CURRICULUM AND SYLLABI

M.Tech.

in

SIGNAL PROCESSING

(With effect from Academic Year 2018-2019)

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

CALICUT - 673601

Vision of the Department of Electronics and Communication Engineering:

The Department of Electronics and Communication Engineering is envisioned to be a leading centre of higher learning with academic excellence in the field of electronics and communication engineering.

Mission of the Department in pursuance of its vision:

The mission of the Department of Electronics and Communication Engineering is to impart high quality technical education by offering undergraduate, graduate and research programs in the domain of Electronics and Communication Engineering with thorough foundation in theory along with strong hands-on design and laboratory components, tools and skills necessary for the students to become successful major contributors to society and profession.

The Program Educational Objectives (PEOs) of M.Tech. in Signal Processing

Sl. No.	Program Educational Objectives
PEO 1	To provide graduates strong mathematical skills and in depth knowledge in signal theory to analyze and solve complex problems in the domain of signal processing, imparting lateral thought, originality and creativity.
PEO 2	To instill research skills and bring in optimal solutions and novel products to signal processing and allied application areas using modern technology and tools that are technically sound, economically feasible and socially acceptable.
PEO 3	To enable the graduates to engage in lifelong learning in signal processing and its broad range of applications to understand the challenges of the rapidly changing environment and adapt their skills through reflective and continuous learning.
PEO 4	To inculcate professionalism, ethical attitude, communication skills, synergetic and leadership qualities and ability to relate engineering solutions to broader social context.

Programme Outcomes (POs) & Programme Specific Outcomes (PSOs) of M.Tech.in Signal Processing

PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PSO 1	Impart strong mathematical skills and in depth knowledge in signal theory and ability to analyze and solve complex problems in the domain of signal processing using modern technology and tools that results in optimal solutions and novel products that are technically sound, economically feasible and socially acceptable.
PSO 2	Ability to engage in lifelong learning so as to understand the challenges of the rapidly changing environment, learn the latest technologies and products and adapt their skills through reflective and continuous learning.

Curriculum for M. Tech. in Signal Processing (ECED)

Semester 1

Sl.No	Code	Title	L	T	P	C
1	EC6401D	Linear Algebra for Signal Processing	4	0	0	4
2	EC6301D	Random Processes	3	0	2	4
3	EC6402D	Digital Signal Processing Algorithms	3	0	2	4
4		Elective 1	3	0	0	3
5		Elective 2	3	0	0	3
		Total credits				18

Semester 2

Sl.No	Code	Title	L	T	P	C
1	EC6403D	Statistical Signal Processing	3	0	2	4
2	EC6404D	Information Theory and Source Coding	3	0	0	3
3	EC6405D	Seminar	0	0	2	1
3		Elective 3	3	0	0	3
4		Elective 4	3	0	0	3
5		Elective 5	3	0	0	3
		Total credits				17

Semester 3

Sl.No	Code	Title	L	T	P	C
1	EC7401D	Project: Part 1	0	0	24	12
		Total credits				12

Semester 4

Sl.No.	Code	Title	L	T	P	C
1	EC7402D	Project: Part 2	0	0	26	13
		Total credits				13

List of Electives

Sl.No	Code	Title	L	T	P	C
1	EC6421D	Digital Image Processing Techniques	3	0	0	3
2	EC6422D	Wavelets: Theory & Construction	3	0	0	3
3	EC6423D	Compressive Sensing: Theory and Algorithms	3	0	0	3
4	EC6424D	Speech Processing	3	0	0	3
5	EC6425D	Video Processing and applications	3	0	0	3

6	EC6426D	Multimedia Security	3	0	0	3
7	EC6427D	Transform Theory	3	0	0	3
8	EC6428D	Neural Networks	3	0	0	3
9	EC6429D	Computer Vision Algorithms	3	0	0	3
10	EC6430D	Multidimensional Signal Processing	3	0	0	3
11	EC6431D	Pattern Recognition and Analysis	3	0	0	3
12	EC6432D	Multirate Signal Processing and Filter Banks	3	0	0	3
13	EC6433D	Adaptive Signal Processing	3	0	0	3
14	EC6434D	Linear and Nonlinear Optimization	3	0	0	3
15	EC6435D	Foundations of Data Analytics	2	0	2	3
16	EC6436D	Reinforcement Learning	3	0	0	3

Notes:

- A minimum of 60 credits have to be earned for the award of M. Tech Degree in this Programme.
- A minimum of three elective courses must be credited from the list of electives given for the specialization. A maximum of two electives can be credited from courses offered in any M.Tech. specialization by the Institute, with the consent of the HOD, the Programme Coordinator and the Course Faculty.

EC6401D LINEAR ALGEBRA FOR SIGNAL PROCESSING

Pre-requisites: Nil

L	T	P	C
4	0	0	4

Total hours: 52

Course Outcomes

CO1: Demonstrate the foundation concepts on Signal Theory and System Theory applicable to communication Engineering and Signal Processing
CO2: Apply the mathematical framework of Signal Theory and System Theory for Analysis and Design
CO3: Recommend basic concepts that enable designs for environment-friendly direct applications
CO4: Develop ability to think clearly and express precisely, coupled with systematic logical reasoning.

Module 1: (17 hours)
Algebraic Structures: Definitions and properties of Semigroups, Groups, Rings, Fields, and Vector Spaces, Homomorphisms.
Vector Spaces and Linear Transformations: Linear Spaces and Subspaces, and Direct Sums; Linear Independence, Bases, and Dimension; Linear Transformations, Linear Functionals, Bilinear Functionals, and Projections.
Finite-Dimensional Vector Spaces and Matrices: Coordinate representation of vectors, change of basis and change of coordinates; Linear operators, Null space and Range space; Rank-Nullity theorem, Operator inverses, Application to matrix theory, Computation of the range space and null space of a matrix;Matrix of an operator, Operator algebra, change of basis and similar matrices.

Module 2: (18 hours)
Inner Product Spaces: Definition of inner product, norms, angle between vectors**;** Orthogonal sets, Fourier coefficients and Parseval's identity, Gram-Schmidt process, QR factorization; Approximation and orthogonal projection, Computations using orthogonal and non-orthogonal sets, Normal equations; Projection operator, Orthogonal complements, Decomposition of vector spaces, Gram matrix and orthogonal change of basis, Rank of Gram matrix.
Normed Linear Spaces: Metric and metric spaces, Neighborhoods, open and closed sets, Sequences and Series, Continuity and convergence; Norms, Completeness and compactness, Continuous linear transformations, Inverses and Continuous inverses, Complete Normed Linear Space; Norm induced by the Inner product, Hilbert spaces.

Module 3: (17 hours)
Diagonalizable linear operators: Eigenvalues and Eigenvectors, Spectrum and Eigen spaces of an operator, Properties of the characteristic polynomial, Geometric and algebraic multiplicities; Linear operators with an Eigen basis, Diagonalizability and Similarity Transformation; Cayley-Hamilton Theorem, Nilpotent Transformations. Jordan Canonical form.
Quadratic forms: Definition and Properties of quadratic forms; Hermitian forms, Orthogonal Diagonalization and the Principal axis theorem, Simultaneous diagonalization of quadratic forms.
Factorizations: Singular value and Polar Decompositions, The pseudoinverse and the generalized pseudoinverse.

