Indian Institute of Space Science and Technology

Thiruvananthapuram

Curriculum and Syllabus for

M.TECH DIGITAL SIGNAL PROCESSING

Department of Avionics

[From Academic Period 2022- 23]
(Approved By Academic Council on 27-4-2022)
Version1/19-5-2022

Program Educational Objectives (PEO)

1. Strengthen analytical skills and the technical knowledge in the area of digital signal processing as well as in allied fields.
2. Enable the graduates to pursue research by adopting dynamic academic curriculum; implement innovative learning and research practices to harness curiosity and creativity; inspire and educate the students to analyze and solve complex problems.
3. Enhance the employability of the graduates in Industry/Academia/R&D organizations by inculcating strong theoretical and experimental knowledge in the domain with exposure to real-life and practical applications.
4. Instill a deep sense of ethics, social values, professionalism, and interpersonal skills among students.

Program Outcomes (PO)

Program Outcomes	Statements
PO1	An ability to independently carry out research/investigation and development work to understand and solve practical problems in applied signal processing.
PO2	Ability to write and present a substantial technical report, dissertation, research publications, or other technical documents.
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO4	Develop the ability of designing data and signal processing systems using principled analytical techniques from a given design goal followed by continuous evaluation and design improvement using experiments, simulations, or mathematical techniques.
PO5	Develop the ability to prototype data and signal processing systems using software frameworks, embedded solutions, or other hardware as the case may be.

COURSE STRUCTURE

Semester I

Code	Course Title	L	T	P	C
MA619	Advanced Mathematics	3	1	0	4
AVD611	Modern Signal Processing	3	0	0	3
AVD612	Computational Methods for Signal Processing	1	0	1	2
AVD613	Machine Learning for Signal Processing	3	0	1	4
E01	Elective 1	3	0	0	3
AVHSD001	Human Values, Professional Ethics and Communication	1	0	0	1
	Total	14	1	2	17

Semester II

Code	Course Title	L	T	P	C
AVD621	Estimation and Detection Theory	3	0	0	3
AVD622	Signal Processing for Communication	3	0	1	4
E02	Elective 2	3	0	0	3
E03	Elective 3	3	0	0	3
E04	Elective 4 (Swayam or Department elective)	3	0	0	3
AVD851	Innovative Design Project	0	0	1	1
	Total	15	0	2	17

Semester III

Code	Course Title	L	T	P	C
AVD852	Project work phase I	0	0	0	18
	Total	0	0	0	18

Semester IV

Code	Course Title	L	T	P	C
AVD853	Project work phase II	0	0	0	18
	Total	0	0	0	18

Summary

Semester	Credit
I	17
II	17
III	18
IV	18
Total	**70**

SEMESTER I

MA619	Advanced Mathematics	(3-1-0) 4 Credits

Vectors: Representation and dot products, Norms, Matrices: The four fundamental spaces of a matrix, matrix as a linear operator, geometry associated with matrix operations, inverses and generalized inverses, matrix factorization/decompositions, rank of a matrix, matrix norms.

Vector spaces: column and row spaces, null space, solving Ax=0 and Ax=b, independence, basis, dimension, linear transformations.

Orthogonality: Orthogonal vectors and subspaces, projection and least squares, Gram Schmidt orthogonalization.

Determinants: Determinant formula, cofactors, inverses and volume, eigenvalues and eigenvectors: characteristic polynomial, eigenspaces, diagonalization, Hermitian and unitary matrices, spectral theorem, change of basis, positive definite matrices and singular value decomposition, linear transformations, quadratic forms.

Review of Probability: Basic set theory and set algebra, basic axioms of probability, conditional probability, random variables - PDF/PMF/CDF - properties, Bayes theorem/law of total probability, random vectors - marginal/joint/conditional density functions, transformation of random variables, characteristic/moment generating functions, random sums of random variables, law of large numbers (strong and weak) limit theorems-convergence types, Inequalities-Chebyshev/Markov/Chernoff bounds.

Random processes: Classification of random processes, wide sense stationary processes, autocorrelation function, and power spectral density and their properties. Examples of random process models-Gaussian/Markov random process, random processes through LTI systems.

References and Textbooks:

1. Introduction to linear algebra-Gilbert Strang, SIAM, 2016.
2. Introduction to probability-Bertsekas and Tsitsiklis, Athena, 2008.
3. Probability and Random processes for Electrical Engineers, Leon Garcia Addison Wesley, 2nd Edition, 1994.
4. Probability and Random Processes, Geoffrey Grimmett, David Stirzaker, 3rd Edition, Oxford University Press, 2001.
5. Probability and Stochastic Process, Roy D Yates, David J Goodman, 2nd edition Wiley, 2010.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand the important properties of eigenvalues and eigenvectors, spectral theorem, singular value decomposition. Recognize matrix as operators and evaluate various norms.
CO2	Analyse the fundamentals of probability theory, multi-dimensional random variables, probability distributions, basics of the limit theorems and apply them for solving various engineering problems.
CO3	Differentiating the random processes with real-valued random variables, classifying the random processes, explaining the properties of stochastic processes, and analyzing LTI systems.

