M. Tech. (Electronics and Telecommunication) Curriculum Structure
Specialization: Signal Processing
(w. e. f. 2015-16)

List of Abbreviations

OEC- Institute level Open Elective Course
PSMC – Program Specific Mathematics Course
PCC- Program Core Course
DEC- Department Elective Course
LLC- Liberal Learning (Self learning) Course
MLC- Mandatory Learning Course (Non-credit course)
LC- Laboratory Course

M Tech-Electronics and Telecommunication

Specialization: Signal Processing

Curriculum (w. e. f. 2015-16)

Semester I

Sr. No.	Course Type/Code	Course Name	Teaching Scheme			Credits
			L	T	P	
1.	ETC(ILE)-15002	Image processing and Applications{for others}	3	0	0	3
2.	ESP-15001	Mathematical Techniques in Signal processing	3	1	0	4
3.	ESP-15002	DSP Architecture	3	0	0	3
4.	ESP-15003	Multirate and Adaptive Signal Processing	3	0	0	3
5.	ESP(DE)-15001	Audio Processing	3	0	0	3
6.	ESP-15004	DSP Architecture Lab	0	0	2	1
7.	ESP-15003	Multirate and Adaptive Signal Processing Lab	0	0	2	1
8.	ESP-15006	Audio processing Lab	0	0	2	1
9.	ESP-15007	Seminar	0	0	2	1
10.	ML-15001	Research Methodology	1	0	0	0
11.	ML-15002	Humanities	1	0	0	0
		Total	**17**	**1**	8	**20**

Semester II

Sr. No.	Course Code/Type	Course Name	Teaching Scheme			Credits
			L	T	P	
1.	ESP-15008	Digital Image and Video Processing	3	1	0	4
2.	ESP-15009	Biomedical Signal Processing	3	0	0	3
3.	ESP-15010	Computer vision and Machine Learning	3	0	0	3
4.	a.ESP(DE)-15002 b.ESP(DE)-15003 c.ESP(DE)-15004	**Elective – II** a. Multispectral Signal Analysis b. Signal Acquisition Devices and System c. Voice and Data Network	3	0	0	3
5.	a. ESP(DE)-15006 b. ESP(DE)-15005 c. ESP(DE)-15007	**Elective – III** a. Soft Computing System b. JTFA and MRA Techniques c. Multimedia Signal Processing	3	0	0	3
6.	ESP-15011	Digital Image and Video Processing Lab	0	0	2	1
7.	ESP-15012	Biomedical Signal Processing Lab	0	0	2	1
8.	ESP-15013	Computer vision and Machine Learning Lab	0	0	2	1
9.	ML-15004	Intellectual Property Rights	1	0	0	0
10.	LL-15002	Liberal Learning Course	0	0	0	1
		Total	**16**	**1**	**6**	**20**

Semester-III

Sr. No.	Course Code	Course Name	Teaching Scheme			Credits
			L	T	P	
1.	ESP-16001	Dissertation Phase – I	0	0	0	14
		Total	**0**	**0**	**0**	**14**

Semester-IV

Sr. No.	Course Code	Course Name	Teaching Scheme			Credits
			L	T	P	
1.	ESP-16002	Dissertation Phase - II	0	0	0	20
		Total	**0**	**0**	**0**	**20**

Semester-I

(OEC) ETC(ILE)-15002- **Image Processing and Applications**

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs/week	T1, T2 – 20 marks each End-Semester Exam – 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand basic image processing techniques.
2. Identify applications of each of the techniques.
3. Apply image processing techniques for real life interdisciplinary applications (based on student's specialization)

Syllabus Contents:

- Image representation: Types of Images, Image acquisition, Fundamental steps in Image processing, Image enhancement, Filtering in spatial and frequency domains
- Image Segmentation: Edge Detection, thresholding, region based segmentation, motion in segmentation.
- Image Morphology: Need of morphology, Morphological applications
- Image Compression: lossy and lossless compression techniques, JPEG standard.
- Reconstruction from projections. Thermal imaging. Color Image Processing
- Case studies: Image Processing Applications in various disciplines.

References:

1. S. Sridhar, "Digital Image Processing", Oxford University Press, 2011
2. Gonzalez and Woods :Digital Image Processing, Pearson Education, Third Edition, 2008

(PSMC) ESP-15001- Mathematical Techniques in Signal Processing

Teaching Scheme	Examination Scheme
Lectures: 3 hrs/week Tutorial : 1hr/week	T1, T2 – 20 marks each End-Semester Exam - 60

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Solve linear system of equations having numbers of unknowns equal to, less or more than number of equations.
2. Factorize matrix into components such as LU, QR, SVD etc.
3. Characterize random variables and its functions with probability distributions and cumulative distributions
4. Specify and apply standard distributions to various applications in engineering

Syllabus Contents:

Linear Algebra

- Vectors and Linear Combinations, Dot Products
- Solving Linear Equations: Elimination, Elimination Matrices, Inverse Matrices, LU Factorization
- Vector Spaces and Subspaces: Solving A.**x**= **0**, Nullspace of A, Rank, Row Reduced Form, Complete solution of A.**x** = **b**, Independence, Basis and Dimension, Dimensions of Four subspaces
- Orthogonality: Orthogonality of Four Subspaces, Projections, Least Squares Approximations, Orthogonal bases, Gram-Schmidt – QR Factorization
- Eigenvalues and Eigenvectors: Diagonalizing a Matrix, Symmetric Matrices, Positive Definite Matrices, Singular Value Decomposition

Probability and Statistics:

- Definitions, conditional probability, Bayes Theorem and independence.
- Random Variables: Discrete, continuous and mixed random variables, probability mass, probability density and cumulative distribution functions, mathematical expectation, moments, moment generating function, Chebyshev inequality.
- Special Distributions: Discrete uniform, Binomial, Geometric, Poisson, Exponential, Gamma, Normal distributions.
- Pseudo random sequence generation with given distribution, Functions of a Random Variable
- Joint Distributions: Joint, marginal and conditional distributions, product moments, correlation, independence of random variables, bi-variate normal distribution.
- Stochastic Processes:Definitionandclassificationof stochastic processes, Poissonprocess

References:

1. Gilbert Strang, "Introduction to Linear Algebra", Wellesley Cambridge Press, 4th Edition
2. William W. Hines, Douglas C. Montgomery, David M. Goldsman, Connie M. Borror, "Probability and Statistics in Engineering", Wiley, 4th Edition
3. Henry Stark, John W. Woods, "Probability and Random Process with Applications to Signal Processing", Pearson Education, 3rd Edition
4. B. A. Ogunnaike, "Random Phenomena: Fundamentals of Probability and Statistics for Engineers", CRC Press, 2010.

(PCC) ESP-15002- DSP Architecture

Teaching Scheme	Examination Scheme
Lectures: 3 hrs/week	T1, T2 – 20 marks each End-Semester Exam – 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Identify and formalize architectural level characterization of P-DSP hardware.
2. Ability to design, programming, and testing code for DSP applications using Code Composer Studio environment in simulation mode and using starter kits.
3. Deployment of DSP hardware for Control, Audio and Video Signal processing applications

Syllabus Contents:

- Programmable DSP Hardware: Processing Architectures (von Neumann, Harvard), DSP core algorithms (FIR, IIR, Convolution, Correlation, FFT), IEEE standard for Fixed and Floating Point Computations, Special Architectures Modules used in Digital Signal Processors (like MAC unit, Barrel shifters), On-Chip peripherals, DSP benchmarking.
- Structural and Architectural Considerations: Parallelism in DSP processing, Texas Instruments TMS320 Digital Signal Processor Families, Fixed Point TI DSP Processors: TMS320C1X and TMS320C2X Family, TMS320C25 –Internal Architecture, Arithmetic and Logic Unit, Auxiliary Registers, Addressing Modes (Immediate, Direct, and Indirect, Bit-reverse Addressing), Basics of TMS320C54x and C55x Families in respect of Architecture improvements and new applications fields, TMS320C5416 DSP Architecture, Memory Map, Interrupt System, Peripheral Devices, Illustrative Examples for assembly coding.
- VLIW Architecture: Current DSP Architectures, GPUs as an alternative to DSP Processors, TMS320C6X Family, Addressing Modes, Replacement of MAC unit by ILP, Detailed study of ISA, Assembly Language Programming, Code Composer Studio, Mixed C and Assembly Language programming, on-chip peripherals, Simple applications developments as an embedded environment.
- Multi-core DSPs: Introduction to Multi-core computing and applicability for DSP hardware, Concept of threads, introduction to P-thread, mutex and similar concepts, heterogeneous and homogenous multi-core systems, Shared Memory parallel programming – OpenMP approach

of parallel programming, PRAGMA directives, OpenMP Constructs for work sharing like for loop, sections, TI TMS320C6678 (Eight Core subsystem).

- FPGA based DSP Systems: Limitations of P-DSPs, Requirements of Signal processing for Cognitive Radio (SDR), FPGA based signal processing design- case study of a complete design of DSP processor,
- High Performance Computing using P-DSP: Preliminaries of HPC, MPI, OpenMP, multicore DSP as HPC infrastructure.

References:

1. Introduction to Parallel Processing by M. Sasikumar, D. Shikhare, Ravi Prakash, PHI
2. Algorithms and Parallel Computing by Fayez Gebali, Wilely
3. Parallel Programming in OpenMP by Rohit Chandra, L. Dagun, Memon- Morgan Kaufman
4. Multicore Embedded systems- GeorgiousKormaros, CRC Press
5. High Performance Embedded Computing: Architectures , applications-- Wayne Wolf, Morgan Kaufman
6. Algorithmic Collections for Digital Signal Processing Applications- E.S. Gopi

(PCC) ESP-15003 -Multirate and Adaptive Signal Processing

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs/week	T1, T2 – 20 marks each End- Semester Exam – 60Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Evaluate the performance of various methods for designing adaptive filters through estimation of different parameters of stationary random process.
2. Ability to experiment and identify merits and demerits of various adaptive algorithms.
3. Design and implement filtering solutions for various applications.

Syllabus Contents:

- **Applications of Multi-rate signal processing**, Fundamentals decimation, interpolation, resampling by rational fractions, Multi rate identities, Poly phase representations, Maximally decimated filter banks Aliasing, amplitude and phase distortion perfect reconstruction conditions
- **Adaptive Filters**, Stochastic Processes, Correlation Structure, Convergence Analysis, LMS Algorithm, Vector Space Treatment to Random Variables, Gradient Adaptive Lattice, Recursive Least Squares, Systolic Implementation & Singular Value Decomposition.

References:

1. Multirate Digital Signal Processing: Multirate Systems - Filter Banks - Wavelets by N. J. Fliege, John Wiley and Sons Ltd.
2. Multirate and Wavelet Signal Processing by Bruce W. Suter, Academic Press

(PCC) ESP(DE)-15001- Audio Processing

Teaching Scheme	Examination Scheme
Lectures: 3 hrs/week	T1, T2 – 20 marks each End-Semester Exam - 60

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand different characteristics of Speech.
2. Identify and analyze different speech analysis system.
3. Write algorithms for Recognition of speech.

