भारतीय सूचना प्रौद्योगिकी संस्थान भागलपुर

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY BHAGALPUR

An Institute of National Importance Under Act of Parliament

भारतीय सूचना प्रौद्योगिकी संस्थान भागलपुर
Indian Institute of Information Technology
Bhagalpur

2nd Meeting of Board of Academic Programs

for

M.Tech in Signal Processing and Machine Learning

Dept. of Electronics and Communication Engineering (ECE)

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY BHAGALPUR

Dept. of Electronics and Communication Engineering (ECE)

M. Tech.

in

Signal Processing and Machine Learning

Curriculum

Code	Course Name	L	T	P	C
1st Semester					
EC501	Signal Processing Algorithms and Architectures	3	1	0	4
CS521	Artificial Intelligence	3	0	2	4
EC502	Medical Imaging and Bio-signal Analysis	3	0	0	3
MA503	Probability and Stochastic Processes	3	0	0	3
	Elective I	3	0	0	3
EC531	Digital Signal Processors Lab	0	0	3	2
EC532	Medical Imaging and Bio-signal Analysis Lab	0	0	3	2
EC581	Capstone Project – I	0	0	0	1
	Total Credits				22
2nd Semester					
CS504	Machine Learning	3	0	0	3
EC503	Computational Intelligence	3	0	0	3
EC504	Statistical Signal Processing	3	0	0	3
	Elective-II	3	0	0	3
	Elective-III	3	0	0	3
EC533	Signal Applications Lab	0	0	3	2
CS533	Machine Learning Lab	0	0	3	2
EC582	Capstone Project – II	0	0	0	1
	Total Credits				20
3rd Semester					
EC591	Major Project-I	0	0	0	10
4th Semester					
EC592	Major Project-II	0	0	0	14
	Total Credits				66

Elective Courses (I, II & III)

Code	Course Name	L-T-P-C
EC551	VLSI for DSP	3-0-0-3
EC552	Image Processing and Computer Vision	3-0-0-3
EC553	Introduction to IoT	3-0-0-3
EC554	Signal Detection and Estimation Theory	3-0-0-3
EC555	Speech and Audio Processing	3-0-0-3
EC556	MIMO Wireless Communications	3-0-0-3
EC557	Microwave Imaging and Radar Signal Processing	3-0-0-3
EC558	Introduction to Pattern Recognition	3-0-0-3
MA521	Statistical Foundation for Data Science	3-0-0-3
CS557	Introduction to Blockchain Technology	3-0-0-3
CS558	Deep Learning and Applications	3-0-0-3

Course Syllabus

Course Code	Course name	L	T	P	C	Semester
EC501	Signal Processing Algorithms and Architectures	3	1	0	4	1st
Topic	**Contents**					**No. of Lectures**
Module-I	**Overview of Digital Signal Processing:** Advantages of DSP over analog systems, salient features and characteristics of DSP systems, applications of DSP systems.					8
Module-II	**Addressing modes:** Assembly instructions. Pipelining. Interrupts. Clock generator. Timer. Serial ports. Parallel ports. Host-port interface (HPI). Comparison with TMS320C67X processor architecture and instruction set.					11
Module-III	Architecture of TMS320C67X processor. CPU data paths and control. Addressing modes. Instruction set. Pipeline operation.					9
Module-IV	Interfacing with serial I/O. A/D, D/A converters. Parallel interfacing. Interfacing with RAM, EEPROMs, FPGAs. Wait state generation. DSP tools: Assembler. Debugger. C compiler. Linker and loader.					9
Module-V	VLIW Architecture. Multiprocessor DSPs, SHARC, SIMD, MIMD Architectures and Analog Devices DSPs. Applications: Digital Filter, Adaptive filter, Spectrum analyzer, Echo cancellation, Modem, Voice synthesis and recognition**.**					11
	Total No. of Lectures					48
Text	1. B. Venkataramani & M Bhaskar, *Digital Signal Processor, Architecture, Programming and Applications*, McGraw- Hill, 2nd edition, 2010. 2. Srinivasan & A. Singh, *Digital Signal Processing, Implementations using DSP Microprocessors*, Cengage Learning; 1st edition, 2004.					
Reference	1. S. M. Kuo & Woon-Seng Gan, *Digital Signal Processors: Architectures, Implementations, and Applications*", Prentice Hall, 1st edition, 2004.					

Course Code	Course name	L	T	P	C	Year	Semester
CS521	Artificial Intelligence	3	0	2	4	1st	1st
Topic	**Contents**						**No. of Lectures**
Module-I	Fundamental issues in intelligent systems: History of artificial intelligence; philosophical questions; fundamental definitions; modeling the world; the role of heuristics.						5
Module-II	Search and constraint satisfaction: Problem spaces; brute-force search; best-first search; two-player games; constraint satisfaction.						10
Module-III	Knowledge representation and reasoning: Formal methods (propositional, predicate logic, first order logic), resolution and unification; Informal methods (frames, scripts), answer extraction; knowledge based systems; logic						8

	programming, User interface: Human Computer Interaction, User Interface Components, modules of user interface.	
Module-IV	AI planning systems: Definition and examples of planning systems; planning as search; operator-based planning; propositional planning; planning algorithms.	8
Module-V	Reasoning under Uncertainty and Learning: probabilistic reasoning; Bayes theorem; Introduction to neural networks and reinforcement learning; Case based reasoning, analytical reasoning, model based reasoning,	9
	Total	40
Text	1. Stuart Russell and Peter Norvig, "*Artifical Intelligence: A Modern Approach*", Pearson; 4th Edition , 2020. 2. Elaine Rich, Kevin Knight and Shivashankar B Nair, "*Artificial Intelligence*", Tata McGraw Hill, 3rd Edition 2017. 3. R.B. Mishra, "*Artificial Intelligence*", PHI Learning Pvt. Ltd., 1st edition, 2010.	
Reference	1. N. J. Nilsson, *"Principles of Artificial Intelligence"*, Narosa Publishing House, 2002. 2. Clocksin & Mellish, "*Programming in PROLOG*", Narosa Publ. House, 2002	

Course Code	**Course Name**	**L**	**T**	**P**	**C**	**Semester**
EC502	Medical Imaging and Bio-signal Analysis	3	0	0	3	1st

Topic	**Contents**	**No. of Lectures**
Module-I	**Introduction:** Genesis and significance of bioelectric potentials, ECG, EOG, EMG and their monitoring and measurement, Spectral analysis, digital and analog filtering, correlation and estimation techniques, AR / ARMA models, Adaptive Filters.	**8**
Module-II	**ECG:** Pre-processing, Measurements of amplitude and time intervals, Classification, QRS detection, ST segment analysis, Baseline wander removal, wave form recognition, morphological studies and rhythm analysis, automated diagnosis based on decision theory ECT compression, Evoked potential estimation.	**8**
Module-III	**EEG:** Evoked responses, Epilepsy detection, Spike detection, Hjorth parameters, averaging techniques, removal of Artifacts by averaging and adaptive algorithms, pattern recognition of alpha, beta, theta and delta waves in EEG waves, sleep stages. **EMG:** Wave pattern studies, biofeedback, Zero crossings, Integrated EMG. Time frequency methods and Wavelets in Biomedical Signal Processing.	**8**

Module-IV	**Medical Imaging Systems**: X-ray system, C.T. Scan, Ultrasound (A, B and M scans). MRI and Positron Emission Tomography. Fundamentals of digital image processing. Storage and display operation properties of digital image.	**8**
Module-V	**Image pre-processing** by statistical and probabilistic methods. Image enhancement and restoration. Segmentation of images by applying Thresh hold, Edge based and Region based techniques. Image feature extraction, analysis of medical images.	**8**
	Total No. of Lectures	**40**
Text	1. W. J. Tompkins, *Biomedical Digital Signal Processing*, PHI, 1st edition, 1996. 2. W. Birkfellner, *Applied Medical Image Processing*, CRC Press, 2nd edition, 2016.	
Reference	1. A. Kohen, *Biomedical Signal Processing*, Volumes I & II, CRC Press, 1st edition, 2019. 2. G. Dougherty, *Biomedical Image Processing*, Springer,1st edition, 2011.	

Course Code	Course name	L	T	P	C	Semester
MA503	Probability and Stochastic Processes	3	0	0	3	1st

Topic	Contents	No. of Lectures
Module-I	Axiomatic definitions of probability; conditional probability, independence and Bayes theorem, continuity property of probabilities.	8
Module-II	Random variable: probability, density and mass functions, functions of a random variable; expectation, characteristic, and moment-generating functions; Chebyshev, Markov and Chernoff bounds;	8
Module-III	Jointly distributed random variables: joint distribution and density functions, joint moments, conditional distributions and expectations, functions of random variables; random vector- mean vector and covariance matrix, Gaussian random vectors; Sequence of random variables: almost sure and mean-square convergences, convergences in probability and in distribution, laws of large numbers, central limit theorem;	8
Module-IV	Random process: probabilistic structure of a random process; mean, autocorrelation and autocovariance functions; stationarity - strict- sense stationary and wide-sense stationary (WSS) processes: time averages and ergodicity; spectral representation of a real WSS process-power spectral density, cross-power spectral density,	8
Module-V	Linear time-invariant systems with WSS process as an input- time and frequency domain analyses; examples of random processes: white noise, Gaussian, Poisson and Markov processes.	8
	Total No. of Lectures	40

Text	1. H. Stark and J. W. Woods, *Probability and Random Processes with Applications to Signal Processing*, Pearson, 3rd Edition, 2002. 2. A. Papoulis and S. U. Pillai, *Probability, Random Variables and Stochastic Processes*, McGraw-Hill, 4th Edition, 2017.
Reference	1. B. Hajek, *An Exploration of Random Processes for Engineers*, Cambridge University Press , 2015. 2. Sheldon M Ross, *Stochastic Processes*, Wiley , 2nd Ed, 2016.

