**Curriculum and syllabus for M.Tech Digital Signal Processing**

| First Semester | | | | | |
|---|---|---|---|---|---|
| **Course Code** | **Course** | **Lecture Hours** | **Tutorial Hours** | **Practical Credits** | **Total Credits** |
| **AVD611** | **Advanced Signal Analysis and Processing** | **3** | **0** | **0** | **3** |
| **AVD612** | **Mathematical Methods for Signal Processing** | **3** | **0** | **0** | **3** |
| **AVD613** | **Communication Systems I** | **3** | **0** | **0** | **3** |
| **AVD614** | **Pattern Recognition and Machine learning for data processing** | **3** | **0** | **0** | **3** |
| **AVD___** | **Elective - 1** | **3** | **0** | **0** | **3** |
| **AVD632** | **Digital Image Processing Lab** | **0** | **0** | **1** | **1** |
| **AVD633** | **Communication Systems Lab** | **0** | **0** | **1** | **1** |
| | **Total** | **15** | **0** | **2** | **17** |

**AVD611 - Advanced Signal Analysis and Processing**

Review of basic DSP concepts: Transform and their properties -Transform Analysis of LTI system: Phase and Magnitude response of system, Minimum phase, maximum phase, Allpass - FIR, IIR filter design: design by Windowing, Impulse invariant and bilinear transformation - Multirate signal Processing: Interpolation, Decimation, sampling rate conversion, Filterbank design, Polyphase structures - Adaptive Filter theory : Wiener filters, LMS and RLS, Linear Prediction.

Text Books:

1. Proakis, John G. - Digital signal processing: principles algorithms and applications, PHI.

2. Oppenheim, Alan V - Discrete-time signal processing, Pearson Education India.

3.Vaidyanathan, Parishwad P - Multirate systems and filter banks, Pearson Education India.

4.Vaidyanathan, Palghat P- The theory of linear prediction, Morgan and Claypool Publishers.

5.Haykin, Simon S. - Adaptive filter theory, Pearson Education India.

Pre-requisites:

1.Undergraduate Signals and Systems

2.Undergraduate Digital Signal Processing

Evaluation:

The course will feature two midterm exams and a final exam. Continuous evaluation by class-tests and problem sets.

**AVD612 - Mathematical methods for signal processing**

Vectors: Representation and Dot products, Matrices: Matrix Multiplication, Transposes, Inverses, Gaussian Elimination, factorization, rank of a matrix, Vector spaces: Column and row spaces, Solving Ax=0 and Ax=b, Independence, basis, dimension, linear transformations, Orthogonality: Orthogonal vectors and subspaces, projection and least squares, Gram-Schmidt orthogonalization, Determinants: Determinant formula, cofactors, inverses and volume, Eigenvalues and Eigenvectors: characteristic polynomial, Diagonalization, Hermitian and Unitary matrices, Spectral theorem, Change of basis, Positive definite matrices and singular value decomposition, Linear transformations

Review of Probability: Basic set theory and set algebra, basic axioms of probability, Conditional Probability, Random variables - PDF/PMF/CDF - Properties, Bayes theorem/Law of total probability, random vectors - marginal/joint/conditional density functions, transformation of Random Variables, characteristic/moment generating functions, Random sums of Random variables, Law of Large numbers (strong and Weak), Limit theorems - convergence types, Inequalities - Chebyshev/Markov/Chernoff bounds.

Random processes: classification of random processes, wide sense stationary processes, autocorrelation function and power spectral density and their properties. Examples of random process models - Gaussian/Markov Random process, Random processes through LTI systems.

**References and Textbooks:**

1.Introduction to linear algebra - Gilbert Strang, SIAM, 2016.

2.Introduction to probability - Bertsekas and Tsitsiklis, Athena, 2008

3.Probability and Random processes for Electrical Engineers, Leon Garcia Addison Wesley, 2nd edition, 1994

4.Probability and Random Processes, Geoffrey Grimmett, David Stirzaker, 3rd Edition, Oxford University Press,2001.

