Estimation and Detection Theory

ECEN:	662-600	**CRN:**	18101
Lecture:	MWF 1:50 pm – 2:40 am	Location:	ETB 1003
Instructor:	Dr. Jean-Francois Chamberland	chmbrlnd@tamu.edu	
	WEB 301RA	979.845.6204	
Prerequisites:	ECEN 646 or approval of instructor		

Course Description: This course will introduce the student to two fundamental concepts in statistical signal processing, detection and estimation, along with their applications to engineering. The initial part of the course will focus on techniques in hypothesis testing, and their performance analysis. This will be followed by the treatment of statistical estimation theory. Properties of optimal estimators will be explored for the estimation of deterministic and random parameters including linear and nonlinear estimation, and filtering. The third part is an introduction to large deviation analysis for detection and estimation problems. Various applications of detection and estimation theory will be introduced and further explored as part of course projects.

Learning Objectives

1. Introduce the student to inference problems and the process of decision making. Provide real-world examples pertaining to the material covered in this course.

2. Formulate the problem of binary hypothesis testing. Distinguish between the Bayesian framework and the Neyman-Pearson approach. Examine the properties of an optimal detector and determine its receiver operating characteristic (ROC). Extend the concept of decision making to composite hypothesis testing, M-ary tests, sequential and robust detection.

3. Provide an overview of classical estimation. Derive the Cramer-Rao lower bound and discuss the notion of sufficient statistics. Study fundamental estimation techniques including the best linear unbiased estimator (BLUE), the maximum likelihood estimator (MLE) and least squares estimation (LSE). Define the expectation-maximization (EM) algorithm.

4. Provide an overview of Bayesian parameter estimation. Gain the ability to employ the maximum a posteriori (MAP) estimator, the minimum mean square error (MMSE) estimator, and the linear minimum mean square error (LMMSE) estimator. Review iterative estimation techniques including the least mean squares (LMS) algorithms and the recursive least square (RLS) algorithms.

5. Explore fundamental concepts in signal estimation. Study Kalman-Bucy Filtering, linear estimation and Wiener-Kolmogorov filters.

6. Carry performance analysis based on large sample sizes. Apply the Chernoff bound to give performance guarantees. Develop the theory of large deviations for independent observations and survey asymptotic performance metrics for inference problems.

7. Engage the student in an active learning experience. Provide an opportunity for the student to conduct original research through small group projects. Initiate the student to team work and collaborative efforts.

8. Expose the student to search engines, scholastic resources, research tools, indexes and databases. Prepare the student to become an active contributor to the common body of knowledge. Encourage the student to participate in shared content creation.

Recommended Materials: There exist several books that offer an excellent introduction to probability. A few such books have been placed on reserve at the library, Course Reserves.

- **Information Theory, Inference and Learning Algorithms** by D. J. C. MacKay, Cambridge University Press.
- **Statistical Inference** by G. Casella and R. L. Berger, Cengage Learning.
- **Fundamentals of Statistical Signal Processing, Vol 1: Estimation Theory** by S. M. Kay, Prentice Hall.
- **An Introduction to Signal Detection and Estimation** by H. V. Poor, Springer-Verlag.
- **Mathematical Methods and Algorithms for Signal Processing** by T. K. Moon and W. C. Stirling, Pearson.

Philosophy of Grading: During the semester, we try to be available to students and to help them understand all of the material covered in class. We also provide early feedback to people who may be in trouble, or may not get the final grade they desire. This gives them an opportunity to learn more and to prepare better for exams. We do realize that classes are demanding and that students come with different backgrounds. We try to minimize the impact of previous experience by focusing on basic material at the beginning of each semester. We also offer office hours and optional review sessions to students. These strategies are intended to give all students an equal chance at doing well.

Final grades are determined numerically based solely on individual standing, as explained in the course outline. This seems to be the only fair procedure to assign grades. Alternate letter assignments with special consideration lead to favoritism. Thus, final grades only reflect how well students did on their assignments, projects and exams. Unfortunately, they do not always represent the amount of work and time invested in the class. This is the nature of learning. Ultimately grades are assigned fairly, if not pleasantly. They are therefore very unlikely to change, unless we made a mistake in grading exams or adding numbers.

Grade Policies: The major grade components for *Detection and Estimation Theory* and their respective weights are listed below. Assignment and test grades will only be discussed after class or during office hours. We reserve the right to ask students to present their concerns or arguments in writing. Failure to meet a deadline may result in a grade of zero for the corresponding work.

Grading Rule

Exams & Quizzes	30 %	Assignments & Challenges	30 %
Projects	30 %	Participation	10 %

If your overall grade falls within one of the prescribed ranges, then you are guaranteed to receive at least the letter grade indicated.

Grading Scale

A:	90 – 100 %	C:	60 – 74 %
B:	75 – 89 %	F:	0 – 59 %

The Academic Rules website at Texas A&M University, and its section on Grading in particular, discusses possible grades and their respective meaning:

`http://student-rules.tamu.edu/rule10`.

Attendance Policy: The University views class attendance as the responsibility of an individual student. Attendance is essential to complete the course successfully. University rules related to excused and unexcused absences are located on-line at `http://student-rules.tamu.edu/rule07`.

If an absence is excused, the instructor will either provide the student an opportunity to make up any quiz, exam or other work that contributes to the final grade or provide a satisfactory alternative by a date agreed upon by the student and instructor. If the instructor has a regularly scheduled make up exam, students are expected to attend unless they have a university approved excuse. The make-up work must be completed in a timeframe not to exceed 30 calendar days from the last day of the initial absence. The student is responsible for providing satisfactory evidence to the instructor to substantiate the reason for the absence. Failure to notify and/or document properly may result in an unexcused absence. Falsification of documentation is a violation of the Honor Code. In cases where prior notification is not feasible (e.g., accident or emergency) the student must provide notification by the end of the second working day after the absence, including an explanation of why notice could not be sent prior to the class.

Classroom Communication Concerns: A student desiring to report a classroom communication concern should initiate the process within the first 12 class days of the semester, whenever possible, in order to identify an alternative course, if necessary. The last date a student may initiate the classroom communication concerns procedure is the same as the Q-drop deadline. For more information, consult the Office of the Registrar and related form.

Miscellaneous: Student dress, behavior, and speech are expected to be courteous and professional. Any deviation from this deemed inappropriate by the professor or any disruptive behavior will result in immediate ejection from the class period with swift and appropriate disciplinary measures.

Academic Integrity Statement and Policy: *"An Aggie does not lie, cheat or steal, or tolerate those who do."* For additional information, please visit: `http://aggiehonor.tamu.edu`.

Americans with Disabilities Act (ADA) Policy Statement: The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact Disability Services, currently located in the Disability Services building at the Student Services at White Creek complex on west campus or call 979-845-1637. For additional information, visit `http://disability.tamu.edu`.

Helpful Links: Academic Calendar, Final Exam Schedule, Student Rules.