Course Code	**Course Name**	**L**	**T**	**P**	**C**	**Year**	**Semester**
CS504	Machine Learning	3	0	0	3	1st	2nd

Topic	**Content**	**No. of Lectures**
Module I	Introduction: History of machine learning, Basic concepts	5
Module II	Supervised learning: Supervised learning setup, LMS, Logistic regression, Perceptron, Backpropagation, neural networks, Exponential family, Generative learning algorithms, Gaussian discriminant analysis, Naive Bayes, Support vector machines, Model selection and feature selection, Ensemble methods: Bagging, boosting.	10
Module III	Learning theory: Bias/variance trade-off, Union and Chernoff/Hoeffding bounds, VC dimension, Worst case (online) learning.	8
Module IV	Unsupervised learning: Clustering K-means, EM. Mixture of Gaussians, Factor analysis, PCA (Principal components analysis), ICA (Independent components analysis).	9
Module V	Miscellaneous topics: Hypothesis testing, cross-validation, quadratic discriminant Analysis, adaptive hierarchical clustering, gradient boosting.	8
	Total No. of Lectures	40
Text	1. Ethem Alpaydin, "*Introduction to Machine Learning*", PHI, Third Edition, 2015. 2. Marsland, Stephen. "*Machine learning: an algorithmic perspective*", Chapman and Hall/CRC, 2nd edition, 2014. 3. Tom Mitchell, "*Machine Learning*", McGraw Hill, First edition 2017.	
Reference	1. Murphy, Kevin, "*Machine Learning: A Probabilistic Perspective (Adaptive Computation and Machine Learning series)*" , The MIT Press; Illustrated edition, 2012. 2. Müller, Andreas C., and Sarah Guido, "*Introduction to machine learning with Python: a guide for data scientists*", O'Reilly, 1st edition, 2016.	

Course Code	Course name	L	T	P	C	Semester
EC503	Computational Intelligence	3	0	0	3	2^{nd}

Topic	Contents	No. of Lectures
Module-I	**Introduction to Computational Intelligence:** Intelligence machines, Computational intelligence paradigms, Soft computing constituents and conventional Artificial intelligence, Neuro-Fuzzy and soft computing characteristics	7
Module-II	**Rule-Based Expert Systems and Fuzzy Expert Systems:** Rule-based expert systems, Uncertainty management, Fuzzy sets and operations of fuzzy sets, Fuzzy rules and fuzzy inference, Fuzzy expert systems, Case study: fuzzy logic controller for various applications	9
Module-III	**Artificial Neural Networks:** Fundamental neuro-computing concepts: artificial neurons, activation functions, Neural network architectures, learning rules, Supervised learning neural networks: multi-layer feed forward neural networks, simple recurrent neural networks, time delay neural networks, supervised learning algorithms, Back propagation algorithm, Radial basis function networks Unsupervised learning neural networks, self-organizing feature maps, Deep neural networks and learning algorithms	9
Module-IV	**Evolutionary techniques**: Genetic Algorithm, Evolutionary computation**:** Chromosomes, fitness functions, and selection mechanisms, Genetic algorithms: crossover and mutation, Genetic programming, Evolution strategies, PSO, ACO, BFO	9
Module-V	**Hybrid Intelligent Systems:** Neural expert system, neuro-fuzzy systems, Evolutionary neural network, case study of Neuro-fuzzy based systems.	7
	Total No. of Lectures	**40**
Text	1. S. Rajasekaran, G. A. Vijayalaksmi Pai, *Neutral Networks, Fuzzy Logic and Genetic Algorithm: Synthesis and Applications*, PHI Learning, 2^{nd} edition, 2017. 2. J. S .R. Jng, C. T. Sun, E. Mizutani, *Neuro-Fuzzy and Soft Computing*, Pearson Education, 1^{st} edition, 2015. 3. S. N. Deepa, S. N. Sivanandam, *Principles of Soft Computing*, John Wiley, 3^{rd} edition, 2018.	
Reference	1. Timothy J. Ross, *Fuzzy logic with Engineering Applications*, McGraw-Hill, 3^{rd} edition,2011. 2. Simon Haykin, *Neural Networks: A Comprehensive Foundation*, Pearson, 3^{rd} edition, 2009.	

Course Code	Course name	L	T	P	C	Semester
EC504	Statistical Signal Processing	3	0	0	3	2^{nd}

Topic	Contents	No. of Lectures
Module-I	**Review of probability theory and random variables**: Transformation (function) of random variables, Sequences of random variables, Random processes, Ergodicity, Mean square continuity, Mean square derivative and mean square integral of stochastic processes, Stochastic systems, Response of linear dynamic systems to stochastic inputs, Lyapunov equations, Correlational function, Power spectral density function	8