Syllabus Contents:

- Principle Characteristics of Speech: Linguistic information, Speech and Hearing, Speech production mechanism, Acoustic characteristic of speech Statistical Characteristics of speech. Speech production models, Linear Separable equivalent circuit model, Vocal Tract and Vocal Cord Model.
- Speech Analysis and Synthesis Systems: Digitization, Sampling, Quantization and coding, Spectral Analysis, Spectral structure of speech, Autocorrelation and Short Time Fourier transform, Window function, Sound Spectrogram, Mel frequency Cepstral Coefficients, Filter bank and Zero Crossing Analysis, Analysis –by-Synthesis ,Pitch Extraction.
- Linear Predictive Coding Analysis: Principle of LPC analysis, Maximum likelihood spectral estimation, Source parameter estimation from residual signals, LPC Encoder and Decoder, PARCOR analysis and Synthesis, Line Spectral Pairs, LSP analysis and Synthesis.
- Speech Coding: Reversible coding, Irreversible coding and Information rate distortion theory, Coding in time domain: PCM, ADPCM, Adaptive Predictive coding, Coding in Frequency domain: Sub band coding, Adaptive transform coding, Vector Quantization, Code Excited Linear Predictive Coding (CELP).
- Speech Recognition: Principles of speech recognition, Speech period detection, Spectral distance measure, Structure of word recognition system, Dynamic Time Warping (DTW), Theory and implementation of Hidden Markov Model (HMM).
- Speaker recognition: Human and Computer speaker recognition Principles Text dependent and Text Independent speaker recognition systems. Applications of speech Processing.

References:

1. SadaokiFurui, “Digital Speech Processing, Synthesis and Recognition” 2/e.
2. Rabiner and Schafer, “Digital Processing of Speech Signals”, Pearson Education.

ESP-15004 DSP Architecture Laboratory

Teaching Scheme	Examination Scheme
Practical: 2 hrs/week	Term work/Practical:100 Marks

Course Outcomes:

At the end of the lab course, the students will demonstrate the ability to:

1. Implement various digital signal processing algorithms using Code Composer Studio in simulation mode.
2. Demonstrate various digital signal processing algorithms on DSP hardware.
3. Deploy DSP hardware using Code Composer Studio for various digital signal processing applications.

Lab Assignments:

1. Study of TMSC6713 DSK and introduction to Code Composer Studio 5.4.0.
2. Bit Reversal using TMSC6713 DSK
3. Signed Integer Division using TMSC6713 DSK.
4. Signed Integer Division using TMSC6713 DSK.
5. Unsigned Integer Division using TMSC6713 DSK.
6. Convolution of 2 sequences using TMSC6713 DSK.
7. Complex Number Multiplication using TMSC6713 DSK.
8. Computation of Radix-2 and Radix-4 FFT using TMSC6713 DSK.
9. Mini Project: Any Signal Processing Application using TMSC6713 DSK.

ESP-15003- Multirate and Adaptive Signal Processing Laboratory

Teaching Scheme	Examination Scheme
Practical: 2 hrs/week	Term work/Practical:100 Marks

Course Outcomes:

At the end of the lab course, the students will demonstrate the ability to:

1. Devise filtering solutions for various applications and appreciate the need for adaptation in design.
2. Analyse convergence and stability issues associated with adaptive filter design

Lab Assignments:

1. Convolution of two sequences in MATLAB.
2. Computation of Discrete Fourier Transform of a given sequence in MATLAB.
3. Implementations of Finite Impulse Response (FIR) filter in MATLAB.
4. Implementations of Infinite Impulse Response (IIR) filter in MATLAB.
5. Implementation of decimation in MATLAB.
6. Implementation of interpolation in MATLAB.
7. Implementation of adaptive filter using Least Mean Squares (LMS) algorithm in MATLAB.
8. Implementation of adaptive filter using Recursive Least Squares (RLS) algorithm in MATLAB.
9. Presentation: Any topic on recent areas of research in Multirate and Adaptive Signal processing.

ESP-15006-Audio Processing Laboratory

Teaching Scheme	Examination Scheme
Practical: 2 hrs/week	Term work/Practical:100 Marks

Course Outcomes:

At the end of the lab course, the students will demonstrate the ability to:

1. Analyze audio signal characteristics using PRAAT software.
2. Process audio signals and implement various speech analysis techniques in MATLAB
3. Implement any audio processing application in MATLAB.

Lab Assignments:

1. Audio signal analysis and introduction to various parameters of audio signal using PRAAT.
2. Writing MATLAB code or function for:
    - Finding energy of an audio frame
    - Detection and removal of silence region in audio
    - Plotting spectrogram for given audio signal
3. Extraction of Mel Frequency Cepstral Coefficients (MFCCs) from an audio signal in MATLAB.
4. Extraction of Linear Predictive Coding (LPC) coefficients from an audio signal in MATLAB.
5. Calculation of minimum edit distance between two strings using Dynamic Programming algorithm in MATLAB.
6. Designing a codebook as stated in VQ method using K-means clustering algorithm in MATLAB.
7. Evaluation of probabilities using HMM and Viterbi algorithm for a given sequence in MATLAB.
8. Presentation: Any topic on Applications of Speech Processing.

ESP-15007 –Seminar

Teaching Scheme	Examination Scheme
Practicals: 2 hrs/week	Term work/Practical:100 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to

- Explore and engage in higher order thinking activities.
- Express themselves clearly and persuasively.
- Practice oral and written communication skills.

Guidelines:

- Each student is expected to give a seminar on a topic of current relevance in signal processing areas.
- Students have to refer published papers from standard journals.
- The seminar report must not be the reproduction of the original papers but it can be used as reference.

