M. Tech.

in

SIGNAL PROCESSING AND MACHINE LEARNING CURRICULUM 2022-23

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA,

SURATHKAL – 575025

NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA, SURATHKAL

Vision

To facilitate transformation of students into good human beings, responsible citizens & competent professionals, focusing on the assimilation, generation and dissemination of knowledge.

Mission

- Impart quality education to meet the needs of profession and society, and achieve excellence in teaching-learning and research.
- Attract and develop talented and committed human resources, and provide an environment conducive to innovation, creativity, team-spirit and entrepreneurial leadership.
- Facilitate effective interactions among faculty and students, and foster networking with alumni, industries, institutions and other stake-holders.
- Practice and promote high standards of professional ethics, transparency and accountability.

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Vision

To be a model for academic excellence in the area of Electronics & Communication Engineering.

Mission

M1. Impart quality teaching-learning-experience with state-of-the-art curriculum.

M2. Enhance Research, Consultancy and Outreach activities.

M3. Increase the visibility of academic programs globally and attract talent at all levels.

M4. Foster sustained interaction with the alumni, industries, R & D organizations, world class universities and other stakeholders to stay relevant in the globalized environment.

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

M. Tech. in Signal Processing and Machine Learning (SPML)

Program Educational Objectives (PEOs)

PEO1: Pursue a successful career in the field of Signal Processing & Machine Learning and related fields in Industry /Research/ Academia.

PEO2: Continuously learn, engage and update in the relevant fields, carry out independent research and solve multidisciplinary technological challenges.

PEO3: Contribute to the welfare of the society as individual or in a team while working on deployable machine learning solutions.

Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: An ability to demonstrate a degree of mastery in the domain of Signal Processing and Machine Learning.

PO4: An ability to apply appropriate techniques and modern engineering tools in the design and implementation of Signal Processing & Machine Learning algorithms

PO5: An ability to understand the impact of professional engineering solutions to healthcare, environment and sustainable development

M. Tech. in Signal Processing and Machine Learning (SPML)

Suggested Plan of Study:

Sl. No.	Semester			
	I	II	III	IV
1	EC791	EC792	EC789	EC790
2	EC793	EC762		
3	EC761	EC763		
4	EC764	Elective 3		
5	Elective 1	EC787		
6	Elective 2	EC788		

Credit Requirements:

Category	Minimum Credits to be Earned
Program Core (Pc)	26
Elective Courses (Ele.)	12
Mandatory Learning Courses (MLC)	04
Major Project (MP)	12
Total	**54**

Program Core (Pc)

EC791	Linear Algebra and Stochastic Processes	(4-0-0) 4
EC792	High Performance Computing Architectures	(4-0-0) 4
EC793	Signal Analysis and Processing	(4-0-0) 4
EC761	Information Processing and Compression	(4-0-0) 4
EC762	Pattern Recognition and Machine Learning	(4-0-0) 4
EC763	Optimization	(4-0-0) 4
EC764	Signal Processing Laboratory	(0-0-3) 2

Electives (Ele)
(At least ONE elective must be chosen from this list)

EC861	Image Processing and Computer Vision	(4-0-0) 4
EC862	Time Series Analysis and Data Science	(4-0-0) 4
EC863	Statistical Signal Processing	(4-0-0) 4
EC864	Speech and Audio Processing	(4-0-0) 4
EC865	Multimedia Systems	(4-0-0) 4
EC866	Deep Learning and Applications	(3-0-2) 4
EC867	Fourier and Wavelet Analysis	(4-0-0) 4
EC868	Time Frequency Analysis	(4-0-0) 4
EC869	Medical Imaging and Biosignal Analysis	(4-0-0) 4
EC870	Architectures for Signal Processing and Machine Learning	(4-0-0) 4
EC871	Selected Topics in Signal Processing	(4-0-0) 4
EC872	Nonlinear Dynamics, Chaos and Fractals	(4-0-0) 4
EC873	Computational Imaging and Physics	(4-0-0) 4
EC874	Detection Estimation and Statistical Learning Theory	(4-0-0) 4
EC875	Probabilistic Models in Machine Learning	(4-0-0) 4
EC876	System Identification and Control	(4-0-0) 4
EC877	Inverse Problems: Theory and Applications	(4-0-0) 4
EC878	Remote Sensing: Techniques, Data Analysis and Applications	(4-0-0) 4
EC879	Compressed Sensing and Sparse Signal Process	(3-1-0) 4
EC880	Deep Learning in Radar Signal Processing	(3-1-0) 4
EC881	Computer Algorithms and Data Structures	(3-0-2) 4
EC734	Signal Detection and Estimation	(4-0-0) 4

Mandatory Learning Courses (MLC)

EC787	Seminar	2
EC788	Minor Project	2

Major Project (MP)

EC789	Major Project - I	6
EC790	Major Project - II	6

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING
M.Tech. in Signal Processing and Machine Learning

EC791 LINEAR ALGEBRA AND STOCHASTIC PROCESSES (4-0-0) 4

Course Contents

Vector Spaces, Subspaces, Linear Independence, Span, Basis, Dimension, Linear Transformations, Orthogonal Transformations, Orthogonal projections, Matrix subspaces and orientation, Eigen decomposition, SVD, Least Squares , Pseudo inverse.