AVD611 Modern Signal Processing (3-0-0) 3 Credits

Analysis of LTI system: Phase and magnitude response of the system, minimum phase, maximum phase, All-pass. Multirate Signal Processing: Interpolation, decimation, sampling rate conversion, filter bank design, poly phase structures. Time-frequency representation; frequency scale and resolution; uncertainty principle, short-time Fourier transform. Multi-resolution concept and analysis, wavelet transform (CWT, DWT). Optimum Linear Filters: Innovations representation of a stationary random process, forward and backward linear prediction, solution of the normal equations. Power spectral estimation: Estimation of spectra from finite duration observations of a signal, Periodogram, Bartlett, Welch and Blackman, Tukey methods, comparison of performance of non-parametric power spectrum estimation methods. Parametric methods: Auto-correlation and model parameters, auto-regressive (AR), moving average (MA), and ARMA spectrum estimation. Frequency estimation- Eigendecomposition of autocorrelation matrix, Piscaranko's harmonic decomposition methods, MUSIC method. Adaptive filter theory: LMS, NLMS and RLS, linear prediction. DSP processor architecture-DSP number representation for signals, study of fixed point and floating-point DSP processor and its architectures.

Reference Books:

1. Digital Signal Processing 3rd Edition, Mitra, S.K, McGraw Hill, 2008.
2. Discrete-time signal processing, Oppenheim, Alan V, Pearson Education India.
3. Multi rate Systems and Filter Banks, P.P. Vaidyanathan, Prentice-Hall,1993.
4. Statistical digital signal processing and modeling, Monson H. Hayes, Jhon Wiley & Sons.
5. Wavelet Basics, Y.T. Chan Kluwer Publishers, Boston, 1993.
6. A Friendly Guide to Wavelets, Gerald Kaiser, Birkhauser, NewYork, 1992.
7. Digital signal processing: principles algorithms and applications, Proakis, John G, PHI.
8. Adaptive filter theory, Haykin, Simon S, Pearson Education India.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Ability to design and analyze LTI systems.
CO2	Understand and apply multi rate signal processing in DSP.
CO3	Designing optimum filters and spectral estimators for different signal processing applications.
CO4	Apply adaptive signal processing algorithms for real time applications.

AVD612 Computational Methods for Signal Processing (1-0-1) 2 Credits

Real Time DSP Module: Fixed point representation of signals and introducing fixed point toolbox in MATLAB. Learning the impact of number representations in signal processing applications-IIR, FIR filter design in C- implementation of signal processing algorithms by applying quantization techniques and analyzing using MATLAB and DSP processor. Audio signal processing-echo cancellation, stream processing, block processing and vector processing of signals using DSP processor application to adaptive filtering, FFT, DCT, wavelet using DSP processor. Learning code optimization techniques-pipelining and scheduling and implementation using TMS processor. Introducing OMAP and implementing simple image processing algorithms in DaVinci processor using real time systems. Mini project using DSP processors-DSP system design.

Python module: Basics of programming in Python, variables and data types, arithmetic and logical operations, functions and flow control. Debugging Python. Scientific computing in Python using numpy and scipy libraries. Linear algebraic functions, optimization, probability and random processes in Python. Object oriented programming in Python. Signals and systems simulation in Python, SVD using python, filtering, convolution, and autocorrelation using Python, image and video processing in Python. Introduction to Pandas as a data processing library. Overview of other useful libraries in Python. Basic machine learning algorithms in Python using sci kit library.

Mini project in Python: Using Python for simulation study of a signal processing (audio or video processing system), or implementation of a machine learning system (e.g. recommendation engine) in Python.

Text books and References:

1. A practical introduction to programming and problem-solving. Attaway, Stormy, Matlab Butterworth-Heinemann, 2013.
2. Essential MATLAB for engineers and scientists, Attaway, Stormy, Valentine, Daniel T., and Brian Hahn. Matlab Academic Press, 2016.
3. Digital signal processing using MATLAB: a problem-solving companion. Ingle, Vinay K., and John G. Proakis. Cengage Learning, 2016.
4. Contemporary communication systems using MATLAB, Proakis, John G., Masoud Salehi, and Gerhard Bauch. Cengage Learning, 2012.
5. Principles of Digital Communications System Simulation, Sam Shanmugam, Tranter, Pearson Education, India.
6. A brain-friendly guide. O'Reilly , Barry, Paul. Head first Python: Media, Inc., 2016.
7. Think Python: How to think like a computer scientist, Downey, Allen B. Green Tea Press, 2012.
8. A primer on scientific programming with Python Langtangen, Hans Petter. Springer.
9. Machine Learning with PyTorch and Scikit-Learn, Raschka, Sebastian, Yuxi Liu, and Vahid Mirjalili. 2022.
10. Other online resources.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand basic programming constructs in python - use of variables, arithmetic and logical operations, functions, control flow to create simple programs in python
CO2	Apply and understand and programming techniques for scientific computing in Python. Understand and apply functions from standard scientific computing libraries such as Numpy and Scipy.
CO3	Analyze user requirements, apply programming techniques to create a standalone Python software. Evaluate performance of the software, analyze performance tradeoffs
CO4	Implementation of DSP algorithm using number representations for real time application
CO5	Evaluate different processor architectural development specifically made for DSP applications and gaining hands on experience on real time experiments.
CO6	Ability to design and implement computational intensive DSP system using DSP hardware and analyze and evaluate the performance in terms of speed and power