ML-15001 -Research Methodology

Teaching Scheme	Examination Scheme
Lectures: 1 hrs/week	End-Sem Exam – 100 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand research problem formulation.
2. Analyze research related information
3. Follow research ethics

Syllabus Contents:

- Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.
- Approaches of investigation of solutions for research problem, data collection,analysis, interpretation, Necessary instrumentations
- Effective literature studies approaches, analysis
- Plagiarism , Research ethics,
- Effective technical writing, how to write report, Paper
- Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

References:

1. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & engineering students’”
2. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
3. by Ranjit Kumar, 2 nd Edition , “Research Methodology: A Step by Step Guide for beginners”

ML-15002 -Humanities

Teaching Scheme	Examination Scheme
Lectures: 1 hrs/week	Mid-Sem Exam – 20 marks Assignments, Quizzes - 50 marks End-Sem Exam - 30 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand the need, basic guidelines, content and process for value education.
2. Understand the harmony in the family, difference between respect and differentiation
3. Understand the harmony in nature, interconnectedness and mutual fulfillment in nature, holistic perception of harmony.
4. Understand natural acceptance of human values, competence in professional ethics.

Syllabus contents:

Unit 1 Communication skills

Introduction to the scope and significance of learning Humanities. And communication.

- Comprehension
- Written communication: Formal letters, CV, Reports, Paragraphs
- Grammar and Vocabulary building exercises

Unit 2

Social Science and Development

Indian and western concept, Process of social change in modern India, Impact of development of Science and technology on culture and civilization, Urban sociology and Industrial sociology

Social problems in India: overpopulated cities, no skilled farmers, unemployment, addictions and abuses, illiteracy, too much cash flow, stressful working schedules, nuclear families etc.

Unit 3

Technology assessment and transfer

Sociological problems of economic development and social change

Assessment and transfer of technology, problems related with tech transfer with reference to India, Roles of an engineer in value formation and their effects on society

References:

1 English for everyone – Mcmillan (India) Ltd.

2 Jude paramjit S and Sharma Satish K, “Ed: dimensions of social change”

3 Raman Sharma, “Social Changes in India”

Semester-II

(PCC) ESP-15008- **Digital Image and Video Processing**

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs/week Tutorial 1hrs/week	T1, T2 – 20 marks each End-Semester Exam – 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand basic principles behind fundamental image and video processing tasks like enhancement, segmentation and compression.
2. Perform the key image and video processing tasks using state of the art techniques and tools.
3. Apply these techniques in solving practical problems.

Syllabus Contents:

- Image Enhancement : Some basic gray level transformations, Histogram Processing, Histogram modification, Image subtraction, spatial filtering, use of first and second derivatives for enhancement ; Log.
- Image Enhancement in the Frequency Domain, Homomorphic filtering, Pseudo coloring.
- Image Analysis : Some Basic Relationships between pixels, point, line and edge detection, Canny edge detection, Edge linking and boundary detection. Boundary descriptors, The role of illumination, global thresholding, adaptive thresholding,
- Region based segmentation, Morphological operations, texture based segmentation
- Image Compression : Data redundancies Elements of information, variable-length coding uniform and non-uniformQuantizers, predictive coding, Transform coding, Image compression standards.
- Motion analysis and estimation.
- Video compression techniques and standards
- Advances in image and video processing

References:

1. Digital Image Processing by Gonzalez and Woods, Third edition, Tata McGraw Hill, 2009.
2. Handbook of Image and Video Processing (Communications, Networking and Multimedia) by Alan C. Bovik, Second edition Elsevier, Academic Press, 2005
3. Practical Image and Video Processing using MATLAB by Marques, John Wiley & Sons Inc., 2011
4. Digital Video Processing by A. Murat Tekalp, Second edition, Prentice Hall, 1995

(PCC) - ESP-15009 Biomedical Signal Processing

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs/week Tutorial 1hrs/week	T1, T2 – 20 marks each End-Semester Exam – 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand different types of biomedical signal.
2. Identify and analyze different biomedical signals.
3. Apply biomedical signal processing concepts to relevant domain.

Syllabus Contents:

- Acquisition, Generation of Bio-signals,Origin of bio-signals, Types of bio-signals, Study of diagnostically significant bio-signal parameters Electrodes for bio-physiological sensing and conditioning, Electrode-electrolyte interface, polarization, electrode skin interface and motion artefact, biomaterial used for electrode,
- Types of electrodes (body surface, internal, array of electrodes, microelectrodes), Practical aspects of using electrodes, Acquisition of bio-signals (signal conditioning) and Signal conversion (ADC's DAC's) Processing, Digital filtering,
- Biomedical signal processing by Fourier analysis, Biomedical signal processing by wavelet (time-frequency) analysis, Analysis (Computation of signal parameters that are diagnostically significant),Classification of signals and noise, Spectral analysis of deterministic, stationary random signals and non-stationary signals
- Coherent treatment of various biomedical signal processing methods and applications.
- Principle component analysis, Correlation and regression, Analysis of chaotic signals Application areas of Bio–Signals analysis

References:

1. Biomedical Digital Signal Processing by W. J. Tompkins, Prentice Hall
2. Biomedical signal processing and signal modeling by Eugene N Bruce, John Wiley & Son's publication
3. Biomedical Engineering and Design Handbook by Myer Kutz, McGraw Hill
4. Biomedical signal processing by D C Reddy, McGraw Hill
5. Practical Biomedical Signal Analysis Using MATLAB (Series in Medical Physics and Biomedical Engineering) 2011 by Katarzyn J. Blinowska (Author), JaroslawZygierewicz CRC Press; 1 edition

(PCC) ESP-15010 -**Computer Vision and Machine Learning**

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs/week Tutorial 1hrs/week	T1, T2 – 20 marks each End-Semester Exam – 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand various image processing, enhancement and segmentation techniques.
2. Study and analysis of various statistical techniques for dimensionality reduction and prediction analysis in computer vision and machine learning.
3. Implement and evaluate the performance of various computer vision algorithms and classifiers.