Review of Probability theory and Random variables, Random vectors and moments, Stochastic Processes and Examples, stochastic processes and linear systems, Gaussian random process, spectral analysis of stationary processes, Power Spectral Densities, Stationarity and Ergodicity.

References

Gilbert Stran, Linear algebra and its applications, Thomson Brooks, 2006.

P Halmos, Finite Dimensional Vector Spaces, Springer, 1993.

Edgar G. Goodaire, Linear Algebra: Pure & Applied, World Scientific, 2014.

Dimitris P. Bertsekas, John N. Tsitsiklis, Introduction to Probability, 2nd Ed, Athena Scientific, 2008.

Alberto Leon-Garcia, Probability, Statistics, and Random Processes for Electrical Engineering, 3rd Ed, Addison-Wesley, 2008.

EC792 HIGH PERFORMANCE COMPUTING ARCHITECTURES (4-0-0) 4

Course Contents

Instruction Level Parallelism: Pipelining, Hazards, Instruction Level Parallelism, Branch prediction, Static and Dynamic Scheduling, Speculation, Limits of ILP. Multicore Memory Hierarchy: Cache trade-offs, Basic and Advanced optimizations, Virtual Memory, DRAM optimizations. Multiprocessors: Symmetric and Distributed architectures, Cache coherence protocols - Snoopy and Directory based, ISA support for Synchronization, Memory Consistency Models. Interconnection Networks: Architectures, Topologies, Performance, Routing, Flow control, Future of NoCs.

References

John Hennessy and David Patterson, Computer Architecture - A Quantitative Approach 6th Edition, Morgan Koufmann, 2017

John Hennessy and David Patterson, Computer Architecture - A Quantitative Approach 5th Edition, Morgan Koufmann, 2011

John Paul Shen and Mikko H. Lipasti, Modern Processor Design: Fundamentals of Superscalar Processors, Tata McGraw Hill, 2013

D. A. Patterson and J. Hennessy, Computer Organization and Design, Harcourt Asia, 1998.

Behrooz Parhami, Computer Arithmetic Algorithms and Hardware Design, Oxford, 2000.

NPTEL Video Lectures

EC793 SIGNAL ANALYSIS AND PROCESSING (4-0-0) 4

Course Contents

Review of Time domain analysis of discrete-time signals & systems, Transform domain analysis of discrete time signals & systems: Z transforms, application of Z transforms to discrete-time systems, Frequency domain analysis of discrete-time signals and systems, Sampling in time and frequency domain, linear convolution using DFT, Fast Fourier Transform algorithms.

Digital Filter Design: Filter Structures; FIR filter design, IIR Filter Design, Filter design using Butterworth, Chebyshev and elliptic approximations, Spectral transformation technique for HP, BP and BS filter design. Direct design of IIR filters, Introduction to multirate Signal Processing, Upsampling, Downsampling, Sample rate conversion.

References

D G Manolakis, V K Ingle, Applied Digital Signal Processing, Cambridge University Press, 2012

Oppenheim, Schaffer, Discrete Time Signal Processing, Prentice Hall,

Ashok Ambardar, Digital Signal Processing – A Modern Introduction, Thomson, 2007

Sanjit K. Mitra, Digital Signal Processing: A computer based Approach, TMH, 2006

EC761 INFORMATION PROCESSING AND COMPRESSION (4-0-0) 4

Course Contents

Introduction to Information theory, Entropy and Inference. Mathematical preliminaries for Lossless compression, Shannon's Source Coding Theorem Huffman coding, Arithmetic Coding, LZW coding. Mathematical preliminaries for lossy compression, quantization and the Lloyd-Max Algorithm, rate-distortion theory, Scalar and vector quantization, Transform coding, Subband coding.

References
Khalid Sayood, Introduction to Data Compression, Morgan Kaufman, 5th Ed. 2018.
David McKay, Information Theory, Inference and Learning Algorithms, Cambridge University Press, 2003.
David Solomon, Handbook of Data Compression, Springer, 2010.

