COEP Technological University Pune

(A Unitary Public University of Govt. of Maharashtra)

NEP 2020 Compliant

Proposed Curriculum Structure

M. Tech.
Electronics – AI in Signal Processing

(Effective from: A.Y. 2025-26)

PG Program [M. Tech. Electronics – AI in Signal Processing]

Proposed Curriculum Structure

w. e. f AY 2025-26

List of Abbreviations

Abbreviation	Title	No. of Courses	Credits	% of Credits
PSMC	Program Specific Mathematics Course	1	4	5.00
PSBC	Program Specific Bridge Course	1	3	3.75
PCC	Program Core Course	6	24	30.0
PEC	Program Specific Elective Course	3	9	11.25
OE	Open Elective	1	3	3.75
SLC	Self-Learning Course	2	6	7.50
AEC	Ability Enhancement Course	1	2	2.50
RM	Research Methodology	1	3	3.75
CCA	Co-curricular & Extracurricular Activities	1	1	1.25
OJT	Internship	1	3	3.75
Project	Project	2	22	27.50
	Total	20	80	100%

PG Program [M. Tech. Electronics – AI in Signal Processing]

Proposed Curriculum Structure

Semester - I

Sr. No.	Course Category	Course Code	Course Name	Teaching Scheme				Credits
				L	**T**	**P**	**S**	
1	PSM	PSMC-01	Applied Mathematics	3	1	--	1	**4**
2	PSBC	PSBC-01	DSP Algorithms	2	--	2	1	**3**
3	PCC	PCC-01	Machine Learning for signal processing	3	--	2	1	**4**
4	PCC	PCC-02	Audio Signal Processing	3	--	2	1	**4**
5	PCC	PCC-03	Digital Image and Video Processing	2	-	2	1	**4**
6	PEC	PEC-01	Program Specific Elective –I	3	--	--	1	**3**
			a) Embedded System Design					
			b) Signal Security					
			c) Optimization techniques for Signal Processing					
7	MLC	MLC-01	Research Methodology	3	--	--	1	**3**
Total				19	1	10	1	**25**

PG Program [M. Tech. Electronics – AI in Signal Processing]

Proposed Curriculum Structure

Semester - II

Sr. No.	Course Category	Course Code	Course Name	Teaching Scheme				Credits
				L	T	P	S	
1	OE	OE-01	Open Elective (Networked Embedded System Design (to be offered to other dept)	3	--	--	1	**3**
2	PCC	PCC-04	AI for Signal Processing	3	--	2	1	**4**
3	PCC	PCC-05	Natural Language Processing	3	--	2	1	**4**
4	PCC	PCC-06	Biomedical Signal Processing	3		2	1	**4**
5	PEC	PEC-02	Program Specific Elective –II	3	--	--	1	**3**
			a) Computational Intelligence					
			b) Cloud Computing					
			c) Edge Computing					
6	PEC	PEC-03	Program Specific Elective –III	3	--	--	1	**3**
			a) AI in Connected devices					
			b) Smart Biosensors and Healthcare system					
			c) Blockchain in AI					
7	MLC	MLC-02	Technical Communication Skills	1	--	2	1	**2**
8	LLC		Liberal Learning Course	--	2	2	1	**1**
Total				17	1	8	8	**24**

PG Program [M. Tech. Electronics – AI in Signal Processing]

Proposed Curriculum Structure

Semester - III

Sr. No.	Course Category	Course Code	Course Name	Teaching Scheme				Credits
				L	T	P	S	
1	VSEC	VSEC-01	Dissertation Phase – I	--	--	22	12	**11**
2	SLC	SLC-01	Massive Open Online Course –I	3	--	--	1	**3**
3	SLC	SLC-02	Massive Open Online Course –II	3	--	--	1	**3**
4	OJT		Internship	--	--	--	--	**3**
Total				3	--	18	14	**20**

PG Program [M. Tech. Electronics – AI in Signal Processing]

Proposed Curriculum Structure

Semester – IV

Sr. No.	Course Category	Course Code	Course Name	Teaching Scheme				Credits
				L	T	P	S	
1	VSEC	VSEC-02	Dissertation Phase – II	--	--	22	12	**11**
Total				--	--	22	12	**11**

SEMESTER – I

[PSMC-01] Applied Mathematics

Teaching Scheme:
Lectures: 3 hrs/week
Tutorial: 1 hr/week
Self-Study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Apply linear algebra concepts like eigenvalues, eigenvectors, and matrix decompositions to signal processing problems.
2. Model and analyse random processes using probability distributions and statistical measures.
3. Estimate parameters using methods like maximum likelihood and assess estimator properties.
4. Apply confidence intervals and hypothesis testing for statistical inference.
5. Perform inference and comparison of population means and variances in signal processing contexts.

   Prerequisite: Matrices and its properties, Basic Linear Algebra (Vectors, Linear dependence/independence, Linear Mappings)

Course contents:

- Linear Algebra and Matrix Theory: vector spaces: Basis, dimension, rank, nullity, Matrix representation of linear mappings, eigenvalues, eigenvectors, and matrix decompositions (SVD etc.), Applications to signal processing
- Probability and Random Processes: Probability Distributions: Binomial, Poisson, Normal, Exponential, distributions with Mean Variance, standard deviation, Covariance and correlation, Bayesian Inference, Applications to signal processing
- Point estimation: sufficiency, Neymann-Fisher factorization theorem, unbiased estimation, method of moments, maximum likelihood estimation, consistency and asymptotic normality of maximum likelihood estimator.
- Confidence Intervals, Concepts of hypothesis testing, Characteristics of Good Hypothesis, null and Alternative Hypotheses, Types of Errors.
- Inference on Population mean, comparing two population means, Inference on Variance, Comparing two population variances.

Textbooks:

1. Elementary Linear Algebra (Sixth Edition) by R. Larson and D. Falvo, Houghton Mifflin Harcourt Publishing company, Boston, New York.
2. Walpole, R.E., Myers, R.H., Myers, S.L. and Ye, K. Probability and statistics for engineers and scientists (Vol. 5). New York: Macmillan. 1993.

References:

1. Moon & Stirling, Mathematical Methods and Algorithms for Signal Processing, Prentice Hall, 2000. (required)
2. P. P. Vaidyanathan, Multirate systems and filter banks, Prentice Hall, 2000. (required)
3. A. Boggess & F. J. Narcowich, A First Course in Wavelets with Fourier Analysis, Prentice Hall, 2001.
4. G. Strang, Introduction to Linear Algebra, 2016

[PSBC-01] DSP Algorithms

Teaching Scheme:
Lectures: 3 hrs/week
Self-study: 2hrs/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Interpret, represent and process discrete/digital signals and systems
2. Understand frequency domain analysis of discrete time signals.
3. Design & analyse DSP systems like FIR and IIR Filter, etc.