Syllabus Contents:

- **Computer Vision:**
  - Image Formation Models, Monocular imaging system, Orthographic & Perspective Projection, Camera model and Camera calibration, Binocular imaging systems, Image Processing and Feature Extraction Image representations (continuous and discrete)
  - **Edge detection Motion Estimation Regularization theory**, Optical computation, Stereo Vision Motion estimation Structure from motion Shape representation and Segmentation, Deformable curves and surfaces Snakes and active contours, Level set representations Fourier and wavelet descriptors, Medial representations
  - **Multi-resolution analysis,** Object recognition, Hough transforms and other simple object recognition methods, Shape correspondence and shape matching, Principal component analysis, Shape priors for recognition.
- **Machine learning:**
  - Introduction to probability, Classification and K-NN, Decision Trees and Rule Learning, The Naive Bayes algorithm, Linear Regression, Logistic Regression,
  - **The Perceptron algorithm,**Neural networks and Deep Belief Networks, SVMs and Margin Classifiers, SVMs: Duality and kernels, Evaluating and Comparing Classifiers Experimentally, PAC Learning, Clustering,
  - **Bias-Variance Decomposition,** Ensemble Methods, Bayesian networks, HMMs - inference, HMMs - learning.

References:

1. Computer Vision: Models, Learning, and InferencebySimon J. D. Prince, Cambridge University Press
2. Computer Vision- A Reference Guide by **Ikeuchi and** Katsushi , springer
3. **Pattern Recognition and Machine Learning by Christopher Bishop,Mcgraw-Hill**

(DEC) ESP(DE)-15002- **Multispectral Signal Analysis**

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs/week Tutorial 1hrs/week	T1, T2 – 20 marks each End-Semester Exam – 60 marks

At the end of the course, students will be able to demonstrate the ability to

1. Distinguish between Hyperspectral and Multispectral systems and select appropriate hyperspectral data for a particular application.
2. Understand basic concepts of data acquisition and image processing tasks required for multi and hyperspectral data analysis.
3. Learn techniques for classification and analysis of multi and hyperspectral data

Syllabus Contents:

- **Hyperspectral Sensors and Applications:**Introduction, Multi-spectral Scanning Systems (MSS), Hyperspectral Systems, Airborne sensors, Spaceborne sensors, Ground Spectroscopy, Software for Hyperspectral Processing, Applications, Atmosphere and Hydrosphere, Vegetation, Soils and Geology, Environmental Hazards and Anthropogenic Activity
- **Over view of Image Processing:** Introduction, Image File Formats, Image Distortion and Rectification, Radiometric Distortion, Geometric Distortion and Rectification, Image Registration, Image Enhancement, Point Operations, Geometric Operation, Image Classification, Supervised Classification, Unsupervised Classification, Crisp Classification Algorithms, Fuzzy Classification Algorithms, Classification Accuracy Assessment, Image Change Detection, Image Fusion, Automatic Target Recognition
- **Mutual Information**:A Similarity Measure for Intensity Based Image Registration: Introduction, Mutual Information Similarity Measure,Joint Histogram Estimation Methods, Two-Step Joint Histogram Estimation, One-Step Joint Histogram Estimation, Interpolation Induced Artifacts, Generalized Partial Volume Estimation of Joint Histograms, Optimization Issues in the Maximization of MI
- **Independent Component Analysis:**Introduction, Concept of ICA, ICA Algorithms, Preprocessing using PCA, Information Minimization Solution for ICA, ICA Solution through Non-Gaussianity Maximization, Application of ICA to Hyperspectral Imagery, Feature Extraction Based Model, Linear Mixture Model Based Model, An ICA algorithm for Hyperspectral Image Processing, Applications using ICA.
- **Support Vector Machines** : Introduction, Statistical Learning Theory, Empirical Risk Minimization, Structural Risk Minimization, Design of Support Vector Machines, Linearly Separable Case, Linearly Non-Separable Case, Non-Linear Support Vector Machines, SVMs for Multiclass Classification, One Against the Rest Classification, Pair wise Classification, Classification based on Decision Directed Acyclic Graph and Decision Tree Structure, Multiclass Objective Function, optimization Methods , Applications using SVM.

- **Markov Random Field Models:** Introduction, MRF and Gibbs Distribution, Random Field and Neighborhood ,Cliques, Potential and Gibbs Distributions, MRF Modeling in Remote Sensing Applications, Optimization Algorithms, Simulated Annealing,Metropolis Algorithm, Iterated Conditional Modes Algorithm

References:

1. Advanced Image Processing Techniques for Remotely Sensed Hyperspectral Data by Pramod K. Varshney, Manoj K. Arora , Springer Science & Business Media
2. Multi-spectral Imaging– from Astronomy to Microscopy; – from Radio waves to Gamma rays by S. Svanberg
3. Pattern Recognition and Machine Learning by Christopher Bishop,Mcgraw-Hill

(DEC) ESP(DE)-15003- Signal Acquisition Devices and System

Teaching Scheme	Examination Scheme
Lectures: 3 hrs/week Tutorial 1hrs/week	T1, T2 – 20 marks each End-Semester Exam – 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understands the elements of data acquisition techniques
2. Critically evaluate and select appropriate techniques and devices for realising a data acquisition system.
3. To design and implement a data acquisition solution for a particular application

Syllabus Contents:

- **Concepts of data acquisition systems**, sample signals that measure real physical conditions and convert the resulting samples into digital, numeric values to be analyzed
- **problem-solving approach to data acquisition**, sensors that convert physical parameters to electrical signals, signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values and analog-to-digital converters, which convert conditioned sensor signals to digital values. hands-on approach, culminating with data acquisition projects
- **data acquisition process** on the fundamental principles of measurement, sensors and signal conditioning. software packages related to data acquisition

References:

1. Data Acquisation systems from Fundamentals To Applied Design Hardcover-March 22,2013 byMaurizio Di Paolo EmilioSpringer; 2013 edition (March 22, 2013)
2. Data Acquisition for Sensor SystemsPaperback– December 3, 2010 by H.R. TaylorSpringer;

Softcover reprint of hardcover 1st ed. 1997 edition (December 3,2010).