5.Probability and Stochastic Process, Roy D Yates, David J Goodman, 2nd edition Wiley, 2010

**Evaluation:**

The course will feature two midterms and a final exam. There will be continuous evaluation using bi-weekly classtests, problem sets, and programming assignments.

**AVD613 - Communication Systems I**

Motivating examples of communication systems. Spectrum availability and channels. Channel modelling - baseband and passband channels. Digital modulation schemes for baseband and passband channels. Line coding, Pulse amplitude modulation, Phase modulation, Frequency shift keying, quadrature amplitude modulation. Synchronization, intersymbol interference, and noise in communication systems.

Noise modelling in communication systems - additive white Gaussian noise (AWGN) channels. Signal space concepts: Geometric structure of the signal space, vector representation, distance, norm and inner product, orthogonality, Gram-Schmidt orthogonalization procedure. Optimum receiver for AWGN channels: Optimal detection and error probability for digital signalling schemes. Matched filter and Correlation receiver.

Bandlimited channels and intersymbol interference (ISI). Signal design for bandlimited channels - Nyquist criterion, Partial response signaling. Non ideal bandlimited channels - receivers for channels with ISI and AWGN - ML receiver, its performance. Linear Equalization. Carrier and Symbol synchronization, Carrier recovery and symbol synchronization in signal demodulation, Carrier Phase estimation: ML estimation, PLL, Symbol timing estimation: ML timing estimation, Joint estimation of carrier phase and symbol timing. Case studies of digital communication receivers.

**Text Books**

1.Communication systems, Simon Haykin, 4 th edition Wiley, 2001.

2.Introduction to Communication Systems, Upamanyu Madhow, Cambridge University Press, November 2014.

3.Fundamentals of Digital Communication, Upamanyu Madhow, Cambridge University Press, February 2008.

4.Digital communication, Bernard Sklar, 2nd edition, Pearson Education, 2000.

5.Digital Communication,, John Proakis & Masoud Salehi, 5 th edition, McGrawHill, 2008.

**Pre-requisites:**

1.Undergraduate probability and random processes

2.Signals and systems, LTI systems and their analysis

Evaluation:

The course will feature two midterm exams and a final exam. Continuous evaluation by class-tests and problem sets.

**AVD614 - Pattern recognition and Machine Learning for data processing**

Review: Linear Algebra, Matrix Calculus, Probability and Statistics. Supervised Learning: Linear Regression (Gradient Descent, Normal Equations), Weighted Linear Regression (LWR), Logistic Regression, Perceptron, Newton's Method, KL-divergence, (cross-)Entropy, Natural Gradient, Exponential Family and Generalized Linear Models, Generative Models (Gaussian Discriminant Analysis, Naive Bayes), Kernel Method (SVM, Gaussian Processes), Tree Ensembles (Decision trees, Random Forests, Boosting and Gradient Boosting), Learning Theory, Regularization, Bias-Variance Decomposition and Tradeoff, Concentration Inequalities, Generalization and Uniform Convergence, VC-dimension, Deep Learning: Neural Networks, Backpropagation, Deep Architectures, Unsupervised Learning, K-means, Gaussian Mixture Model (GMM), Expectation Maximization (EM), Variational Auto-encoder (VAE), Factor Analysis, Principal Components Analysis (PCA), Independent Components Analysis (ICA), Reinforcement Learning (RL) : Markov Decision Processes (MDP), Bellmans Equations, Value Iteration and Policy Iteration, Value Function Approximation, Q-Learning, Application: Advice on structuring an ML project, Evaluation Metrics, Missing data techniques and tracking, Special Topic: Computer Vision. Special Topic: NLP, Special topic: Machine listening and Music Information Retrieval, Special Topic: Speech, Special Topic: Compressive Sensing, Special topics: Array processing, beamforming, independent component analysis, MIMO/SIMO models, under-constrained separation, spectral factorizations.