AVD613 Machine Learning for Signal Processing (3-0-1) 4 Credits

Review: Linear algebra, matrix calculus, probability and statistics. Supervised learning: linear regression (gradient descent, normal equations), weighted linear regression (LWR), logistic regression, perceptron Newton's method, KL-divergence, (cross-) entropy, natural gradient, exponential family and generalized linear models, generative models (Gaussian discriminant analysis, Naive Bayes), kernel method (SVM, Gaussian processes), tree ensembles (decision trees, random forests, boosting and gradient boosting), learning theory, regularization, bias-variance decomposition and tradeoff, concentration inequalities, generalization and uniform convergence, VC-dimension.
Deep Learning: Neural networks, back propagation, deep architectures, unsupervised learning, K-means, Gaussian mixture model (GMM), expectation maximization (EM), variational auto-encoder (VAE), factor analysis, principal components analysis (PCA), independent components analysis (ICA), introduction to reinforcement learning (RL).
Application: Advice on structuring an ML project, evaluation metrics, missing data techniques and tracking.
Special Topic: Computer vision, NLP, machine listening and music information retrieval, speech, compressive sensing, array processing, beamforming, independent component analysis, MIMO/SIMO models, under-constrained separation, spectral factorizations.

Text books and References:

1. Pattern Recognition and Machine Learning, C.M. Bishop, 2nd Edition, Springer, 2011.
2. Probabilistic Machine Learning, Kevin P. Murphy.
3. Pattern Recognition, Duda and Hart.
4. Machine Learning for Signal Processing: Data Science, Algorithms, and Computational Statistics, Max A. Little.
5. Deep Learning, Ian Good fellow, Yoshua Bengio, Aaron Courville (Online book), 2017.
6. Deep Learning with Python, J. Brownlee.
7. Deep Learning Step by Step with Python: A Very Gentle Introduction to Deep Neural Networks for Practical Data Science, N.D. Lewis.
8. Machine Learning for Audio, Image and Video Analysis, F.Camastra, Vinciarelli, Springer,2007.

Course Outcomes	Statements
CO1	Understand the application of linear algebra, statistics, and probability theory used in various machine learning models under supervised and unsupervised learning.
CO2	Utilize different models for supervised, unsupervised, and reinforcement machine learning
CO3	Implement Bayes decision theory and density estimation techniques with an aim to understand the fundamental concepts of supervised and unsupervised machine learning
CO4	Apply the essential knowledge in the field of machine learning and signal processing for an in-depth study of emerging areas of engineering applications.

EO1	Elective1	(3-0-0) 3 Credits

Refer list of Electives

AVHSD001	Human Values, Professional Ethics and Communication	(1-0-0) 1 Credits

Module 1: Human Values (5hrs)

Need for value education, continuous happiness and prosperity as basic human aspirations, right understanding, relationship and physical facility, self-exploration, 'natural acceptance' and experiential validation- as the process for self-exploration, method to fulfill the human aspirations understanding and living in harmony at various levels – self, family, society and nature, a survey of eastern and western philosophy on human values. Understanding values in human-human relationship; meaning of justice (nine universal values in relationships) and program for its fulfillment to ensure mutual happiness; Trust and respect as the foundational values of relationship. Basis for humanistic education, humanistic constitution and humanistic universal order.

Module 2: Professional Ethics and Attitude (2hrs)

Introduction to Ethics and linkage between attitude and ethics - Workplace and professional ethics -Taking moral decisions at the workplace - Workplace Rules and codes of ethics - Social responsibility and why it adds to the bottom line. Role of Ethics in artificial intelligence, role of privacy in Artificial intelligence etc. Meaning of Trust; Difference between intention and competence. Competence in professional ethics.

Module 3: Entrepreneurial and financial skills (2hrs)

Entrepreneur- Qualities and characteristics of an entrepreneur –Creativity techniques- Invention Vs Innovation; From idea to startups- Intellectual Property Rights, copyright, trademarks – saving and investment habits – financial behavior – investment attitudes - types of investments – sources of funding–attitude towards money and capital market.

Module 4: Communication and soft skills (3hrs)

Writing and Research Skills for Professionals–Professional writing-structure of written documents–scientific writing–academic writing–publishing in journals–resume preparation–portfolio preparation–interview skills.

Module 5: Gender in Science and Technology (3hrs)

History of women in science and engineering– expectations of women-disparity in representation – racial and ethnic group differences – cultural differences – critics of modern scientific thinking –nature and objectivity in various disciplines.

Text books/References:

Module1:

1. Human Values and Professional Ethics, RR Gaur, RS Angal, GP Bagaria, Excel Books, New Delhi, 2010.
2. Jeevan Vidya: Ek Parichaya, A Nagaraj, Jeevan Vidya Prakashan, Amarkantak, 1999.
3. Human Values, A.N. Tripathi, New Age International Publishers, New Delhi, 2004.
4. The Story of My Experiments with Truth, Mohandas Karamchand Gandhi.