References:

1. Gilbert Strang, "Introduction to Linear Algebra," 4th Edition, Wellesley-Cambridge Press, MA, 2009.
2. Kenneth Hoffman, Ray Kunze, "Linear Algebra," 2nd Edition, PHI Learning, Delhi, 2014.
3. Anthony N. Michel, Charles J. Herget, "Applied Algebra and Functional Analysis," Dover Publications, NY, 1993.
4. Arch W. Naylor, George R. Sell, "Linear Operator Theory in Engineering and Science," Springer-Verlag, NY, 2000
5. James M. Ortega, "Matrix Theory: A Second Course," Plenum Press/Kluwer Academic, NY, 1987.

EC6301D: RANDOM PROCESSES

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total hours: 39

Course Outcomes:

CO1: Define random variables and random vectors corresponding to random experiments and to derive their probability distribution functions.
CO2: Demonstrate the use of conditional distributions and moments, Markov and Chebyshev inequalities, and the fundamental laws of large numbers.
CO3: Apply the concept of correlation, covariance and power spectral density of stationary random processes.
CO4: Analyze linear systems involving random processes with special focus on telecommunications and signal processing applications.

Module I: (13 hours)
Probability axioms, conditional probability, discrete and continuous random variables, cumulative distribution function (CDF), probability mass function (PMF), probability density function (PDF), conditional PMF/PDF, expected value, variance, functions of a random variable, expected value of the derived random variable, multiple random variables, joint CDF/PMF/PDF ,functions of multiple random variables, multiple functions of multiple random variables, independent/uncorrelated random variables, sums of random variables, moment generating function, random sums of random variables.

Module 2: (13 hours)
Sample mean, laws of large numbers, central limit theorem, convergence of sequence of random variables, Introduction to random processes, specification of random processes, nth order joint PDFs, independent increments, stationary increments, Markov property, Markov process, Gaussian process, Poisson process and Brownian motion.

Module 3: (13 hours)
Mean and correlation of random processes, stationary, wide sense stationary and ergodic processes. Random processes as inputs to linear time invariant systems, power spectral density, Gaussian processes as inputs to LTI systems, white Gaussian noise, In-Phase and quadrature representation of random processes.

References:

1. Papoulis and S. U. Pillai, Probability, Random Variables and Stochastic Processes, 4th Edition, McGraw Hill 2002.
2. Geoffrey Grimmett, Probability and Random Processes, 3rd edition, Oxford University Press 2001.
3. Henry Stark and John W. Woods, Probability and Random Processes with Applications to Signal Processing, Prentice Hall, 3rd Edition 2001.
4. Sheldon M. Ross, A First Course in Probability, Prentice Hall, 2013.
5. Anurag Kumar, Discrete Event Stochastic Processes, Lecture Notes for an Engineering Curriculum,Department of Electrical Communication Engineering. Indian Institute of Science, Benguluru, 2012.

EC6402D DIGITAL SIGNAL PROCESSING ALGORITHMS

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total hours: 39

Course Outcomes:

CO1: Acquire concrete knowledge on various signal representations and their applications.
CO2: Identify formulate and design techniques and transformations for signal processing algorithms which aid in efficient hardware implementation of them in terms of computational complexity.
CO3: Apply software based modeling, simulation and design tools necessary for practical implementation of DSP architectures recognizing the needs and challenges of our age and assessing the global and social impacts of familiar signal processing applications.
CO4: Develop skills to explore advanced topics in the latest research areas of DSP system design at the algorithmic and architectural levels through case studies, group works and seminars which will enable them to engage in lifelong learning in specific areas of interest.

Module 1: (15 hours)
Digital Signal Representations: Basic representation of 1-D, 2-D and 3-D signals for processing in digital domain. Signal representation using transforms - Fourier and its variations, Signal decomposition using KLT, SVD and applications.
Filter structures for efficient hardware implementation: Review of FIR and IIR filter structures, Lattice filter structures - Schur Algorithm - derivation of basic, one multiplier and normalized lattice filter. Applications.
Review of number representation - Fixed point and floating point number representations - Finite word length effects in digital filters

Module 2: (11 hours)
Efficient DSP hardware architecture: Overview of various implementation platforms and various levels of optimization for DSP algorithms, Algorithm level optimizations and computational reduction for DSP - Fast algorithms for convolution, Algorithmic strength reduction in filters and transforms.

Module 3: (13 hours)
Representation of DSP algorithms: Block diagrams, Signal Flow graph, data flow graph, dependence graph.
DSP Arithmetic: Algorithms and Arithmetic architectures for addition, multiplication, and division - High performance arithmetic unit architectures (adders, multipliers, dividers) - bit-parallel, bit-serial, digit-serial, carry-save architectures - Canonic Sign Digit arithmetic - Distributed arithmetic- Introduction to redundant arithmetic and architectures - Numerical strength reduction.
VHDL / C programming to assess the computational advantages of various methods covered.

References:
1. Keshab K. Parhi, VLSI Signal Processing Systems, Design and Implementation.John Wiley & Sons, 2008.
2. Bhattacharyya, S.S., Deprettere, E.F., Leupers, R., Takala, J. (Eds.), Handbook of Signal Processing Systems, 2nd Edition, 2013.
3. Roger Woods, John McAllister, Ying Yi, and Gaye Lightbody, FPGA-based implementation of signal processing systems, John Wiley & Sons, 2008.
4. Lars Wanhammar, DSP Integrated Circuits, , Academic Press, 1999
5. John G. Proakis , Dimitris Manolakis K, DSP Principles, Algorithms and Applications, Prentice Hall 1995
6. L. R. Rabiner, B. Gold, Theory and Application of Digital Signal Processing, Prentice-Hall, 1975.

EC6403D STATISTICAL SIGNAL PROCESSING

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total hours: 39

Course Outcomes:

CO1: Analyse signals and develop their statistical models for efficient processing
CO2: Formulate filtering problems from real life applications and design filtering solutions to estimate a desired signal from a given mixture by minimizing a cost function
CO3: Design and analyse efficient algorithms for estimation of various parameters of signals with different constraints
CO4: Develop efficient methods for spectrum and frequency estimation suiting the requirements derived from practical problems

Module 1: (15 hours)

Signal Modelling and Estimation: Statisticalmodelling of signals – Spectral factorization – AR, MA and ARMA models- Yule Walker equations- Estimating signal from a mixture – MMSE estimation - Weiner filtering – FIR and IIR Wiener filter – Prediction –Levinson-Durbin recursion- Lattice filter- Cholesky decomposition- Least Squares filtering

Module 2: (14 hours)

Classical Parameter Estimation Techniques: Signal parameter estimation –Minimum Variance Unbiased Estimators (MVUE)- Scalar and Vector parameter estimation scenarios, Cramer Rao Lower Bound (CRLB),Parameter estimation with linear models, Best Linear Unbiased Estimator (BLUE), Maximum Likelihood Estimator (MLE), Non-linear MLE

Module 3: (10 hours)

Spectrum Estimation:Non parametric spectrum estimation –Periodogram – Bartlett’s method - Minimum variance estimation- Parametric methods – Frequency estimation – Eigen decomposition of auto correlation matrix - MUSIC –Principal components spectral estimation

References:

1. Dimitris G. Manolakis, Vinay K. Ingle, Stephen M. Kogon, “Statistical and Adaptive Signal Processing: Spectral Estimation, Signal Modeling, Adaptive Filtering, and Array Processing”, McGraw-Hill, 2005
2. Monson H. Hayes, “Statistical Digital Signal Processing And Modeling”, 1st Edition, Wiley India Pvt Ltd, 2008
3. Steven M. Kay, “Fundamentals of Statistical Signal Processing, Volume I: Estimation Theory”, Prentice Hall, 1993
4. Harry L. Van Trees,Kristine L. Bell,“ ,Zhi TianDetection Estimation and Modulation Theory, Part I: Detection, Estimation, and Filtering Theory”, 2nd Edition, Wiley-Blackwell, 2013.