Course contents:

- Introduction to DSP: Overview: Signals, systems and signal processing, classification of signals, elements of digital signal processing system, concept of frequency in continuous and discrete time signals, Periodic Sampling, Frequency domain representation of sampling, Reconstructions of band limited signals from its samples, Hilbert algorithm.
- Discrete-Time Signals and Systems (Frequency Domain analysis): Z-transform & Inverse z-transform, Linear convolution and its properties, Linear Constant Coefficient Difference equations, Frequency domain representation of Discrete-Time Signals & Systems, Representation of sequences by discrete time Fourier Transform, (DTFT), Properties of discrete time Fourier Transform, and correlation of signals, Fourier Transform Theorems
- Analysis of Linear Time Invariant System: Analysis of LTI systems in time domain and stability considerations. Frequency response of LTI system, System functions for systems with linear constant-coefficient Difference equations, Freq. response of rational system functions relationship between magnitude & phase, All pass systems, inverse systems, Minimum/Maximum phase systems, systems with linear phase.
- A Digital Signal-Processing System, The Sampling Process, Discrete Time Sequences, Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT), Linear Time-Invariant Systems, Digital Filters, Decimation and Interpolation.
- Detailed Designing and analysis of FIR Filters, IIR Filters, Interpolation and Decimation Filters, An FFT Algorithm for DFT Computation, Overflow and Scaling

References:

1. Proakis, John G. - Digital signal processing: principles algorithms and applications, PHI.
2. Oppenheim, Alan V - Discrete-time signal processing, Pearson Education India.
3. Vaidyanathan, Parishwad P - Multirate systems and filter banks, Pearson Education India.
4. Vaidyanathan, Palghat P- The theory of linear prediction, Morgan and Claypool Publishers.
5. Haykin, Simon S. - Adaptive filter theory, Pearson Education India.
6. H. Stark & J. W. Woods, Probability and Random Processes with Applications to Signal Processing, 2014

[PCC-01] Machine Learning for signal processing

Teaching Scheme:	**Examination Scheme:**
Lectures: 3 hrs/week	Mid Sem Evaluation-30 Marks TA-20 Marks End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Understand and explain fundamental machine learning concepts and algorithms.
2. Apply supervised and unsupervised learning techniques to real-world signal processing problems.
3. Evaluate and compare the performance of different machine learning models.
4. Implement machine learning algorithms using appropriate programming tools and libraries.
5. Integrate machine learning methods into signal processing applications to enhance performance and capabilities.

Course contents:

- Supervised Learning: Linear regression, logistic regression, support vector machines, decision trees, and ensemble methods.
- Unsupervised Learning: Clustering algorithms like k-means, hierarchical clustering, and dimensionality reduction techniques such as PCA.
- Neural Networks: Introduction to neural networks, backpropagation, and basics of deep learning.
- Model Evaluation: Techniques for assessing model performance, including cross-validation, confusion matrices, and ROC curves.
- Applications in Signal Processing: Implementing machine learning algorithms for tasks like signal classification, noise reduction, and feature extraction.

References:

1. Pattern Recognition and Machine Learning, C.M. Bishop, 2nd Edition, Springer, 2011.
2. Neural Networks, C.M. Bishop, Oxford Press, 1995.
3. Deep Learning, I. Goodfellow, Y, Bengio, A. Courville, MIT Press, 2016. html
4. Digital Image Processing, R. C. Gonzalez, R. E. Woods, 3rd Edition, Prentice Hall, 2008.
5. Fundamentals of speech recognition, L. Rabiner and H. Juang, Prentice Hall, 1993

[PCC-02] Audio Signal Processing

Teaching Scheme:
Lectures: 3 hrs/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Understand different characteristics of Audio signals
2. Analyze different speech analysis and synthesis systems.
3. Design models and algorithms for audio and speech processing applications.

Course contents:

- Introduction to Audio Signal Processing: Nature and characteristics of audio signals, Human auditory system fundamentals, Digital representation of sound.
- Time and Frequency Domain Analysis: Short-Time Fourier Transform (STFT), Wavelet transform and multi-resolution analysis, Spectrograms and audio feature extraction.
- Audio Perception and Psychoacoustics: Signal processing models of audio perception, Psychoacoustic models and masking effects, Spatial audio perception and rendering techniques, Binaural and ambisonics audio
- Room Acoustics and Reverberation: Room impulse response modelling, Acoustic environment simulation and compensation, Echo and reverberation cancellation.
- Audio Filtering and Enhancement: Noise suppression and dereverberation, Dynamic range compression and equalization, Adaptive filters for audio enhancement.
- Audio Coding and Compression: Transform coding techniques (e.g., MDCT, DCT), Parametric coding of multi-channel audio, Standards: MP3, AAC, Opus, Dolby AC-4, Audio quality evaluation.
- Speech and Music Processing: Basic speech production models, Voice activity detection, speech enhancement, Music genre and instrument classification, Beat tracking and pitch estimation
- Assistive and Interactive Applications: Design and DSP algorithms for hearing aids, Real-time audio effects and virtual instruments, Embedded audio DSP systems

References:

1. Sen, Soumya, Dutta, Anjan Dey, Nilanjan, Audio Processing and Speech Recognition,1st edition, 2019, Springer
2. Gold, B.; Morgan, N.; Ellis, D. Speech and audio signal processing: processing and perception of speech and music. 2nd rev. ed. Wiley-Blackwell, 2011.
3. Sadaoki Furui, "Digital Speech Processing, Synthesis and Recognition" 2/e.
4. Moon & Stirling, Mathematical Methods and Algorithms for Signal Processing, Prentice Hall, 2000.

[PCC-03] Digital Image and Video Processing

Teaching Scheme:
Lectures: 3 hrs/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Explain the fundamental concepts and techniques of digital image processing.
2. Apply image enhancement and restoration techniques in both spatial and frequency domains.
3. Implement image segmentation and feature extraction methods for various applications.
4. Analyse and apply appropriate image compression techniques.
5. Develop practical solutions for real-world problems using image processing algorithms.

Course contents:

- Introduction to image processing: Applications and fields of image processing, Fundamental steps in Digital image processing, Elements of visual perception, Image sensing and acquisition, Basic Concepts in Sampling and Quantization, representing digital images.
- Image Enhancement: Some basic gray level transformations, Histogram Processing, Sharpening Spatial filters, Image Enhancement in the spatial and Frequency domain, Pseudocolouring
- Segmentation: Some Basic Relationships between pixels, point, Edge based segmentation, Boundary detection, extraction and representation, Threshold based segmentation, Region based segmentation, Texture based segmentation. Morphological operations, Use of motion in segmentation.
- Image Compression: Data redundancies Variable-length coding, Quantizers, Predictive coding, Transform coding, Image compression standards.
- Stereoscopic vision: Depth perception from stereo
- Video processing: Basics of video processing, Motion analysis, video compression, video compression standards Case studies: Watermarking, Biometrics, Document analysis, Moving object detection

References:

5. Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing, Pearson , 4rd Edition
6. Anit K. Jain, Fundamentals of Digital Image Processing, Prentice Hall.
7. Digital Video Processing by A. Murat Tekalp, first edition, Prentice Hall.

[LC-01] Machine Learning for Signal Processing Lab

Teaching Scheme:
Practical: 2 hrs/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Implement supervised and unsupervised learning algorithms for signal classification and clustering tasks.
2. Preprocess and extract relevant features from signal data using domain-specific techniques.
3. Evaluate ML models using appropriate performance metrics (accuracy, precision, recall, F1-score, etc.).
4. Integrate ML models with DSP pipelines for tasks like denoising, classification, and segmentation.
5. Design and demonstrate ML solutions for real-world signal processing applications (audio, biomedical, radar, etc.).