5. Small is Beautiful, E.F. Schumacher.
6. Slow is Beautiful, Cecile Andrews.

Module 2:

1. Business Ethics, DeGeorge, R. T., Pearson Education India, 2011.
2. For Business Ethics, Jones, C., Parker, M., and Ten Bos, R., Routledge, 2005.
3. Business Ethics, Hartman, L. P., DesJardins, J., and MacDonald, C., McGraw-Hill Publishing, 2010.
4. Contemporary Issues in Business Ethics, DesJardins, J. R., and McCall, J. J., Cengage Learning, 2014
5. Organizational Ethics: A Practical Approach, Johnson, C. E., SAGE Publications, Incorporated, 2021.
6. Professional Ethics, Subramanian, R., Oxford University Press, 2013
7. Absolute Essentials of Business Ethics, Stanwick, P. A., and Stanwick, S. D., Routledge,2020.

Module 3:

1. Innovation and Entrepreneurship, Drucker, F. Peter. Harper Business, 2006.
2. Entrepreneurship, Rai, Rajiv. Oxford University Press, 2011.
3. Creating Innovators: The Making of Young People Who Will Change the World, Wagner, Tony. New York: Scribner, 2012.
4. Macroeconomics, Dornbusch, Rudiger, Stanley Fischer, and Richard Startz. McGraw Hill, 2006.

Module 4:

1. Writing at Work: Professional Writing Skills for People on the Job, Smith, Edward L and Stephen A. Bernhardt McGraw Hill Professional., 1997.
2. How to Fix Your Academic Writing Trouble: A Practical Guide, McGraw-Hill Mewburn, Ingeretal, 2018

Module 5:

1. Asking Different Questions: Feminist Practices for the Natural Sciences, in Women Science and Technology Deboleena,R, 2004.
2. Lab Girl. NewYork: Jahren,H., Alfred A. Knopf, 2016.
3. Gender and Science. In Reflections on Gender and Science, Keller,E.F. 1985.
4. Has Feminism Changed Science?, Schiebinger,L., 1999.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand the process of self-exploration as a tool to gain insights into oneself, family, society, and nature.
CO2	Gain a basic understanding of the interconnectedness and harmony among humans, families, societies, and nature.
CO3	Understand the significance of effective communication
CO4	Evaluate various critical situations in life

SEMESTER II

AVD621	Estimation and Detection Theory	(3-0-0) 3 Credits

Maximum likelihood estimation (MLE): Exact and approximate methods (EM algorithm, alternating maximization, etc.), Cramer-Rao lower bound (CRLB), minimum variance unbiased estimation (MVUE), sufficient statistics best linear unbiased estimation (BLUE), large and small sample properties of estimators: Understanding the behavior of estimators in both large and small sample sizes, Bayesian Inference and estimation: minimum mean square error (MMSE) estimation, MAP Estimation (maximum a posteriori estimation), Wiener and Kalman filtering (sequential bayes) detection theory: Likelihood ratio testing, Bayes detectors, minimax detectors, multiple hypothesis tests, Neyman-Pearson detectors (matched filter, estimator-correlator, etc.), Wald's sequential test generalized likelihood ratio tests (GLRTs), Wald and Rao scoring tests.

Assessment:

The course will feature midterm and final exams. There will be continuous evaluation using class tests, problem sets, and programming assignments.

Textbooks and References:

1. Fundamentals of Statistical Signal Processing: Estimation Theory (Vol1), Detection Theory (Vol2), M. Kay's, Prentice-Hall Signal Processing Series, 1993.
2. Linear Estimation, Kailath, Sayed and Hassibi, Prentice-Hall Information and Sciences Series, 1st edition, 2000.
3. Statistical Signal Processing (Paperback) by LouisScharf,1st edition.
4. An Introduction to Signal Detection and Estimation, Poor, H. Vincent, Springer Text in Electrical Engineering,1994.
5. Detection, Estimation, and Modulation Theory –Part I,H.Van Trees,et.al,2nd edition, Wiley.
6. Monte Carlo Strategies in Scientific Computing, J.S.Liu, Springer-Verlag, 2001.
7. Stochastic Simulation, B.D.Ripley, Wiley, 1987.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand various methods of statistical inferencing, namely, estimation and detection techniques
CO2	Ability to apply those methods for solving real life problems - both engineering and otherwise.
CO3	Design and Implementation of various algorithms for various problems using standard simulation tools such as MATLAB, Python etc.
CO4	Provide a platform for more advanced methods and algorithms from machine and deep learning.

AVD622	Signal Processing for Communication	(3-0-1) 4 Credits

Motivating examples of digital communications. Spectrum availability and channels. Channel modeling base band and pass band channels. Digital modulation schemes for base band and pass band channels. Line coding, pulse amplitude modulation, phase modulation, CPFSK, frequency shift keying, QAM.
Band limited channels and inter symbol interference (ISI). Signal design for band limited channels -Nyquist criterion and pulse shaping, partial response signaling. Non-ideal bandlimited channels -receivers for channel with ISI and AWGN-ML receiver, its performance. Signal processing algorithms for linear equalization. Carrier and symbol synchronization, carrier phase estimation: ML estimation, PLL, symbol timing estimation: ML timing estimation, joint estimation of carrier phase and symbol timing. Case studies of digital communication receivers.
Noise modeling in communication systems-additive white Gaussian noise (AWGN) channels. Signal space concepts: Geometric structure of the signal space, vector representation, signal norms, and inner product, orthogonality, Gram-Schmidt orthogonalization. Optimum receiver for AWGN channels: Optimal detection and error probability for digital signaling schemes. Matched filter and correlation receiver.
Case study of design of digital communication system receiver with emphasis on signal processing algorithms.