Module-II	**Parameter estimation:** Non-Bayesian Estimation, Necessary and sufficient conditions, Biased and unbiased estimator, Minimum variance unbiased estimator (MVUE), Cramer-Rao Inequalities, Best Linear Unbiased Estimator (BLUE)	8
Module-III	**Maximum likelihood**: Efficient estimator; Bayesian Estimation: Minimum mean square-error (MMSE), Linear MMSE, Minimum probability of error (MAP) estimator; Binary hypothesis testing, Bayes risk and Bayes decision rule	8
Module-IV	**Neyman Pearson based detector**: Receiver operating characteristics and its properties, Energy detector, Matched filter; Composite hypothesis testing: Universally Most Powerful (UMP) Test, Karlin Rubin Theorem, Generalized Likelihood Ratio Test (GLRT); Applications: System identification, Communication system	8
Module-V	**Optimal Linear Filter**: Wiener Filter, Linear prediction of signals, Adaptive Filters, Application of adaptive filters, Least mean square (LMS) algorithm, Recursive least square algorithms, Levinson-Durbin Algorithm, Spectrum estimation, Kalman filter.	8
	Total No. of Lectures	40
Text	1. M. H. Hayes, *Statistical Digital Signal Processing and Modeling*, John Wiley & Sons, Inc., 2nd edition, 2009. 2. J. G. Proakis et. al., *Algorithms for Statistical Signal Processing*, Pearson Education, 1st edition, 2002.	
Reference	1. A. Papoulis & S. Pillai, *Probability, Random Variables and Stochastic Processes*, McGraw Hill, 4th edition, 2017. 2. Steven M. Kay, *Fundamentals of Statistical Signal Processing, Volume II: Detection Theory*, Pearson Education, 1st edition, 2009. 3. Steven M. Kay, *Fundamentals of Statistical Signal Processing, Volume I: Estimation Theory*, Pearson Education, 1st edition, 2009.	

ELECTIVES (I, II, III) Syllabus

Course Code	Course name	L	T	P	C	Semester
EC551	VLSI for DSP	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	Graphical Representation of Signals, Signal Flow Graph, Data Flow Graph, Critical Path, Dependence Graph, Retiming Theorem.					**7**
Module-II	Forward Path and Loop Retiming, Loop Bound and Iteration Bound, Cutset Retiming, Retiming IIR Filters, Adaptive Filter Basics (LMS Algorithm), Retiming LMS, Retiming Delayed LMS.					**7**
Module-III	Parallel Processing in DSP by Unfolding, Basic Unfolding Relation, Retiming for Unfolding, Loop Unfolding, Iteration bound for Loops, Bitserial, Digit serial and Word serial Structures, Unfolding a Switch, Unfolding Bit Serial Systems, Folding of DFG, Folding Examples - IIR Filter, Retiming for Folding.					8
Module-IV	Introduction to Delay Optimization by Folding, Life Time Analysis of Storage Variables, Forward Backward Data Allocation, Life Time Analysis of Storage Variables in a Digital Filter, Delay Folded Realization of a Digital Filter, Polyphase Decomposition of Sequences, Hardware Efficient 2-Parallel FIR Filters.					**9**

Module-V	Hardware Efficient 3-Parallel FIR Filters, Introduction to First Level Architectures, 2's Complement Number Systems, Multiplication of Two Binary Numbers, Carry Ripple and Carry Save Array, Bit Serial Multipliers, Bit Serial Digital Filters, Baugh Wooley Multiplier, Distributed Arithmetic.	**9**
	Total No. of Lectures	**40**
Text	1. Keshab K. Parhi, *VLSI Digital Processing System: Design and Implementation*, Wiley, 2nd edition, 2011. 2. S. Monk, Programming FPGAs: Getting Started with Verilog, Prentice Hall, 1st edition, 2016.	
Reference	1. R. Woods, J. McAllister, G. Lightbody, Y. Yi, *FPGA-based Implementation of Signal Processing Systems*, Wiley, 2nd edition 2017.	

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Semester**
EC552	Image Processing and Computer Vision	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	**Introduction:** Light, Brightness adaption and discrimination, Pixels, coordinate conventions, Spatial Domain Filtering, sampling and quantization; **Spatial Domain Filtering:** Intensity transformations, contrast stretching, histogram equalization, Correlation and convolution, Smoothing filters, sharpening filters, gradient and Laplacian.					07
Module-II	**Filtering in the Frequency domain:** Hotelling Transform, Fourier Transforms and properties, FFT (Decimation in Frequency and Decimation in Time Techniques), Convolution, Correlation, 2-D sampling, Discrete Cosine Transform, Frequency domain filtering.					07
Module-III	**Image Restoration:** Basic Framework, Interactive Restoration, Image deformation and geometric transformations, image morphing, Restoration techniques, Noise characterization, Noise restoration filters, Adaptive filters, Linear, Position invariant degradations, Estimation of Degradation functions, Restoration from projections **Image Compression:** Encoder-Decoder model, Types of redundancies, Lossy and Lossless compression. **Morphological Image Processing**: Basics, SE, Erosion, Dilation, Opening, Closing, Hit-or-Miss Transform, Boundary Detection.					10
Module-IV	**Image formation and representation:** imaging geometry, radiometry, digitization, cameras and projections, rigid and affine transformations. **Filtering:** convolution, smoothing, differencing, and scale space. Feature matching and model fitting.					8
Module-V	**Motion analysis:** The motion field of rigid objects; motion parallax; optical flow, the image brightness constancy equation, affine flow; differential techniques; feature-based techniques; regularization and robust estimation; motion segmentation through EM. **Motion tracking:** statistical filtering; iterated estimation; observability and linear systems; the Kalman filter; the extended Kalman filter, Object recognition and shape representation: alignment, appearance-based methods, invariants, image eigenspaces, data-based techniques.					8
	Total No. of Lectures					40