Tools Used: MATLAB, Python

List of Experiments:

1. To perform normalization, noise removal, and filtering on time-domain signal data (e.g., EEG or audio signals).
2. To extract features such as MFCCs, Zero Crossing Rate, RMS Energy, and statistical features from raw signal data.
3. To classify simple time-series signal datasets using the k-NN algorithm and evaluate model performance.
4. To apply unsupervised learning for grouping similar signal patterns without using labeled data.
5. To visualize high-dimensional signal feature data and reduce complexity using Principal Component Analysis.
6. To train and evaluate decision-make-based models on biomedical signals for detecting abnormalities.
7. To implement a basic neural network to classify speech signals (e.g., vowel/consonant recognition).
8. To use an unsupervised neural network (Autoencoder) for denoising audio or biomedical signals.
9. To implement RNN for modeling and classifying time-series sequences such as phoneme or ECG beat patterns.
10. To assess model performance using statistical metrics and validation strategies.

[LC-02] Audio signal Processing Lab

Teaching Scheme:
Practical: 2 hrs/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Implement and analyze basic audio signal processing techniques, such as filtering, feature extraction, and spectral analysis.
2. Apply psychoacoustic models to enhance audio quality and simulate audio perception effects.
3. Design and evaluate audio compression and coding techniques, including the implementation of real-world standards like MP3.
4. Develop practical audio processing systems, including speech enhancement, noise reduction, and real-time audio applications

Tools Used: MATLAB

List of Experiments:

1. Time and Frequency Domain Analysis: Analyse audio signals using Fourier Transform and Short-Time Fourier Transform (STFT) to extract time and frequency domain features.
2. Noise Reduction Techniques: Implement spectral subtraction and Wiener filtering to reduce noise in audio signals and enhance speech quality.
3. Audio Compression Using Transform Coding: Apply MDCT (Modified Discrete Cosine Transform) for audio compression and evaluate compression efficiency with MP3 and FLAC codecs.
4. Psychoacoustic Analysis: Implement psychoacoustic models to simulate the masking effects of human hearing and apply them to audio signal enhancement.
5. Dynamic Range Compression and Equalization: Apply dynamic range compression and frequency equalization to improve audio signal quality for various applications.
6. Speech Enhancement Algorithms: Implement speech enhancement techniques to improve the clarity of speech signals in noisy environments.
7. Spatial Audio and Binaural Processing: Simulate spatial audio effects using stereo and binaural processing for 3D audio rendering.
8. Room Acoustics Modelling and Echo Cancellation: Model room acoustics and apply echo cancellation techniques to improve audio clarity in reverberant environments.

[LC-03] Digital Image and Video Processing Lab

Teaching Scheme:	**Examination Scheme:**
Practical: 2 hrs/week	Mid Sem Evaluation-30 Marks TA-20 Marks End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Implement various image processing and image enhancement techniques in MATLAB and identify their application areas.
2. Execute various image segmentation techniques.
3. Implement image and video compression techniques.

List of Experiments:

1. Obtaining row profile of a given row of an image in MATLAB
2. Plotting histogram of an image in MATLAB
3. Adjusting the brightness of an image using a constant value in MATLAB
4. Calculating mean and variance of an image in MATLAB
5. Histogram Equalization of an image in MATLAB
6. Spatial Filtering: Applying low pass, high pass and median filters on an image in MATLAB
7. Pseudo Coloring an image using sinusoidal transforms in MATLAB
8. Detection of edges of an image using Canny Edge Detection algorithm in MATLAB.
9. Image Thresholding using OTSU Thresholding algorithm in MATLAB.
10. Region-based Image Segmentation using region growing in MATLAB.
11. Apply Discrete Cosine Transform (DCT) on an image in MATLAB.
12. Motion Estimation for video sequence using full search algorithm.
13. Tutorial: Presentation of some topics in Digital Image and Video Processing.

Elective-1 [PEC-01--] Embedded System Design

Teaching Scheme:
Lectures: 3 hrs/week
Self-Study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
Lab based TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Develop embedded programs using assembly and C, applying instruction scheduling, pointer operations, and arithmetic for low-level system design.
2. Explain the architecture and functionality of real-time operating systems, covering task management, scheduling, and inter-process communication mechanisms.
3. Analyze RTOS features and synchronization techniques, including thread management, semaphores, message queues, and interrupt handling.
4. Evaluate the role of RTOS in real-world applications, such as automotive, industrial automation, IoT, robotics, and medical systems.
5. Implement and test embedded applications using Embedded C, FreeRTOS, and RT Linux on ARM-based development kits through lab sessions.
   Pre-requisite: Knowledge microprocessor, microcontroller, CORTEX ARM 9 architectures.

Course contents:

- Assembly Code using Instruction Scheduling, Register Allocation, Conditional Execution and Loops Simple C Programs using Function Calls, Pointers, Structures, Integer and Floating-Point Arithmetic. Challenges in Embedded System Design, Design Process.
- Real time operating System: Tasks, Process and Threads, Multiprocessing and Multitasking, Task Scheduling. Shared Memory, Message Passing, Remote Procedure Call and Sockets.
- Consideration of RTOS for programming, System architecture of RTOS, Thread creation, thread management, synchronization mechanism for RTOS, Semaphores, message Queues, Pipes, Interrupts for RTOS.
- RTOS Case studies and Applications: Automotive system, Industrial Automation, Medical devices, IoT devices, Defense system, Robotics, Aerospace and rail.
- **Lab based topics:** Embedded C, RT Linux, FreeRTOS, ARM-based kits.
- **Self-Study:** Basic Embedded C programming, microcontroller GPIO control, and peripheral interfacing (ADC, UART, SPI, I2C). Interrupt handling, and sensor integration for development boards, RTOS fundamentals such as task scheduling, semaphores, and queues will be practiced using FreeRTOS. Introductory exercises on RT Linux, including GPIO access and real-time task execution, will be included.

References:

1. "Embedded System Design" by Frank Vahid and Tony Givargis
2. "Embedded Systems: Introduction to ARM Cortex-M Microcontrollers" by Jonathan W. Valvano
3. "Real-Time Concepts for Embedded Systems" by Qing Li and Caroline Yao

Elective-1 [PEC-01--] System Security

Teaching Scheme:
Lectures: 3 hrs/week
Self-Study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Analyse security requirements and vulnerabilities in signal-based systems.
2. Apply cryptographic methods to secure digital signals in both time and transform domains.
3. Design and evaluate watermarking and steganography systems for media authentication and protection.
4. Implement secure signal processing solutions considering real-time, embedded, and multimedia constraints.

Course contents:

- Introduction to Signal Security: Need for signal security in modern systems, Signal vulnerabilities and threat models, Overview of security goals: confidentiality, integrity, authenticity.
- Cryptographic Techniques in Signal Processing: Basics of symmetric/asymmetric cryptography, Stream and block ciphers in signal protection (AES, RSA, ECC), Signal encryption techniques in time and transform domains, Lightweight cryptography for embedded signal systems.
- Watermarking and Steganography: Digital watermarking principles for audio, image, video, Robustness, imperceptibility, and capacity trade-offs, Spatial and transform domain watermarking, Steganographic methods and detection.
- Secure Signal Processing Architectures: Hardware implementation of cryptographic functions, Trusted Platform Modules (TPM), secure boot, and signal hardware protection, Real-time constraints in secure signal applications, Side-channel attacks on signal processors.
- Applications and Case Studies: Signal security in communication systems (e.g. IoT), Secure biometric signal processing, Multimedia content protection (DRM), Case study: Speech signal security, ECG signal authentication.