(DEC) ESP(DE)-15004- **Voice and Data Network**

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs/week	T1, T2 – 20 marks each
Tutorial 1hrs/week	End-Semester Exam – 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand switching and routing protocols used in data communication system.
2. Analyze network design issues and learned queuing models of networks.
3. Acquired the knowledge about next generation network architecture.

Syllabus Contents:

- **Network Design Issues**:- Network Performance Issues, Network Terminology, centralized and distributed approaches for networks design, Issues in design of voice and data networks. Layered and Layer less Communication, Cross layer design of Networks
- **Switching in Networks**:- Voice Networks (wired and wireless) and Switching, Circuit Switching and Packet Switching, Statistical Multiplexing,
- **Data Link in Networks and their Design**:- Link layer design, Link adaptation, Link Layer Protocols, Retransmission Mechanisms (ARQ) , Hybrid ARQ (HARQ), Go Back N, Selective Repeat protocols and their analysis.
- **Queuing Models of Networks**:- Traffic Models , Little's Theorem**,** Markov chains, M/M/1 and other Markov systems.
- **Multiple Access Protocols**:- Aloha System, Carrier Sensing, Examples of Local area networks, Internetworking , Bridging, Global Internet ,
- **Routing and Congestion Control in Internet**:-IP protocol and addressing , Subnetting, Classless Interdomain Routing (CIDR) , IP address lookup , End to End Protocols, TCP and UDP. Congestion Control , Additive Increase/Multiplicative Decrease , Slow Start, Fast Retransmit/ Fast Recovery , Congestion avoidance , RED TCP Throughput Analysis, Quality of Service in Packet Networks. Network Calculus, Packet Scheduling Algorithms.

References:

1. Data Networks by D. Bertsekas and R. Gallager, Prentice Hall
2. Computer Networks: A Systems Approach by L. Peterson and B. S. Davie, Morgan Kaufman.
3. Communication Networking: An analytical approach by Kumar, D. Manjunath and J. Kuri, Morgan Kaufman.
4. Communications Network: A First Course by Walrand, McGraw Hill
5. Queueing Systems: Theory by Leonard Kleinrock, Volume I, John Wiley and Sons.
6. Telecommunication Network Design Algorithms by Aaron Kershenbaum, McGraw Hill

(DEC) ESP(DE)-15006- **Soft computing Systems**

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs/week	T1, T2 – 20 marks each
Tutorial 1hrs/week	End-Semester Exam – 60 marks

Course Outcomes:

At the end of the course, the students will be able to

1. Implement Artificial Intelligence algorithms
2. Apply fuzzy logic and reasoning to handle uncertainty and solve engineering problems,
3. Demonstrate genetic algorithms to combinatorial optimization problems and neural networks to pattern classification and regression problems

Syllabus Contents:

- **Knowledge Representation**: Prepositional Logic, Inference Rules in Prepositional Logic, Knowledge representation using Predicate logic, AI Programming- Declarative versus procedural programming, introduction to LISP and PROLOG Predicate Calculus, Applications- Inference engine using PROLOG.
- **Inconsistent Information Systems:**Basic Concepts of Rough Sets, Equivalence Class and Discernibility Relations, Lower and Upper approximations, Information Systems Framework using Rough Sets, Reducts and Core, Introduction to Rough Set Software ROSE, Rules extractions, Missing Attributes computations, Outsourcing Resource Selection using Rough set, Applications - Information Gain and data mini
- **Non-linear Dynamical Systems and Chaos:** 1-D and 2-D Maps, cobweb diagrams, Fractals, Cantor set, Mandelbrot set, Chaotic orbits, Chaotic attractors, Bifurcations, delay coordinate and dimension embedding, computer hardware systems as non-linear dynamics, Applications- cryptography, video compression.
- **Representation and Manipulation of Imprecision and uncertainty :** Fuzzy Sets, Type-I Membership Functions – Triangular, Trapezoidal, PI, T-Norm, S-Norm Fuzzy Operations, Fuzzy Hedges, Convex combination of fuzzy sets, Fuzzy Relations & composition, Fuzzy Object Class, Applications- Fuzzy Logic Support in DoS commands,Email filters Documentation systems.
- **Engineering Adaptations of Fuzzy Systems:** Fuzzy Logic IC chips, Fuzzy Inference Engine and rule based systems, Fuzzy Controllers, Stability computations, Embedded Fuzzy Controllers using ARM and DSP Chips, Decision Making with Fuzzy information, Machine Intelligence Quotient, Applications-Fuzzy Median Filters, Imageprocessing on DSP platforms like TMS320C6713

- **Evolutionary Computing: Genetic Algorithms,** Schemata Representation, Introduction to Genetic Programming, Examples using GA/GP, Application- Optimization problems

Term Paper: Students will identify, submit and present a Term Paper on a current topic.

References:

1. Fundamentals of the New Artificial Intelligence by ToshinoriMunakata, Springer
2. Artificial Intelligence: A Modern Approach by Stuart Russell & Peter Nerving, Prentice Hall
3. Artificial Intelligence by Elaine Rich, Kevin Knight, B. Nair, Tata McGraw-Hill
4. Chaos-An introduction to Dynamical Systems by K.T. Alligood, T.D. Sauer, J.A. Yorke, Springer
5. Fuzzy Logic with engineering Applications by T.J. Ross, Wiley
6. Fuzzy Logic for Embedded Systems Applications by Ahmed M. Ibrahim, Elsevier Publications
7. Soft Computing- Techniques and its Applications in electrical Engg. by D. K. Chaturvedi, Springer
8. An Introduction to Genetic Algorithms (Complex Adaptive Systems) by Melanai Mitchell
9. A field Guide to Genetic Programming by R. Poli, W. Langdon, N. McPhee

(DEC)- ESP(DE)-15005- **JTFA and MRA Techniques**

Examination Scheme T1, T2 – 20 marks each, End-Sem Exam - 60	

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand the limitations of Fourier Transform and the significance of Wavelets Time-Frequency.
2. Analysis and study of techniques for Time-Frequency Analysis and Multi-Resolution Analysis.
3. Understand applications of Time-Frequency and Multi-Resolution Analysis techniques.