Textbooks and References:

1. Communication systems, Simon Haykin,4th edition Wiley, 2001.
2. Introduction to Communication Systems, Upamanyu Madhow, Cambridge University Press, 2014.
3. Fundamentals of Digital Communication, Upamanyu Madhow, Cambridge University Press, 2008.
4. Digital communication, Bernard Sklar,2nd edition, Pearson Education, 2000.
5. Digital Communication, John Proakis & Masoud Salehi,5th edition, McGraw-Hill, 2008.
6. Signal processing for communications, Prandoni, Paolo and Martin Vetterli. EPFL press, 2008.

Pre-requisites: Under graduate probability and random processes. Signals and systems, LTI systems and their analysis.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Design different digital modulation system and analyze the performance in terms of error rate and spectral efficiency
CO2	Develop skills to design and implement multi-carrier modulation system including techniques for channel estimation, synchronization, and equalization.
CO3	Analyze the performance of the multi-carrier modulation system in terms of PAPR, error rate and spectral efficiency
CO4	Understand the concepts of MIMO system to configure the antenna for beam forming, spatial multiplexing and spatial diversity to achieve the desired performance in terms of data rate, reliability, and coverage
CO5	Design and develop MIMO OFDM, hybrid beam forming, OTFS systems for 5G/6G.

EO2	**Elective 2**	**(3-0-0) 3 Credits**

Refer list of Electives

EO3	**Elective 3**	**(3-0-0) 3 Credits**

Refer list of Electives

EO4	**Elective 4 (Swayam or Department Elective)**	**(3-0-0) 3 Credits**

Refer list of Electives

AVD851	**Innovative Design Project**	**(0 0 1) 1 Credit**

Semester III

AVD852	**M. Tech Project-Phase 1**	**(1 0 0) 18 Credits**

Semester IV

AVM853	**M. Tech Project-Phase 2**	**(0 0 0) 18 Credits**

Electives: with specialization modules

AI, Image, Video, and Computer Vision, Speech and Language Processing Stream

Sl.No	Course Code	Course Name
1	AVD861	Speech Signal Processing and Coding
2	AVD862	Digital Image Processing
3	AVD863	Soft Computing and its Application in Signal Processing
4	AVD864	Computer Vision
5	AVD865	Multimedia Processing
6	AVD866	Virtual Reality
7	AVD867	Pattern Recognition and Machine Learning
8	AVD868	Advanced Image Processing
9	AVD869	Image and Video Processing Algorithms
10	AVD870	Deep Learning for Computational Data Science
11	AVD871	Applied Markov Decision Processes and Reinforcement Learning
12	AVD872	Advanced Deep Learning
13	AVD873	Deep Learning: Theory and Practice
14	AVD874	Optimization Methods for Machine Learning
15	AVD875	Biomedical Signal and image Processing
16	AVD876	Selected Topics in Computer Vision
17	AVD877	Introduction to Intelligent Robotics
18	AVD878	Algorithms and Architectures for Signal/Image Processing

Communication Stream

19	AVD879	Information Theory and Coding
20	AVD880	Multi rate Signal Processing
21	AVD881	Compressed Sensing and Sparse Signal Processing

22	AVD882	Wireless Communications
23	AVD883	Multi carrier Communication
24	AVD884	MIMO Signal Processing
25	AVD885	Adaptive Signal Processing
26	AVD886	Software Defined Radio
27	AVD887	Internet of Things
28	AVD888	Complex Networks
29	AVD889	Graph Theory
30	AVD890	Wireless Mesh Networks
31	AVD891	Radar Signal Processing
32	AVD892	Case Studies in Signal Processing
33	AVD893	Machine Learning for Digital communication

****Electives** may also be chosen outside of those listed above, from the vast array of courses offered in the Institute regardless of which department offers them, with prior permission from the faculty advisor. In addition, any one relevant NPTEL/Swayam course can be taken as an elective.

Electives:

AVD861 Speech Signal Processing and Coding (3-0-0) 3 Credits

Introduction: speech production and perception, information sources in speech, linguistic aspect of speech, acoustic and articulatory phonetics, nature of speech ,models for speech analysis and perception; Short - term processing: need, approach, time, frequency and time-frequency analysis; Short - term Fourier transform (STFT): overview of Fourier representation, non-stationary signals, development of STFT, transform and filter - bank views of STFT; cesptrum analysis: Basis and development, delta, delta - delta and mel-cepstrum, homomorphic signal processing, real and complex cepstrum; Linear prediction (LP) analysis: Basis and development, Levinson-Durbin's method, normalized error, LP spectrum, LP cepstrum, LP residual; Sinusoidal analysis: Basis and development, phase unwrapping, sinusoidal analysis and synthesis of speech; Speech coding: Need and parameters, classification, waveform coders, speech - specific coders, GSM, CDMA and other mobile coders; Applications: Some applications like pitch extraction, spectral analysis and coding standard.