EC6404D INFORMATION THEORY AND SOURCE CODING

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total hours: 39

Course Outcomes:

CO1: Acquire mathematical preliminaries for the theory behind Lossy and Lossless Compression of data and understand basic compression algorithms for Lossless and Lossy data Compression.
CO2: Identify, formulate and solve signal compression problems using modern signal processing tools recognizing the needs and challenges of our age and assessing the global and social impacts of data compression problems and its solutions.
CO3: Design data compression systems by choosing appropriate model for the data and integrate algorithms which leads to optimal solution satisfying the rate constraints of the given application.
CO4: Develop skills to explore advanced topics in the recent research areas of data compression through active cooperative learning, that enable them to solve complex problems and engage in lifelong learning.

Module 1: (15 hours)
Information Theory: Entropy- Memory less sources- Markov sources- Entropy of a discrete Random variable- Joint, conditional and relative entropy- Mutual Information and conditional mutual information- Differential Entropy- Joint, relative and conditional differential entropy- Mutual information
Lossless source coding- Uniquely decodable codes- Instantaneous codes- Kraft's inequality - Optimal codes- Huffman code- Shannon's Source Coding Theorem. Extended Huffman Coding - Adaptive Huffman Coding - Arithmetic Coding - Adaptive Arithmetic coding, Run Length Coding, Dictionary Techniques - Lempel-Ziv coding, Applications - Predictive Coding Techniques.

Module 2: (12 hours)
LossyCompression:Rate distortion theory: Rate distortion function R(D),Properties of R(D); Calculation of R(D) for the binary source and the Gaussian source, Rate distortion theorem, Converse of the Rate distortion theorem, Quantization - Uniform &Nonuniform - optimal and adaptive quantization, vector quantization and structures for VQ, Optimality conditions for VQ, Predictive Coding - Differential Encoding Schemes.

Module 3: (12 hours)
Review of Transforms - Transform coding - Subband coding - Wavelet Based Compression - Analysis/Synthesis Schemes - Data Compression standards: Speech Compression Standards,Audio Compression standards, Image Compression standards, Video Compression Standards.

References:

1. Khalid Sayood, Introduction to Data Compression, Morgan Kaufmann Publishers., Second Edn., 2005.
2. David Salomon, Data Compression: The Complete Reference, Springer Publications, 4th Edn., 2006.
3. Thomas M. Cover, Joy A. Thomas, Elements of Information Theory, John Wiley & Sons, Inc., 2006.
4. David J. C. MacKay, Information Theory, Inference and Learning Algorithms, Cambridge University Press, 2003
5. Toby Berger, Rate Distortion Theory: A Mathematical Basis for Data Compression, Prentice Hall,1971

EC6405D SEMINAR

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total Hours: 26P

Course Outcomes:

CO1: Survey the literature on new research areas and compile findings on a particular topic
CO2: Organize and illustrate technical documentation with scientific rigor and adequate literal standards on the chosen topic strictly abiding by professional ethics while reporting results and stating claims.
CO3: Demonstrate communication skills in conveying the technical documentation via oral presentations using modern presentation tools.

The objective of the seminar is to impart training to the students in collecting materials on a specific topic in the broad domain of Engineering/Science from books, journals and other sources, compressing and organizing them in a logical sequence, and presenting the matter effectively both orally and as a technical report. The topic should not be a replica of what is contained in the syllabi of various courses of the M.Tech program. The topic chosen by the student shall be approved by the Faculty-in-Charge of the seminar. The seminar evaluation committee shall evaluate the presentation of students. A seminar report duly certified by the Faculty-in-Charge of the seminar in the prescribed form shall be submitted to the department after the approval from the committee.

EC7401D PROJECT: PART 1

Pre-requisites: Nil

Total Hours: 312P

L	T	P	C
0	0	24	12

Course Outcomes:

CO1: Develop aptitude for research and independent learning.
CO2: Demonstrate the ability to carry out literature survey and select unresolved problems in the domain of the selected project topic.
CO3: Gain the expertise to use new tools and techniques for the design and development.
CO4: Acquire the knowledge and awareness to carry out cost-effective and environment friendly designs.
CO5: Develop the ability to write good technical report, to make oral presentation of the work and to publish the work in reputed conferences/journals.

The major project in the third and fourth semesters offer the opportunity to apply and extend knowledge acquired in the first year of the M. Tech. program. The major project can be analytical work, simulation, hardware design or a combination of these in the emerging areas of Signal Processing and Communication Engineering under the supervision of a faculty from the ECE Department. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students will be required to1) perform a literature search to review current knowledge and developments in the chosen technical area; 2) undertake detailed technical work in the chosen area using one or more of the following:

- Analytical models
- Computer simulations
- Hardware implementation

The emphasis of major project shall be on facilitating student learning intechnical, project management and presentation spheres. Project work will be carried out individually. The M. Tech. project evaluation committee of the department shall evaluate the project work during the third semester in two phases. The first evaluation shall be conducted in the middle of the semester. This should be followed by the end semester evaluation. By the time of the first evaluation, students are expected to complete the literature review, have a clear idea of the work to be done, and have learnt the analytical / software / hardware tools. By the time of the second evaluation, they are expected to present the results of their advancements in the chosen topic, write an interim technical report of the study and results and clearly state the work plan for the next semester..

EC7402D PROJECT: PART 2

Pre-requisites: Successful completion of EC7401D Project: Part 1

L	T	P	C
0	0	26	13

Total Hours: 338P

EC7402D Project: Part 2 is a continuation of EC7401D Project: Part 1in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their innovative ideas and results in reputed conferences and/or journals. The M. Tech. project evaluation committee of the department shall evaluate the project work during the fourth semester in two phases. The first evaluation shall be conducted towards the end of the semester. This should be followed by a second evaluation by the committee including an external examiner.

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Detailed Syllabus: Electives

EC6421D DIGITAL IMAGE PROCESSING TECHNIQUES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Demonstrate the methods of image acquisition, representation and manipulation to design and develop algorithms for solving image processing problems related to various applications like medicine, industry, communications etc.
CO2: Analyze various image processing algorithms for preprocessing, restoration, compression and segmentation using various spatial and frequency domain methods
CO3: Identify and solve complex real world problems in image processing using modern signal processing tools, active cooperative learning and be able to demonstrate them effectively.
CO4: Acquire skills to conduct independent study and analysis of image processing problems and techniques that would engage in lifelong learning.

Module 1: (12 hours)
Image representation: Gray scale and colour Images, image sampling and quantization, colour spaces. Connectivity and relations between pixels.Simple manipulations of pixels - arithmetic, logical and geometric operations. Various techniques for image enhancement and restoration - filters in spatial and frequency domains, histogram-based processing, homomorphic filtering, Image Registration. Examples and case studies.

Module 2: (13 hours)
Morphological Image Processing: The structuring element, Basic operations on sets, Erosion, Dilation, Opening and Closing, Hit-or-Miss Transform, Basic Morphological Algorithms and applications.
Image segmentation: Edge detection, line detection, curve detection, Edge linking and boundary extraction, boundary representation, region representation and segmentation - Thresholding, Otsu's Method, Variable and multi variable thresholding, Similarity based Segmentation - Segmentation Using Morphological Watersheds, Use of Motion in Segmentation.Image representation and object recognition: Descriptors for boundaries and regions, global descriptors – Pattern recognition as applied to images.

Module 3: (14 hours)
Fundamental concepts of image compression - Compression models - Information theoretic perspective - Fundamental coding theorem - Lossless Compression: Huffman Coding- Arithmetic coding - Bit plane coding - Run length coding - Lossy compression: Quantization – Scalar and Vector, Transform coding - Image compression standards, Introduction to Sub band coding. Basic concepts of video compression, Introduction to video compression standards.

