IIT Mandi
Proposal for a New Course

Course Number: EE 531

Course Name: Estimation and Detection Theory

Credits: 3-0-0-3 (L-T-P-C)

Prerequisites: EE304/ EE503/ EE305/ MA524 or equivalent, or instructor consent

Intended for: B.Tech./M.S./M.Tech./Ph.D.

Distribution: Core for M.Tech.(CSP), Elective for B.Tech. 3rd and 4th year, M.S., M.Tech(non-CSP), Ph.D.

Semester: Even/Odd

Preamble: Many problems in communication, statistical signal processing, and control involve processing of information signals corrupted by noise to make inferences about the information they contain. This course intends to provide fundamental theoretical ideas and techniques to develop and evaluate common frameworks to address myriad of such inferencing problems in communication, signal processing, and control.

Modules:

1. **Mathematical background:** **(3 lectures)**

   Random variables and processes: vector spaces of random variables, CLT, stochastic processes, stationarity, spectral representation of stochastic processes, Wiener-Khinchin theorem, Gaussian process, white noise, stochastic processes through LTI systems.

   Modeling of signals and noise: models, and selection of model and model order.

2. **Ideal estimation for deterministic parameters:** **(6 lectures)**

   Principle of estimation and its applications, properties of estimators.

   Minimum Variance Unbiased Estimation: existence and search of MVU estimators, sufficient statistics and its role in finding MVU estimator, extension to vector parameters, Neyman-Fisher factorization and Rao-Blackwell theorems.

   Cramer-Rao Lower Bound: signals in white Gaussian noise, parameter transformation, vector parameters, general Gaussian case, and WSS Gaussian random processes, efficiency.

3. **Practical estimation for deterministic parameters:** **(5 lectures)**

   Linear Models and Unbiased Estimators, scalar and vector Best Linear Unbiased Estimators (BLUE); Maximum Likelihood estimation, expectation-maximization (EM) algorithm; Least Squares estimation: linear, order-recursive, sequential, constrained, and non-linear.

4. **Estimation for random parameters:** **(6 lectures)**

Bayesian Estimation: Bayesian linear model, nuisance parameters, Bayesian estimation for deterministic parameters, risk functions, MMSE and MAP estimators, scalar, vector, and sequential Linear MMSE estimators, Wiener filtering.

Advanced topics: Levinson-Durbin and Innovation algorithms, graphical models, hidden Markov models.

5. **Estimation beyond stationarity:** **(4 lectures)**

Kalman filtering: State-space modeling, scalar, vector, and extended Kalman filters.

6. **Statistical Detection Theory:** **(5 lectures)**

Binary and multiple hypothesis testing, Neyman-Pearson theorem, receiver operating characteristics, minimum Bayes risk detectors, sequential detection, Composite hypothesis testing: Bayesian and generalized likelihood ratio test (GLRT), locally most powerful (LMP) detectors, asymptotically equivalent tests.

7. **Detection of deterministic signals:** **(4 lectures)**

Signals with known parameters: matched filter, linear model, multiple signal detection.

Signals with unknown parameters: signal modeling and detector performance, sinusoidal detection, linear models, energy detectors.

8. **Detection of random signals:** **(5 lectures)**

Signals with known parameters: Estimator-correlator, linear model, general Gaussian detection.

Signals with unknown parameters: incompletely known signal covariance, weak signal detection.

9. **Detection with non-Gaussian and colored noise:** **(4 lectures)**

Signals with known and unknown parameters, Karhunen–Loeve expansion and whitening filters.

Advanced topics: Complex and vector extensions of detectors: known deterministic signal in CWGN, spatially/temporally uncorrelated noise, random signal in CWGN.

Textbooks:

1. S. M. Kay, *Fundamentals of Statistical Signal Processing, Vol 1: Estimation Theory*, Prentice Hall, 1993.
2. S. M. Kay, *Fundamentals of Statistical Signal Processing, Vol 2: Detection Theory*, Prentice Hall, 1998.

Reference books:

1. L. L. Scharf, *Statistical Signal Processing: Detection, Estimation, and Time Series Analysis*, Addison-Wesley, 1991.
2. H. V. Poor, *An Introduction to Signal Detection and Estimation*, Springer-Verlag, 1994.
3. C. W. Helstrom, *Elements of Signal Detection and Estimation*, Prentice Hall, 1995.
4. G. Casella and R. L. Berger, *Statistical Inference*, Duxbury Press, 2002.
5. H. L. van Trees, K. L. Bell, and Z. Tian, *Detection, Estimation, and Modulation Theory, Part 1: Detection, Estimation, and Filtering Theory*, Wiley, 2013.

Similarity Content Declaration with Existing Courses:

Sr. No.	Course code and Title	Similarity content	Approx. % of content	Remarks
1	EE304: Communication Theory	MAP and ML detectors	< 10%	EE304 merely introduces these techniques while discussing optimum receiver design for various modulation schemes. However, the proposed course discusses these schemes in the general framework of Bayesian estimation.
2	EE503: Advanced Communication Theory	ML, MSE, and LS estimation	<10%	The topics are dealt with only at an introductory level while discussing their applications to carrier phase estimation, timing estimation, channel equalization.

Justification for new course proposal if cumulative similarity content is > 30%: NA
Approvals:

Other faculty interested in teaching this course: Renu Rameshan

Proposed by: Samar School: SCEE

Signature: Date: 3 November 2017

Recommended/Not recommended, with comments

Chairperson, Course proposal committee (CPC) Date:

Approved / Not Approved

Chairperson, Senate Date: