

Proceedings of Board of Studies Meeting

(Held on July 21, 2026)

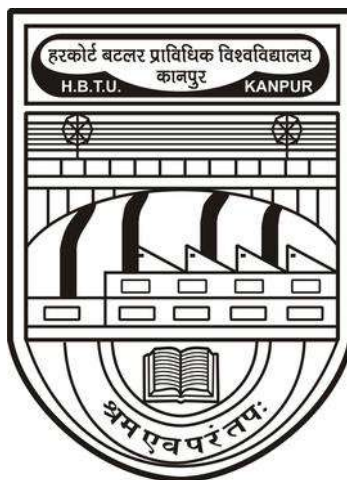
Course Structure & Syllabus for the programs:

Master of Technology

in

SIGNAL PROCESSING AND MACHINE LEARNING

(As per the Ordinances for Master of Technology)



Submitted By

Department of Electronics Engineering,

Harcourt Butler Technical University,

Nawabganj, Kanpur-208002 (UP)

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Vipin

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K. Ganesh

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VISION AND MISSION OF THE DEPARTMENT

Vision

Department of Electronics Engineering aims to deliver Technical Education in the field of Electronics and Communication Engineering, for producing Engineers and Technologists who are happy, healthy and competent professionals, motivated to serve the society through research & innovation.

Mission

1. To educate and train the students with state-of-the-art in Electronics and Communication Engineering.
2. To prepare the students who are fit for meeting the requirements and challenges of the Industry right at the time of their graduation by evolving a sustainable Industry-University interaction system for this.
3. To upgrade the teaching standards through continued efforts toward improvement of the qualification and expertise of the teachers as well as supporting staff.
4. To create awareness amongst the students towards socio environmental technologies by offering related courses and organizing seminars/workshops on these topics in the university and by encouraging participation in similar activities at other places.
5. To expand research and development activities in the frontier areas related to Electronics and Communication.
6. To include the aspect of integration of environmental balance and human values in the curriculum.
7. To provide academic support to other technical institutions at state & national level through the process of networking.
8. To start social service programs like education for masses, particularly using the enhanced means of communication.

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VISION AND MISSION OF THE UNIVERSITY

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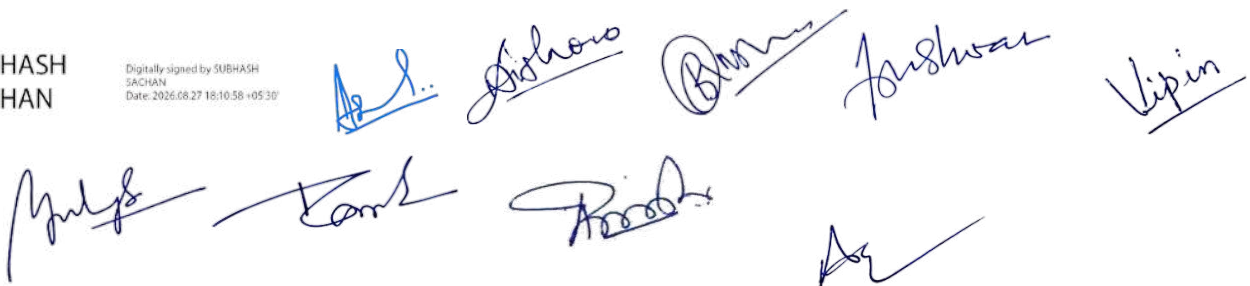
“To achieve excellence in technical education, research and innovation”.

MISSION

1. Imparting Knowledge to develop analytical ability in science and technology to serve the industry and society at large.
2. Equip and enable students with conceptual, technical and managerial skills to transform the organization and society.
3. Inculcating entrepreneurial philosophy and innovative thinking to promote research, consultancy and institutional social responsibility.
4. Serving people, society and nation with utmost professionalism, values and ethics to make development sustainable and quality of life.

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Program Educational Objectives (PEOs)

Program graduates, within three years from their graduation will

- PEO 1:** have knowledge of basic and applied sciences, so as to apply the necessary competence for technically sound, economically feasible and socially acceptable solutions of real life complex engineering problems.
- PEO 2:** be fit for meeting the requirements and challenges of industries, research and academic institutions both at the national and International level, by applying expertise gained in area of electronics and communication engineering.
- PEO 3:** be professionally competent with excellent communication and management skills along with being enterprising professionals and responsible citizens capable of delivering their services individually as well as in a collaborative framework.

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K. Ganesh V.



Structure of the Curriculum
Semester Wise Course Structure & Evaluation Scheme (effective from 2026-27 onwards)
For M.Tech. in Signal Processing and Machine Learning

I Semester

Sl. No.	Course Type	Subject code	Course title	Credits	Sessional Marks				End Semester	Total Marks
					MSE	TA	Lab	Total		
1.	PCC	NET 511	Digital Signal Processing (Theory cum Lab	4(3-0-2)	15	20	15	50	50	100
2.	PCC	NET 513	Introduction to Machine Learning (Theory cum Lab Course)	4(3-0-2)	15	20	15	50	50	100
3.	PCC	NET 515	Research Processes and Matrix Theory	4(3-1-0)	30	20	-	50	50	100
4.	PEC		PEC-I (Program Elective- I)	4(3-1-0)	30	20	-	50	50	100
Total Credits				16						

II Semester

Sl. No.	Course Type	Subject code	Course title	Credits	Sessional Marks				End Semester	Total Marks
					MSE	TA	Lab	Total		
1.	PCC	NET 512	Adaptive Signal Processing	4(3-1-0)	30	20	-	50	50	100
2.	PCC	NET 514	Deep Learning	4(3-1-0)	30	20	-	50	50	100
3.	PCC	NET 516	Learning on Graphs	4(3-1-0)	30	20	-	50	50	100
4.	PEC	NET	PEC-II (Program Elective- II)	4(3-1-0)	30	20	-	50	50	100
Total Credits				16						

III Semester

Sl. No	Course Type	Subject code	Course Title	Credits	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1.	PEC	NET	PEC-III (Program Elective- III)	4(2-2-0)	30	20	-	50	50	100
2.	OEC	NET	OEC (Open Elective)	3(3-0-0)	30	20	-	50	50	100
3.	PCC	NET 671	Seminar	1(0-0-2)	-	50	-	50	50	100
4.	PCC	NET 691	Dissertation (Part-I)	8(0-0-16)	-	50	-	50	50	100
Total Credits				16						

IV Semester

Sl. No	Course Tyne	Subject code	Course title	Credits	Sessional Marks				ESM	Total Marks
					MSE	TA	Lab	Total		
1	PCC	NET 692	Dissertation (Part-II)	16(0-0-32)	-	50	-	50	50	100
Total Credits				16						