EC762 PATTERN RECOGNITION AND MACHINE LEARNING (4-0-0) 4

Course Contents
Statistical foundations, Different Paradigms of Pattern Recognition, Probability estimation, Proximity measures, Feature extraction, Different approaches to Feature selection, Nearest Neighbor Classifier and variants, Bayes classification.
Linear models, regression, logistic regression, neural networks, objective function and learning, back propagation. Kernel based methods, support vector machines. Dimensionality reduction, principal component analysis, reconstruction, discriminant analysis. Clustering, K-means algorithm, distance measure, objective function, initialization. Anomaly detection, recommender systems. Scaling of algorithms.

References
R. O. Duda, P. E. Hart and D. G. Stork Pattern Classification, Wiley Publications, 2001.
D. McKay, Information Theory, Inference, and Learning Algorithms, Cambridge University Press 2003.
C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.

EC763 OPTIMIZATION (4-0-0) 4

Course Contents
Convex sets and Convex functions, Level sets and Gradients. Unconstrained Optimization: Search methods, Gradients Methods, Newton Method, Conjugate Direction Methods, Quasi-Newton Methods. Linear Programming: Standard Form Linear Programs, Simplex method, Duality and Non Simplex Methods. Nonlinear Constrained Optimization: Problems with equality constraints, Problems with Inequality Constraints, Convex Optimization Problems. Algorithms for Constrained Optimization: Projected Gradient Methods and Penalty Methods.

References
Lieven Vandenberghe and Stephen P. Boyd, Convex Optimization, Cambridge University Press, 2004.
Dimitris Bertsekas, John N. Tsitsiklis, Introduction to Linear Optimization, Athena Scientific Series, 1997.
Aharon Ben-Tal and Arkadi Nemirovski, Lectures on Modern Convex Optimization: Analysis, Algorithms, and Engineering Applications, SIAM, 2001.

EC764 SIGNAL PROCESSING LABORATORY (0-0-3) 2

Course Contents
Signals and spectral analysis, Transform domain analysis of systems, Sampling and Quantization effects, Digital Filter Design, Applications in Image and Speech – Compression Schemes, Denoising, Real Time DSP experiments.

References
D G Manolakis, V K Ingle, Applied Digital Signal Processing, Cambridge University Press, 2012
Donald Reay, Digital Signal Processing using ARM Cortex-M4, John-Wiley, 2015.

ELECTIVE COURSES

EC861 IMAGE PROCESSING AND COMPUTER VISION (4-0-0) 4

Course Contents

Overview of image processing systems, image formation and perception, continuous and digital image representation, image quantization, image contrast enhancement, histogram equalization, 2D signals and systems, 2D sampling, linear convolution in 2D, continuous and Discrete Fourier transform in 2D, image filtering in the DFT domain, color representation and display; true and pseudo color image processing, image compression, imaging geometry, model of image degradation/restoration process, texture analysis, motion analysis, geometric camera models, stereopsis, structure from motion, tracking, robot vision, object identification.

References

Anil K. Jain, Fundamentals of digital image processing, Prentice Hall, 1989.
Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing, 2nd Ed, Prentice Hall, 2002.
Forsth D. A. and Ponce J., Computer Vision: A Modern Approach, Prentice Hall, 2003.
Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010.
Hartley and Zisserman, Multiple Geometry in Computer Vision, Cambridge University Press, 2004.

EC862 TIME SERIES ANALYSIS AND DATA SCIENCE (4-0-0) 4

Course Contents

Identifying patterns in time series data, inference, estimation, prediction, general properties of time series models, systematic pattern and random noise, trend and seasonality analysis, time domain and frequency domain analysis, data visualization, linear and mixed models, AR models, ARMA models, ARIMA models, identification and parameter estimation, model estimation and forecasting, Akaike information criterion, mixed models, single spectrum and cross spectrum analysis, higher order statistics, state space models, Kalman filter, non-Gaussian linear models, Generalized autoregressive conditional hetereoskedastic (GARCH) models, stochastic volatility models, extreme value theory, nonlinear time series models, applications in data science.

References

Peter J. Brockwell, Richard A. Davis, Introduction to Time Series and Forecasting, Springer, 2001.
George E. P. Box, Gwilym M. Jenkins, Gregory C. Reinsel, Time Series Analysis: Forecasting and Control 4th Ed, Wiley, 2008.
Andrew C. Harvey, Forecasting, Structural Time Series Models and the Kalman Filter, Reprint Ed, 2001.
Box-Steffensmeier, Janet M., John R. Freeman, Matthew P. Hitt, Jon C. W. Pevehouse, Time Series Analysis for the Social Sciences, Cambridge University Press. 2014.
James Fahl, Data Analytics, Paperback, 2017.