Textbooks and References:

1. Digital Processing of Speech Signals Pearson Education, L.R..Rainer and R.W.Schafer, Delhi, India, 2004.
2. Discrete-Time Processing of Speech Signals, J.R.Deller, Jr., J.H.L.Hansen, and J.G.Proakis, Wiley-IEEE Press, NY,USA, 1999.
3. Human and Machine, D.O' Shaughnessy, Speech Communications: Second Edition, University Press, 2005.
4. Discrete-time processing of speech signals, T.F.Quatieri, Pearson Education, 2005.
5. Fundamentals of speech recognition, L.R.Rabiner, B.H. Jhuang and B.Yegnanarayana Pearson Education, 2009.

AVD862 Digital Image Processing (3-0-0) 3 Credits

Digital Image Fundamentals: Elements of visual perception–Image sampling and quantization, basic relationship between pixels– basic geometric transformations. Image fundamentals and image restoration: Spatial domain methods-Spatial filtering- Frequency domain filters –Model of image degradation/restoration process – Noise models – Inverse filtering- Least mean square filtering –Constrained least mean square filtering – Blind image restoration – Pseudo inverse – Singular value decomposition.

Multi-resolution Analysis and Compression: Multi resolution analysis: Image pyramids – Multi resolution expansion–Wavelet transforms. Image compression: Fundamentals elements of information theory–Error free compression–Lossy compression–Compression standards. Wavelet coding–Basics of image compression standards: JPEG, MPEG, basics of vector quantization.

Image Segmentation and Image Analysis: Edge detection–Thresholding-Region based segmentation –

Boundary representation: boundary descriptors: Texture, motion image analysis. Color image processing–Color models-Color image enhancement-Segmentation object recognition and image understanding: Patterns and pattern classes - Decision-Theoretic methods - Structural methods-3DVision.

Textbooks and References:

1. Digital Image Processing, Rafael C Gonzalez, Richard E Woods 2nd Edition, -Pearson Education 2009.
2. Digital Image Processing, William K Pratt , John Wiley & Sons, 2001.
3. Image Processing Analysis and Machine Vision, Millman Sonka, Vaclavhlavac, Roger Boyle, Broos/colic, Thompson Learniy, 1999.
4. Fundamentals of Digital Image Processing, A.K.Jain, PHI, New Delhi, 1995.
5. Digital Image Processing and Applications, Chanda Dutta Magundar, Prentice Hall of India, 2000.

AVD863	Soft Computing and its Application in Signal Processing	(3-0-0) 3 Credits

Soft Computing: Introduction, requirement, different tools and techniques, usefulness and applications.
Fuzzy Sets and Fuzzy Logic: Introduction, fuzzy sets versus crisp sets, operations on fuzzy sets, Extension principle, fuzzy relations and relation equations, fuzzy numbers, linguistic variables, fuzzy logic, linguistic hedges, applications, fuzzy controllers, fuzzy pattern recognition, fuzzy image processing, fuzzy database. Artificial Neural Network: Introduction, basic models, Hebb's learning, Adaline, perceptron, multilayer feed forward network, back propagation, different issues regarding the convergence of multilayer perceptron, competitive learning, self-organizing feature maps, adaptive resonance theory, associative memories, applications. Evolutionary and Stochastic techniques: Genetic algorithm (GA), different operators of GA, analysis of selection operations, hypothesis of building blocks, Schema theorem and convergence of Genetic algorithm, simulated annealing and stochastic models, Boltzmann machine, applications. Rough Set: Introduction, imprecise categories approximations, and rough sets, reduction of knowledge, decision tables, and applications. Hybrid systems: Neural-network-based fuzzy systems, fuzzy logic-based neural networks, genetic algorithm for neural network design and learning, fuzzy logic and genetic algorithm for optimization, applications. Applications of soft computing to signal processing.

Textbooks and References:

1. Neural Fuzzy Systems, Chin-Teng Lin & C.S. George Lee, Prentice Hall PTR, 2000.
2. Fuzzy Sets and Fuzzy Logic, Klir & Yuan, PHI, 1997.
3. Neural Networks, S. Haykin, Pearson Education, 2nd edition, 2001.
4. Genetic Algorithms in Search and Optimization, and Machine Learning, D.E. Goldberg, Addison-Wesley, 1989.
5. Neural Networks, Fuzzy Logic, and Genetic Algorithms, S. Rajasekaran & G.A.V. Pai, PHI.
6. Neuro-Fuzzy and Soft Computing, Jang, Sun, & Mizutani, PHI.
7. Learning and Soft Computing, V. Kecman, MIT Press, 2001.
8. Rough Sets, Z. Pawlak, Kluwer Academic Publisher, 1991.
9. Intelligent Hybrid Systems, D. Ruan, Kluwer Academic Publisher, 1997.

AVD864 Computer Vision (3-0-0) 3 Credits

Basic topics of computer vision, and image processing -Introduce some fundamental approaches for computer vision research: Image filtering, edge detection, interest point detectors, motion and optical flow, object detection and tracking, region/boundary segmentation, shape analysis, and statistical shape models, deep learning for computer vision, imaging geometry, camera modeling, and calibration. Recent advances in computer vision.