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 Ashwani, K. Ganekar, Ashwani, Vipin, Gulab, Kamal

Program Elective-I (PEC-1)

Sl. No.	Course Code	Name of the course	Credit
1.	NET 541	Optimization Theory for Machine Learning	4(3-1-0)
2.	NET 543	Audio & Speech Processing	4(3-1-0)
3.	NET 545	Computational Statistics	4(3-1-0)

Program Elective-II (PEC-2)

Sl. No.	Course Code	Name of the course	Credit
1.	NET 542	Image Processing	4(3-1-0)
2.	NET 544	Estimation & Detection Theory	4(3-1-0)
3.	NET 546	Reinforcement Learning	4(3-1-0)

Program Elective-III (PEC-3)

Sl. No.	Course Code	Name of the course	Credit
1.	NET 641	Technical Research and Scientific Communication	4(3-1-0)
2.	NET 643	Research Methodology	4(3-1-0)
3.	NET 645	Research Ethics & Plagiarism	4(3-1-0)

Open Elective (OEC)

Sl. No.	Course Code	Name of the course	Credit
1.	OET 601	Digital Signal Processing	3(3-0-0)
2.	OET 603	Linear Algebra for Machine Learning	3(3-0-0)

NOTE: In view of providing flexibility to the students for year-long internship at industry, during the final year (II year M. Tech.), option for recognized online courses is provided as detailed below.

1. PEC-3 (III Semester): During III Semester, any of PEC-III Courses can be replaced by an NPTEL/SWAYAM course with the same credits as defined for Program Elective in the above structure and with the same or most similar name with the same credits with the permission of thesis supervisor.

2. OEC (III Semester): For Open Elective Course, students will have an option to do any Open Elective Course being floated by any other department of HBTU for M. Tech. students **OR** it can be any relevant course with the same credits as defined for Open Elective in the above structure, available on NPTEL/SWAYAM. In both the cases consent of the thesis supervisor will be necessary.

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The components of the curriculum

Table (a) Program curriculum grouping based on course components

Course Component	Curriculum Content (% of total Credits of the program)	Total number of credits
Program Core (PCC)	37.5	24
Program Electives (PEC)	18.75	12
Open Elective (OEC)	4.68	3
Seminar (S)	1.56	1
Dissertation (D)	37.5	24
Total		64

Table (b) Program curriculum grouping based on course components as per semester: Frequency & Credits

Sem	PCC		PEC		OEC		Seminar		Dissertation		Total
	Credits	No. of courses	Credits	No. of courses	Credit	No. of courses	Credit	No. of courses.	Credit	No. of courses	Credit
I	12	3	4	1	-	-	-	-	-	-	16
II	12	3	4	1	-	-	-	-	-	-	16
III	-	-	4	1	3	1	1	1	8	1	16
IV	-	-	-	-	-	-	-	-	16	1	16
Tot	24	6	12	2	3	1	1	1	24	2	64

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PCC	NET-511: Digital Signal Processing	3L:0T:2P	4 Credits
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Course Objectives:

To develop a deep understanding of discrete-time signal processing techniques with an emphasis on their theoretical foundations and practical applications in modern signal processing and machine learning systems.

Syllabus

Discrete time Fourier transform, sampling and z-transform. Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT).

Digital filter design techniques, transformation of digital filters, Optimum Linear filters .

Multirate Signal Processing, Decimation and interpolation, analysis and synthesis filter banks.

Wavelets and Multiresolution Signal Analysis; filter banks; time frequency decomposition, short term Fourier transform.

Sparse Signal Processing and compressive sensing.

List of Experiments

1. Verification of Sampling Theorem by demonstrating the reconstruction of a signal when sampled above, at, and below the Nyquist rate.
2. To observe the aliasing effects in undersampled signals by analyzing the distortion when the sampling rate is below the Nyquist limit.
3. To compute and plot the spectrum of a square wave using Fourier Transform techniques.
4. To perform interpolation and reconstruct a higher-rate signal from its lower-rate version.
5. To understand and implement upsampling by integer factors and observe spectral changes.
6. To perform non-integer (fractional) sampling rate conversion and analyze the output signal.
7. To design and implement a low-pass filter using the rectangular window method and evaluate performance.
8. To compare the filter performance for triangular, Hanning, and Hamming window functions.
9. To design a low-pass FIR filter using the Blackman window and analyze its frequency response.
10. To compare the magnitude responses, transition bands, and stopband attenuations of filters designed using different windows.

Course Outcomes:

1. Understand and apply core concepts of discrete-time signal processing
2. Design and analyze digital filters using various techniques, and apply transformations for realizing efficient and stable digital filtering systems
3. Analyze and implement multirate signal processing techniques
4. Apply wavelet-based and multiresolution analysis methods for time-frequency representation of signals
5. Understand the principles of sparse signal processing and apply compressive sensing techniques for efficient signal acquisition, representation, and reconstruction.

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References/Text Books:

1. Alan V. Oppenheim and Ronald W. Schafer, "Discrete-time Signal Processing", Prentice Hall, 1999.
2. John G. Proakis and Dimitris G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", Cambridge University Press, 2011.
3. P. P. Vaidyanathan, "Multirate Systems and Filter Banks", Pearson Publication, 2006.
4. Gilbert Strang and T. Nguyen, "Wavelets and Filter Banks", Wellesley Cambridge Press, 1996.
5. Martin Vitterli, Jelena Kovacevic and Vivek Goyal, "Foundations of Signal Processing", Cambridge University Press, 2014.
6. Martin Vitterli and Jelena Kovacevic, "Wavelets and subband coding", Prentice Hall, 1995.
7. Stephane Mallat, "A wavelet Tour of signal Processing- The sparse way", Elsevier, 2014.
8. Simon Foucart and Holger Rauhut, "A Mathematical Introduction to Compressive Sensing", Springer, 2013.

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PCC	NET- 513: Introduction to Machine Learning	3L:0T:2P	4 Credits
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Course Objectives:

To provide students with a comprehensive understanding of foundational machine learning concepts and techniques while equipping them with the analytical and algorithmic skills necessary to design, implement, and evaluate learning models for applications in signal processing and electronics engineering.