EC863 STATISTICAL SIGNAL PROCESSING (4-0-0) 4

Course Contents

Introduction to Adaptive Filters: General properties, filtering, prediction and smoothing, Applications in Communications, Optimal Signal Processing, Principles of orthogonality, minimum square error, Wiener Hopf equations, state space model, innovations process, Kalman filter equations. Linear Adaptive Equalisation, Gradient search and steepest descent adaptation algorithms, Transient and Steady state properties including convergence rate and mis-adjustment, least square estimation, Recursive Least Squares (RLS) algorithms, Introduction to Fast Recursive Algorithms for Equalization, lattice filtering for RLS. Tracking time-varying systems.

References

S.J. Orfanidis, Optimum Signal Processing, McGraw Hill, 1989.
S. Haykin, Adaptive FilterTheory, Pearson, 1996.
Mayson H. Hayes, Statistical Digital Signal Processing and Modeling, Wiley, 1996.

EC864 SPEECH AND AUDIO PROCESSING (4-0-0) 4

Course Contents

Speech Production–human speech production mechanism, digital models for speech production, Speech perception, Speech Analysis–Time and frequency domain analysis of speech, Linear prediction, Speech compression, Audio processing–characteristics of audio signals, sampling, Audio compression techniques, Standards for audio compression in multimedia applications, MPEG audio encoding and decoding, audio databases and applications. Speech synthesis–text to speech synthesis, letter to sound rules, syntactic analysis, timing and pitch segmental analysis. Speech recognition.

References
Douglas O'Shaugnessy, Speech Communication–Human and Machine, IEEE Press, 2000
L R Rabiner, Digital Processing of Speech Signals, Pearson,1978.
T.F Quatieri , Discrete-time speech signal processing: Principles and Practise Pearson,2002.
Zi Nian Li, Fundamentals of Multimedia, Pearson Education, 2003.

EC865 MULTIMEDIA SYSTEMS (4-0-0) 4

Course Contents
Computer information representation through text, graphics, images, sound, audio, animation, video, processing, storage, generation, manipulation, rendition, transmission of multimedia information, psycho acoustic models, synthesis and recognition, color models for video, television, video formats, text in multimedia and internet, image compression, video indexing and content based image/video retrieval, audio coding, storage, retrieval and presentation of media, multimedia annotation and indexing, multimedia recommendation and summarization, multimodal translation between language and vision, DLT for audio, multimedia synchronization, multimedia databases, multimedia communications, network applications, distributed multimedia systems, multimedia system integration.

References
Ze-Nian Li, Mark S. Drew, Fundamentals of Multimedia. Prentice-Hall/Pearson Education, 2004.
P. K. Andleigh, Kiran Thakrar, Multimedia Systems Design, 1/e, Prentice Hall, 1995.
R. Steinmetz, K. Nahrstedt, Multimedia Fundamentals, Volume 1: Media Coding and Content Processing, Prentice Hall, 2002.
F. Kuo, J. J. Garcia Luna-Aceves, W. Effelsberg, Multimedia Communications: Protocols and Applications, 1/e 1998.
Milovanovic, Zoran S. Bojkovic, Dragorad A. Milovanovic, Kamisetty Ramamohan Rao: Multimedia Communication Systems: Techniques, Standards, and Networks, Prentice Hall, 2002.

EC866 DEEP LEARNING AND APPLICATIONS (3-0-2) 4

Course Contents
Linear Regression , Logistic regression, Basic neuron structure, Perceptron, error functions, optimization – gradient descent, Multilayer perceptron, transfer function, nonlinearities, learning, backpropagation, function approximations, overfitting, underfitting, Deep networks, challenges, regularization techniques – Norm penalties, early stopping, drop outs, dataset augmentation, bagging and ensemble methods, Convolutional Networks – Convolution, pooling, variants, transfer learning, Sequence Modeling – Recurrent neural networks, Bidirectional RNNs, architectures, LSTM, Application examples – Computer Vision, Speech recognition, NLP.

References
Simon S. Haykin, Neural Networks and Learning Machines, 3rd Ed, Pearson, 2009.
José C. Principe, Neil R. Euliano, W. Curt Lefebvre, Neural and Adaptive Systems: Fundamentals through Simulations, John Wiley and Sons, 2000.
Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 2016.