References:

1. R. C. Gonzalez, R. E. Woods*,* Digital Image Processing, Pearson Education. III Ed.,2016
2. Jain A.K., Fundamentals of Digital Image Processing, Prentice-Hall, 2002.
3. Jae S. Lim, Two Dimensional Signal And Image Processing, Prentice-Hall, Inc, 1990.
4. Pratt W.K., Digital Image Processing, John Wiley, IV Edition, 2007.
5. K. R. Castleman, Digital image processing, Prentice Hall, 1996.

EC6422D WAVELETS: THEORY & CONSRUCTION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply the mathematical basis of the wavelet transform and its performance in the analysis of non-stationary signals
CO2: Apply the concepts, theory and algorithms behind wavelet transform and wavelet packet transform from an interdisciplinary perspective.
CO3: Build the concept of dyadic multi resolution analysis and relate it to filter banks
CO4: Construct Wavelets using the time domain and frequency domain approaches
CO5: Explore the applications of wavelets and wavelet packets in transient analysis, biomedical signal processing, speech, audio, image and video coding, signal denoising, pattern recognition etc.

Module I (12 hrs)
Introduction - Stationary and non-stationary signals - Signal representation using basis and frames-Brief introduction to Fourier transform and Short time Fourier transform - Time frequency analysis- The uncertainty principle and its implications- Piecewise Constant Approximation – the Haar Wavelet – Building up the concept of Multi resolution Analysis (MRA) and Relating it to filter banks.

Module 2 (14 hrs)
Continuous wavelet transform (CWT) - Condition of admissibility and its implications – Inverse Continuous Wavelet Transform - Discrete Wavelet Transform And Filter banks - Construction of wavelets using time domain and frequency domain approaches - Computation of the discrete wavelet transform using Mallat Algorithm and Lifting Scheme - Two dimensional wavelet transforms and Extensions to higher dimensions.

Module 3 (13 hrs)
Wavelet Packet Transform – Signal representation using wavelet packet analysis – selection of best basis. Applications of Wavelets and Wavelet Packets in Signal and Image compression - Detection of signal changes - analysis and classification of audio signals - Wavelet based signal de-noising and energy compaction - Image fusion, Edge Detection and object isolation – Biomedical Signal Processing Applications.

References

1. M. Vetterli, J. Kovacevic, Wavelets and Subband Coding, Prentice Hall Inc, 1995.
2. Gilbert Strang and Truong Q. Nguyen, Wavelets and Filter banks, 2nd Edition, Wellesley-CambridgePress,1998.
3. Raghuvir Rao and Ajit S. Bopardikar, Wavelet Transforms : Introduction, Theory and Applications, Pearson Education , 2000.
4. J.C. Goswami and A.K. Chan, Fundamentals of Wavelets: Theory, Algorithms and Applications, 2nd Ed, WILEY, 2011.
5. K. P.Soman and K L Ramachandran*,* Insight into wavelets from theory to practice, PHI, 2008

EC6423D COMPRESSIVE SENSING: THEORY AND ALGORITHMS

Pre-requisites: EC6401D Linear Algebra for Signal Processing

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Develop mathematical framework for multi-rate systems, and multi-band and multi-resolution representation of signals.
CO2: Apply compressed sampling for energy-efficient designs.
CO3: Apply mathematical principles for cost-effective practical designs.
CO4: Develop ability to think clearly with sound logical reasoning to unfold new theory and design methods.

Module 1: (15 Hours)
Fundamentals of Sampling Analog Signals: Classical sampling theorem for band-limited signals; Bandpass sampling theorem; Sample-rate reduction and multi-channel sampling; Sampling of random signals; Sampling of duration-limited signals and motivation for compressed sampling.
Signal Models - Mathematical Preliminaries: Sampling as a signal representation problem; Signal spaces: normed linear spaces - topology, Convergence, completeness and stable signal synthesis; Finite and infinite dimensional signal spaces; Hamel basis, Schauder basis and Riesz basis; Orthogonality and bi-orthogonality; Frames; Linear transformations and change of basis; Sampling as an isomorphism; Separable signal spaces, Quotient spaces and, Decomposition of signals; Under-determined system of equations - methods of solution, sparse solution.

Module 2: (12 Hours)
Compressed Sensing: Sparse representation of signals - Sparsity and compressibility; Construction of measurement basis - Sensing matrix; Null-space conditions and the spark; Johnson-Lindenstrauss (JL) lemma; The Restricted Isometry Property(RIP); relation between JL lemma and the RIP; RIP and null-space property; Measurement bounds and condition for stable recovery; Coherence of measurement basis; mutual coherence between sensing and representation bases.

Module 3: (12 Hours)
Sparse Signal Recovery: Recovery through l_1-norm minimization; Recovery under noiseless and noisy conditions; Algorithms for sparse recovery - Design requirements; Convex optimization based methods: linear programming, fixed-point continuation, Bergman iteration; Greedy algorithms: Matching pursuit, Orthogonal matching pursuit, Stage-wise orthogonal matching pursuit, Regularized orthogonal matching pursuit (ROMP); Compressive sampling matching pursuit (CoSaMP); Iterative reweighted least squares (IRLS) algorithm; Performance analysis.

References
1. Yonina C. Eldar and Gitta Kutyniok, Compressed Sensing: Theory and Applications, Cambridge University Press, 2012.
2. Richard G. Baraniuk, Mark A. Davenport, Marco F. Duarte, Chinmay Hegde (Collection Editors), An Introduction to Compressive Sensing, CONNEXIONS (Publishing) Rice University, Houston, Texas, 2012.
3. Michael Elad, Sparse and Redundant Representations, Springer, New York, 2010.
4. S. G. Mallat, A Wavelet Tour of Signal Processing: The Sparse Way, Academic Press/Elsevier, 2009.
5. Simon Foucart, Holger Rauhut, A Mathematical Introduction to Compressive Sensing, Birkhauser, 2013.

EC6424D SPEECH PROCESSING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Derive the digital model of speech production
CO2: Develop algorithms for speech analysis and synthesis
CO3: Implement, compare and critically analyze various speech coding techniques in terms of bit rate and perceptual quality
CO4: Apply programming tools to implement systems for speech enhancement, speech and speaker recognition, digital hearing aids etc.

Module I (13 hrs)
Digital models for the speech signal - mechanism of speech production - acoustic theory - lossless tube models – digital models - linear prediction of speech – auto correlation - formulation of LPC equation - solution of LPC equations - Levinson Durbin algorithm - Levinson recursion - Schur algorithm - lattice formulations and solutions – PARCOR coefficients - Spectral analysis of speech - Short Time Fourier analysis - filter bank design. Auditory Perception : Psychoacoustics- Frequency Analysis and Critical Bands - Masking properties of human ear.

Module 2 (13 hrs)
Speech coding -subband coding of speech - transform coding - channel vocoder - formant vocoder - cepstral vocoder -vector quantizer coder- Linear predictive Coder. Speech synthesis - pitch extraction algorithms - Gold Rabiner pitch trackers - autocorrelation pitch trackers - voice/unvoiced detection - homomorphic speech processing – homomorphic systems for convolution - complex cepstrum - pitch extraction using homomorphic speech processing. Sound Mixtures and Separation - CASA, ICA & Model based separation.