References:

1. "Cryptography and Network Security: Principles and Practice" by William Stallings
2. "Digital Watermarking and Steganography" by Ingemar J. Cox, Matthew L. Miller, Jeffrey A. Bloom
3. "Secure Signal Processing: Theory and Applications" by Jean-Luc Danger, Sven Bayon, Daniel Etiemble.
4. "Multimedia Security: Steganography and Digital Watermarking Techniques for Protection of Intellectual Property" by Frank Y. Shih.
5. "Introduction to Modern Cryptography" by Jonathan Katz and Yehuda Lindell.

Elective-1 [PEC-01--] Optimization techniques for Signal Processing

Teaching Scheme:
Lectures: 3 hrs/week
Self-Study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Formulate and classify signal processing problems as optimization tasks and analyse their properties.
2. Apply convex and non-convex optimization methods for designing and improving signal processing algorithms.
3. Utilize sparse and structured optimization approaches for efficient signal recovery and reconstruction.
4. Integrate modern optimization techniques into machine learning and deep learning-based signal processing applications.

Course contents:

- Introduction to Optimization: Optimization problem formulation, Convex vs. non-convex optimization, Linear and quadratic programming basics, Feasibility, optimality conditions,
- Convex Optimization for Signal Processing: Gradient descent and Newton's method, Lagrange multipliers and KKT conditions, Constrained optimization and duality, Applications: FIR filter design, spectral estimation, adaptive filtering
- Sparse and Structured Optimization: L1-norm minimization, basis pursuit, Compressed sensing principles, Matching pursuit, orthogonal matching pursuit, Applications: Image/audio signal recovery, denoising, sparse representation,
- Stochastic and Iterative Optimization Methods: Stochastic gradient descent (SGD), Adaptive methods: RMSprop, Adam, AdaGrad, Expectation-maximization (EM) for signal models, Applications in blind source separation, speech enhancement
- Optimization in Machine Learning for Signal Processing: Optimization in neural networks (backpropagation), Regularization techniques (L1, L2, dropout), Deep unfolding and learned iterative schemes, Case studies: Image deblurring, super-resolution, beamforming

References:

1. S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004.
2. Panos Pardalos and Mauricio G. C. Resende, Handbook of Applied Optimization, Oxford University Press, 2002.
3. Dimitri P. Bertsekas,Nonlinear Programming, Athena Scientific, 2nd edition, 1999.

SEMESTER – II

(OE) [OE-01] Networked Embedded System Design

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20
Marks End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Implement simple sketches on the Arduino boards involving several peripherals
2. Identify, design and implement applications on the Arduino boards producing custom shields.
3. Deploy low-end applications using low- and high-level languages on microcontroller platform.

Course contents:

- Introduction to processors: Introduction of Microprocessors and Microcontrollers, Introduction of Arduino Microcontrollers.
- Introduction to architecture: Atmega328: Basics and Architecture, Instruction Set
- Arduino programming: Arduino programming basics, Analog/Digital components and its application with Arduino, IDE for Arduino.
- Other utilities in Arduino: Timers, Analog comparators and hardware interrupts
- Interfacing with peripherals: Communication buses, Interfacing of I/O devices
- Case studies: Case studies of a few projects using Arduino boards and Shields

References:

1. Brian Evans, "Beginning Arduino Programming", Springer, 2011
2. Michael J. Pont , "Embedded C", Pearson Education, 2nd Edition, 2008
3. Raj Kamal, " Embedded Systems – Architecture: Programming and Design", TMH
4. Frank Vahid and Tony Givargis, "Embedded System Design", Wiley

[PCC-04] AI for Signal Processing

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks End Sem Evaluation-50 Marks

Course Outcomes:
After successful completion of this course the students will be able to
1. Explain machine learning fundamentals (supervised vs. unsupervised) and key algorithms (linear models, SVM, neural nets, etc.)
2. Apply ML techniques to signal data (regression, classification, clustering, denoising) and extract relevant features.
3. Implement models (CNNs, RNNs, autoencoders) using standard tools (e.g. Python/TensorFlow/Pytorch).
4. Analyze and compare algorithm performance (cross-validation, ROC, confusion matrix) on signal tasks.
5. Integrate AI methods into signal processing systems (e.g. speech/music recognition, ECG anomaly detection).

Course contents:
- Mathematical and Optimization Foundations for AI in Signal Processing (6 Hours):
  Vector and matrix representation of signals; norms, inner products, projections. Eigenvalues, eigenvectors and signal subspaces; introduction to PCA for signal representation. Random processes and noise modelling in signals; covariance, correlation, stationarity, Bayes rule for probabilistic signal classification and detection, Cost functions for signal models; constrained and unconstrained optimization, Gradient-based optimization in signal models; convergence and conditioning issues
- AI Frameworks for Signal Processing (6 Hours):
  Data-driven signal models vs classical parametric models (AR, ARMA, state-space), Feature spaces for signals: time, frequency, and time–frequency representations, Supervised learning pipeline for signals: dataset design, train–validation–test splits, Regularization for signal models: early stopping, weight decay, dropout (concept only), Model evaluation for signal tasks: classification metrics, regression metrics, ROC–AUC, Deployment aspects: latency, memory, and real-time constraints in signal AI systems.
- Feature Engineering and Unsupervised Methods for Signals (6 Hours):
  Time-domain features: energy, RMS, zero-crossing rate, higher-order statistics. Frequency-domain features: FFT-based features, band powers, spectral moments, Time–frequency features: STFT, filter-banks, wavelets; MFCC pipeline (speech focus). Clustering of signal segments: DBSCAN and hierarchical clustering for pattern discovery, Dimensionality reduction of signal features: PCA and low-rank representations, Outlier and anomaly detection in signals using unsupervised models
- Deep Learning Architectures for Signal Processing (8 Hours):
  Multilayer perceptron's for regression and classification of 1D signal features. 1D convolutional neural networks for raw time-series and sensor data. 2D CNNs for spectrograms and other time–frequency images. Autoencoders for signal denoising, compression, and representation learning. Sequential models: RNN, LSTM, GRU architecture for temporal signals. Attention-based and Transformer models for long-range temporal dependencies in signals, Training deep models: choice of loss, optimizers (SGD, Adam), mini-batching and normalization,

Comparison of deep models with classical DSP and parametric models for signal tasks.