EC867 FOURIER AND WAVELET ANALYSIS (4-0-0) 4

Course Contents
Hilbert Spaces, Review of sequences and discrete time systems, functions, DTFT, convergence, multi rate systems, polyphase representation, stochastic processes and systems. Continuous time systems, Fourier transform, definition, existence, spectral decay, Fourier series. Sampling and Interpolation–finite dimensional vectors, sequences, functions, periodic functions, approximation and compression polynomial and spline approximation. Localization and uncertainity, Filter banks–Localization, two channel orthogonal filter banks, design, biorthogonal filter banks, design, Local fourier bases–N channel filter banks, exponentially modulation filter banks, cosine modulated filter banks. Wavelet bases on sequences, Tree structured filter banks, orthogonal, biorthogonal bases, wavelet packets, frames. Wavelet bases on functions–local Fourier transforms.

References
Martin Vetterli Jelena Kovacevic & Vivek K. Goyal, Foundations of Signal Processing, Cambridge University Press, 2015.
J. Kovacevic, V. K. Goyal and Martin Vetterli, Fourier and Wavelet Signal Processing, Cambridge University Press, 2013.

EC868 TIME FREQUENCY ANALYSIS (4-0-0) 4

Course Contents

The need for Time-frequency analysis: introduction, Time and Frequency Description of Signals, Instantaneous Frequency and the Complex Signal, Densities and Characteristic functions: one and two dimensional density functions and their characteristic functions, Fundamentals of Time-Frequency Distribution (TFD), Different Types of TFD, Generation of TFD Using Kernel Methods. Kernel design for reduced interference in TFD. Positive Distributions Satisfying the Marginals. Applications of TFD in the fields of Radar, Speech, Sonar Signal Processing.

References

Leon Cohen, Time-Frequency Analysis, Prentice-Hall PTR, Upper Saddle River, 1995.
S. Mallat, A wavelet tour of signal processing - The sparse way, Elsevier, Third Edition, 2009.
D. Gabor, Theory of communication, Proceedings of IEE, pp. 429-457, 1946.

EC869 MEDICAL IMAGING AND BIOSIGNAL ANALYSIS (4-0-0) 4

Course Contents

Bio-electromagnetism, bioelectric sources and conductor modeling, image formation in modern medical imaging modalities, radiography, fluoroscopy, and computed tomography, magnetic resonance imaging, ultrasound, acoustic and photoacoustic imaging, X-Ray tomography, radiation measurements, safety issues, and physiological signals and responses, Bioelectrical signals, Evoked potentials, Electromyogram, respiration and heart rate variability, mathematical modeling and techniques for image and bio-signal analysis and diagnostic decision-making, detection, segmentation and classification techniques, Computational Bio-imaging, data interpolation, registration, acquisition and compression.

References

Jaakko Malmivuo, Bioelectromagnetism - Principles and Applications of Bioelectric and Biomagnetic Fields, Oxford University Press, 1995.
John L. Semmlow, Benjamin Griffel, Biosignal and Medical Image Processing, 3rd Ed, CRC Press, 2014.
E. Russell Ritenour and William Hendee, Medical Imaging Physics, 4th Ed, 2002.
Rangaraj M. Rangayyan, Biomedical image analysis, CRC Press, 2004.
B.H Brown, R.H Smallwood, D.C. Barber, P.V Lawford, D.R Hose, Medical Physics and Biomedical Engineering, CRC Press, 1998.

EC870 ARCHITECTURES FOR SIGNAL PROCESSING AND MACHINE LEARNING (4-0-0) 4

Course Contents

Representation of digital signal processing systems: block diagrams, signal flow graphs, data-flow graphs, dependence graphs; pipelining and parallel processing for high-speed and low power realizations; iteration bound, algorithms to compute iteration bound, retiming of data-flow graphs; unfolding transformation of data-flow graphs; systolic architecture design, architectures for real and complex fast Fourier transforms; stochastic logic based computing, computing digital filters, arithmetic functions and machine learning functions using stochastic computing; Neural Network architectures.

References

K.K. Parhi, VLSI Digital signal processing systems: Design and implementation, John Wiley, 1999.
Lars Wanhammar, DSP Integrated Circuits, Academic Press, 1999.
Sen M. Kuo Bob H. LeeWenshun Tian, Real-Time Digital Signal Processing: Implementations and Applications, John Wiley & Sons, Ltd, 2006.
Roger Woods, John McAllister, Gaye Lightbody, Ying Yi, FPGA Based Implementation of Signal Processing Systems, John Wile, 2017.
U. Meyer-Baese, Digital Signal Processing with Field Programmable Gate Arrays, 4th Ed. Springer, 2014. Recent literature

EC871 SELECTED TOPICS IN SIGNAL PROCESSING (4-0-0) 4

Course Contents

Current advances in Signal Processing as defined by the instructor.