Text	1. R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, Pearson Education, 3rd edition, 2012. 2. R.J. Schalkoff, *Digital Image Processing and Computer Vision*, Wiley and Sons, 2nd edition, 2017.
Reference	1. R. Hartley and A. Zisserman, *Multiple View Geometry in Computer Vision*, Cambridge University Press, 2nd edition, 2004. 2. David A. Forsyth, J. Ponce, *Computer Vision: A Modern Approach*, Pearson, 2nd edition, 2011.

Course Code	Course name	L	T	P	C	Semester
EC553	Introduction to IoT	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	An Introduction to Internet-of-Things, architectural overview, main design principles and needed capabilities, An IoT architecture outline, standards considerations, M2M and IoT Technology fundamentals					8
Module-II	State of art, reference model and architecture, IoT reference architecture, functional view, Deployment and Operational view, other relevant architectural views.					8
Module-III	Sensing, transducers classification, Actuation, Smart sensors, Basics of Networking; Communication Protocols, Sensor Networks, Machine to-Machine Communications, Wireless medium access issues, MAC protocol survey, Survey routing protocols, Sensor deployment & Node discovery, Data aggregation & dissemination.					8
Module-IV	Sensor Technology, RFID Technology, WPAN Technologies for IoT/ M2M, Cellular and mobile network technologies for IoT/ M2M CoAP, REST, Zigbee, Bluetooth, transport and session layer protocols – TCP, MPTCP, UDP, DCCP, HTTP, CoAP, XMPP, AMQP, MQTT					8
Module-V	Developing IoTs, Introduction to Python, Introduction to different IoT tools, developing applications through IoT tools, developing sensor-based application through embedded system platform, Integration of Sensors and Actuators with Arduino, Implementing IoT concepts with python; Domain specific applications of IoT: Home automation, Industry applications, Surveillance applications, other IoT applications.					8
	Total No. of Lectures					40
Text	1. J. Holler, V. Tsiatsis, C. Mulligan, S. Avesand, S. Karnouskos, D. Boyle, *From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence*, Academic Press, 1st edition, 2014. 2. A. Bahga, V. Madisetti, *Internet of Things: A Hands-on Approach*, Universities Press, 1st edition, 2015. 3. P. Raj, Anupama C. Raman, *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC Press, 1st edition, 2017.					
Reference	1. O. Hersent, D. Boswarthick, O. Elloumi, *The Internet of Things: Key Applications and Protocols*, Wiley Press, 2nd edition, 2012. 2. D. Uckelmann, M. Harrison, F. Michahelles, *Architecting the Internet of Things*, Springer, 1st edition, 2011.					

Course Code	Course name	L	T	P	C	Semester
EC554	Signal Detection and Estimation Theory	3	0	0	3	

Topic	Contents	No. of Lectures
Module-I	**Introduction of detection and estimation theory**: Review of random processes, Problem formulation, Applications, Detection of deterministic signals, Matched filter and its performance, Detection of random signals, Energy detector and its performance, Detection of signals with unknown parameters and Sinusoid detection example, Chernoff and related performance bounds.	9
Module-II	**Hypothesis testing**: Neyman-Pearson, minimax, and Bayesian detection criteria; Randomized decision; Compound hypothesis testing; Locally and universally most powerful tests, generalized likelihood-ratio test; Chernoff bound, asymptotic relative efficiency; Sequential detection; Nonparametric detection, sign test, rank test.	8
Module-III	**Parameter Estimation**: Bayesian formulation, Minimum mean squared error and MAP estimation, Linear MMSE estimation, Orthogonality principle, Applications to channel estimation problems Minimum Variance Unbiased Estimation: MVUE criterion, finding MVUE, sufficient statistics, Neyman-fisher factorization, Rao-Blackwell theorem, Cramer-Rao lower bound, Fisher information matrix.	9
Module-IV	**Minimum Variance Unbiased Estimation**: MVUE criterion, finding MVUE, sufficient statistics, Neyman-fisher factorization, Rao-Blackwell theorem, Cramer-Rao lower bound, Fisher information matrix.	6
Module-V	**Non-Random Parameter Estimation**: Least squares estimation, Best linear unbiased estimation, Geometric interpretations, Maximum likelihood Estimation, Efficiency and consistency of estimators and asymptotic properties.	8
	Total No. of Lectures	40
Text	1. H. L. Van Tre, *Detection, Estimation, and Modulation Theory, Part I*, John Wiley, 1st edition, 2012. 2. H. V. Poor, *An Introduction to Signal Detection and Estimation*, Springer, 2nd edition, 2010.	
Reference	1. M. H. Hayes, *Statistical Digital Signal Processing and Modeling*, John Wiley & Sons, Inc., 2nd edition, 2009. 2. S. M. Kay, *Fundamentals of Statistical Signal Processing: Detection Theory*, Pearson Education, 1st edition, 2009. 3. S. M. Kay, *Fundamentals of Statistical Signal Processing: Estimation Theory*, Pearson Education, 1st edition, 2009.	