Syllabus Contents:

- **A Beginning with some practical situations,** which call for multiresolution/ multiscale analysis - and how time-frequency analysis and wavelets arise from them. Examples: Image Compression, Wideband Correlation Processing, Magnetic Resonance Imaging, Digital Communication.
- **Piecewise constant approximation -** the Haar wavelet, Building up the concept of dyadic Multiresolution Analysis (MRA),
- Relating dyadic MRA to filter banks, review of discrete signal processing, Elements of multirate systems and two-band filter bank design for dyadic wavelets,
- Families of wavelets: Orthogonal and biorthogonal wavelets, Daubechies' family of wavelets in detail, Vanishing moments and regularity, Conjugate Quadrature Filter Banks (CQF) and their design, Dyadic MRA more formally, Data compression – fingerprint compression standards, JPEG-2000 standards,
- **The Uncertainty Principle:** and its implications: the fundamental issue in this subject - the problem and the challenge that Nature imposes, The importance of the Gaussian function:

the Gabor Transform and its generalization; time, frequency and scale - their interplay, The Continuous Wavelet Transform (CWT), Condition of admissibility and its implications, The Uncertainty Principle: and its implications: the fundamental issue in this subject - the problem and the challenge that Nature imposes, The importance of the Gaussian function: the Gabor Transform and its generalization; time, frequency and scale - their interplay, The Continuous Wavelet Transform (CWT), Condition of admissibility and its implications, Application of the CWT in wideband correlation processing,

- **Journey from the CWT to the DWT:** Discretization in steps, Discretization of scale generalized filter bank, Discretization of translation - generalized output sampling, Discretization of time/ space (independent variable) - sampled inputs,
- **Variants of the wavelet transform and its implementational structures,** The wavepacket transform, Computational efficiency in realizing filter banks - Polyphase components, The lattice structure, The lifting scheme,
- **An exploration of applications** Examples: Transient analysis; singularity detection; Biomedical signal processing applications; Geophysical signal analysis applications; Efficient signal design and realization: wavelet based modulation and demodulation; Applications in mathematical approximation; Applications to the solution of some differential equations; Applications in computer graphics and computer vision; Relation to the ideas of fractals and fractal phenomena.

References:

1. Wavelet Analysis: The Scalable Structure of Information by Howard L. Resnikoff, Raymond O. Wells, Springer
2. Wavelet Transforms: Introduction by Raghuveer M. Rao, Ajit S. Bopardikar
3. Insight Into Wavelets - From Theory to Practice by K. P. Soman, K. I. Ramachandran, Prentice Hall
4. An Introduction to Wavelets Through Linear Algebra by Michael W. Frazier, Springer
5. Multirate Systems and Filter Banks by P. P. Vaidyanathan, Pearson Education

(DEC)- ESP(DE)-15007- **Multimedia Signal Processing**

Examination Scheme	
T1, T2 – 20 marks each, End-Sem Exam - 60	

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand the fundamentals of multimedia signal processing.
2. Use model based approach for signal processing.
3. Apply the acquired knowledge to specific multimedia related problems.

Syllabus Contents:

- **Theoretical background of one- and multidimensional signal processing**, statistical analysis and modeling, coding and information theory with regard to the principles and design of image, video and audio compression systems. The theoretical concepts by practical examples of algorithms for multimedia signal coding technology, and related transmission aspects, principles behind multimedia coding standards, including most recent developments like High Efficiency Video Coding
- **Basic Digital Signal Processing** gives an introduction to the topic, discussing sampling and quantization, Fourier analysis and synthesis, Z-transform, and digital filters.
- **Model-based Signal Processing** covers probability and information models, Bayesian inference, Wiener filter, adaptive filters, linear prediction hidden Markov models and independent component analysis.
- **Applications of Signal Processing in Speech, Music and Telecommunications** explains the topics of speech and music processing, echo cancellation, deconvolution and channel equalization, and mobile communication signal processing.
- music signal processing, explains the anatomy and psychoacoustics of hearing and the design of MP3 music coder
- speech processing technology including speech models, speech coding for mobile phones and speech recognition
- single-input and multiple-inputs denoising methods, bandwidth extension and the recovery of lost speech packets in applications such as voice over IP (VoIP)
- Illustrated throughout, including numerous solved problems, Matlab experiments and demonstrations
- Companion website features Matlab and C++ programs with electronic copies of all figures

References:

1. Multimedia Signal Coding and Transmission (Signals and Communication Technology)March 17, 2015 by Jens-Rainer Ohm Springer; 2015 edition (March 17, 2015)
2. Multimedia Signal Processing: Theory and Applications in Speech, Music and CommunicationsNovember 12, 2007 by Saeed V. Vaseghi ,Wiley; 1 edition (November 12, 2007)
3. Signal Processing March 8, 2003 by James H. McClellan Ronald W. Schafer(Author), Mark A. Yoder Prentice Hall; 1 edition (March 8, 2003)

ESP-15011 Digital Image and Video Processing Laboratory

Teaching Scheme	Examination Scheme
Practical: 2 hrs/week	Term work/Practical:100 Marks

Course Outcomes:

At the end of the lab course, the students will demonstrate the ability 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.