References

Current literature from IEEE and other quality journals and recent books in the field.

EC872 NONLINEAR DYNAMICS, CHAOS AND FRACTALS (4-0-0) 4

Course Contents

Review of linear systems; discrete and continuous, difference and differential equation modeling and solution, dynamics of linear and nonlinear systems, maps and flows, phase-plane analysis, bifurcations, limit cycles, attractors, chaotic behavior, strange attractors, chaotic systems and their analysis, fractals, Mandlebrot and Julia sets, iterated function systems, fractal dimension, stable and unstable manifolds, multifractals, applications.

References

Steven H. Strogatz, Nonlinear Dynamics And Chaos: With Applications To Physics, Biology, Chemistry, And Engineering, Addison-Wesley, 1994.
MW Hirsch, S. Smale, RL Devaney, Differential equations, dynamical systems, and an introduction to chaos, Academic Press. 2012.
Drazin, P. G. Nonlinear systems. Cambridge, UK: Cambridge University Press, 1992.
Peitgen, H-O., H. Jurgens, and D. Saupe. Chaos and Fractals: New Frontiers of Science, Springer, 2004.
M. Barnsley, Fractals everywhere, Academic Press, 1993.

EC873 COMPUTATIONAL IMAGING AND PHYSICS (4-0-0) 4

Course Contents

Imaging methods and modalities, computational aspects of analysis, theoretical and applied; modalities in medical imaging, geophysics, applied physics, biology, astronomy, remote sensing and optics; methods and applications in nuclear medical imaging physics and radiology, image guided radiotherapy; computational photography, inverse problems and reconstruction, modeling, analysis; use of optimization, compressed sensing and pattern recognition and machine learning theory; applications of deep learning and artificial intelligence.

References

Kedar Khare, Fourier Optics and Computational Imaging, Wiley, 2015.
B.H Brown, R.H Smallwood, D.C. Barber, P.V Lawford, D.R Hose, Medical Physics and Biomedical Engineering, CRC Press 1998.
S Webb, The Physics of Medical Imaging, Institute of Physics, 1988.
Paul Suetens, Fundamentals of Medical Imaging, Cambridge University Press, 2009.
Thayalan K, The Physics Of Radiology And Imaging, Jaypee Brothers 2014.
Tetsuo Asano, Geometry, Morphology, and Computational Imaging, Springer 2002.

EC874 DETECTION, ESTIMATION AND STATISTICAL LEARNING THEORY (4-0-0) 4

Course Contents

Non-Bayesian Detection: Hypothesis test, Neyman-Pearson lemma, Likelihood ratio test, Kullback-Leiblerdivergence, Matched filter, Sequential test; Minimum mean square-error (MMSE), Linear MMSE, Minimum probability of error (MAP), Stationarity and power spectral density, Wiener filter, Kalman filter, Non-Bayesian Estimation: Sufficient Statistic, Bias, Minimum variance unbiased estimator. Cramer-Rao bound. Maximumlikelihood, Expectation maximization, Bayesian inference, empirical risk minimization, concentration inequalities, PAC learning, nonparametric inference.

References

HV. Poor, An Introduction to Signal Detection and Estimation, 2nd Ed., Springer-Verlag, 1994.
HL. Van Trees, Detection, Estimation and Modulation Theory, Parts 1and 2, John WileyInter-Science.
SM. Kay, Fundamentals of Statistical Signal Processing, vol 1and vol 2, Prentice Hall, 1993.
Kailath, sayed, and Hassibi, Linear Estimation, Prentice Hall, 2000.
MD,Srinath and PK. Rajasekharan, An Introduction to Statistical Signal Processing with Applications, John Wiley & Sons, 1979.
LL. Scharf, Statistical Signal Processing; Detection, Estimation, and Time Series Analysis, Addison-Wesley, 1991.

EC875 PROBABILISTIC MODELS IN MACHINE LEARNING (4-0-0) 4

Course Contents

Probabilistic graphical models, belief networks, decision making, Bayesian linear models, linear Gaussian state space models, Expectation Maximization, Markov models, Bayesian networks, Markov random fields, Markov networks, variational inference, latent variable models, Markov chain Monte Carlo, Kalman Filtering, Particle Filters, Dynamic Bayesian Networks.