Course Code	Course name	L	T	P	C	Semester
EC555	Speech and Audio Processing	3	0	0	3	

Topic	Contents	No. of Lectures
Module-I	Speech production and perception mechanisms, Speech signal processing methods, Frequency analysis methods, Auto and cross correlation functions.	7
Module-II	Time domain and frequency domain knowledge sources, Spectrograms, Knowledge sources at segmental, sub-segmental and supra-segmental (prosodic) levels, excitation source, vocal tract system, linguistic knowledge.	7
Module-III	Vector quantization, Hidden Markov models, Gaussian mixture models, Support vector machines and Neural networks.	7
Module-IV	Prediction coding, line spectral frequencies (LSF), Issues in speech recognition, Connected word recognition, Continuous speech recognition, Issues in speech synthesis, Models for speech synthesis, Different speech synthesis systems	9
Module-V	Issues in speaker recognition, Speaker verification vs identification, Text-dependent vs text-independent speaker recognition, Development of speaker recognition systems, Speaker detection based on MFCC combined with LDA and PCA, Acoustic Classification Methods, Music Signal Processing, e.g. beat detection	10
	Total No. of Lectures	40
Text	1. L. R. Rabiner and B. H. Juang, *Fundamentals of Speech Recognition*, Pearson Education, 1st edition, 2009. 2. L. Rabiner, & R. Schafer, *Introduction to Digital Speech Processing*, Now Publishers Inc., Vol. 1, 2007.	
Reference	1. B. Gold and N. Morgan, *Speech and Audio Signal Processing*, Wiley Student edition, 2004.	

Course Code	Course name	L	T	P	C	Semester
EC556	MIMO Wireless Communications	3	0	0	3	

Topic	Contents	No. of Lectures
Module-I	Evolution of Wireless Communication Systems 1G - 5G, Elements of Wireless Communication System, Modelling Wireless Channel, Overview of MIMO Communication Systems, Wireless Fading Channel Model, Bit Error Rate (BER) Performance of AWGN Channels	7
Module-II	Large Scale Propagation Models, Path Loss, Small Scale Propagation Model, Small Scale Propagation Frequency Flat Fading, Envelope Distribution	7
Module-III	Small Scale Propagation Received Signal Correlation, Max Delay Spread, Coherence Time, Mobility and Doppler Effect in Wireless Channels, Impact of Doppler Effect on Wireless Channel, Frequency Selective Fading, Delay Doppler Characteristics	8

Module-IV	LTE (Long Term Evolution) and WiMAX, Introduction to Code Division Multiple Access (CDMA), Analysis of Multi-user CDMA, Multiple Input Multiple Output (MIMO) Systems, Expression of MIMO Channel, Examples of MIMO Systems, MIMO Channel Characteristics	9
Module-V	Spatial Diversity, Selection Combining, MIMO Transmit Diversity, Capacity of Deterministic MIMO Channels, MIMO Receivers, SVD based MIMO Transmission, Orthogonal Frequency Division Multiplexing (OFDM), BER Performance of OFDM Systems	9
	Total No. of Lectures	40
Text	1. E. Biglieri, R. Calderbank, A. Constantinides, A. Goldsmith, A. Paulraj, H. V. Poor, *MIMO wireless communications*, Cambridge University Press, Illustrated edition 2009. 2. A. Paulraj, C. Nabar, D. Gore, *Introduction to Space-Time Wireless Communications*, Cambridge University Press, 1st edition, 2008.	
Reference	1. G. L. Stuber, *Principles of Mobile Communications*, Springer, 2nd edition., 2017. 2. Rappaport, *Wireless Communications*, *Principles and Practice*, Pearson, 2nd edition, 2018. 3. A. Goldsmith, *Wireless Communications*, Cambridge University Press, Illustrated edition 2005.	