- AI for Speech, Image, and Biomedical Signal Processing (10 Hours):
  Speech signals: feature extraction (MFCC, filter-banks), acoustic modeling with DNN/CNN/RNN. Speech applications: keyword spotting, speaker identification, speech enhancement, Audio and environmental sound classification using CNNs on spectrograms, Image-like signals: spectrograms, medical images, remote-sensing images; CNN-based processing, Biomedical time-series: ECG, EEG, PPG – preprocessing and feature extraction, Deep learning for ECG beat classification and arrhythmia detection, Deep learning for EEG-based state detection and seizure prediction, AI for medical image analysis: segmentation, detection, and classification (basic pipelines), Evaluation and regulatory considerations in medical AI signal systems, Practical issues: data imbalance, annotation noise, and interpretability in critical applications
- Case Studies in AI for Signal Processing (4 Hours):
  AI-based acoustic event detection or speech command recognition system, CNN-based ECG or EEG classification pipeline from raw signals to decision. AI-assisted image or spectrogram-based defect/fault detection in engineering systems, Speech/music processing (voice activity detection, genre/instrument classification, pitch estimation), Radar/Communications: Target classification from radar returns; modulation recognition in communication signals.

References:

1. Christopher M. Bishop, Pattern Recognition and Machine Learning, 2nd Ed., Springer (2011)
2. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press (2016)
3. B. Gold, N. Morgan, D. Ellis, Speech and Audio Signal Processing, Wiley (2011)
4. Soumya D. Sen et al., Audio Processing and Speech Recognition, Springer (2019)
5. R.C. Gonzalez, R.E. Woods, Digital Image Processing, 3rd Ed., Prentice Hall (2008)
6. L.R. Rabiner & B.-H. Juang, Fundamentals of Speech Recognition, Prentice Hall (1993)
7. NPTEL online courses: Machine Learning for Signal Processing (Prof. S.R.M. Prasanna, IIT Madras), Applied Machine Learning (Prof. Mukesh Rao, IISc), Deep Learning (Prof. Balaraman Ravindran, IIT Madras).

[LC-04] AI for Signal Processing Lab

Teaching Scheme:
Self-Study: 2 hr/week

Examination Scheme:
CIE-100 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Implement signal preprocessing techniques such as normalization, filtering, windowing, and noise removal for real-world signal data
2. Extract and analyze time-domain, frequency-domain, and time–frequency features from raw signal data using appropriate signal processing methods.
3. Implement classical supervised and unsupervised machine learning algorithms (e.g., regression, k-NN, SVM, clustering, PCA) for signal classification, regression, and pattern discovery tasks.
4. Design, train, and evaluate basic neural network models (MLP, CNN, Autoencoder, RNN/LSTM) for signal-based applications using standard AI frameworks.
5. Evaluate and compare the performance of different AI models using appropriate statistical metrics and validation strategies.
6. Integrate signal processing techniques with AI models to develop end-to-end solutions for real-world signal processing applications such as speech recognition, biomedical signal analysis, and pattern recognition.

List of Experiments:

1. Linear/Logistic Regression (Signal Prediction/Classification): Implement linear regression on a time-series (e.g. predict future ECG sample) and logistic regression for binary classification (e.g. speech vs. music segments).
2. Clustering with K-Means: Apply K-means to group signal feature vectors (e.g. cluster different musical instruments or EEG patterns). Visualize clusters in 2D (using PCA reduction).
3. Support Vector Machine Classification: Use SVM to classify signals (e.g. classify different types of pulses or voice commands) and analyze kernel effects.
4. Decision Tree / Random Forest: Train a decision tree and/or random forest on a signal dataset (e.g. arrhythmia types) and evaluate performance.
5. Principal Component Analysis (PCA): Perform PCA on an image-based signal (spectrogram or radar image) or multi-channel signal (EEG) to compress data and reconstruct signals.
6. Feedforward Neural Network: Build a small MLP in Keras/PyTorch for a classification/regression task on 1D signals (e.g. classify digitized speech patterns).
7. Convolutional Neural Network (CNN): Train a CNN on signal spectrograms or small images (e.g. classify spoken digits or radar targets). Use a simple architecture (few convolution layers) to ensure feasibility.
8. Autoencoder for Denoising: Design a shallow autoencoder to remove noise from a signal (e.g. denoise a musical clip or ECG corrupted by baseline noise).
9. Recurrent Network (RNN/LSTM): Implement an RNN/LSTM for sequence prediction or classification (e.g. predict the next few samples of a waveform or classify heartbeats).
10. Ensemble Learning (AdaBoost/Bagging): Apply ensemble methods on a feature-engineered signal dataset (e.g. combine weak learners for ECG beat classification).

[PCC-05] Natural Language Processing

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Understand signals and language as sequential data representations.
2. Apply NLP techniques to speech and time-series signal processing tasks.
3. Develop sequence and generative models for signal analysis and synthesis.
4. Use foundation and multimodal models for audio-text-sensor fusion.
5. Evaluate ethical, robustness, and deployment challenges in GenAI-based signal systems.

Course contents:

- Foundations: Overview of Signal Processing and NLP, Introduction and basic text processing, Signals, text, and tokens as sequences, Review of DSP fundamentals: Fourier Transform, STFT, spectrograms, Feature extraction techniques: MFCCs, filter banks
- Representation Learning: Text representations: Bag-of-Words, TF-IDF, word embeddings, Signal representations: handcrafted vs learned features, Self-supervised learning for signals, Audio and time-series representation learning (wav2vec, HuBERT)
- Sequence and Generative Models: Statistical sequence models and HMMs, Recurrent Neural Networks (RNNs, LSTM, GRU), Transformer architectures and attention mechanisms, Generative models: Variational Autoencoders (VAEs), Generative Adversarial Networks (GANs), Diffusion models for signals
- Multimodal and Foundation Models: Multimodal learning: audio-text-sensor fusion, Foundation models for speech and time-series signals, Prompting and adapting Large Language Models (LLMs) for signal tasks, Cross-modal embeddings and alignment
- Advanced Topics and Ethics: Explainable AI (XAI) for generative signal models, Model robustness, bias, and reliability, Privacy and ethical issues in GenAI systems, Deployment challenges in healthcare, IoT, and industrial environments
- NLP and Generative AI Applications: Automatic Speech Recognition (ASR), Speech-to-Text and Text-to-Speech systems, Speech enhancement, denoising, and super-resolution, Emotion, intent, and event detection from speech and signals, Signal generation and data augmentation using GenAI

Textbooks:

1. Jurafsky, D. & Martin, J. H., Speech and Language Processing, Pearson.

References:

1. Goodfellow, I., Bengio, Y., & Courville, A., Deep Learning, MIT Press
2. Goldberg, Y., Neural Network Methods in Natural Language Processing
3. Rabiner, L. & Juang, B., Fundamentals of Speech Recognition
4. Prince, S., Understanding Deep Learning

[LC-05] Natural Language Processing Lab

Teaching Scheme:
Self-Study: 2 hr/week

Examination Scheme:
CIE-100 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Understand the preprocessing steps for NLP.
2. Apply Python libraries like NLTK for NLP to work on stop words, tokenization, corpus etc.
3. Understand the importance of lemmatization and stemming concepts for NLP.
4. Understand the process of applying NLP for various applications.

List of Experiments:

Python packages like Scikit-learn (SKLearn), NLTK, spaCy, gensim, PyTorch, transformers (HuggingFace) etc., may be used for programming.