References

David Barber, Bayesian Reasoning and Machine Learning, 1st Ed, Cambridge University Press, 2012.
Jerome H, Friedman, Robert T'ibshirani, Trevor Hastie, The Elements of Statistical Learning; Data Mining, Inference, and Prediction, Springer, 2nd Ed, 2009.
Kevin P. Murphy, Machine Learning; A Probabilistic Perspective, MIT, 2012.
Zoubin Ghahramani, Probabilistic Modelling, Machine Learning and the Information Revolution, MIT Tutorial 2012.

EC876 SYSTEM IDENTIFICATION AND CONTROL (4-0-0) 4

Course Contents

Dynamic Systems and Models, mathematical models of systems from observations of their be6av,ior: time series. state-space' and input-output models; model structures, parametrization, and identifiability; non-parametric methods; prediction error methods for parameter estimation, convergence., consistency, and asymptotic distribution: relations to maximum likelihood estimation; recursive estimation; relation to Kalman filters; structure determination: order estimation; parametric identification by linear regression (least squares method, instrumental variables method, recursive algorithms); Subspace identification methods; Prediction' error methods (ARX. ARMAX, OE and BJ structures). Practical aspects of identification (input design, order estimation, model validation): Identification of Linear-Parameter Varying (LPV) models, Nonlinear system- identification, control, Adaptation and learning; Adaptive control: certainty Equivalence, Stability Issues in Time-varying Systerns, stability of Adaptive Systerns; Learning and Adaption Based Control; Direct and indirect adaptive control, model reference control (MRC), rnodel reference adaptive control (MRAC), pole placement control (PPC) and adaptive pole placernent control (APPC).

References

Ljung, L. System identification; Theory for the user. 2nd ed. PTR Prentice Hall, 1999.
Toffner Clausen, Steen, System Identification and Robu.st Control, Springer, 1996.
Ljung, L and T. Glad. Modeling of Dynamic systems. PTR Prentice Hall, 1994.
Soderstrom,T., and P. Stoica. System identification. Prentice Hall Inrernational, London, 1989.
NS Nise, Control Systems Engineering, 6th Ed., Wiley, 2011.

EC877 INVERSE PROBLEMS: THEORY AND APPLICATIONS (4-0-0) 4

Course Contents

Introduction and Basic Concepts: Ill-Posedness in inverse Problems, linear inverse problems, Classical Regularization Methods, Tikhonov Regularization, SVD, Projection Methods, Inverse Eigenvalue Problems, Besov space regularization, Inverse Scattering Problem, Variational Regularization Methods, Convex Regularization, Nonconvex Regularization, Statistical Inversion Theory, Nonlinear inverse problems, Inverse problems in imaging modalities and radar, applications in remote sensing, geoscience, biomedical, Computational inverse problems.

References

Jennifer L. Muller, Samuli Siltanen, Linear and nonlinear inverse problems with practical applications-Society for Industrial and Applied Mathematics 2012.
Per Christian Hansen, Discrete Inverse Problems; Insight and Algorithms, Society for Industrial and Applied Mathematics 2010.
Aster, Richard C. Borchers, Brian Thurber, Clifford H, Parameter estimation and inverse problem.Elsevier 2019.
J. C. Santamarina, Dante Fratta, Discrete signals and inverse problems: an introduction for engineers and scientists, Wiley 2005..

EC878 REMOTE SENSING: TECHNIQUES, DATA ANALYSIS AND APPLICATIONS (4-0-0) 4

Course Contents

Introduction, Nature and Properties of Electromagnetic Waves, Interactions of electromagnetic radiation with matter, Surfaces Sensing in the Visible, Near Infrared and thermal infrared, microwave and radio frequencies. Millimeter and Submillimeter Sensing, ocean and Atmospheric Remote Sensing, Ionospheric Sensing, Imaging, Platforms used for RS data acquisition and characteristics, Hyperspectral Remote Sensing, Information Extraction from the Image Data, Radar, Lidar, Common remote sensing datasets and data portals, mathematical techniques and algorithms for processing the RS data, acquisition and analysis, estimation, detection, recognition, classification techniques, Applications of RS for land use and land cover monitoring, water resources management, agricultural, environmental, forestry, geology applications, and etc.

References

W.G. Rees, Physical Principles of Remote Sensing, Cambridge University Press, 2012.
Charles Elachi Jakob vanZyl, Introduction to the Physics and Techniques of Remote sensing, 2nd Ed, John Wiley & Sons, Inc, 2006.
Chipman Lillesand Kiefer, Remote Sensing and Image Interoretation, 6th Ed, Wiley, 2008.
J. Richards, Remote Sensing with Imaging Radar, Springer 2020.

Pimliang Dong and Qi Chen, LiDAR Remote Sensing and Applications, CRC Press, 2017.
Marcus Borengasser, William S. Humgate, Russell Watkins: Hyperspectral Remote Sensing Principles and Applications, 1 Ed, CRC Press, 2007.