Course Code	Course name	L	T	P	C	Semester
EC557	Microwave Imaging and Radar Signal Processing	3	0	0	3	
Topic	**Contents**					**No. of Lectures**
Module-I	Electromagnetic Scattering, Wave Equations and Their Solutions, Volume Scattering by Dielectric Targets, Volume Equivalence Principle, Integral Equations, Surface Scattering by Perfectly Electric Conducting Targets. Electromagnetic Inverse Scattering Problem: Two-Dimensional Inverse Scattering					7
Module-II	Imaging Configurations and Model Approximations: Objectives of the Reconstruction, Tomographic configurations, Configurations for Buried-Object Detection, Born-Type Approximations, Extended Born Approximation, Rytov Approximation					7
Module-III	Qualitative Reconstruction Methods: Generalized Solution of Linear Ill-Posed Problems, Regularization Methods, Singular Value Decomposition, Regularized Solution of a Linear System Using Singular Value Decomposition, Qualitative Methods for Object Localization and Shaping, Back projection, w-k, beamforming, Civil and Industrial Applications, Medical Applications of Microwave Imaging, Shallow Subsurface Imaging.					9
Module-IV	Basic radar definitions; radar range equation, receiver noise, probability of detection and signal-to-noise ratio, RCS, CW, FMCW and multiple-frequency CW radars, delay line canceler, error signal of conical-scan radar, monopulse radars, clutter, jamming, doppler shift, Radar waveforms, waveform matched filter, pulse burst waveform, frequency-modulated pulse compression waveforms					9

Module-V	Phase array working and feed systems; Synthetic aperture radars (SAR), pulse compression techniques, Doppler processing, Alternate forms of the Doppler spectrum, Moving target indication (MTI), Pulse Doppler processing, Dwell-to-dwell stagger, Clutter mapping and the moving target detector, Detection of radar signals in noise.	8
	Total No. of Lectures	40
Text	1. M. Pastorino, *Microwave Imaging*, Wiley & Sons, 1st edition, 2010. 2. Mark A. Richards, *Fundamentals of Radar Signal Processing*, McGraw-Hill, 2nd edition, 2014. 3. S. Haykins, *Adaptive Radar Signal Processing*, John Wiley & Sons, Inc. 1st edition, 2007.	
Reference	1. M. I. Skolnik, *Introduction to Radar Systems*, McGraw-Hill, 2nd edition, 2018. 2. V. C. Chen and H. Ling, *Time-Frequency Transforms for Radar Imaging and Signal Analysis*, Artech House,1st edition, 2002. 3. Bernard D. Steinberg, H. M. Subbaram, *Microwave Imaging Techniques*, Wiley & Sons.,1st edition, 1991.	

Course Code	Course name	L	T	P	C	Semester
EC558	Introduction to Pattern Recognition	3	0	0	3	

Topic	Contents	No. of Lectures
Module-I	**Introduction:** Introduction fundamentals and definitions, Feature vectors, Classifiers, Supervised and Unsupervised learning, Bayesian decision theory	7
Module-II	**Features**: types and traits, scaling ordering, measurements, normalization, invariance, feature properties, dimensionality reduction of feature space, dimensionality reduction by feature selection, PCA, KPCA, ICA	8
Module-III	**Parameter estimation**: Maximum likelihood estimation (MLE), least squares estimation (LSE), Method of minimum variance & unbiased Estimation (MVUE); parameter free methods: KNN, Clustering; Special classifiers: linear regression, LDA, SVM, CNN.	8
Module-IV	**Classifiers and learning:** Fundamentals of classifiers, Linear Classifiers, Nonlinear Classifiers. Unsupervised and semi supervised learning: Learning from unclassified data, **Clustering:** Basic Concepts of clustering, Hierarchical agglomerative clustering, K-means partitional clustering, semi-supervised learning with expectation maximization using labelled and unlabelled data; Characteristics analysis of different classifiers	9
Module-V	**Classification with nominal features** : decision tree, random forest; classifier independent concepts, **Combinations of classifiers:** boosting, voting , stacking	8
	Total No. of Lectures	40
Text	1. Christopher Bishop, *Pattern Recognition and Machine Learning*, Springer, 2nd printing edition, 2011. 2. Richard O. Duda, Peter E. Hart, David G. Stork, *Pattern Classification*, John Wiley, 2nd edition, 2002.	
Reference	1. Kevin P. Murphy, *Machine Learning: A Probabilistic Perspective*, The MIT Press; Illustrated edition, 2012. 2. S. Theodoridis, K. Koutroumbas, "*Pattern Recognition"*, Academic Press, 4th edition, 2008.	

