AE/ME 5336-001, OPTIMAL ESTIMATION OF DYNAMIC SYSTEMS
Fall 2017

Instructor: Dr. Kamesh Subbarao

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Office hours: TuTh 1230 - 1330, 0930 - 1030 HRS OR By Appointment

Time and Place of Class Meetings: 2:00 PM - 3:20 PM at GACB 105

Description of Course Content: AE/ME 5336 - Optimal Estimation of Dynamic Systems (3-0) 3 hours credit. To learn about concepts and advances in estimation theory and relate them to modern dynamic systems found in aerospace, mechanical and electrical engineering disciplines. Emphasis will be on modeling of physical problems (aerospace, robotics) into mathematical terms. Some specific problems include, state and parameter estimation in flight control applications, mechanical & robotic systems, target tracking and sensor fusion.

Prerequisites: Basic courses in Linear Systems and/or Automatic Control

Teaching Assistant(s): None

Course Content: The topics to be covered are listed below.

1. Review of linear dynamical systems, matrix algebra, statistics and basic probability concepts
   (a) Random variables, Gaussian Processes
   (b) Covariance and Correlation Function, Maximum Likelihood
   (c) Matrix norms, definiteness, decompositions and calculus
   (d) State Space representations of linear systems, controllability, observability, stability, parametric differentiation, discrete-systems.
2. Least squares estimation
   (a) Linear least squares
   (b) Nonlinear least squares estimation
   (c) Maximum likelihood estimation
   (d) Bayesian estimation
3. State & Parameter Estimation
   (a) Linear Kalman Filter (continuous, discrete, hybrid)
   (b) Neighboring Optimal Linear Estimator
   (c) Extended Kalman Filter for nonlinear systems
   (d) Colored-noise Kalman filtering, Adaptive filtering, and Robust filtering.
   (e) Batch state estimation, Fixed interval smoothing (continuous, discrete, nonlinear)
   (f) Innovations Process
   (g) Covariance Decompositions
4. Case Studies

(a) Sensor Modeling - GPS, IMU, Gyros (Bias estimation and calibration)
(b) Vehicle state determination, localization problems, as well as dynamic state estimation.
(c) Sensor fusion - GPS + INS + Vision
(d) Target Tracking using filters
(e) Parameter Identification in dynamical systems

5. Additional Topics
   (a) Unscented Kalman Filtering
   (b) Particle Filters, Feedback Particle Filters
   (c) System Identification - Eigen system Realization Algorithm, Observer Kalman Identification Algorithm.
   (d) Smoothing Algorithms

Student Learning Outcomes: This course will assess the following,

Analysis: understanding the measurement process and modeling input/output behavior

Design: use linear/nonlinear estimation techniques to estimate parameters and/or states of a dynamic system

Software: learn to use computer aided design and analysis tools for estimator design (MATLAB/SIMULINK).

Required Textbooks and Other Course Materials: The following materials are required for the class.

- (Textbook) Optimal Estimation of Dynamic Systems by John L. Crassidis & John L. Junkins, Chapman & Hall/CRC, Second Edition.
- (Software) MATLAB Student Edition/Control Toolbox by Mathworks Inc.

Descriptions of major assignments and examinations: The students will be tested using the following instruments.

Mid-Term Examinations: There will be **two take-home exams** during this course. **(October 17, 2017, November 30, 2017)**.

Projects: A number of project assignments (**five**) will be given during this course. MATLAB/SIMULINK will be used extensively for the projects. Students are allowed to discuss concepts. Any other form of collaboration such as sharing code, results is not allowed.

NOTE: All mid-term exams and project reports (code, writeup, analysis etc.) will be submitted as a single archive file (.zip) via Blackboard. If your name is **Usain Bolt** and you are an AE student and you are submitting Project 1, your archive file will be named `AE5336-Fall2017-P1-Usain-Bolt.zip`. Usain Bolt will also submit Mid Term 2 as, `AE5336-Fall2017-MT2-Usain-Bolt.zip`. Any deviations from the naming convention will earn a penalty.

Attendance: Students are expected to attend class! Timely attendance is expected.

Grading: Grading follows the standard format. A = 90% and above, B = 80% - 89%, C = 70% - 79%, D = 60% - 69%.
Weightages for final grade calculation: Midterms 50%; Projects 50%

Grade Grievances: Any appeal of a grade in this course must follow the procedures and deadlines for grade-related grievances as published in the current graduate calalog. See http://grad.pci.uta.edu/about/catalog/current/general/regulations/#gradegrievances

Drop Policy: Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. Students will not be automatically dropped for non-attendance. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (http://wweb.uta.edu/aao/fao/).

Americans with Disabilities Act: The University of Texas at Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including the Americans with Disabilities Act (ADA). All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students with disabilities, so as not to discriminate on the basis of that disability. Any student requiring an accommodation for this course must provide the instructor with official documentation in the form of a letter certified by the staff in the Office for Students with Disabilities, University Hall 102. Only those students who have officially documented a need for an accommodation will have their request honored. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at www.uta.edu/disability or by calling the Office for Students with Disabilities at (817) 272-3364.

Academic Integrity: Students enrolled in this course are expected to adhere to the UT Arlington Honor Code:

I pledge, on my honor, to uphold UT Arlington's tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence. I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.

UT Arlington faculty members may employ the Honor Code as they see fit in their courses, including (but not limited to) having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System Regents' Rule 50101, section 2.2, suspected violations of university's standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student's suspension or expulsion from the University.

Student Support Services: UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may visit the reception desk at University College (Ransom Hall), call the Maverick Resource Hotline at 817-272-6107, send a message to resources@uta.edu, or view the information at www.uta.edu/resources.

Electronic Communication: UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at http://www.uta.edu/oit/cs/email/mavmail.php

Student Feedback Survey: At the end of each term, students enrolled in classes categorized as "lecture," "seminar," or "laboratory" shall be directed to complete an online Student Feedback Survey (SFS). Instructions on

how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student's feedback enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit http://www.uta.edu/sfs

Final Review Week: A period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week unless specified in the class syllabus. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

Emergency Exit Procedures: Should we experience an emergency event that requires us to vacate the building, students should exit the room and move toward the nearest exit. When exiting the building during an emergency, one should never take an elevator but should use the stairwells. Faculty members and instructional staff will assist students in selecting the safest route for evacuation and will make arrangements to assist handicapped individuals.

Course Schedule: Please see the table below.

Date	Topics	Reading Assignment	Deliverables
Week 1	Review of Mathematical Concepts		
Week 2	Linear/Nonlinear Least Squares		
09-14-2017	Project 1 Submission		
Week 3	Parameter Estimation		
Week 4	Parameter Estimation		
Week 5	Applications - Parameter Estimation		
10-05-2017	Project 2 Submission		
Week 6	Linear State Estimation		
Week 7	Kalman Filter Variants		
10-17-2017	Mid-Term 1		
Week 8	Sensor Fusion		
Week 9	Nonlinear Filtering - EKF, UKF		
10-26-2017	Project 3 Submission		
Week 10	Nonlinear Filtering - PF		
Week 11	Multiple Model Filtering		
Week 12	System Identification		
11-16-2017	Project 4 Submission		
Week 13	Applications - State Estimation		
Week 14	Advanced Topics - Gaussian Mixtures		
11-30-2017	Mid-Term 2		
12-12-2017	Project 5 submission		

Notice: As the instructor for this course, I reserve the right to adjust this schedule in any way that serves the educational needs of the students enrolled in this course. Kamesh Subbarao