Module 3 (13 hrs)
Speech Transformations - Time Scale Modification - Voice Morphing. Automatic speech recognition systems – isolated word recognition - connected word recognition -large vocabulary word recognition systems - pattern classification – Dynamic Time Warping – Hidden Markov Modeling - speaker recognition systems - speaker verification systems – speaker identification Systems - ANN techniques for Speech and Speaker recognition . Speech Enhancement Techniques –– Approaches and Challenges in the design of Digital Hearing Aids.

References
1. Lawrence R. Rabiner and Ronald W. Schafer, Theory and Applications of Digital Speech Processing Pearson, 2010
2. O'Shaughnessy, D, Speech Communication, Human and Machine*,* Addison-Wesley, 1987
3. Thomas F. Quatieri , Discrete-time Speech Signal Processing: Principles and Practice, Prentice Hall, Signal Processing Series, 2002
4. Philipos C. Loizou, Speech Enhancement – Theory and Practice, CRC Press, 2013
5. John N. Holmes, Wendy J. Holmes, Speech Synthesis and Recognition, Taylor and Francis, 2nd Edition, 2003.
6. Tokunbo Ogunfunmi, Roberto Togneri, Madihally Narasimha, Speech and Audio Processing for Coding, Enhancement and Recognition, Springer, 2015

EC6425D VIDEO PROCESSING AND APPLICATIONS

Pre-requisites: EC6421D Digital Image Processing Techniques

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Demonstrate the methods of video representation, motion estimation and manipulation to design and develop algorithms for solving video processing problems related to various applications fields involving video data.

CO2: Develop mathematical skills to solve video processing problems and apply them to model real life problems in video processing that meets the challenges of our age considering its social impacts.

CO3: Identify and solve complex real world problems in video processing using modern signal processing tools, active cooperative learning and be able to demonstrate them effectively.

CO4: Acquire skills to conduct independent study and analysis of video processing problems and techniques that would also engage the scholar in lifelong learning

Module 1: (14 hours)

Representation of digital video: Introduction and fundamentals, Time-varying image formation models: Motion models, Geometric image formation.Spatio-temporal sampling: Sampling of analog and digital video, Two-dimensional rectangular and periodic sampling, Sampling of 3-D structures, Reconstruction from samples.

Video Motion estimation**:** Two dimensional, Optical flow, General methodologies, Pixel based motion estimation, Block matching algorithm, Deformable block matching algorithm, Mesh based motion estimation, Global motion estimation, Region based motion estimation, Multiresolution motion estimation

Feature based Motion Estimation, Direct motion Estimation, Iterative model.

Module 2: (13 hours)

Video coding: Basics of video coding, Content dependent video coding, Two dimensional shape coding, Texture coding for arbitrarily shaped region, Joint shape and texture coding, Region based video coding, Object based video coding, Knowledge based video coding, Semantic video coding, Layered coding system, Scalable video coding, Basic modes of scalability, Object based scalability, Wavelet transform based coding, Application of motion estimator in video coding.

Video Compression Standards; MPEG-4 Visual and H.264/AVC: Standards for Modern Digital Video; H.265/HEVC, HEVC Coding tools and extensions.

Module 3: (12 hours)

Stereo and multi view sequence processing: Depth perception Stereo imaging principle Disparity estimation Intermediate view synthesis Stereo sequence coding. Video Segmentation: Motion Segmentation; Tracking; Motion Tracking in Video: 2D and 3D Motion Tracking in Digital Video, Methods using Point Correspondences, Optical Flow and Direct Methods, Applications

References:

1. A. Murat Tekalp, Digital Video Processing, Prentice Hall, 2nd Edition, 2015.
2. Alan C. Bovik, The Essential Guide to Video Processing, Elsevier Science, 2nd Edition, 2009.
3. Yao Wang, Jorn Ostermann, Ya-Qin Zhang, Video Processing and Communications, Prentice Hall, 2002.
4. Iain E. Richardson, H.264 and MPEG-4 Video Compression: Video Coding for Next-generation Multimedia, John Wiley & Sons, 2nd Edition, 2003.
5. J.W. Woods, Multidimensional Signal, Image and Video Processing and Coding, Academic Press, 2nd edition, 2012.

EC6426D MULTIMEDIA SECURITY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyse the security challenges in distribution of multimedia contents in a network and identify the possible solutions

CO2: Devise efficient steganographic methods for hiding various types of data such as secret information, watermark in different types of multimedia data with high packing density and low probability of detection

CO3: Design encryption schemes for ensuring the secrecy of multimedia data such audio, image and video facilitating real time operation

CO4: Devise fingerprinting methods for securely distributing the multimedia data in public without risk of illegal copying and redistribution

Module 1: (15 hours)
Basic Cryptography: Basic cryptographic services- confidentiality- integrity verification – authentication – primitives for the services – one way functions - symmetric and asymmetric schemes- encryption – block ciphers and stream ciphers - hashing – authentication codes – digital signatures.

Module 2: (14 hours)
Data hiding and authentication: Data hiding algorithms and applications – steganography and steganalysis- statistical techniques-authentication of audio, image and video data - digital rights management – watermark embedding and retrieval - digital fingerprinting – anti collusion codes-biometrics and digital forensics – biometric encryption - privacy preserving data mining.

Module 3: (10 hours)
Multimedia Encryption: Protection of multimedia data during distribution – vulnerabilities and challenges– encryption schemes for audio, image and video data – streaming of encrypted multimedia – partial and progressive encryption techniques- signal processing in encrypted domain.

References:

1. William Stallings, Cryptography and Network Security: Principles and Practice, 7th Edition, Pearson Education Limited, 2016
2. BorkoFurht, DarkoKirovski, Multimedia Encryption and Authentication Techniques and Applications, Auerbach Publications, 2006
3. BorkoFurht, DarkoKirovski, Multimedia Security Handbook, CRC Press, 2004.
4. Alfred J. Menezes, Jonathan Katz, Paul C. van Oorschot, Scott A. Vanstone, Handbook of Applied Cryptography, 5th Edition, CRC Press, 2001

EC6427D TRANSFORM THEORY

Pre-requisites: EC6401D Linear Algebra for Signal Processing

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes

CO1: Develop foundation concepts of Transformations on vector spaces.
CO2: Interpret representations of signals in various domains amenable for further processing.
CO3: Develop analytical skills and ability to synthesize starting from first principles.
CO4: Develop creative, scientific thinking and ability to visualize subtle concepts leading to cost effective and environment-friendly designs.
CO5: Develop clarity of thoughts, logical reasoning and ability to express thoughts with precision

Module 1: (8 Hours)
Linear Operators on Finite-dimensional Vector Spaces: Eigenvalue problems, Eigenspace of a linear operator, Linear operators with an Eigenbasis, decomposition of vector spaces, Similarity transformation; Simultaneous Diagonalization of linear operators, Primary decomposition theorem, Jordan Canonical form/decomposition; Fredholm alternative theorem, Least squares solutions and pseudo-inverses, LU decomposition, Orthogonal transformations, Householder transform.

Module 2: (16 Hours)
Bounded Linear Operators on Hilbert spaces and Spectral Theory: Bounded linear operators in finite dimensional inner product spaces - Adjoint of an operator, Norm of an operator; Self-adjoint operators - Spectral analysis of self-adjoint operators; Bessel's inequality, Parseval's identity; Reisz Representation Theorem, Compact linear operators.
Bases and Frames: Reisz basis, Resolution of unity, Definition of frames, Geometrical considerations and the general notion of a frame, Frame projector, Example - windowed Fourier frames; wavelet frames.