EC879 COMPRESSED SENSING AND SPARSE SIGNAL PROCESSING (3-1-0) 4

Course Contents

Basis and Frames, Low dimensional signal models, Sensing matrices, Signal recovery via l1 minimization, Necessary and sufficient conditions for L0-L1 equivalence. RIP and random matrices. Johnson-Lindenstrauss Lemma, Stable signal recovery and restricted eigen value property. Recovery algorithms and their performance guarantees. Multiple measurement models.

References

M. Elad, "Sparse and Redundant Representations" Springer 2010 H.
Rauhut, "Compressive Sensing and structured random matrices",Radon series, Comp. applied math.
Compressive Sensing Resources - http://dsp.rice.edu/cs/

EC880 DEEP LEARNING IN RADAR SIGNAL PROCESSING (3-1-0) 4

Course Contents

Review of machine learning (ML) algorithms. Applications of ML to Radar System design and analysis, processing range-Doppler using learning algorithms, various techniques applied to radar data acquisition, applications of ML algorithms to radar detection, designing ML algorithms for Radar target tracking and recognition. Principles of deep learning: various approaches of deep learning, Deep Learning Methods for Radar Detection, Classification/Estimation, and Tracking, tracking algorithms of multiple targets in multi-static configurations, Compressive-sensing-based learning technique, Through-the-wall imaging radars, MIMO radar applications, Deep-learning-based adaptive radar detection and tracking, and automotive applications.

References

Martin T. Hagan, Howard B. Demuth, Mark Hudson Beale, Orlando De Jesús, Neural Network Design, 2nd Edtion, eBook. (Available for download from the author: https://hagan.okstate.edu/NNDesign.pdf)
James A., Mark A., Richards, William A., Scheer, Holm, Principles of Modern Radar, Volume I - Basic Principles, Scitech 2010.
J.D. Kelleher, Deep Learning, MIT Press, 2019.
E Charniak, Introduction to Deep Learning, The MIT Press, 2018.
Lee Andrew Harrison, Introduction to Radar Using Python and MATLAB Illustrated Edition, Kindle Edition, Artech house, 2020.
Mark A. Richards - Fundamentals of Radar Signal Processing - McGraw-Hill 2014.

EC881 COMPUTER ALGORITHMS AND DATA STRUCTURES (3–0–2) 4

Course Contents

Algorithm analysis, Asymptotic notations. Divide and Conquer algorithms, Analysis of divide and conquer algorithms, master method, examples - merge sort, quick sort, binary search, Data structures, Linked list, stacks and queues, insertion/deletion and analysis, Binary search trees Hash Tables – hash function and properties, collision handling, bloom filters, Greedy algorithms and Dynamic programming examples. Graph traversal, DFS, BFS, shortest path algorithms Dijkstra's and Bellman Ford algorithm.

References

A.V. Aho, J.E. Hopcroft and J. D. Ullman, Data structures and Algorithms, Pearson, 2004.
T.H.Cormen, C.E. Leiserson, R.L. Rivest, C. Stein, Introduction to Algorithms, PHI, 2004.
Mark Allen Weiss, Data Struct & Algorithm Analysis in C Second Edition Pearson 2002

EC734 SIGNAL DETECTION AND ESTIMATION (4-0-0) 4

Course Contents

Hypothesis Testing, Neyman Pearson Lemma, UMP test, Decision Theoretic framework, Multiple-Decision Problem. Parameter Estimation - Unbiasedness, Consistency, asymptotic normality, sufficient statistics, minimax estimation, decision theoretic framework, Rao-Blackwell theorem, Cramer – Rao inequality. Estimation: Minimum mean square linear estimation, Wiener filter, Kalman filter, Levinson – Durbin and innovation algorithms.

References

H. L. Van Trees Detection, Estimation and Modulation Theory, Part I, John Wiley, 1968.
Srinath, Rajasekaran and Viswanathan, Introduction to Statistical Signal Processing with applications, PHI, 1995.
Steven M. Kay, Fundaments of Statistical Signal Processing, Vol. I:Estimation Theory, Vol. II: Detection Theory, Prentice Hall International, 1993

Papoulis A., Probability Random Variables and Stochastic Processes, McGraw Hill, 2002
H. Stark and J. W Woods, Probability and Random Processes with applications to signal processing, Pearson Education, 2002.

EC787	**Seminar**	**2**
EC788	**Minor Project**	**2**
EC789	**Major Project – I**	**6**
EC790	**Major Project – II**	**6**

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