**Textbook**

1. Pattern Recognition Machine Learning by Bishop

**Course evaluation:** 4 Programming assignments 20% (5% each), Term project 20%, Exam 20%, End Sem 40 %.

| **Second Semester** | | | | | |
|---|---|---|---|---|---|
| **Course Code** | **Course** | **Lecture Hourse** | **Tutorial Hours** | **Practical Credits** | **Total Credits** |
| **AVD621** | **Statistical Signal Processing** | **3** | **0** | **0** | **3** |
| **AVD622** | **DSP System design** | **3** | **0** | **0** | **3** |
| **AVD623** | **Communication Systems II** | **3** | **0** | **0** | **3** |
| **AVD624** | **Computer Vision** | **3** | **0** | **0** | **3** |
| **AVD___** | **Elective 2** | **3** | **0** | **0** | **3** |
| **AVD** | **Deep learning for visual computing lab** | **0** | **0** | **1** | **1** |
| **AVD** | **DSP System design lab** | **0** | **0** | **1** | **1** |
| | **Innovative design project** | **0** | **0** | **0** | **1** |
| | **Total** | **15** | **0** | **2** | **18** |

**AVD621 - Statistical Signal Processing**

Estimation Theory, Maximum Likelihood estimation (MLE): exact and approximate methods (EM, alternating max, etc), Cramer - Rao lower bound (CRLB), Minimum variance unbiased estimation, best linear unbiased estimation, Bayesian inference & Least Squares Estimation , Basic ideas, adaptive techniques, Recursive LS, etc, Kalman filtering (sequential Bayes), Finite state Hidden Markov Models: forward - backward algorithm, Viterbi (ML state estimation), parameter estimation (f - b + EM), Monte Carlo methods: importance sampling, MCMC, particle filtering, applications in numerical integration (MMSE estimation or error probability computation) and in numerical optimization (e.g. annealing). Detection Theory: Likelihood Ratio testing, Bayes detectors, Minimax detectors, Multiple hypothesis tests Neyman - Pearson detectors (matched filter, estimator - correlator etc), Wald sequential test, Generalized likelihood ratio tests (GLRTs), Wald and Rao scoring tests, Applications Power Spectrum Estimation - Parametric and Maximum Entropy Methods, Wiener, Kalman Filtering, Levinson - Durban Algorithms Least Square Method, Adaptive Filtering, Nonstationary Signal Analysis, Wigner - Ville Distribution, Wavelet Analysis. Power Spectrum Estimation, model order selection, Prony, Pisarenko, MUSIC, ESPRIT algorithms, least square estimation, cholesky, LDU - OR, SV decomposition. Transversal & reasnic least square lattice filters, Signal Analysis with Higher order Spectra, Array processing, Beam forming, Time - delay estimation

**Text Books and References**


1. Statistical Signal Processing (Paperback) by Louis Scharf, 1 st edition,
2. Fundamentals of Statistical Signal Processing: Estimation Theory (Vol 1), Detection Theory (Vol 2), .M. Kay's, Prentical Hall Signal Processing Series, 1993
3. Linear Estimation, Kailath, Sayed and Hassibi, Prentical Hall Information and Sciences Series, 1 st edition, 2000.
4. An Introduction to Signal Detection and Estimation, Poor, H. Vincent , Springer Text in Electrical Engineering, 1994
5. Detection, Estimation, and Modulation Theory –Part I, H.Van Trees, et.al, 2 nd edition, Wiley.
6. Monte Carlo Strategies in Scientific Computing, J.S. Liu, Springer - Verlag, 2001. Stochastic Simulation, B.D. Ripley, Wiley, 1987.


**AVD622 - DSP System Design**

Computational characteristics of DSP algorithms and applications; Architectural requirement of DSPs: high throughput, low cost, low power, small code size, embedded applications. Numerical representation of signals-word length effect and its impact. Carry free adders, Multiplier. Representation of digital signal processing systems: block diagrams, signal flow graphs, data-flow graphs, dependence graphs; Techniques for enhancing computational throughput: parallelism and pipelining.