<table>
<tr><th>Course Code</th><th>Course name</th><th>L</th><th>T</th><th>P</th><th>C</th><th>Year</th><th>Semester</th></tr>
<tr><td>MA521</td><td>Statistical Foundations for Data Science</td><td>3</td><td>0</td><td>0</td><td>4</td><td>1st</td><td>1st</td></tr>
<tr><th>Topic</th><th colspan="6">Contents</th><th>No. of Lectures</th></tr>
<tr><td>Module-I</td><td colspan="6">Theory of Probability: Bayes theorem, Random variables, functions of random variables and distribution functions, probability distributions (Binomial, Poisson, Normal), Beta and Gamma Distribution expectations and moments, moment generating functions. Joint, marginal, and conditional distribution’s function. Conditional expectations. Covariance, correlation and regression, standard multivariate distributions, Sequence of random variables</td><td>6</td></tr>
<tr><td>Module-II</td><td colspan="6">Statistics: convergences in probability and in distribution, law of large numbers, linear Regression; Central limit theorem. Application of Central Limit Theorem.</td><td>8</td></tr>
<tr><td>Module-III</td><td colspan="6">Sampling distributions of the sample mean and the sample variance for a normal population; Characteristics of Estimators ,Point and interval estimation; Sampling distributions (Chi-square, t, F,Z). Application of t distribution</td><td>8</td></tr>
<tr><td>Module-IV</td><td colspan="6">Basics of hypothesis testing, The Wald test, Type I and Type II errors, t-test Kolmogorov-Smirnov test (KS test), p-values, Permutation test, Pearson correlation coefficient. Neyman Pearson Lemma Theorem. Chi-square test for independence</td><td>8</td></tr>
<tr><td>Module-V</td><td colspan="6">Bayesian inference: Bayesian reasoning, Conjugate priors
Regression: Simple Linear Regression, Multiple Linear Regression</td><td>10</td></tr>
<tr><td colspan="7" align="right">Total No. of Lectures</td><td>40</td></tr>
<tr><td>Text</td><td colspan="7">1. Walepole, Myers, Myers, Ye; Probability and Statistics for Engineers and Scientists, Pearson, 9th Edition, 2013.
2. S.C.Gupta and V.K.Kapoor, Fundamental of Mathematical Statistics, Sultan Chand & Sons, 12th Edition, 2020.
3. H.C. Saxena and P.U. Surendran, Statistical Inference, S Chand & Company Pvt Ltd., 1994.</td></tr>
<tr><td>Reference</td><td colspan="7">1. R. V. Hogg, J. W. McKean and A. Craig, Introduction to Mathematical Statistics, Pearson, 8th Edition, 2019.
2. Larry Wasserman, All of Statistics: A Concise Course in Statistical Inference, Springer, Springer Texts in Statistics, 2010.
3. Peter Bruce, Andrew Bruce, Peter Gedeck, Practical Statistics for Data Scientists, 2nd Edition, O′Reilly, 2020.</td></tr>
</table>

Course Code	Course name	L	T	P	C	Year	Semester
CS557	Introduction to Blockchain Technology	3	0	0	3	1st	
Topic	**Contents**						**No. of Lectures**
Module-I	Basics of Blockchain Technology: Cryptography, Hashing, MD5 message digest algorithm, secure hash algorithm (SHA-1), security of hash functions, digital signatures.						8
Module-II	Introduction to Blockchain Technology: Blockchain introduction, applications, opportunities and challenges in blockchain technology.						6
Module-III	Bitcoin and Cryptocurrency: Bitcoin introduction, bitcoin mining, bitcoin case studies, understanding cryptocurrency.						9
Module-IV	Blockchain Technology Applications: Ethereum blockchain, ethereum virtual machine and gas, smart contracts.						9
Module-V	Blockchain Case studies: ICO case study, banking case study, blockchain white papers, study of recent trends and features of blockchain technology.						8
	Total No. of Lectures						40
Text	1. Roger Wattenhofer, "*The Science of the Blockchain*", Createspace Independent Pub, 1st edition, 2016 2. Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, and Steven Goldfeder, "*Bitcoin and cryptocurrency technologies: a comprehensive introduction*", Princeton University Press; Illustrated edition, 2016						
Reference	1. Behrouz A Forouzan, Debdeep Mukhopadhyay, "*Cryptography and Network Security*", Mc-GrawHill, 3nd Edition, 2016. 2. Melanie Swan, "*Blockchain*", O'Reilly, 1st Edition, 2015.						

Course Code	Course name	L	T	P	C	Year	Semester
CS558	Deep Learning and its Applications	3	0	0	6	1st	
Topic	**Contents**						**No. of Lectures**
Module-I	**Introduction**: Review of Feedforward neural network, brief review of concepts from optimization, Multilayer Perceptron, Difficulty of training deep neural networks, Discussion on deep learning frameworks.						06

Module-II	**Convolutional Neural Networks**: Construction of foundational layers of CNNs (pooling, convolutions) and to stack them properly in a deep network to solve multi-class image classification problems. Discussions on various convnet architectures: LeNet, AlexNet.	09
Module-III	**Recurrent Neural Networks**: Back propagation through time, Long Short Term Memory, Gated Recurrent Units, Bidirectional LSTMs, Bidirectional RNNs	10
Module-IV	**Generative models:** Generative Adversarial Networks (GAN), Deep Convolutional GAN (generative adversarial network).	10
Module-V	Recent trends: Variational Autoencoders, Multi-task Deep Learning, Applications: Vision, NLP (just an overview of different applications in PyTorch)	5
	Total No. of Lectures	40
Text	1. Ian Goodfellow and Yoshua Bengio and Aaron Courville, "*Deep Learning*," MIT Press, 2016. 2. Christopher Bishop, "*Pattern Recognition and Machine Learning*" , Springer; 1st edition, 2006.	
Reference	1. Ian Pointer, "*Programming PyTorch for Deep Learning*", Shroff/O'Reilly; First edition 2019. **2.** Sherin Thomas & Sudhanshu Passi, "*PyTorch Deep Learning Hands-On*" , Packt Publishing, 2019	