Syllabus

Basics of Python Programming, Introduction to pattern recognition: Features, Feature vectors, Categorization of learning algorithms, Supervised vs. Unsupervised Learning, Classification vs. Regression, loss functions;

Bayes Classification: Class conditional probability, Bayes classifier, minimum risk classifier, minimum distance classifier, generalized Bayes classifier, Cost function, cost minimization, gradient descent,

Dimensionality Reduction: Curse of dimensionality, PCA, Kernel methods; Linear Discriminant Analysis; Linear discriminator: Linear Discriminator, Perceptron criterion, MSE criterion, Decision tree

Unsupervised frameworks: Introduction to unsupervised learning, k-means clustering, Hierarchical clustering;

Supervised frameworks: Introduction to supervised frameworks, KNN classifier, Margins, Max margin classifier, Support vectors

Experiments

1. Implement KNN for classification tasks and evaluate performance using different distance metrics and values of k .
2. Train a decision tree classifier on a labeled dataset and interpret the learned model through tree visualization and feature importance.
3. Fit linear regression and Ridge/Lasso regression models to data and analyze the impact of regularization parameters.
4. Apply logistic regression to solve a binary classification problem and analyze decision boundaries.
5. Implement linear and non-linear SVMs using kernel tricks and visualize the decision margin and support vectors.
6. Implement the basic perceptron learning algorithm and observe its convergence on linearly separable datasets.
7. Use ensemble methods to improve classifier performance and compare ensemble models against base learners.
8. Apply K-means, K-medoids, and mini-batch K-means for unsupervised clustering and visualize cluster assignments.
9. Explore DBSCAN and agglomerative clustering on complex datasets and evaluate cluster quality using silhouette score.
10. Apply PCA for dimensionality reduction and use anomaly detection techniques to identify outliers in high-dimensional data.

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Course Outcomes:

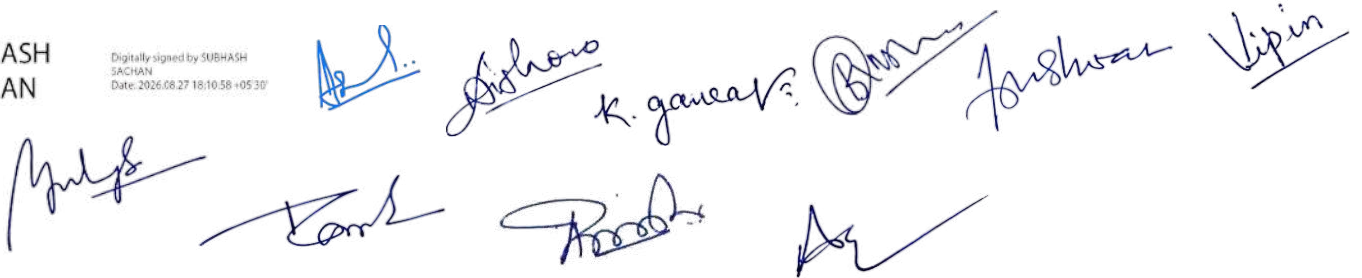
1. Understand and differentiate between various learning paradigms, and evaluate models based on their objectives, feature representation, and loss functions.
2. Apply probabilistic classification approaches by analyzing decision boundaries and optimizing cost functions
3. Implement dimensionality reduction techniques and discriminative models to enhance learning efficiency and address high-dimensional data challenges.
4. Analyze and apply unsupervised learning algorithms to discover patterns and structure in unlabeled datasets.
5. Design and evaluate supervised learning models using proximity-based and margin-based classifiers for classification tasks.

References/Text Books:

1. Duda, R. O., Hart, P. E., and Stork, D. G., "Pattern Classification", 2nd Edition, John Wiley & Sons, New York, USA, 2001.
2. Bishop, C. M., "Pattern Recognition and Machine Learning", Springer, New York, USA, 2006.
3. Müller, A. C., and Guido, S., "Introduction to Machine Learning with Python: A Guide for Data Scientists", O'Reilly Media, Sebastopol, California, USA, 2016.
4. Mitchell, T. M., "*Machine Learning*", McGraw-Hill Education (India) Pvt. Ltd., New Delhi, India, Reprint Edition, 2017. (*Originally published by McGraw-Hill, 1997.*)
5. Burkov, A., "The Hundred-Page Machine Learning Book", Andriy Burkov (Self-published), Quebec, Canada, 2019.

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PCC	NET-515: Random Processes & Matrix Theory	3L:1T:0P	4 Credits
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Course Objectives:

To equip students with a strong foundational understanding of random processes and matrix algebra essential for modeling, analysis, and algorithm development in signal processing and machine learning applications.

Syllabus

Linear Algebra: Vector Spaces, Orthogonality, Eigenvalues and Eigenvectors

Derivatives of vectors, Continuity and Differentiability, Partial Derivative of Vectors, Vector Integration

Matrix Analysis, Tensor Analysis

Axioms of Probability, Central limit theorem, Random Variables, Functions of Random Variable, Sequences of Random Variables

Random Walk, Brownian Motion, Finite State Markov Chain

Course Outcomes:

1. To apply vector calculus to functions of multiple variables, including differentiation and integration of vectors and scalar fields.
2. Use matrix algebra and tensor analysis to represent, manipulate, and analyze data in high-dimensional linear systems.
3. To understand basic probability theory, random variables, and fundamental theorems.
4. Analyze and compute transformations and sequences of random variables.
5. To model and evaluate discrete and continuous stochastic processes

References/Text Books:

1. Gilbert Strang, "Linear Algebra and Its Applications", 4th Edition, Wellesley-Cambridge Press, 2006.
2. Murray R. Spiegel, Seymour Lipschutz, and John Liu, "Vector Analysis and an Introduction to Tensor Analysis", 2nd Edition, McGraw-Hill, 2009.
3. Jan R. Magnus and Heinz Neudecker, "Matrix Differential Calculus with Applications in Statistics and Econometrics", 3rd Edition, John Wiley & Sons, 2019.
4. R. Syski, "Random Processes: A First Look", 2nd Edition, CRC Press, Taylor & Francis Group, 2011.
5. Athanasios Papoulis and S. Unnikrishna Pillai, "Probability, Random Variables, and Stochastic Processes", 4th Edition, McGraw-Hill Education, 2002.
6. Sheldon M. Ross, "Stochastic Processes", 2nd Edition, John Wiley & Sons, 1996.

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PEC-I	NET-543: Audio & Speech Processing	3L:1T:0P	4 Credits
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Course Objectives:

To develop the theoretical foundations and practical techniques for analyzing, processing, and interpreting audio and speech signals using classical signal processing and modern machine learning methods.

Syllabus

Fundamentals of Audio and Speech Signals: Introduction to Audio and Speech Processing, Speech Production and Perception Mechanism, Characteristics of Speech and Audio Signals, Digital Representation of Speech, Short-Time Analysis of Speech Signals, Time-Domain Processing of Speech Signals.

Speech Analysis and Feature Extraction: Speech Spectrum Analysis, Linear Predictive Coding (LPC), Cepstral Analysis, Mel-Frequency Cepstral Coefficients (MFCC), Pitch Detection, Voice Activity Detection (VAD).