Lab Assignments

1.
   - Obtaining row profile of a given row of an image in MATLAB
   - Plotting histogram of an image in MATLAB
   - Adjusting the brightness of an image using a constant value in MATLAB
   - Calculating mean and variance of an image in MATLAB
2.
   - Histogram Equalization of an image in MATLAB
   - Spatial Filtering: Applying low pass, high pass and median filters on an image in MATLAB
3.
   - Pseudo Coloring an image using sinusoidal transforms in MATLAB
   - Detection of edges of an image using Canny Edge Detection algorithm in MATLAB.

4. Image Thresholding using OTSU Thresholding algorithm in MATLAB.
5. Region-based Image Segmentation using region growing in MATLAB.
6. Apply Discrete Cosine Transform (DCT) on an image in MATLAB.
7. Motion Estimation for video sequence using full search algorithm.
8. Tutorial: Presentation of some topics in Digital Image and Video Processing.

ESP-15012 Biomedical Signal Processing Laboratory

Teaching Scheme	Examination Scheme
Practical: 2 hrs/week	Term work/Practical:100 Marks

Course Outcomes:

At the end of the lab course, the students will demonstrate the ability to:

1. Analyze ECG signal and process ECG signal for noise removal.
2. Implement various techniques for analysis and classification of biomedical signals.
3. Implement any biomedical signal processing application in MATLAB.

Lab Assignments

1. Mixing signals by addition and convolution and their separation in MATLAB.
2. Generation of ECG signal and detection of P, Q, R, S, T waves in MATLAB.
3. Analysis and filtering of ECG signal in MATLAB.
4. Noise removal from ECG signal using band-pass filtering in MATLAB.
5. Principle Component Analysis on a given dataset in MATLAB.
6. Application of Regression modeling in prediction from a given dataset in MATLAB.
7. Presentation: Any topic on Applications of Biomedical Signal Processing.

ESP-15013 Computer vision and Machine Learning Laboratory

Teaching Scheme	**Examination Scheme**
Practical: 2 hrs/week	Term work/Practical:100 Marks

Course Outcomes:

At the end of the lab course, the students will demonstrate the ability to:

1. Implement various algorithms for computer vision and machine learning in MATLAB.
2. Apply computer vision and machine learning approach for various image processing applications.
3. Execute different machine learning based classifiers.

Lab Assignments

1.
- Tracking single and multiple objects in videos in MATLAB
- Triangulation and depth extraction from stereo vision in MATLAB
- Recognizing objects using template matching in MATLAB
- Recognizing objects using clustering in MATLAB

2
- Segmentation using level sets in MATLAB
- Obtaining Eigen and PCA (covariance and SVD method) features of an image in MATLAB
- Nearest neighbor classification on a given dataset in MATLAB
- Using Hidden Markov Model (HMM) for image classification in MATLAB

3
- Boundary extraction from an image in MATLAB
- Region filling in an image in MATLAB
- Recognition using Naïve Bayes' classifier in MATLAB

- Recognition using nearest neighbor in MATLAB

4

- Edge detection in gray scale and multispectral images in MATLAB
- Shape based segmentation of objects in MATLAB
- Extraction of texture features of an image in MATLAB
- Object recognition using linear regression in MATLAB

5

- Histogram based image segmentation in MATLAB
- Obtaining statistical parameters of an image in MATLAB
- Object Recognition using ANN in MATLAB

6

- Image filtering in spatial and frequency domain in MATLAB
- Motion detection in video using optical flow in MATLAB
- Extraction of boundary based features in MATLAB
- Object recognition using SVM in MATLAB

7

- Image sharpening in spatial and frequency domain in MATLAB
- Region based segmentation in MATLAB
- Extraction of region based features in MATLAB
- Object recognition using syntactic method in MATLAB

8

- Color based segmentation in MATLAB
- Space scale based segmentation in MATLAB
- Finding shapes and linking edges using Hough transform in MATLAB
- Object recognition using Fuzzy Logic in MATLAB

9

- Morphological operations on an image in MATLAB
- Size based segmentation of objects in MATLAB
- Image segmentation using snake in MATLAB
- Object classification using decision tree in MATLAB

10 Mini Project: Any Application of Computer Vision and Machine Learning

ML-15004 Intellectual Property Rights

Teaching Scheme	**Examination Scheme**
Practical: 1 hr/week	100 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Understand that today's world is controlled by Computer, Information Technology, but tomorrow's world will be ruled by ideas, concept, and creativity.
2. Understand that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular.
3. Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

Syllabus Contents:

Introduction

- Nature of Intellectual Property: Patents, Designs, Trademarks and Copyright. Process of Patenting and Development: Technological research, Innovation, Patenting, Development.

International Scenario

- International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Patent Rights

- Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

New Developments in IPR

- Administration of Patent System. New developments in IPR; IPR of Biological Systems,Computer Software etc. Traditional knowledge, Case Studies.

References:

1. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd , 2007
2. Mayall , "Industrial Design", McGraw Hill
3. Niebel , "Product Design", McGraw Hill
4. Asimov , "Introduction to Design", Prentice Hall
5. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", Aspen Publishers, 6th Edition.
6.T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand.

LL-15002 Liberal Learning Course	
	Examination Scheme Term work:100 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Exhibit self learning capabilities and its use in effective communication.
2. Inculcate impact of various areas to relate with society at large.

Syllabus Contents:

Identification of topic and resources, scope, and synthesize viewpoints for the areas such as performing arts, social sciences, business, philosophy, Agriculture sports and athletics, Fine Arts Medicine and Health Linguistics, defence studies and education

(Dissertation) Dissertation Phase – I and II

Examination Scheme

Marks: 100 each for phase I and II

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Conceive a problem statement either from rigorous literature survey or from the requirements raised by external entity.

2. Design, implement and test the prototype/algorithm in order 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), Communication-Networking and Security, Robotics and Control Systems, Signal Processing and Analysis and any other related domain. In case of Industry sponsored projects, the relevant application notes, while 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.

PhaseI-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.