Introduction, Basic Architectural Features, DSP Computational Building Blocks, Bus Architecture and Memory, Data Addressing Capabilities, Address Generation Unit, Programmability and Program Execution, Features for External Interfacing. VLIW architecture. Basic performance issue in pipelining, Simple implementation of MIPS, Instruction Level Parallelism, Dynamic Scheduling, Dynamic Hardware Prediction, Memory hierarchy.Study of FIxed point and floating point DSP architectures

Analysis of basic DSP Architectures on programmable hardwares. Algorithms for FIR , IIR, Lattice filter structures, architectures for real and complex fast Fourier transforms, 1D/2D Convolutions, Winograd minimal filtering algorithm. FPGA: Architecture, different sub-systems, design flow for DSP system design, mapping of DSP alrorithms onto FPGA.

Examples of digital signal processing algorithms suitable for parallel architectures such as GPUs and multiGPUs. Interfacing: Introduction, Synchronous Serial Interface CODE, A CODEC Interface Circuit, ADC interface.

**References**


1. Sen M Kuo, Woon Seng S Gan, Digital Signal Processors
2. Digital Signal Processing and Application with C6713 and C6416 DSK, Rulph Chassaing, Worcester Polytechnic Institute, A Wiley Interscience Publication
3. Architectures for Digital Signal Processing, Peter Pirsch John Weily, 2007
4. DSP Processor and Fundamentals: Architecture and Features. Phil Lapsley, JBier, AmitSohan, Edward A Lee; Wiley IEEE Press
5. K. K. Parhi - VLSI Digital Signal Processing Systems - Wiley - 1999


**AVD623 - Communication Systems II**

Wireless Communications and Diversity: Introduction to 3G/4G Standards, Wireless Channel and Fading, Rayleigh Fading and BER of Wired Communication, BER for Wireless Communication. Introduction to Diversity, Multi-antenna Maximal Ratio Combiner, BER with Diversity, Spatial Diversity and Diversity Order. Broadband Wireless Channel Modeling: Wireless Channel and Delay Spread, Coherence Bandwidth of the Wireless Channel, ISI and Doppler in Wireless Communications, Doppler Spectrum and Jakes Model. Spread spectrum: PN Sequences, DSSS with BPSK, Signal space dimensionality and processing gain, Frequency-Hop SS. CDMA- Introduction to CDMA, Multipath diversity, RAKE Receiver. OFDM: Introduction to OFDM, Multicarrier Modulation and Cyclic Prefix, Channel model and SNR performance, OFDM Issues – PAPR, Frequency and Timing Offset Issues, channel estimation. MIMO: Introduction to MIMO, MIMO Channel Capacity, SVD and Eigenmodes of the MIMO Channel, MIMO Spatial Multiplexing – BLAST, MIMO Diversity – Alamouti, OSTBC, MRT, MIMO - OFDM. UWB (Ultra wide Band): UWB Definition and Features, UWB Wireless Channels, UWB Data Modulation, Uniform Pulse Train, Bit-Error Rate Performance of UWB.

**Textbook and References:**


1.Fundamentals of Wireless Communications – David Tse and Pramod Viswanath, Publisher - Cambridge University Press.

2.Wireless Communications: Principles and Practice –Theodore Rappaport - Prentice Hall.

3. Wireless Communications: Andrea Goldsmith, Cambridge University Press.

4. MIMO Wireless Communications – Ezio Biglieri – Cambridge University Press

5.Modern Wireless Communications- Simon Haykin and Michael Moher, Person Education, 2007

6.Kamilo Feher-Wireless Digital Communications: Modulation and Spread Spectrum Techniques, Prentice-Hall, Inc., 1995.

7.Ipatov Valery, P- Spread Spectrum and CDMA. Principles and Applications. - John Wiley & Sons Ltd.