Module 3: (15 Hours)
Theory of Distributions: Generalized functions and the Dirac's delta; Differential operators - Green's function and the inverse linear operators.
The Making of Integral Transforms: The making of Laplace transform and Fourier transform, Self-reciprocal functions and operators under Fourier transform - The construction of Fractional Fourier transform; Construction of z-transform - Discrete-time Fourier transform and discrete Fourier transform.
Lapped Transforms: Karhunen-Loevetransform; Lapped orthogonal transforms and biorthogonal transforms; Construction of discrete cosine and sine transforms.

References

1. Arch W. Naylor and George R. Sell, Linear Operator Theory in Engineering and Science, 2nd Edition, Springer-Verlag, New York, 2000.
2. LokenathDebnath and PiotrMikusinski, Hilbert Spaces with Applications, 3rd Edition, Academic Press, 2006.
3. Erwin Kreyszig,Introductory Functional Analysis with Applications, John Wiley and Sons, 2007.
4. Stephen G. Mallat, A Wavelet Tour of Signal Processing, 2nd Edition, Academic Press, 2000.
5. Ole Christensen, Frames and Bases: An Introductory Course, Birkhauser, 2008.

EC6428D NEURAL NETWORKS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyze basic mathematical and statistical techniques to build basic neural networks.
CO2: Design and implement neural networks to classify real world data.
CO3: Create learning systems by forming sound decisions on real world problems.
CO4: Develop skill to conduct independent research in the area of neural networks for feature extraction and classification.

Module 1: (13 hours)
Biological Model, computational models, neurons, network of neurons, artificial networks, McCulloh-Pitts network, Boolean function synthesis, feed forward and recurrent networks, weighted and non-weighted networks, Hadamard-Walsh transform, perceptrons, geometric interpretation, implementation of logical functions, separable functions, X-OR problem, error functions.
Pyramidal networks, perceptron learning, supervised and unsupervised networks, pocket algorithm, perception learning complexity. Competitive learning algorithm, clustering, unsupervised reinforcement learning, principal components, PCA.

Module 2: (15 hours)
Multiple layered networks, solution of X-OR problem, over-fitting, local minima, learning as gradient descent, differentiable activation functions, back propagation algorithm, fast back propagation, logistic regression, Bootstrap algorithm, hidden Markov models, Viterbi algorithm.
Associative networks - types of networks, associative learning, Hebbian learning, Hopfield model, simulated annealing, stochastic neural networks, Boltzmann learning, Self-organizing networks-Kohonen learning.

Module 3: (11 hours)
Deep network – bias-variance trade-off, regularization, output units - linear, softmax.Hidden units –tanh, ReLU, RLU. Dropout, Convolutiuonal neural networks, Deep belief nets, recurrent neural networks, unsupervised deep learning - auto encoders, deep reinforcement learning.

References:

1. Raul Rojas, Neural Networks – A systematic introduction, Springer-Verlag, Berlin, New-York, 1996.
2. Ian Goodfellow and YoshuaBengio and Aaron Courville, Deep learning, MIT Press, 2016.
3. S Theodoridis, K Koutroumbas, Pattern Recogntion, 4th Edition, Academic Press, 2009.
4. C. Bishop, Pattern Recognition and Machine Learning, Springer, 1st ed. 2006

EC6429D COMPUTER VISION ALGORITHMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Outline the foundation of image formation and image analysis
CO2: Analyze the basic techniques commonly used in depth estimation and multi-camera views.
CO3: Develop the basic skill to address feature extraction and image segmentation problems.
CO4: Obtain the fundamental knowledge to analyze pattern and motion analysis.

Module 1: (13 hours)
Digital Image Formation and low-level processing: Overview and State-of-the-art, Fundamentals of Image Formation, Transformation: Orthogonal, Euclidean, Affine, Projective, etc; Fourier Transform, Convolution and Filtering, Image Enhancement, Restoration, Histogram Processing.
Depth estimation and Multi-camera views: Perspective, Binocular Stereopsis: Camera and Epipolar Geometry; Homography, Rectification, DLT, RANSAC, 3-D reconstruction framework; Auto-calibration. apparel
.
Module 2: (13 hours)
Feature Extraction: Edges - Canny, LOG, DOG; Line detectors (Hough Transform), Corners - Harris and Hessian Affine, Orientation Histogram, SIFT, SURF, HOG, GLOH, Scale-Space Analysis- Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT.
Image Segmentation: Region Growing, Edge Based approaches to segmentation, Graph-Cut, Mean-Shift, MRFs, Texture Segmentation; Object detection.

Module 3: (13 hours)
Pattern Analysis: Clustering: K-Means, K-Medoids, Mixture of Gaussians, Classification: Discriminant Function, Supervised, Un-supervised, Semi-supervised;Classifiers: Bayes, KNN, ANN models; Dimensionality Reduction: PCA, LDA, ICA; Non-parametric methods.
Motion Analysis: Background Subtraction and Modeling, Optical Flow, KLT, Spatio-Temporal Analysis, Dynamic Stereo; Motion parameter estimation.
Object Recognition: Hough transforms and other simple object recognition methods, Shape correspondence and shape matching, Shape priors for recognition.

References:

1. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer-Verlag London Ltd. 2011.
2. Richard Hartley and Andrew Zisserman, Multiple View Geometry in Computer Vision, Second Edition, Cambridge University Press, 2004.
3. K. Fukunaga, Introduction to Statistical Pattern Recognition, 2nd Edn, Academic Press, Morgan Kaufmann, 2014.
4. R.C. Gonzalez and R.E. Woods, Digital Image Processing, Prentice Hall, 3rdEdn, 2007.

EC6430D MULTIDIMENSIONAL SIGNAL PROCESSING

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Comprehend the concepts of multi-dimensional signals and systems, Apply these concepts to acquire, process and display two or multi-dimensional signals
CO2: Understand the concept of 2D sampling theorem and sampling with different sampling geometries
CO3: Design and implement various types of two-dimensional digital filters given a set of specifications.
CO4: Explore various applications and related research areas

Module 1: (13 hours)
Multidimensional Systems- Fundamental operations on Multidimensional signals, Linear Shift - Invariant systems-cascade and parallel connection of systems- separable systems, stable systems- Frequency responses of 2D LTI Systems- Impulse response, Multidimensional Fourier transforms, z-transforms, properties of the Fourier and z-transforms

Module 2: (13 hours)
Multidimensional Discrete Fourier Transform: - Properties of DFT, Circular convolution- Calculation of DFT- Fast Fourier transform for periodically sampled signals
Sampling continuous 2D signals Periodic sampling with rectangular geometry- sampling density, Aliasing effects created by sampling - Periodic sampling with different sampling geometrics: rectangular, hexagonal and Quincunx - comparison

Module 3: (13 hours)
Multidimensional Digital Filter Design- Separable Filters- Linear phase filters- FIR Filters- Implementation of FIR filters - design of FIR filters using windows-Two dimensional window functions, Filter design using transformations, McClellan transformation-disadvantages, New transformations such as T1, T2, P1, and H1 transformations-Contour approximation errors-Circularly symmetric and fan type filters – implementation- applications in image processing

References:
1. John W Woods, Multidimensional Signal Image and Video Processing and Coding, Academic Press, 2006
2. Dudgeon Dan E., Multidimensional Digital Signal Processing, Prentice Hall, Englewood Cliffs, New Jersey, 1989
3. Jae S. Lim, Two- Dimensional Signal and Image Processing, Prentice Hall Englewood Cliffs, New Jersey, 1990.