Programming:

Python will be the main programming environment for the assignments. The following book (Python programming samples for computer vision tasks) is freely available. Python for computer vision. For mini-projects, a processing programming language can be used too (strongly encouraged for android application development).

Textbooks and References:

1. Computer Vision: Models, Learning, and Interface, Simon Prince, Cambridge University Press.
2. Fundamentals of Computer Vision, Mubarak Shah, University of Central Florida, 1997.
3. Computer Vision: Algorithms and Applications Richard Szeliski, Springer, 2010.
4. Computer Vision: A Modern Approach", Forsyth and Ponce, Prentice-Hall, 2002.
5. Vision Science, Palmer, MIT Press,1999.
6. Pattern Classification, Duda, Hart and Stork, 2^{nd} Edition, Wiley, 2000.
7. Probabilistic Graphical Models: Principles and techniques, Koller and Fried man, MIT Press, 2009.
8. Linear Algebra and Its Applications, Strang, Gilbert. 2/e, Academic Press, 1980.

AVD865 Multimedia Processing (3-0-0) 3 Credits

International standards related to image/ video/ audio formulated by ISO/ IEC/ ITU. Short-term Fourier transform & continuous wavelet transform, CWT and its discretization, discrete wavelet transforms, 2-D wavelet transforms, coding techniques in 2-D wavelet transforms, family of MPEG 1/2/4 (moving picture experts group), H.26x (x=1,2,3), JPEG/JPEG-LS/JPEG2000 (joint photographic experts group), JBIG1/2 (joint binary image group), H.264/MPEG - 4 Part 10 AVC (advanced video coding) and the emerging H.265 standard (HEVC) and latest standard such as H.264 etc.

Motion Estimation: Matching criteria, generalized matching, generalized deformation model in motion estimation, synchronization of media multimedia content representation and retrieval, video content representation, content-based video: Motion representation, content - based video: low to high - level representation, content retrieval schemes.

Textbooks and References:

AVD866 Virtual Reality (3-0-0) 3 Credits

1. Practical image and video processing using MATLAB, O. Marques, Hoboken, NJ: Wiley, 2011.

Introduction: What is VR, applications, basic components of VR, success stories of VR and challenges, VR hardware, visualization, VR content generation, and storing.

Human Senses and VR: Discussion on how human senses correlate to VR such as visual system, auditory system, olfaction, gustation, etc.
Three-dimensional geometry theory: coordinate system, vectors, line, plane transformation etc.
The rendering pipeline: Geometry and vertex operations, culling and clipping, screen mapping, scan conversion or rasterization, fragment processing, texturing, etc.
Image-based rendering: General approaches to IBR, acquiring images for IBR, mosaicking, making panoramic images, etc. Computer vision in VR: The mathematical language of geometric computer vision, cameras, CV application in VR, virtual worlds using computer vision.
Stereopsis: parallax, HMD, active, passive, and other stereoscopic systems, etc.
Navigation and Movement in VR: computer animation, moving and rotating in 3D, robotic motion, inverse kinematics, etc.

Textbooks and References:

1. Ahitchhiker's Guide to Virtual Reality, by Karen Mc Menemy, Stuart Ferguson, A.K.Peter's, 2007.
2. Teacher in a Book from Vizard, Vizard, 2008.
3. IEEE conferences and Journals on Graphics, VR and computer vision.
4. Virtual Reality System, John Vince, Addison-Wesley Publishing Company,1995.

AVD867 Pattern Recognition and Machine Learning (3-0-0) 3 Credits

PR overview - Feature extraction - Statistical pattern recognition - Supervised learning - Parametric methods - non-parametric methods; ML estimation - Bayes estimation - KNN approaches. Dimensionality reduction, data normalization. Regression, and time series analysis. Linear discriminant functions. Fisher's linear discriminant and linear perceptron. Kernel methods and support vector machine. Decision trees for classification. Unsupervised learning and clustering. K-means and hierarchical clustering. Decision Trees for classification. Ensemble/Adaboost classifier, soft computing paradigms for classification and clustering. Applications to document analysis and recognition.

Textbooks and References:

1. Pattern classification, Duda and Hart, John Wiley and sons,2001.
2. Machine learning, TM Mitchel, Mc Graw Hills, 1997.
3. Pattern Recognition and Machine Learning, Christopher M.Bishop, Springer, 2006.

AVD868 Advanced Image Processing (3-0-0) 3 Credits

Feature detection and characterization, scale space idea, Laplacian and Gaussian derivatives, differential invariant structure–Nonlinear scale space, anisotropic diffusion, PDE for image processing.
Image Enhancement-Noise models, image de-noising using linear filters, order statistics-based filters and wavelet shrinkage methods, image sharpening, image super-resolution using Bayesian methods.
Image segmentation: Graph-based techniques, active contours, active shape models, shape analysis, fundamentals in shape analysis – Moment invariants, contour-based invariants, active appearance models (AAM), elliptical harmonics, medial axis representation.
Object segmentation, generalized Hough transform – 3D deformable models, snakes, level set evolution.
Image Quality-Natural scene statistics, quality assessment based on structural and statistical approaches, blind quality assessment.
High Dynamic Range (HDR) Imaging - Multi-exposure fusion for static and dynamic scenes, low light image enhancement, retinex methods, dark channel prior, defogging.

