

EE 501	Linear Algebra and Optimization	3-0-0	6
--------	---------------------------------	-------	---

Course Contents:

Linear Algebra - vector spaces, linear independence, bases and dimension, linear maps and matrices, eigenvalues, invariant subspaces, inner products, norms, orthonormal bases, spectral theorem, isometries, polar and singular value decomposition, operators on real and complex vector spaces, characteristic polynomial, minimal polynomial; optimization - sequences and limits, derivative matrix, level sets and gradients, Taylor series; unconstrained optimization - necessary and sufficient conditions for optima, convex sets, convex functions, optima of convex functions, steepest descent, Newton and quasi Newton methods, conjugate direction methods; constrained optimization - linear and non-linear constraints, equality and inequality constraints, optimality conditions, constrained convex optimization, projected gradient methods, penalty methods.

Texts / References:

1. S. Axler, *Linear Algebra Done Right*, 2nd Edn., Springer, 1997.
2. E. K. P. Chong and S. H. Zak, *An Introduction to Optimization*, 2nd Edn., Wiley India Pvt. Ltd., 2010.
3. G. Strang, *Linear Algebra and Its Applications*, Nelson Engineering, 2007.
4. D. C. Lay, *Linear Algebra and Its Applications*, 3rd Edition, Pearson, 2002.
5. D. G. Luenberger and Y. Ye, *Linear and Nonlinear Programming*, 3rd Edn., Springer, 2010.

EE 504	Probability and Stochastic Processes	3-0-0	6
--------	--------------------------------------	-------	---

Course Contents:

Axiomatic definitions of probability; conditional probability, independence and Bayes theorem, continuity property of probabilities, Borel-Cantelli Lemma; random variable: probability distribution, density and mass functions, functions of a random variable; expectation, characteristic and moment-generating functions; Chebyshev, Markov and Chernoff bounds; jointly distributed random variables: joint distribution and density functions, joint moments, conditional distributions and expectations, functions of random variables; random vector- mean vector and covariance matrix, Gaussian random vectors; sequence of random variables: almost sure and mean-square convergences, convergences in probability and in distribution, laws of large numbers, central limit theorem; random process: probabilistic structure of a random process; mean, autocorrelation and autocovariance functions; stationarity - strict-sense stationary and wide-sense stationary (WSS) processes: time averages and ergodicity; spectral representation of a real WSS process-power spectral density, cross-power spectral density, linear time-invariant systems with WSS process as an input- time and frequency domain analyses; examples of random processes: white noise, Gaussian, Poisson and Markov processes.

Texts / References:

1. H. Stark and J. W. Woods, *Probability and Random Processes with Applications to Signal Processing*, Prentice Hall, 2002.
2. A. Papoulis and S. U. Pillai, *Probability, Random Variables and Stochastic Processes*, 4th Edn., McGraw-Hill, 2002.
3. B. Hajek, *An Exploration of Random Processes for Engineers*, ECE534 Course Notes, 2011.
<http://www.ifp.illinois.edu/~hajek/Papers/randomprocesses.html>

EE 524	Signal Processing Algorithms and Architectures	3-0-0	6
--------	--	-------	---

Course Contents:

Orthogonal transforms: DFT, DCT and Haar; Properties of DFT; Computation of DFT: FFT and structures, Decimation in time, Decimation in frequency; Linear convolution using DFT; Digital filter structures: Basic FIR/IIR filter structures, FIR/IIR Cascaded lattice structures, Parallel allpass realization of IIR transfer functions, Sine-cosine generator; Computational complexity of filter structures; Multirate signal processing: Basic structures for sampling rate conversion, Decimators and Interpolators; Multistage design of interpolators and decimators; Polyphase decomposition and FIR structures; Computationally efficient sampling rate converters; Arbitrary sampling rate converters based on interpolation algorithms: Lagrange interpolation, Spline interpolation; Quadrature mirror filter banks; Conditions for perfect reconstruction; Applications in subband coding; Digital Signal Processors introduction: Computational characteristics of DSP algorithms and applications; Techniques for enhancing computational throughput: Harvard architecture, parallelism, pipelining, dedicated multiplier, split ALU and barrel shifter; TMS320C64xx architecture: CPU data paths and control, general purpose register files, register file cross paths, memory load and store paths, data address paths, parallel operations, resource constraints.

Texts / References:

1. R. Chassaing and D. Reay, *Digital signal processing and applications with TMS320C6713 and TMS320C6416*, Wiley, 2008.
2. S. K. Mitra, *Digital Signal Processing: A Computer Based Approach*, 3rd Edn., TMH, 2008.
3. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, Pearson Prentice Hall, 2007

EE 528	Signals and Systems Simulation Lab	0-0-3	3
--------	------------------------------------	-------	---

Course Contents:

Fundamentals: Generation of signals, study of system properties; convolution and correlation; z-transform; DFT using FFT; Linear convolution using circular convolution; aliasing due to sampling in time and frequency domains; Design of FIR and IIR filters; Estimation of power spectral density using periodogram and Welch's method; Generation of discrete and continuous random variables, statistical analysis and validation, Monte-Carlo simulation. Applications: Array Signal Processing, Communication Systems, Multirate Signal Processing, Image Processing, Speech Processing.