Speech Enhancement and Coding: Noise Characteristics, Speech Enhancement Techniques, Adaptive Noise Cancellation, Wiener Filtering, Speech Coding Techniques, Waveform and Parametric Coders, Audio Compression Standards.

Speech Recognition and Speaker Recognition: Fundamentals of Automatic Speech Recognition (ASR), Acoustic and Language Models, Hidden Markov Models (HMMs), Speaker Recognition and Verification, Speech Emotion Recognition, Performance Evaluation Metrics.

Modern Audio and Speech Learning: Deep Learning for Speech Processing, Convolutional and Recurrent Neural Networks for Speech, Transformer-based Speech Models, Self-supervised Speech Representation Learning, Applications in Speech Assistants, Speech Translation and Voice Biometrics.

Course Outcomes:

1. Explain the principles of speech production, perception, and digital representation of audio and speech signals.
2. Analyze speech signals using spectral analysis and feature extraction techniques.
3. Apply speech enhancement and coding techniques for improving speech quality and efficient transmission.
4. Develop speech and speaker recognition systems using classical statistical methods.
5. Apply modern deep learning techniques for speech analysis and intelligent audio applications.

References/Text Books:

1. Lawrence R. Rabiner and Ronald W. Schafer, "Theory and Applications of Digital Speech Processing", Pearson, 2011.
2. Thomas F. Quatieri, "Discrete-Time Speech Signal Processing: Principles and Practice", Pearson, 2002.
3. Douglas O'Shaughnessy, "Speech Communications: Human and Machine", Universities Press, 2001. Convex Optimization by Boyd and Vandenberghe, Cambridge University Press, 2016.
4. Ben Gold and Nelson Morgan, "Speech and Audio Signal Processing: Processing and Perception of Speech and Music", Wiley, 2011.

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PEC-I	NET-545 Computational Statistics	3L:1T:0P	4 Credits
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Course Objectives:

To develop the statistical foundations and computational techniques required for analyzing data, drawing inferences, and building statistical models for signal processing and machine learning applications.

Syllabus

Probability and Statistical Foundations: Review of Probability Theory, Random Variables and Probability Distributions, Joint and Conditional Distributions, Mathematical Expectation, Covariance and Correlation, Common Statistical Distributions.

Statistical Inference: Sampling Distributions, Point and Interval Estimation, Maximum Likelihood Estimation, Bayesian Estimation, Hypothesis Testing, Goodness-of-Fit Tests.

Computational and Bayesian Methods: Monte Carlo Methods, Bootstrap and Resampling Techniques, Markov Chain Monte Carlo (MCMC), Bayesian Networks, Introduction to Probabilistic Graphical Models, Statistical Computing using Python.

Regression and Multivariate Analysis: Linear and Multiple Regression, Logistic Regression, Regularization Methods (Ridge and LASSO), Principal Component Analysis (PCA), Multivariate Statistical Analysis, Model Selection and Validation.

Statistical Learning and Applications: Bias-Variance Trade-off, Cross Validation, Kernel Density Estimation, Gaussian Mixture Models, Statistical Learning for Signal Processing, Applications in Machine Learning and Data Analytics.

Course Outcomes:

1. Explain the probabilistic and statistical foundations for data analysis.
2. Apply statistical inference techniques for estimation and hypothesis testing.
3. Analyze data using computational and Bayesian statistical methods.
4. Develop regression and multivariate statistical models for real-world data.
5. Apply statistical learning techniques to signal processing and machine learning applications.

References/Text Books:

1. Larry Wasserman, "All of Statistics: A Concise Course in Statistical Inference", Springer, 2004.
2. Trevor Hastie, Robert Tibshirani, and Jerome Friedman, "The Elements of Statistical Learning", 2nd Edition, Springer, 2009.
3. Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani, "An Introduction to Statistical Learning", 2nd Edition, Springer, 2021.
4. Kevin P. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.

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PCC	NET-512: Adaptive Signal Processing	3L:1T:0P	4 Credits
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Course Objectives:

To develop the ability to analyze and design adaptive systems capable of learning from dynamic environments, with a focus on real-time signal processing applications and algorithmic optimization strategies.

Syllabus

Concepts of random processes, wide sense stationary (WSS) processes and their correlation structures, power spectral density, parametric modeling of WSS processes – AR, MA and ARMA processes.

Optimal FIR filters, real and complex valued optimal filters, method of steepest descent. Least mean square (LMS) algorithm; convergence of LMS algorithm; normalized LMS, affine projection.

Examples of adaptive filters : channel equalization, echo cancellation, interference cancellation, line enhancement, beamforming etc.

Limitations of LMS algorithm, formulation of recursive least squares (RLS) based adaptive filters, Moore-Penrose pseudo inverse, matrix inversion lemma.

Development of the RLS transversal adaptive filter, properties, variants of the RLS family.

Course Outcomes:

1. Analyze and model wide sense stationary (WSS) random processes
2. Design and implement optimal FIR filters and evaluate their performance in practical scenarios.
3. Apply adaptive filtering techniques to solve real-world problems
4. Identify limitations of the LMS algorithm and formulate adaptive filters using the RLS approach
5. Develop and analyze the RLS transversal filter and its variants, and assess their properties and suitability for various signal processing applications.

References/Text Books:

1. Simon Haykin, “Adaptive Filter Theory”, 5th Edition, Pearson Education, Upper Saddle River, New Jersey, USA, 2014.
2. Ali H. Sayed, “Adaptive Filters”, Wiley-IEEE Press, Hoboken, New Jersey, USA, 2008.
3. Behrouz Farhang-Boroujeny, “Adaptive Filters: Theory and Applications”, 2nd Edition, John Wiley & Sons, Hoboken, New Jersey, USA, 2013.

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PCC	NET-514: Deep Learning	3L:1T:0P	4 Credits
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Course Objectives:

To equip students with a deep conceptual and practical understanding of modern deep learning architectures and training techniques, enabling them to design, optimize, and apply neural networks to solve complex problems in data analysis, signal processing, and intelligent systems.

Syllabus

Introduction to Deep Learning, Bayesian Learning, Decision Surfaces, Supervised and Unsupervised Learning, Feature Map; Multilayer Perceptron, Gradient descent and Backpropagation Learning, Vanishing Gradient and Exploding Gradient Problem, Stochastic and Batch Gradient Descent; Optimization Algorithms – Momentum Optimizer, RMSProp, ADAM.

Convolutional Neural Network, building blocks, Examples of some popular CNN Architectures; Capacity, Overfitting and Underfitting, Regularization for effective training- early stopping, Dropout, Batch Normalization, Instance Normalization, Group Normalization; Residual Network, Skip Connection; Recurrent Neural Network (RNN), Gated RNN, Long Short Term Memory.