1. Prepare / pre-process a text corpus to make it more usable for NLP tasks using tokenization, stopword removal, punctuation removal, stemming, and lemmatization.
2. Perform POS tagging in each text file.
   - Extract all the nouns present in the text.
   - Create and print a dictionary with frequency of parts of speech present in the document.
   - Find the similarity between any two text documents.
3. Perform dependency analysis of a text file and print the root word of every sentence.
4. Create the TF–IDF (Term Frequency–Inverse Document Frequency) matrix for a given set of text documents.
5. Extract all bigrams and trigrams using n-grams from the NLTK library.
6. Identify and print the named entities using Named Entity Recognition (NER) for a collection of news headlines.
7. Classify movie reviews as positive or negative using the IMDB movie dataset of 50K reviews.
   Dataset link:
   https://www.kaggle.com/datasets/lakshmi25npathi/imdb-dataset-of-50k-movie-reviews
8. Convert speech signals to text and perform sentiment analysis
9. Analyze vibration signals using Symbolic Aggregate Approximation (SAX) and apply NLP techniques for similarity detection.

[PCC-06] Biomedical Signal Processing

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. To Understand the Sources, Types & Characteristics of Different Noises and Artifacts Present in Biomedical Signals.
2. Design of Time Domain and Frequency Domain Filters for Noise and Artifact Removal from Biomedical signals.
3. Apply Various Methods for Analyzing Biomedical Signal Characteristics.
4. Alternative Techniques of Analyzing Biomedical Signals in Time and Frequency Domain.

Course contents:

- Introduction to Biomedical Signals: Action Potential and Its Generation, Origin and Waveform Characteristics of Basic Biomedical Signals Like: Electrocardiogram (ECG), Electroencephalogram (EEG), Electromyogram (EMG), Phonocardiogram (PCG), Electroneurogram (ENG), Event-Related Potentials (ERPS), Electrogastrogram (EGG), Objectives of Biomedical Signal Analysis, Difficulties in Biomedical Signal Analysis, Computer-Aided Diagnosis.
- Removal of Noise and Artifacts from Biomedical Signal: Random and Structured Noise, Physiological Interference, Stationary and Nonstationary Processes, Noises and Artifacts Present in ECG, Time and Frequency Domain Filtering.
- EEG Signal Processing and Event Detection in Biomedical Signals: EEG Signal and Its Characteristics, EEG Analysis, Linear Prediction Theory, Autoregressive Method, Sleep EEG, Application of Adaptive Filter for Noise Cancellation in ECG and EEG Signals; Detection of P, Q, R, S and T Waves in ECG, EEG Rhythms, Waves and Transients, Detection of Waves and Transients, Correlation Analysis Ad Coherence Analysis of EEG Channels.
- Analysis of Nonstationary Signals: Heart Sounds and Murmurs, Characterization of Nonstationary Signals and Dynamic Systems, Short-Time Fourier Transform, Considerations in Short-Time Analysis and Adaptive Segmentation.

Textbooks:

1. Rangayyan, R.M., 2015. Biomedical signal analysis (Vol. 33). John Wiley & Sons.
2. 2. Reddy, D.C., 2005. Biomedical signal processing: principles and techniques. McGraw-Hill

References:

1. Tompkins, W.J., 1993. Biomedical digital signal processing. Editorial Prentice Hall.
2. Sörnmo, L. and Laguna, P., 2005. Bioelectrical signal processing in cardiac and neurological applications (Vol. 8). Academic Press.

[LC-06] Biomedical Signal Processing Lab

Teaching Scheme:
Self-Study: 2 hr/week

Examination Scheme:
CIE-100 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. To design and realize biosignal generators such as ECG, EEG, and EMG
2. To analyze and interpret normal and abnormal biosignals

List of Experiments:

1. Acquire and Obtain the Limb Lead ECG Signal and Display
2. Design a Notch Filter of 50 Hz to Remove the Power Line Interference in Acquired ECG Signal
3. Design a Low Pass Filter of Defined Cut-Off Frequency to Remove the High Frequency Noises in Acquired ECG Signal
4. Design a High Pass Filter of Defined Cut-Off Frequency to Remove the Low Frequency Noises in Acquired ECG Signal
5. Compare Different Types of FIR Filter for LPF of ECG Signal
6. Compare Different Types of IIR Filter for LPF of ECG Signal
7. To Perform a Spectral Analysis of ECG Signal
8. Detection of R Peak and R-R Interval from Acquired ECG Signal
9. Acquire and Obtain the 20-20 Lead ECG Signal and Display
10. To Perform a Spectral Analysis of ECG Signal

[PEC-02: A] Computational Intelligence

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Differentiate between Artificial Intelligence and Computational Intelligence. State various signal processing applications of CI, and emerging trends.
2. Design and analyze a fuzzy inference system by defining fuzzy sets, membership functions, and rule bases for a basic signal processing problem.
3. Implement and evaluate supervised or unsupervised neural network models using appropriate learning algorithms and assess performance using standard metrics.
4. Apply regression and optimization techniques to solve parameter estimation or minimization problems in CI-based models.
5. Analyze and compare evolutionary and swarm intelligence algorithms (GA, PSO, ACO) and apply them for optimization or hyperparameter tuning in signal processing tasks.

Course contents:

- Introduction to Computational Intelligence (CI) (5 hrs)
  Comparison of AI with CI, Characteristics of CI systems: learning, adaptation, robustness, CI paradigms, Applications of CI in signal processing and AI, Emerging trends in computational intelligence
- Fuzzy Logic and Fuzzy Inference Systems (8 hrs)
  Fuzzy sets, Fuzzy logic and reasoning, Membership functions and linguistic variables, Fuzzy controllers, Applications of Fuzzy systems in signal processing, Neuro-fuzzy systems (ANFIS).
- Artificial Neural Networks (7 hrs)
  The artificial neuron models, supervised, unsupervised and reinforcement learning, Gradient descent and backpropagation, Convergence, overfitting, and regularization, Performance measures of supervised learning.
- Regression and Optimization (7 hrs)
  Least square methods, Derivative-based optimization, Derivative-free optimization, CI-assisted deep learning optimization.
- Evolutionary and Swarm Intelligence (8 hrs)
  Optimization and search strategies, Genetic Algorithms: Representation and encoding, Selection, crossover, mutation, Fitness evaluation, Convergence behavior and parameter tuning, Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Comparative study: GA vs PSO vs ACO, Applications in signal processing: Hyperparameter optimization, Evolutionary neural networks.

Textbooks:

1. Engelbrecht, Computational Intelligence, Wiley
2. J. S. R. Jang et al., Neuro-Fuzzy and Soft Computing, Pearson

References:

1. S. Haykin, Neural Networks and Learning Machines, Pearson
2. D. E. Goldberg, Genetic Algorithms in Search, Optimization and Machine Learning, Pearson

[PEC-02: B] Cloud Computing

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:
After successful completion of this course the students will be able to

1. Analyze distributed and cloud system models and enabling technologies
2. Design cloud architecture using IaaS, PaaS, SaaS, and federated models
3. Evaluate virtualization platforms, VM migration, and load balancing
4. Apply performance, scalability, and QoS metrics to cloud environments
5. Assess security, privacy, capacity planning, and disaster recovery strategies
6. Model and simulate cloud systems using cloud sim.