Texts / References:

1. A. V. Oppenheim, R. W. Schaffer and J. R. Buck, *Discrete-time Signal Processing*, 2nd Edn., Prentice Hall, 1999.
2. V. K. Ingle and J. G. Proakis, *Digital signal processing using MATLAB*, Thompson Brooks/Cole, Singapore, 2007.
3. *MATLAB and Signal Processing Toolbox User's Guide* (www.mathworks.com).
4. *SCILAB and Signal Processing User's Guide* (www.scilab.org).
5. *OCTAVE* (<http://www.gnu.org/software/octave/>)
6. D. H. Johnson and D. E. Dudgeon, *Array Signal Processing: Concepts and Techniques*, Prentice Hall PTR, 1993.
7. T. S. Rappaport, *Wireless Communications: Principles and Practice*, Prentice Hall PTR, 2002.
8. A. K. Jain, *Fundamentals of Digital Image Processing*, Tata McGraw Hill, 1997.
9. T. F. Quatieri, *Discrete-time Speech Signal Processing: Principles and Practice*, Pearson, 2006.

EE 525	Optimal and Adaptive Signal Processing	3-0-0	6
--------	--	-------	---

Course Contents:

Review: Hilbert space of random variables; response of linear systems to wide-sense stationary inputs, spectral factorization theorem and innovation processes, autoregressive moving average processes; Linear minimum mean-square error (LMMSE) estimation: minimum mean-square error (MMSE) estimation of jointly Gaussian random variables, LMMSE, orthogonality principle and Wiener Hoff equation; FIR Wiener filters, linear prediction-forward and backward predictions, Levinson-Durbin Algorithm and lattice filter; IIR Wiener filters: non-causal Wiener filter, innovation and causal Wiener filter; Kalman filters: Gauss-Markov state variable models; innovation and Kalman recursion, steady-state behaviour of Kalman filters; Adaptive filters: steepest descent solution of FIR Wiener filter, LMS algorithm-convergence, steady-state behaviour and practical considerations, RLS algorithm- method of least-squares, recursive solution and square-root algorithms, application of adaptive filters-equalization and noise cancellation. Spectral Estimation: Smoothed and windowed periodograms, minimum variance, maximum entropy and parametric methods for spectral estimation, frequency estimation.

Texts / References:

1. M. H. Hayes, *Statistical Digital Signal Processing and Modeling*, John Wiley & Sons, Inc., 2002.
2. S. Haykin, *Adaptive Filter Theory*, Prentice Hall, 2001.
3. D.G. Manolakis, V.K. Ingle and S.M. Kogon, *Statistical and Adaptive Signal Processing*, McGraw Hill, 2000.
4. S. J. Orfanidis, *Optimum Signal Processing*, 2nd Edition, 2007 republication of the 1988 McGraw-Hill edition.
5. S. M. Kay, *Fundamentals of Statistical Signal Processing: Estimation Theory*, Prentice Hall, 1993.
6. B. Widrow and S. D. Stearns, *Adaptive Signal Processing*, Prentice Hall, 1985.

EE 636	Detection and Estimation Theory	3-0-0	6
--------	---------------------------------	-------	---

Course Contents:

Review of random process, problem formulation and objective of signal detection and signal parameter estimation; Hypothesis testing: Neyman-Pearson, minimax, and Bayesian detection criteria; Randomized decision; Compound hypothesis testing; Locally and universally most powerful tests, generalized likelihood-ratio test; Chernoff bound, asymptotic relative efficiency; Sequential detection; Nonparametric detection, sign test, rank test. Parameter estimation: sufficient statistics, minimum statistics, complete statistics; Minimum variance unbiased estimation, Fisher information matrix, Cramer-Rao bound, Bhattacharya bound; Linear models; Best linear unbiased estimation; Maximum likelihood estimation, invariance principle; Estimation efficiency; Least squares, weighted least squares; Bayesian estimation: philosophy, nuisance parameters, risk functions, minimum mean square error estimation, maximum a posteriori estimation.

Texts / References:

1. H. V. Poor, *An Introduction to Signal Detection and Estimation*, 2nd edition, Springer, 1994.
2. S. M. Kay, *Fundamentals of Statistical Signal Processing: Detection Theory*, Prentice Hall PTR, 1998.
3. S. M. Kay, *Fundamentals of Statistical Signal Processing: Estimation Theory*, Prentice Hall PTR, 1993.
4. H. L. Van Trees, *Detection, Estimation and Modulation Theory, Part I*, John Wiley, 1968.
5. D. L. Melsa and J. L. Cohn, *Detection and Estimation Theory*, McGraw Hill, 1978.
6. L. L. Scharf, *Statistical Signal Processing: Detection, Estimation, and Time Series Analysis*, Addison-Wesley, 1990.
7. V. K. Rohatgi and A. K. M. E. Saleh, *An Introduction to Probability and Statistics*, 2nd edition, Wiley, 2000.

EE 529	Digital Signal Processors Lab	0-0-3	3
--------	-------------------------------	-------	---

Course Contents:

Fundamentals: Familiarization to Code Composer Studio; development cycle on TMS320C64xx kit; Generation of signals, Fourier representation and z-transform, sampling theorem in time and frequency domains, convolution and correlation, DFT and FFT; FIR and IIR filters; sampling rate converters. Applications: Adaptive filter and experiments on communication such as generation of a n-tuple PN sequence, generation of a white noise sequence using the PN sequence, restoration of a sinusoidal signal embedded in white noise by Wiener Filtering; speech and multi-media applications.

Texts / References:

1. R. Chassaing and D. Reay, *Digital signal processing and applications with TMS320C6713 and TMS320C6416*, Wiley, 2008.
2. *TMS320C64x Technical Overview*, Texas Instruments, Dallas, TX, 2001.
3. *TMS320C6000 Peripherals Reference Guide*, Texas Instruments, Dallas, TX, 2001.
4. *TMS320C6000 CPU and Instruction Set Reference Guide*, Texas Instruments, Dallas, TX, 2000.
5. IEEE Signal Processing Magazine: Oct 88, Jan 89, July 97, Jan 98, March 98 and March 2000.