Generative Model: Variational Autoencoder (VAE), Generative Adversarial Network (GAN), Conditional GAN, Cycle GAN, PatchGAN, InfoGAN etc.

Transformer Networks: Multihead Attention, Transformer Architecture, Spatial and Spatio-Temporal Transformer.

Deep Learning Applications: Fault Detection and Diagnosis, Predictive Maintenance, Edge AI and Intelligent IoT Systems; Applications in Biomedical Signal Processing, Radar and Remote Sensing.etc.

Course Outcomes:

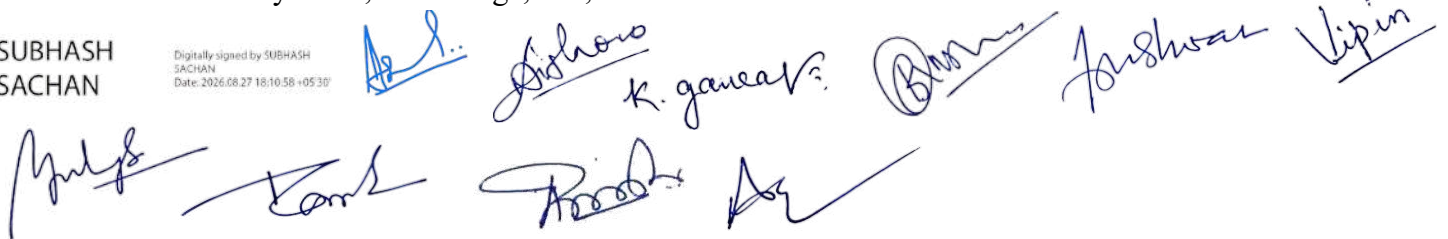
1. Design, implement, and optimize advanced neural network architectures.
2. Understand the fundamental principles of deep learning and apply optimization strategies to effectively train neural networks.
3. Develop and apply generative models for tasks like data synthesis and enhancement.
4. Understand and implement Transformer-based architectures for tasks in sequence processing and natural language understanding.
5. Apply deep learning techniques to solve real-world problems across various domains.

References/Text Books:

1. Goodfellow, I., Bengio, Y., and Courville, A., “Deep Learning”, The MIT Press, Cambridge, Massachusetts, USA, 2016.
2. Bishop, C. M., and Bishop, H., “Deep Learning: Foundations and Concepts”, Springer, Cham, Switzerland, 2024.
3. Subramanian, V., “Deep Learning with PyTorch”, Packt Publishing Ltd., Birmingham, UK, 2024 (2nd Edition).
4. Chollet, F., “Deep Learning with Python”, 2nd Edition, Manning Publications, Shelter Island, New York, USA, 2021..
5. Zhang, A., Lipton, Z. C., Li, M., and Smola, A. J., “Dive into Deep Learning”, Cambridge University Press, Cambridge, UK, 2023.

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PCC	NET-516: Learning on Graphs	3L:1T:0P	4 Credits
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Course Objectives:

To provide theoretical foundations and computational techniques for analyzing, representing, processing and learning of signals defined on graph-structured data.

Syllabus

Node Domain Processing: Introduction to Graphs, Graph as Signals, Graphs in Classical signal Processing, Mathematical Models of Graph, Locality, Algebraic Representations of Graphs, Node Domain Graph Filters, Graph Operators and Invariant Subspaces

Spectral Graph Theory: Graph Fourier Transforms (GFTs), Graph Filtering, Graph Structure and Graph Spectra

Sampling and Graph Signal Representation: Sampling Constraints, Frequency Domain Sampling, Reconstruction of Bandlimited Signals, Random Sampling, Compact Support in the Node and Frequency Domains, Representing Graph Signals, Node Domain Graph Signal Representations, Frequency (Spectral) Domain Graph Signal Representations,

How to choose a graph: Graph Approximation, Constructing Graphs from Node Similarity, Learning Graphs from Signals, Learning Unrestricted Operators from Data

Applications of Graphs: Physical, Biological and Social Networks, Image and Video Processing using graphs, Graphs and Graph Signals in Learning Applications, Unsupervised Learning and Clustering, Semi-supervised Learning, Graph Convolutional Neural Networks

Course Outcomes:

1. Explain the fundamentals of graphs, graph signals, graph operators, and node-domain graph filtering.
2. Analyze graph signals using Graph Fourier Transform and spectral graph filtering techniques.
3. Apply graph signal sampling, reconstruction, and representation techniques.
4. Construct and learn graph structures from data using graph learning methods.
5. Apply graph signal processing techniques to network analysis, graph-based learning, and Graph Convolutional Neural Networks.

References/Text Books:

1. Antonio Ortega, "Introduction to Graph Signal Processing", Cambridge University Press, 2022.
2. Dimitri P. Bertsekas, "Introduction to Data Networks and Graph Signal Processing", Athena Scientific, 2022.
3. Piet Van Mieghem, "Graph Spectra for Complex Networks", Cambridge University Press, 2010
4. Antonio Ortega, Pascal Frossard, Jelena Kovačević, José M. F. Moura, and Pierre Vanderghenst, "Graph Signal Processing: Overview, Challenges, and Applications," Proceedings of the IEEE, vol. 106, no. 5, pp. 808–828, 2018.

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PEC-II	NET-542: Image Processing	3L:1T:0P	4 Credits
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Course Objectives:

To provide students with a strong theoretical and practical foundation in image processing techniques, enabling them to analyze, enhance, restore, segment, and extract meaningful features from visual data using both spatial and frequency domain methods for real-world applications in engineering and intelligent systems.

Syllabus

Image fundamentals: Visual perception, sensing and acquisition, spatial and spatiotemporal sampling and quantization, basic relationship between pixels and their neighborhood properties, interlacing and deinterlacing ; Edges and image descriptors: First and second derivative filters, Sobel, Canny, Laplacian and Laplacian of Gaussian, Harris corner, Gabor filter, image pyramid, shift invariant feature transform, local binary pattern

Transformations and Enhancement: DFT, DCT, DWT, Gray-level transformations, histogram equalization, spatial filters- averaging, order statistics, unsharp masking, spatiotemporal filters; Frequency domain - Smoothing and sharpening, Ideal and Butterworth filters, Homomorphic filtering

Restoration: Degradation model estimation, restoration process, noise models, restoration in presence of noise, linear position invariant degradations, inverse filtering, Wiener filtering, constrained least square filtering

Color: Color models- RGB, HIS, YUV, pseudo-color image processing, full-color image processing;

Morphological image processing: Basic operations- dilation, erosion, opening, closing, Hit-Mis transformations, Basic morphological algorithms- boundary extraction, region filling, connected components, convex hull, thinning, thickening, skeletons, pruning, extensions to gray-scale morphology;

Segmentation: Edge linking and boundary detection, Hough transforms, Graph-theoretic techniques, global and adaptive thresholding, Region based segmentation, Segmentation by morphological watershed, Texture analysis- Co-occurrence matrix

Course Outcomes:

1. Demonstrate understanding of image formation, acquisition, and sampling principles, and analyze the structural and perceptual properties of digital images.
2. Apply edge detection and feature extraction techniques to identify meaningful patterns and descriptors in image data.
3. Implement image enhancement techniques in spatial and frequency domains to improve image quality for further processing.
4. Analyze and apply restoration models and noise reduction techniques to recover degraded images using both deterministic and statistical approaches.
5. Develop methods for image segmentation and morphological processing to extract meaningful structures and regions for high-level interpretation.