Course contents:

- Foundations of Cloud Computing:
  Introduction to cloud computing, Evolution of cloud computing, Distributed system models, Parallel computing paradigms, Grid computing architecture, Peer-to-peer computing models, benefits, challenges and risk management in cloud environment
- Cloud Architecture & Services:
  Cloud system architecture and layered models, Infrastructure, Platforms and Services: IaaS, PaaS, SaaS; Development models: Public, Private, Hybrid, Federated cloud; Service oriented architecture (SOA) in cloud.
- Virtualization and Resource Management:
  Introduction to Virtualization platform, principles of working, Hypervisors: Type-I, Type-II, Virtual machine lifecycle; Load balancing strategies in cloud, VMWare ESX memory management, Capacity planning in cloud infrastructures.
- Data Center and Cloud Platform Architectures
  Data center architecture for cloud computing, Scalability and performance modeling, Quality of service parameters, architecture for cloud computing, Cloud platform architectures: Amazon Web Services (AWS), Microsoft Azure, Google App Engine, MapReduce framework, Yahoo Hadoop ecosystem, Open-source cloud platforms: Eucalyptus, Nimbus, OpenStack;
- Data Management & Security
  Data management challenges in cloud computing, Security threats and attack vectors, Cloud security architectures, Privacy and trust models, Disaster recovery and business continuity planning.
- Cloud Simulation and Emerging Trends
  Cloud programming models, Resource monitoring and management, VM resource allocation, management, and monitoring, Cloud simulation tools: CloudSim architecture and use cases; Performance evaluation using simulation; Open-source vs commercial clouds; Fog computing architecture, Cloud–Fog–Edge enabled analytics, Serverless computing, Function-as-a-Service (FaaS) model.

Textbooks:

1. Elementary Linear Algebra (Sixth Edition) by R. Larson and D. Falvo, Houghton Mifflin Harcourt Publishing company, Boston, New York.
2. K. Chandrasekaran — A concise but solid resource on cloud fundamentals, virtualization, and services (CRC Press, 2023).
3. Mastering Cloud Computing: Foundations and Applications Programming by Rajkumar Buyya, Christian Vecchiola, and Thamarai Selvi. Published by McGraw Hill Education

(2nd edition around 2024/2025)

References:

1. Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, and IaaS) by Michael J. Kavis. Published by Wiley in 2015
2. Cloud Computing for Dummies by Judith S. Hurwitz, Robin Bloor, Marcia Kaufman, and Fern Halper (2nd Edition). Published by John Wiley & Sons
3. Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance by Tim Mather, Subra Kumaraswamy, and Shahed Latif. Published by O'Reilly Media.

[PEC-02: C] Edge Computing

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Understand the fundamental concepts and components of edge computing and its significance.
2. Understand and implement the technologies and architectures for specific applications.
3. Ability to design edge computing solutions, including architectures, models, and platforms. Apply performance analysis and optimization techniques to evaluate the effectiveness and efficiency of edge computing solutions.
4. Identify the challenges in edge computing. Analyze future directions and innovations in the field of edge computing.

Course contents:

- Introduction to Edge Computing (7 Hours)
  Overview of Edge Computing: Definition and key concepts, History and evolution of edge computing. Edge vs. Cloud Computing: Differences and similarities, When to use edge computing. Key Components of Edge Computing: Edge devices and sensors, Edge gateways and nodes, Data processing at the edge
- Core Technologies and Architectures (8 Hours)
  Technologies Supporting Edge Computing: IoT (Internet of Things), 5G and network technologies, Edge AI and machine learning. Architectural Models: Edge-centric architecture, Fog computing and mist computing, Hybrid edge-cloud models. Key Use Cases and Applications: Smart cities, Healthcare, Manufacturing and industrial IoT
- Implementing Edge Computing Solutions (8 Hours)
  Edge Computing Platforms: Overview of popular platforms (e.g., AWS IoT Greengrass, Azure IoT Edge), Platform capabilities and features. Developing Edge Applications: Building simple edge applications, Using containers and lightweight runtimes. Deployment and Management: Provisioning and configuring edge devices, Monitoring and managing edge environments
- Challenges and Future Trends (7 Hours)
  Challenges in Edge Computing: Security and privacy concerns, Data management and synchronization, Scalability and performance issues. Emerging Trends and Technologies: Edge computing in conjunction with 5G and AI, Advances in edge device capabilities. Future Directions and Innovations: Potential impact of edge computing on various industries, Innovations on the horizon

Textbooks:

1. Anitha Kumari, G. Sudha Sadasivam, D. Dharani and M. Niranjana Murthy, "Edge Computing Fundamentals, Advances and Applications", CRC Press, 2022.
2. Perry Lea, "IoT Edge Computing for Architects" –Second Edition, Publisher: Packet Publishing, 2020, ISBN: 9781839214806

References:

1. Xin Sun and Amin Vahdat, "Edge Computing: A Primer", CRC Press, 2019.
2. Daniel Situnayake, Jenny Plunkett, "AI at the Edge", O'Reilly Media, Inc, 2023.
3. Rajkumar Buyya and Satish Narayana Srirama, "Fog and Edge Computing Principles and Paradigms", John Wiley & Sons, Inc.

[PEC-03: A] AI in Connected devices

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Understand the fundamentals of AI and IoT integration.
2. Identify real-world applications of AI in IoT-enabled devices and systems.
3. Apply machine learning and Deep Learning techniques to sensor-generated data
4. Discuss key challenges, ethical considerations, and data privacy issues related to AI and IoT.

Course contents:

- FUNDAMENTALS OF AI AND IoT
  What is AI? Key concepts and definitions, Overview of IoT: connected devices, sensors, and data streams, The synergy between AI and IoT: unlocking insights from sensor data
- IOT ARCHITECTURE AND COMMUNICATION
  IoT system architecture (Perception, Network, Application layers), Sensors and actuators, Communication protocols: MQTT, CoAP, HTTP, LoRaWAN, NB-IoT, Device-to-device (D2D) and device-to-cloud communication, Data acquisition and preprocessing in connected devices
- MACHINE LEARNING FOR CONNECTED DEVICES
  Machine learning workflow for IoT data, Supervised, unsupervised, and reinforcement learning for IoT, Feature extraction from sensor data, Classical ML models for connected devices, Model evaluation and validation in real-time systems
- DEEP LEARNING FOR CONNECTED DEVICES
  Deep learning models for sensor data, CNNs for image-based IoT applications, RNN/LSTM for time-series sensor data, Spatio-temporal learning for connected systems, Energy-efficient deep learning techniques
- CHALLENGES AND CONSIDERATIONS
  Data privacy and security issues in AI-powered IoT applications, Overcoming interoperability and scalability challenges, Ethical considerations in AI-driven decision-making with IoT data, Case study: Ensuring ethical AI usage in smart city projects
- REAL-WORLD APPLICATIONS OF AI IN IoT
  Smart homes: AI-driven automation and energy optimization, Industrial IoT (IIoT): predictive maintenance and process efficiency, Healthcare IoT: AI-enhanced remote patient monitoring and diagnostics, Case study: AI and IoT in supply chain optimization

Textbooks:

1. Charu C. Aggarwal, Neural Networks and Deep Learning, Springer
2. Rajkumar Buyya et al., Internet of Things: Principles and Paradigms, Elsevier

References:

1. Al-Fuqaha et al., Internet of Things: A Survey, IEEE
2. Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow

[PEC-03: B] Smart Biosensors and Healthcare system

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Explain and apply the principles of biosensors, biomedical signals and conditioning techniques for healthcare diagnostics.
2. Describe, apply, and analyze sensor fabrication processes, BioMEMS techniques, and sensor testing and characterization methods.
3. Analyze and evaluate smart healthcare and IoMT systems using wearable biosensors, and propose ethically sound, regulation-compliant solutions based on real-world case studies and emerging trends.