EC6413D PATTERN RECOGNITION AND ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Apply knowledge of linear systems, probability theory, statistics and optimization theory for data representation.
CO2: Analyze basic mathematical and statistical techniques in pattern recognition.
CO3: Design and implement pattern recognition algorithms to classify real world data.
CO4: Create pattern recognition systems by forming sound decisions on real world problems.
CO5: Develop skill to conduct independent research in the area of pattern recognition

Module 1: (12 hours)
Introduction - features, feature vectors and classifiers, Classifiers based on Bayes Decision theory - discriminant functions and decision surfaces, Bayesian classification for normal distributions, Estimation of unknown probability density functions, the nearest neighbour rule. Linear classifiers - Linear discriminant functions and decision hyper planes.

Module 2: (15 hours)
The Perceptron algorithm, MSE estimation, Non-Linear classifiers- Two layer and three layer Perceptrons, Back propagation algorithm, Networks with Weight sharing, Polynomial classifiers, Radial Basis function networks, Support Vector machines, Decision trees, Boosting - combining classifiers. Feature selection, Class separability measures, Optimal feature generation, The Bayesian information criterion, representation of images in spaces, KL transform, Nonlinear transform - kernel PCA, Isomap, LLE. Speech and audio features - Cepstrum, Mel-cepstrum, Spectral features. Context dependent classification - Bayes classification, Markov chain models, HMM, Viterbi Algorithm. Training Markov models on neural networks.

Module 3: (12 hours)
Datasets, training and testing methods, accuracy, Receiver Operating Characteristics (ROC) curveClustering- Cluster analysis, Proximity measures, Clustering Algorithms - Sequential algorithms, neural network implementation. Hierarchical algorithms - Agglomerative algorithms, Divisive algorithms, Probabilistic clustering, K - means algorithm. Clustering algorithms based on graph theory, Competitive learning algorithms, Valley seeking clustering, Clustering validity.

References:
1. C. Bishop, Pattern Recognition and Machine Learning, Springer, 1st ed. 2006
2. Richard O. Duda, Hart P.E, and David G Stork, Pattern classification , 2nd Edn., John Wiley & Sons Inc., 2001.
3. S Theodoridis, K Koutroumbas, Pattern Recogntion, 4th Edition, Academic Press, 2009.

EC6432D MULTIRATE SIGNAL PROCESSING AND FILTER BANKS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyze sampling rate alteration devices in time and frequency domains and develop efficient poly-phase implementations of sampling rate converters.
CO2: Design uniform and non-uniform multirate filter banks, which have perfect reconstruction and near perfect reconstruction and assess the computational efficiency of multi rate systems.
CO3: Analyze the hardware complexity in the implementation of filter banks.
CO4: Apply filter banks in Signal Processing and Communication applications.

Module 1: (13 hours)
Multi-rate System Fundamentals: Basic multi-rate operations: up sampling and down sampling - time domain and frequency domain analysis; Aliasing and imaging, Interpolator and decimator design, Identities of multi-rate operations, Fractional sampling Rate operation, poly-phase representation.
Multi-rate Filter Banks: Maximally decimated filter banks: - Design of uniform DFT prefect reconstruction (PR) QMF banks, uniform and non-uniform tree structured filter banks.

Module 2: (13 hours)
Near perfect reconstruction (NPR) filter banks: Design of uniform and non-uniform cosine modulated filter banks and modified DFT filter banks, Reducing amplitude distortion-meta heuristic optimization techniques
Use of Interpolated FIR (IFIR) filters, Frequency response masking (FRM) filters and Farrow structure filters in filter banks, Multiplier-less filter banks to reduce hardware complexity, implementation

Module 3: (13 hours)
Quantization effects - Types of quantization effects in filter banks – Hardware complexity of filters and filter banks, Implementation
Applications of filter banks in Signal Processing and Communication such as hearing aids, cognitive radio, Software design radio channelizers

References:

1. P. P. Vaidyanathan, Multirate Systems and Filter Banks, Pearson Education, 2006.
2. N.J. Fliege, Multirate Digital Signal Processing, John Wiley, 1994.
3. Sanjit K. Mitra, Digital Signal Processing: A Computer based Approach, Special Indian Edition,McGraw Hill, 2013.
4. Fredric J Harris, Multirate Signal Processing for Communication Systems, 1st Edition, Pearson Education, 2007

EC6433D ADAPTIVE SIGNAL PROCESSING

Pre-requisites: EC6403D Statistical Signal Processing, EC6401D Linear Algebra for Signal Processing

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyse the filtering tasks in real life applications and identify the need for adaptation in filtering
CO2: Design filtering solutions to meet performance requirements derived from various real life applications such as channel equalization, echo cancellation and noise filtering by optimising estimation error cost function.
CO3: Evaluate the performance of the developed filter in terms computational complexity, convergence time and stability
CO4: Develop algorithms for the design of filters to track variations of non-stationary random process meeting performance requirements.

Module 1: (14 hours)
LMS Algorithm: Need for adaptive filtering - FIR adaptive filters – Newton's method - Steepest descent method –Convergence analysis - Performance surface – Least Mean Square (LMS) adaption algorithms – Convergence – Excess mean square error –Leaky LMS - Normalized LMS – Block LMS

Module 2: (13 hours)
Least Squares Algorithm: Recursive least squares (RLS) algorithm for adaptive filtering of stationary process- Matrix inversion – Comparison with LMS – RLS for quasi-stationary signals- Exponentially weighted RLS- Sliding window RLS – RLS algorithm for array processing – Adaptive beam forming – Other applications of adaptive filters – Echo cancellation – Channel Equalization

Module 3: (12 hours)
Kalman Filtering: Statistical filtering for non-stationary signals – Kalman filtering- Principles - Initialization and tracking – Scalar and vector Kalman filter – Applications in signal processing – Time varying channel estimation – Radar tracking

References:

1. Simon O. Haykin, Adaptive Filter Theory, 5th Edition, Pearson Education Limited, 2014.
2. Dimitris G. Manolakis, Vinay K. Ingle, Stephen M. Kogon, Statistical and Adaptive Signal Processing: Spectral Estimation, Signal Modeling, Adaptive Filtering, and Array Processing, McGraw-Hill, 2005.
3. Bernard Widrow, Samuel D Stearns, Adaptive Signal Processing, Pearson Education; 2002
4. Ali H. Sayed, Fundamentals of Adaptive Filtering, Wiley-IEEE Press, 2003.
5. Monson H. Hayes, Statistical Digital Signal Processing And Modeling, 1st Edition, Wiley India Pvt Ltd, 2008.
6. Michael G. Larimore, C. Richard Johnson, Theory and Design of Adaptive Filters, Pearson, 2001.

EC6434D LINEAR & NONLINEAR OPTIMIZATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Outline an adequate mathematical background on optimization theory.
CO2: Analyze the basic techniques commonly used in linear programming problems.
CO3: Develop the basic skill to address the nonlinear programming problems.
CO4: Obtain the fundamental knowledge to oversee the constrained and unconstrained optimization problems.

Module 1: (10 hours)
Mathematical background: sequences and subsequences, mapping and functions, continuous functions infimum and supremum of functions minima and maxima of functions, differentiable functions. Vectors and vector spaces, matrices, linear transformation, quadratic forms, gradient and Hessian- Linear equations, solution of a set of linear equations, basic solution and degeneracy, convex sets and convex cones, convex hulls, extreme point, convex and concave functions, differentiable convex functions.

Module 2: (13 hours)
Linear Programming: introduction, optimization model, formulation and applications, classical optimization techniques: single and multi variable problems, types of constraints, graphical method, linear optimization algorithms: simplex method, basic solution and extreme point, degeneracy, primal simplex method, dual linear programs, primal, dual, and duality theory, dual simplex method, primal-dual algorithm. Post optimization problems: sensitivity analysis and parametric programming.