8.Cho, Y. S., Kim, J., Yang, W. Y., & Kang, C. G. MIMO-OFDM wireless communications with MATLAB. John Wiley & Sons.2010.

Pre-requisites:

1.Undergraduate Communication system

2.Undergraduate probability and random processes

Evaluation:

The course will feature two midterm exams and a final exam. Continuous evaluation by class-tests and problem sets.

**AVD624 - Computer Vision**

The course is an introductory level computer vision course, suitable for graduate students. It will cover the basic topics of computer vision, and introduce some fundamental approaches for computer vision research: Image Filtering, Edge Detection, Interest Point Detectors, Motion and Optical Flow, Object Detection and Tracking, Region/Boundary Segmentation, Shape Analysis and Statistical Shape Models, Deep Learning for Computer Vision, Imaging Geometry, Camera Modeling and Calibration.

Prerequisities: Basic Probability/Statistics, a good working knowledge of any programming language (python, matlab, C/C++, or Java), Linear algebra, Vector calculus.

Grading: Assignments and the term project should include explanatory/clear comments as well as a short report describing the approach, detailed analysis, and discussion/conclusion.

Course evaluation: 4 Programming assignments 20% (5% each), Term project 20%, Exam 20%, End Sem 40 %.

Recommended books:

1. Simon Prince, Computer Vision: Models, Learning, and Interface, Cambridge University Press

2. Mubarak Shah, Fundamentals of Computer Vision

3. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010

4. Forsyth and Ponce, Computer Vision: A Modern Approach, Prentice Hall, 2002

5. Palmer, Vision Science, MIT Press, 1999,

6. Duda, Hart and Stork, Pattern Classification (2nd Edition), Wiley, 2000,

7.Koller and Friedman, Probabilistic Graphical Models: Principles and Techniques, MIT Press, 2009,

8. Strang, Gilbert. Linear Algebra and Its Applications 2/e, Academic Press, 1980.

Programming: Python will be main programming environment for the assignments. Following book (Python programming samples for computer vision tasks) is freely available. Python for Computer Vision. For mini-projects, a Processing programming language can be used too (strongly encouraged for android application development)

| **Third Semester** | | | | | |
|---|---|---|---|---|---|
| **Course Code** | **Course** | **Lecture Hours** | **Tutorial Hours** | **Practical Credits** | **Total Credits** |
| | **Summer Design Project** | **0** | **0** | **0** | **2** |
| **AVD852** | **Project Work Phase I** | **0** | **0** | **0** | **15** |
| | **Total** | **0** | **0** | **0** | **17** |

| **Fourth Semester** | | | | | |
|---|---|---|---|---|---|
| **Course Code** | **Course** | **Lecture hours** | **Tutorial hours** | **Practical Credits** | **Total Credits** |
| **AVD853** | **Project Work Phase II** | **0** | **0** | **0** | **18** |
| | **Total** | | | | **18** |

| **Elective List - Course names** |
|---|
| |
| Speech Signal Processing and Coding |
| Information Theory and Coding |
| Soft Computing and its Application in Signal Processing |
| Computer Vision |
| Multimedia Processing |
| Virtual Reality |
| Pattern Recognition and Machine Learning |
| VLSI Signal Processing |

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|---|
| Deep Learning and Computational data sciences |
| Applied Markov Decision Processes and Reinforcement Learning |
| Wireless Communication |
| Adaptive Signal Processing |
| RADAR Signal Processing |
| Time Frequency Analysis |
| Natural Language Processing |
| Machine Learning for signal processing |
| Biomedical Signal and Image Processing |
| Optimization techniques |
| Sparse Signal Processing |
| Artificial Intelligence |
| Computational Imaging |
| Compressive sensing |
| Natural Language Understanding |
| Deep Learning: Theory and Practice |
| Convex Optimization and Applications |
| Speech Information Processing |
| Data Structures and Algorithms |
| Wireless Mesh Networks |