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References/Text Books:

1. Gonzalez, R. C., and Woods, R. E., "Digital Image Processing", 4th Edition, Pearson Education, New York, USA, 2018.
2. Jain, A. K., "Fundamentals of Digital Image Processing", Prentice-Hall of India Pvt. Ltd., New Delhi, India, 1989.
3. Sonka, M., Hlavac, V., and Boyle, R., "Image Processing, Analysis, and Machine Vision", 4th Edition, Cengage Learning, Boston, USA, 2014.
4. Pratt, W. K., "Digital Image Processing: PIKS Scientific Inside", 4th Edition, John Wiley & Sons, Hoboken, New Jersey, USA, 2007.
5. Szeliski, R., "Computer Vision: Algorithms and Applications", 2nd Edition, Springer, Cham, Switzerland, 2022.

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PEC-II	NET-544: Estimation & Detection Theory	3L:1T:0P	4 Credits
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Course Objectives:

To develop the ability to formulate, analyze, and apply advanced estimation and detection techniques for statistical signal processing in noisy and uncertain environments, enabling them to design optimal algorithms for inference and decision-making in engineering systems.

Syllabus

Estimation theory: Minimum variance unbiased estimation, best linear unbiased estimation, Cramer-Rao Lower Bound (CRLB), General CRLB for signals in White Gaussian Noise, CRLB for General Gaussian Noise,

Linear Models, BLUE, MLE, Least Squares,

Bayesian Estimator, Wiener Filter, Kalman Filter.

Detection Theory: Neyman-Pearson Theorem, Likelihood Ratio testing, Bayes Risk, Bayes detectors, Neyman-Pearson detectors, Multiple Hypothesis Testing

Matched Filters, Generalized Matched Filters, Generalized Likelihood ratio Tests (GLRTs)

Course Outcomes:

1. To evaluate the performance and limitations of statistical estimators under various conditions using theoretical bounds.
2. Perform the estimation of unknown parameters using different techniques
3. Design and implement Bayesian estimators including Wiener and Kalman filters for dynamic systems
4. Analyze and apply statistical detection strategies for binary and multiple hypothesis testing problems.
5. Develop matched filters and generalized likelihood ratio tests (GLRTs) for optimal signal detection in noisy environments.

References/Text Books:

1. S.M. Kay, "Fundamental of Statistical Signal Processing: Estimation Theory", Vol-I, Prentice Hall PTR, 2009
2. S.M. Kay, "Fundamental of Statistical Signal Processing: Detection Theory", Vol-II, Prentice Hall PTR, 1998
3. H.V. Poor, "An Introduction to Signal Detection and Estimation", Springer, 2/e, 1998
4. Harry L. Van Trees, "Detection, Estimation and Modulation Theory" (Detection, Estimation and Modulation Theory, Part-I), John Wiley & Sons, 2002

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Vipin *Subhash* *K. Ganekar* *Subhash* *Subhash*

PEC-II	NET-546 Natural Language Processing	3L:1T:0P	4 Credits
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Course Objectives:

To develop a fundamental understanding of reinforcement learning principles and algorithms for sequential decision-making under uncertainty, with applications to signal processing, communication, control, and intelligent electronic systems.

Syllabus

Foundations of Reinforcement Learning: Introduction to Reinforcement Learning, Agent–Environment Interaction, Markov Decision Processes, States, Actions and Rewards, Policies, Value Functions, Bellman Equations, Exploration and Exploitation.

Dynamic Programming and Temporal-Difference Learning: Policy Evaluation, Policy Improvement, Policy Iteration, Value Iteration, Monte Carlo Methods, Temporal-Difference Learning, SARSA, Q-Learning.

Function Approximation and Deep Reinforcement Learning: Function Approximation, Neural Networks for Reinforcement Learning, Deep Q-Networks, Experience Replay, Target Networks, Double DQN, Dueling Networks.

Policy-Based and Actor-Critic Methods: Policy Gradient Methods, REINFORCE, Actor-Critic Methods, Advantage Functions, Proximal Policy Optimization, Continuous Action Spaces.

Applications of Reinforcement Learning: Reinforcement Learning for Signal Processing and Communications, Adaptive Resource Allocation, Wireless Communication Systems, Network Optimization, Robotics and Control, Edge/IoT Systems, Autonomous Systems, Introduction to Multi-Agent Reinforcement Learning.

Course Outcomes:

1. Explain the fundamental concepts of reinforcement learning and Markov decision processes.
2. Apply dynamic programming, Monte Carlo, and temporal-difference methods for reinforcement learning.
3. Implement value-based and policy-based reinforcement learning algorithms.
4. Analyze deep reinforcement learning methods for complex sequential decision-making problems.
5. Apply reinforcement learning techniques to signal processing, communication, control, and intelligent electronic systems.

References/Text Books:

1. Daniel Jurafsky and James H. Martin, “Speech and Language Processing”, 3rd Edition (Online Draft), Pearson.
2. Jacob Eisenstein, “Introduction to Natural Language Processing”, MIT Press, 2019.
3. Delip Rao and Brian McMahan, “Natural Language Processing with PyTorch”, O'Reilly Media, 2019.
4. Yoav Goldberg, “Neural Network Methods for Natural Language Processing”, Morgan & Claypool Publishers, 2017.
5. Christopher D. Manning and Hinrich Schütze, “Foundations of Statistical Natural Language Processing”, MIT Press, 1999.

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III Semester

PEC-III	NET-641: Technical Research and Scientific Communication	2L:2T:0P	4 Credits
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Course Objectives:

To develop the knowledge and practical skills required for conducting, documenting, presenting, and communicating engineering research using standard scientific practices, tools, and ethical guidelines.

Syllabus

Engineering Research Process: Introduction to Engineering Research, Types of Research, Problem Identification, Research Questions and Objectives, Literature Review, Technical Literature Search using Digital Libraries, Research Planning and Design.