Module 3: (16 hours)
Nonlinear Programming: minimization and maximization of convex functions, local & global optimum, convergence. Unconstrained optimization: one dimensional minimization, elimination methods: Fibonacci & Golden section search, gradient methods. Constrained optimization: Lagrangian method, Kuhn-Tucker optimality conditions, convex programming problems. Augmented Lagrangian method (ALM)
Applications of optimization theory in signal processing: signal processing via convex optimization, applications in weight design, linearizing pre-equalization, robust Kalman filtering, online array weight design, basis pursuit denoising (BPDN), compressive sensing and orthogonal matching pursuit (OMP).

References:

1. David G Luenberger, Linear and Non Linear Programming., Addison-Wesley, 2ndEdn., 2001.
2. S.S.Rao, .Engineering Optimization.; Theory and Practice; John Wiley, 4thEdn.., 2013.
3. S.M. Sinha, Mathematical programming: Theory and Methods, Elsevier, 2006.
4. Hillier and Lieberman Introduction to Operations Research, McGraw-Hill, 8th Ed., 2005.
5. Kalyanmoy Deb, Optimization for Engineering: Design Algorithms and Examples, Prentice Hall, 1998.
6. Igor Griva, ArielaSofer, Stephen G. Nash: Linear and Nonlinear Optimization, SIAM, 2009.

EC6435D FOUNDATIONS OF DATA ANALYTICS

Pre-requisites: Fundamentals of Probability and Statistics, Computer Programming

L	T	P	C
2	0	2	3

Total hours: 26L + 26P

Course Outcomes

CO1: Demonstrate ability to identify and integrate data of various types from a variety of sources, and make informed judgements about their use in data science research.

CO2: Critically evaluate the methodologies applied in data gathering, data processing and data exploration to disseminate findings using data visualization tools.

CO3: Apply different data science tools to create appropriate visualization of high dimensionality data, aligned to the student's area of interest.

Module 1: (9 hours)

Introduction to Data Science: Data, knowledge and information. Structured, semi-structured, and un-structured data. Database theory for data science. Relational database, primary key, secondary key. Database normal form: First normal form, second normal form, and third normal form. SQL database for structured data: adding/deleting/modifying tables, adding/deleting/modifying rows, searching and other essential operations. Semi-structured data: XML for semi-structured data, XML syntax and parsing XML using python. Big data: Characteristics of big data, Big data models: key value model, column model, document model, graph model. High level architecture of NoSQL systems.

Module 2: (6 hours)

Data pre-processing: Introduction to Pandas in Python, Data cleaning and preparation: Duplicates, Missing data, transformation using a function/mapping, discretisation of data, errors and outliers. Data wrangling: Hierarchical indexing, combining and merging data, reshaping and pivoting. Data munging, Data cleaning. Quality of data, meta-data, Canonicalization, legal and ethical aspects.

Module 3: (11 hours)

Introduction to data visualization. Visualization plots: Bar graph and pie charts, box plots, scatter plots and bubble charts, KDE plots. Introduction to data visualization libraries in Python: matplotlib, pandas and seaborn. Data transformation: Indexing, slicing, splitting, iterating, filtering, sorting, combining and reshaping. Introduction to data transformation libraries in Python: numpy and pandas. Exploratory data analytics: Univariate analytics, bivariate analytics and multi-variate analytics. Measures of central tendency and dispersion. Data aggregation, pivot tables and correlation. Scraping online/website data, Interactive visualization plots.

References:

1. Meysman, A., Cielen, D. and Ali, M, Introducing Data Science: Big data, machine learning, and more, using Python tools, Manning Publishers, 2016.
2. C J Date. Database Design and Relational Theory: Normal Forms and All That Jazz, O′Reilly, 2012
3. Cathy Tanimura. SQL for Data Analysis: Advanced Techniques for Transforming Data into Insights, O′Reilly, 2021
4. Deborah Nolan, Duncan Temple Lang XML and Web Technologies for Data Sciences with R, Springer, 2014.
5. Andreas Meier, Michael Kaufmann. SQL & NoSQL Databases: Models, Languages, Consistency Options and Architectures for Big Data Management, Springer, 2019.
6. Andy Kirk. Data Visualisation: A Handbook for Data Driven Design, SAGE Publications Ltd, 2016.
7. Kyran Dale. Data Visualization with Python and JavaScript: Scrape, Clean, Explore & Transform Your Data, O′Reilly, 2016.
8. Abha Belorkar, Sharath Chandra Guntuku. Interactive Data Visualization with Python: Present your data as an effective and compelling story, Packt Publishing Limited, 2020

EC6436D REINFORCEMENT LEARNING

Pre-requisites: Linear Algebra, Probability and Statistics, Computer Programming in Python. Familiarity with machine learning and training neural networks with modern libraries.

L	T	P	C
3	0	0	3

Total hours: 39L

Course Outcomes

CO1: Model real-world sequential decision-making problems using Markov decision process and knowledge of associated solution methodologies.

CO2: Analyze classical model-free reinforcement learning algorithms and state-of-art deep reinforcement learning algorithms.

CO3: Solve sequential decision-making problems with hidden dynamics using exact and reinforcement learning techniques

CO4: Demonstrate the potential of reinforcement learning in real-world problems through a course project.

Module 1: (10 hours)

Review of probability and statistics: Random variable, Expectation, Conditional Probability, Conditional Expectation, Markov Property, and Markov Chains.

Markov Reward Process: Definition, Finite and Infinite horizon reward process, Value function and Bellman equation.

Markov Decision Process (MDP): Definition, Finite and Infinite horizon MDP, Bellman dynamic programming equations for MDP. Numerical solution methods: Value iteration, Policy iteration (Generalized policy iteration), Linear programming.

Module 2: (20 hours)

Reinforcement learning: model free and model-based methods.

Monte Carlo and Temporal Difference Learning methods: Estimation of value function using Monte Carlo: first-visit and every-visit. Q-learning and Q-learning with exploration. Temporal difference methods: TD (0) and TD (λ). Policy iteration using TD learning. Double Learning. Deep reinforcement methodologies: Deep Q-learning (DQN), Double DQN, and Duelling DQN.

Policy Gradient reinforcement learning methods: Policy gradient, Policy gradient theorem (finite and infinite horizon), REINFORCE, REINFORCE with baseline. Actor-Critic algorithm. Advantage Actor-Critic (A2C) and Asynchronous A2C (A3C). Exploration in policy gradient.

Recent advances in policy gradient reinforcement learning: Trust region policy gradient algorithms and its variants such as Natural Policy Gradient, Trust Region Policy Optimization, Proximal Policy Optimization, Deterministic Policy Gradient and Deep Deterministic Policy Gradient, Soft-Q learning and Soft actor-critic

Module 3: (9 hours)

Partially Observed Markov Decision Process (POMDP): Definition, Belief and Belief state formulation of POMDP, Belief computation using Hidden Markov Model (HMM). Bellman dynamic programming for Finite and Infinite horizon POMDP. Exact algorithms for POMDP, Reinforcement learning in POMDP: Policy gradient and Deep Recurrent Q-learning networks (DQRN).

Other topics in reinforcement learning: Multi-agent learning, Meta-learning, Ethics in reinforcement learning, Application of reinforcement learning to real-world problems.

References:

1. Artificial Intelligence and Machine Learning: Theory and Practice, Lyla B. Das, Sudhish N. George, Anup Aprem, IK International Publishing House, 2022
2. Reinforcement Learning: An Introduction (second edition). R. Sutton and A. Barto. MIT Press, 2018
3. Algorithms for Reinforcement Learning. C. Szepesvari. Morgan and Claypool Publishers, 2010
4. Reinforcement Learning: State-of-the-Art. M. Wiering and M. van Otterlo. Springer, 2012