi-sensor estimation.

Goals of the course

The attendees will become familiar with practical methods for real-time filtering, estimation and prediction. The material will cover the theory of the selected methods and show numerous application examples. Class- and homework assignments will vary from theoretical aspects to computer exercises using Matlab for the actual design of some filters, estimators and predictors.

Lecture 1: Probability Theory

- Historic of the field of parameter identification and filtering technique (show chronology and major achievements in the past)
- Motivation (relevant examples where filtering and/or parameter estimation is needed).
- Linear Differential Equation and State Space representation
- Discretization, Linearization, Difference equation
- Definition of a random variable, probability density
- Mean value, expectation, …
- Bayes Theorem

Exercise 1 + discussion

Lecture 2: Least Squares, Recursive Least Squares

- Least squares as a batch algorithm
- Recursive least squares: derivation and properties

Exercise 2 + discussion

Lecture 3: Linear Discrete-time Kalman Filter

- Derivation of the filter
- The filtering cycle
- Polynomial Kalman filters, examples

Exercise 3 + discussion

Lecture 4: Nonlinear Kalman Filters part 1

- Extended Kalman Filters
- Examples

Exercise 4 + discussion

Lecture 5: Multiple Model Adaptive Estimation Method

- Designing a bank of Kalman filters and fusing each filter result by the probabilistic Bayes' approach

Exercise 5 + discussion

Lecture 6: Nonlinear Kalman Filters part 2

- Unscented Kalman Filters
- Examples

Final Exam (1h) + final thoughts

Extra : if time allows other related topics may be covered
Multi-sensor KF, Group-sensor method, Sequential-sensor method, Inverse-Covariance method