Scientific Writing and Technical Documentation: Structure of Technical Reports and Research Papers, Writing Abstracts, Introductions, Literature Review, Methodology, Results and Discussion, Conclusions, Citation Styles, Reference Management Tools, Introduction to LaTeX for Technical Writing.

Publication Process and Research Ethics: Scientific Publishing Process, Journal and Conference Selection, Peer Review Process, Publication Ethics, Plagiarism and Similarity Analysis, Authorship Ethics, Copyright, Open Access Publishing, Introduction to Intellectual Property Rights.

Technical Presentation and Scientific Visualization: Principles of Technical Presentations, Preparing Technical Slides, Scientific Figures and Tables, Data Visualization, Technical Poster Design, Oral Presentation Skills, Communicating Technical Concepts to Technical and Non-Technical Audiences.

Research Dissemination and Modern Research Tools: Research Proposal Writing, Thesis and Dissertation Preparation, Academic Profiles (ORCID, Google Scholar), AI-assisted Scientific Writing Tools, Research Collaboration Platforms, Research Reproducibility and Open Science.

Course Outcomes:

1. Explain the engineering research process and conduct effective literature surveys.
2. Develop technical reports and research papers using standard scientific writing practices and LaTeX.
3. Apply ethical principles in scientific publishing, citation, and research dissemination.
4. Prepare and deliver effective technical presentations and scientific posters for diverse audiences.
5. Utilize modern tools for research documentation, collaboration, and dissemination.

References/Text Books:

1. Robert A. Day and Barbara Gastel, "How to Write and Publish a Scientific Paper", Cambridge University Press.
2. Michael Alley, "The Craft of Scientific Presentations", Springer.
3. Leslie Lamport, "LaTeX: A Document Preparation System", Addison-Wesley.
4. Heather Silyn-Roberts, "Writing for Science and Engineering: Papers, Presentations and Reports", Elsevier.
5. David F. Beer and David McMurrey, "A Guide to Writing as an Engineer", Wiley.

Tutorial Components

Each student shall develop a Research Portfolio by completing the following activities, preferably aligned with their proposed M.Tech. dissertation topic.

Unit	Practical Activity
Unit 1	Conduct a literature survey and prepare an annotated bibliography using IEEE Xplore, ScienceDirect, SpringerLink, or Google Scholar.
Unit 2	Prepare a technical paper in IEEE conference format using LaTeX
Unit 3	Perform plagiarism analysis, identify a suitable journal/conference, and prepare a publication plan.
Unit 4	Design a scientific poster and deliver a conference-style technical presentation for both technical and non-technical audiences.
Unit 5	Prepare a mini research proposal including problem statement, objectives, methodology, expected outcomes, timeline, and references.

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PEC-III	NET-643: Research Methodology	2L:2T:0P	4 Credits
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Course Objectives:

To develop the knowledge and analytical skills required for planning, designing, conducting, and evaluating engineering research using appropriate research methodologies and statistical techniques.

Syllabus

Foundations of Engineering Research: Introduction to Research, Types of Research, Research Process, Identification of Research Problems, Formulation of Research Objectives and Hypotheses, Variables in Research, Research Design.

Literature Review and Research Planning: Literature Survey Techniques, Review of Research Articles, Identification of Research Gaps, Research Questions, Research Proposal Development, Planning and Scheduling of Research Activities.

Data Collection and Experimental Design: Primary and Secondary Data, Sampling Methods, Experimental Design, Measurement Techniques, Reliability and Validity, Questionnaire Design, Data Acquisition in Engineering Research.

Data Analysis and Interpretation: Descriptive Statistics, Hypothesis Testing, Correlation and Regression, Analysis of Variance (ANOVA), Interpretation of Experimental Results, Data Visualization, Use of Statistical Software.

Research Reporting: Structure of Technical Reports, Thesis and Dissertation Organization, Writing Research Papers, Interpretation of Results, Research Dissemination, Case Studies in Engineering Research.

Course Outcomes:

1. Explain the principles and methodologies used in engineering research.
2. Conduct literature reviews and formulate research problems and objectives.
3. Design experiments and apply appropriate data collection methods.
4. Analyze and interpret research data using statistical techniques.
5. Prepare research reports and communicate research findings effectively.

References/Text Books:

1. C. R. Kothari and Gaurav Garg, "Research Methodology: Methods and Techniques", 4th Edition, New Age International Publishers, New Delhi, India, 2019.
2. John W. Creswell and J. David Creswell, "Research Design: Qualitative, Quantitative, and Mixed Methods Approaches", 6th Edition, SAGE Publications, Thousand Oaks, California, USA, 2023.
3. William M. K. Trochim, "Research Methods: The Essential Knowledge Base", 2nd Edition, Cengage Learning, Boston, USA, 2020.
4. Wayne C. Booth, Gregory G. Colomb, Joseph M. Williams, et al., "The Craft of Research", 4th Edition, University of Chicago Press, Chicago, USA, 2016.
5. Ranjit Kumar, "Research Methodology: A Step-by-Step Guide for Beginners", 5th Edition, SAGE Publications, London, UK, 2019.

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Vipin

PEC-III	NET-645: Research Ethics and Plagiarism	2L:2T:0P	4 Credits
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Course Objectives:

To develop an understanding of ethical principles, responsible research practices, publication ethics, and plagiarism prevention for conducting and disseminating high-quality engineering research.

Syllabus

Foundations of Research Ethics: Introduction to Ethics, Responsible Conduct of Research, Ethical Principles in Engineering Research, Research Misconduct, Ethical Decision Making, Institutional Ethics Committees.

Publication Ethics: Scientific Publishing Process, Authorship and Contributorship, Peer Review Process, Conflict of Interest, Duplicate Submission, Predatory Journals and Conferences, Open Access Publishing.

Plagiarism and Academic Integrity: Academic Integrity, Types of Plagiarism, Self-Plagiarism, Copyright and Fair Use, Similarity Assessment, Plagiarism Detection Software, Avoiding Plagiarism through Proper Citation.

Intellectual Property Rights: Patents, Copyrights, Trademarks, Industrial Design, Technology Transfer, Licensing, Innovation and Intellectual Property Management.

Responsible Research Practices: Research Data Management, Data Sharing, Reproducibility of Research, AI in Research and Ethical Considerations, Case Studies on Research Misconduct, National and International Ethical Guidelines.

Course Outcomes:

1. Explain the ethical principles governing engineering research.
2. Apply ethical practices in scientific publication and authorship.
3. Identify and prevent plagiarism using appropriate citation and referencing practices.
4. Explain the role of intellectual property rights in research and innovation.
5. Demonstrate responsible research practices for conducting and disseminating engineering research.