Course contents:

- Fundamentals of Biosensors
  Introduction to biosensors, classification, sensing and transduction mechanisms, electrochemical, optical and piezoelectric biosensors, performance characteristics, sensitivity, selectivity, applications in healthcare diagnostics.
- Sensor fabrication
  Basics of microfabrication processes: substrate preparation, thin-film and thick-film deposition techniques, oxidation and diffusion. Photolithography process: mask design, photoresists, UV exposure, development, and pattern transfer. BioMEMS fabrication and role of electronics in biosensor fabrication.
- Biomedical Signals and Signal Acquisition
  Origin and characteristics of biomedical signals (ECG, EEG, EMG, PPG), electrodes and sensors, signal acquisition systems, noise sources and artefacts, signal conditioning, sampling and quantization.
- Sensor Testing and Characterization
  Introduction to sensor testing and characterization in biomedical applications. Static and dynamic characteristics of sensors: sensitivity, accuracy, precision, resolution, linearity, hysteresis, repeatability, and drift. Calibration Techniques for Biosensors. Noise analysis and signal-to-noise ratio (SNR) in sensors. Testing standards and protocols for biomedical sensors.
- Smart Healthcare Systems and IoMT
  Wearable biosensors, Internet of Medical Things (IoMT), edge and cloud computing for healthcare, remote patient monitoring, telemedicine, interoperability standards.
- Case Studies, Ethics, and Regulations
  Case studies on smart healthcare and point-of-care diagnostics, medical device regulations, healthcare data privacy and security, ethical considerations, emerging trends.

Textbooks:

1. John G. Webster, Medical Instrumentation: Application and Design, Wiley.

References:

1. W. J. Tompkins, Biomedical Digital Signal Processing, Prentice Hall.
2. Rangaraj M. Rangayyan, Biomedical Signal Analysis, Wiley.
3. Relevant NPTEL course materials on Biomedical Instrumentation and Biosensors.
4. Biosensors for Personalized Healthcare — Springer (Kuldeep Mahato, Pranjal Chandra)

[PEC-03: C] Blockchain in AI

Teaching Scheme:
Self-Study: 3 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:
After successful completion of this course the students will be able to
1. To state concepts, benefits, and the challenges of Blockchain Technology.
2. To analyze and use some of the commonly used Crypto techniques for Blockchain
3. To use different development platforms to build applications on Blockchain.
4. To integrate AI techniques, IoT with Blockchain.
5. To design and develop secure systems for different application domains.

Course contents:
- Fundamentals of Blockchain:
  Overview of Blockchain, History of Blockchain, Technical Concepts of Blockchain Technology, Blockchain Characteristics, Design Methodology for Blockchain Applications, Domain Specific Blockchain Applications, Research Aspects, Blockchain Benefits and Challenges.
- Crypto Primitives and Overview of Cryptocurrencies
  Cryptographic Hash Functions, Digital Signature; Hashchain to Blockchain; Overview of Crypto currencies, Bitcoin overview, Mining and Consensus, Mathematical analysis of properties of Bitcoin.
- BLOCKCHAIN COMPONENTS:
  Ethereum, Ethereum Virtual Machine (EVM), Ethereum Languages, Smart Contracts, Structure of a Contract, Smart contracts Vulnerabilities, Development Tools and Frameworks- Metamask, Truffle, Decentralized Applications (Dapps).
- INTEGRATION OF ARTIFICIAL INTELLIGENCE (AI) WITH BLOCKCHAIN:
  How to adopt AI in Blockchain, Role of AI in Blockchain, Methods to implement AI in Blockchain, Concept of Internet of Things (IoT), Secure and Smart IoT, Blockchain-enabled smart IoT with AI.
- BLOCKCHAIN USE-CASES:
  Blockchain for Healthcare Informatics, Blockchain for Agricultural Supply chain Management, Blockchain for Financial Technology, Blockchain for Smart Applications, Blockchain for Government Applications.

Textbooks:
1. Arshdeep Bahga and Vijay K. Madisetti, Blockchain Applications: A Hands-on Approach, ISBN: 9780996025560, 2018

References:
1. Josh Thompsons, Blockchain: The Blockchain For Beginners Guide To Blockchain Technology And Leveraging Blockchain Programming, Kindle Edition, ISBN: 1546772804
2. Arvind Narayanan, J. Bonneau, E Felten, A Miller, and S Goldfeder, Bitcoin and Crypto currency Technologies: A comprehensive Introduction, Princeton University Press, 2016.
3. Andreas M. Antonopoulos, Mastering Bitcoin: Programming The Open Blockchain, O'Reilly, ISBN: 9789352135745, 2017

Sem III and IV

SBC Dissertation Phase – I and II

Teaching Scheme: -

Examination Scheme:
For both phase I and II
Mid Sem Evaluation-30 Marks
End Sem Evaluation-70 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. Conceive a problem statement either from rigorous literature surveys or from the requirements raised by external entity.
2. Design, implement and test the prototype/algorithm to solve the conceived problem.
3. Publish the research work in journals/conferences of repute contributing to growth of technology in the domain.

Guidelines:

As per the AICTE directives, the dissertation is a yearlong activity, to be carried out and evaluated in two phases i.e. Phase – I: July to December and Phase – II: January to June.

The dissertation may be carried out preferably in-house i.e. department's laboratories and centers OR in industry allotted through department's T & P coordinator.

After multiple interactions with guide and based on comprehensive literature survey, the student shall identify the domain and define dissertation objectives. The referred literature should preferably include IEEE/IET/IETE/Springer/Science Direct/ACM journals in the areas of Computing and Processing (Hardware and Software), Circuits-Devices and Systems, Communication- Networking and Security, Robotics and Control Systems, Signal Processing and Analysis, Machine Learning, IoT and any other related domain. In case of Industry sponsored projects, the relevant application notes, white papers, product catalogues should be referred and reported.

Student is expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and phase wise work distribution and submit the proposal within a month from the date of registration.

Phase – I deliverables:
A document report comprising of summary of literature survey, detailed objectives, project specifications, paper and/or computer aided design, proof of concept/functionality, part results, A record of continuous progress.

Phase – I evaluation:
A committee comprising of guides of respective specialization shall assess the progress/performance of the student based on report, presentation and Q & A. In case of unsatisfactory performance, committee may recommend repeating the phase-I work.

During phase – II, student is expected to exert on design, development and testing of the proposed work as per the schedule. Accomplished results/contributions/innovations should be published in terms of research papers in reputed journals and reviewed focused conferences OR IP/Patents.

Phase – II deliverables:
A dissertation report as per the specified format, developed system in the form of hardware and/or software, A record of continuous progress.

Phase – II evaluation:

Guide along with appointed external examiner shall assess the progress/performance of the student based on report, presentation and Q & A. In case of unsatisfactory performance, committee may recommend for extension or repeating the work.