References/Text Books:

1. Nicholas H. Steneck, "ORI Introduction to the Responsible Conduct of Research", U.S. Government Printing Office, Washington, D.C., USA, 2007.
2. Committee on Publication Ethics (COPE), "COPE Guidelines: A Short Guide to Ethical Editing for New Editors", Committee on Publication Ethics (COPE), Eastleigh, UK.
3. R. Subramanyam, "Research Ethics and Publication Ethics", Notion Press, Chennai, India, 2021.
4. Elizabeth Wager and Sabine Kleinert, "Responsible Research Publication: International Standards for Authors", World Association of Medical Editors (WAME), 2011.
5. University Grants Commission (UGC), "Academic Integrity and Prevention of Plagiarism Regulations", University Grants Commission, New Delhi, India. (latest version).

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OEC-I	OET-601 Digital Signal Processing	3L:0T:0P	3 Credits
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Course Objectives:

To introduce the fundamental concepts of discrete-time signals and systems and develop an understanding of basic digital signal processing techniques and their applications in engineering and other interdisciplinary domains.

Syllabus

Introduction to Signals and Systems: Introduction to Signals and Systems, Continuous-Time and Discrete-Time Signals, Basic Sign Operations, Elementary Discrete-Time Signals, Classification of Signals, Discrete-Time Systems, Linear and Time-Invariant Systems, Impulse Response and Convolution.

Sampling and Frequency-Domain Analysis: Sampling of Continuous-Time Signals, Nyquist Sampling Theorem, Aliasing, Signal Reconstruction, Fourier Series, Discrete-Time Fourier Transform (DTFT), Frequency Response of Discrete-Time Systems, Introduction to Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT).

Digital Filters: Concept of Digital Filtering, Low-Pass, High-Pass, Band-Pass and Band-Stop Filters, FIR and IIR Filters, Frequency Response of Digital Filters, Basic FIR Filter Design using Window Techniques, Introduction to IIR Filter Design, Applications of Digital Filtering.

Time-Frequency and Multirate Signal Processing: Time-Frequency Representation of Signals, Short-Time Fourier Transform (STFT), Spectrogram, Introduction to Multirate Signal Processing, Decimation and Interpolation, Sampling Rate Conversion, Introduction to Wavelets and Multiresolution Analysis.

Applications of Digital Signal Processing: DSP in Audio and Speech Processing, Image and Video Processing, Biomedical Signal Processing, Sensor and IoT Data Processing, Communication Systems, Noise Reduction and Signal Enhancement, Introduction to DSP in Machine Learning Applications.

Course Outcomes:

1. Explain the basic concepts of discrete-time signals, systems, and convolution.
2. Analyze signals using sampling and frequency-domain techniques.
3. Explain the principles and applications of digital filters.
4. Describe time-frequency and multirate signal processing techniques.
5. Explain the applications of DSP in audio, image, biomedical, communication, and sensor systems.

References/Text Books:

1. Alan V. Oppenheim and Ronald W. Schaffer, "Discrete-Time Signal Processing", 3rd Edition, Pearson, Upper Saddle River, New Jersey, USA, 2009.
2. John G. Proakis and Dimitris G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", 4th Edition, Pearson, Upper Saddle River, New Jersey, USA, 2007.
3. Sanjit K. Mitra, "Digital Signal Processing: A Computer-Based Approach", 4th Edition, McGraw-Hill Education, New York, USA, 2011.
4. Richard G. Lyons, "Understanding Digital Signal Processing", 3rd Edition, Pearson Education, Upper Saddle River, New Jersey, USA, 2011.

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OEI-I	OET-603 Linear Algebra for Machine Learning	3L:0T:0P	3 Credits
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Course Objectives:

To develop a fundamental understanding of linear algebra and its applications in data representation, dimensionality reduction, optimization, and machine learning.

Syllabus

Fundamentals of Linear Algebra: Scalars, Vectors and Matrices, Vector Operations, Matrix Operations, Transpose, Symmetric and Skew-Symmetric Matrices, Matrix Inverse, Linear Equations, Systems of Linear Equations, Gaussian Elimination, Elementary Matrix Operations, Applications of Vectors and Matrices in Data Representation.

Vector Spaces and Linear Transformations: Vector Spaces, Subspaces, Linear Independence and Dependence, Basis and Dimension, Row Space, Column Space and Null Space, Rank of a Matrix, Linear Transformations, Matrix Representation of Linear Transformations, Applications to Data and Feature Representation.

Eigenvalues, Eigenvectors and Matrix Decompositions: Eigenvalues and Eigenvectors, Characteristic Equation, Diagonalization, Symmetric Matrices, Orthogonal Vectors and Matrices, Quadratic Forms, Positive Definite Matrices, Singular Value Decomposition (SVD), Introduction to QR and LU Decomposition, Applications in Machine Learning.

Geometry and Optimization: Vector Norms and Matrix Norms, Inner Product and Orthogonality, Projections, Least-Squares Problems, Orthogonal Projection, Distance and Similarity Measures, Gradient and Directional Derivatives, Quadratic Functions, Basic Matrix Calculus, Applications to Linear Regression and Optimization.

Linear Algebra in Machine Learning: Principal Component Analysis (PCA), Dimensionality Reduction using Eigenvalue and SVD Methods, Linear Regression in Matrix Form, Covariance Matrices, Data Transformation and Feature Representation, Linear Classification, Kernel Matrices, Low-Rank Approximation, Applications of Linear Algebra in Neural Networks and Machine Learning.

Course Outcomes:

1. Explain fundamental concepts of vectors, matrices, and systems of linear equations.
2. Apply vector space concepts, linear transformations, rank, and matrix properties to data representation.
3. Analyze eigenvalues, eigenvectors, and matrix decompositions relevant to machine learning.
4. Apply vector projections, least-squares methods, norms, and basic optimization concepts to learning problems.
5. Explain the role of linear algebra in PCA, regression, dimensionality reduction, and machine learning algorithms.

References/Text Books:

1. Alan V. Oppenheim and Ronald W. Schaffer, "Discrete-Time Signal Processing", 3rd Edition, Pearson, Upper Saddle River, New Jersey, USA, 2009.
2. John G. Proakis and Dimitris G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", 4th Edition, Pearson, Upper Saddle River, New Jersey, USA, 2007.
3. Sanjit K. Mitra, "Digital Signal Processing: A Computer-Based Approach", 4th Edition, McGraw-Hill Education, New York, USA, 2011.
4. Richard G. Lyons, "Understanding Digital Signal Processing", 3rd Edition, Pearson Education, Upper Saddle River, New Jersey, USA, 2011.

The Bos Approved the course Syllabi for all the courses for M.Tech. Programme in Signal Processing and Machine Learning (SPML) as above.



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