Textbooks and References:

1. Natural Image Statistics, Aapo Hyvarinen, Jarmo Hurriand Patrick Hoyer, Springer Verlag 2009.
2. Research papers from peer reviewed journals and conferences.

AVD869 Image and Video Processing Algorithms (3-0-0) 3 Credits

Human visual system and image perception; monochrome and color vision models; image digitization, display, and storage; 2-D signals and systems; image transforms- 2D DFT, DCT, KLT, Harr transform and discrete wavelet transform; image enhancement: histogram processing. Spatial-filtering, frequency-domain filtering; image restoration: linear degradation model, inverse filtering, Wiener filtering; image compression: lossy and lossless compression, image compression standards, image analysis: edge and line detection, segmentation, feature extraction, classification; image texture analysis; morphological image processing: binary morphology-erosion, dilation, opening and closing operations, applications; basic gray-scale morphology operations; color image processing: color models and color image processing. Fundamentals of digital video processing-Coverage includes spatio-temporal sampling, motion analysis, parametric motion models, motion-compensated filtering, and video processing operations. advanced topics related to recent trends in image processing and computer vision

Textbooks and References:

1. Digital Image Processing, Rafael C. Gonzalez, Pearson.
2. Image Processing: The Fundamentals, Second Edition, Maria M.P. Petrou, Costas Petrou.
3. TMs Lecture Notes on Digital Video, A.C. Bovik, Al Bovik, The University of Texas at Austin, 2017.
4. Digital Video Processing, M.Tekalp, PrenticeHall,1995.
5. The Essential Guide to Video Processing, A. C. Bovik, Academic Press, 2009.

AVD 870 Deep Learning for Computational Data Science (3-0-0) 3 Credits

Introduction of deep learning- Foundations of deep learning, basics aspects of machine learning, artificial intelligence, mathematics, statistics, and neurosciences (both theory and applications)- Applications in self-driving cars, new kinds of video games, AI, automation, object detection and recognition, surveillance tracking etc.- Introduce to neural networks and deep learning approaches (mainly convolutional neural networks) and give a few typical applications.
CNN, RNN, GAN, VAE and transformer-based architecture- for application to problem domains like speech recognition and computer vision.

Assessment:

There will be assignments and a final project.

1. Introduction to Visual Computing and Neural Networks
2. Basics of Multilayer Perceptron to Deep Neural Networks with Auto encoders
3. Unsupervised deep learning:
4. Auto encoders for Representation Learning and MLP Initialization
5. Stacked, S parse, Denoising Autoencoders and Ladder Training
6. Cost functions, Learning Rate Dynamics and Optimization
7. Introduction to Convolutional Neural Networks (CNN)and LeNet
8. Convolutional Autoencoders and Deep CNN (AlexNet, VGGNet)
9. Very Deep CNN architecture for Classification (GoogleNet, ResNet, DenseNet)
10. Computational Complexity and Transfer Learning of a Network
11. Object Localization (RCNN) and Semantic Segmentation
12. Generative Models with Adversarial Learning
13. Recurrent Neural Networks (RNN) for Video Classification13 Deep reinforcement learning
14. NLP/Vision Application

Textbooks and References:

1. Deep Learning, Ian Good fellow, Yoshua Bengio and Aaron Courville, ISBN-13:978-0262035613, MIT Press, 2016.
2. Pattern Classification, Duda, R.O., Hart, P.E., and Stork, D.G. Wiley-Interscience. 2nd Edition, 2001.
3. Pattern Recognition, Theodoridis, S. and Koutroumbas, K. 4th Edition. Academic Press, 2008.
4. Artificial Intelligence: A Modern Approach. Prentice-Hall Series in Artificial Intelligence, Russell, S. and Norvig, N., 2003.
5. Neural Networks for Pattern Recognition, Bishop, C.M. Oxford University Press, 1995.
6. The Elements of Statistical Learning, Hastie, T., Tibshirani, R. and Friedman, J. Springer, 2001.
7. Probabilistic Graphical Models, Koller, D. and Friedman, N. MIT Press, 2009.

AVD871	Applied Markov Decision Processes and Reinforcement Learning	(3-0-0) 3 Credits

Review of basic probability and stochastic processes. Introduction to Markov chains. Markov models for discrete time dynamic systems, reward, policies, policy evaluation, Markov decision processes, optimality criteria, Bellman's optimality principle, dynamic programming, optimality equations, policy search, policy iteration, value iteration. Generalized policy iteration, approximate dynamic programming. Exploration versus exploitation in reinforcement learning, multi armed and contextual Bandits, reinforcement learning setup and model free learning, Monte Carlo learning, Q-learning & SARSA, temporal difference learning, function approximation, policy gradient methods, actor-critic methods, stochastic approximation and its applications to reinforcement learning, neural networks in reinforcement learning, deep reinforcement learning. Applications and case studies of Markov decision processes and reinforcement learning in machine learning, control, communication, robotics, and optimization.

Textbooks and References:

1. Reinforcement learning: An introduction, Richard S. Sutton and Andrew G. Barto. MIT press, 2018.
2. Dynamic programming and optimal control, Dimitri P. Bertsekas, Vols. I and II, Athena scientific, 2005.
3. Applied probability models with optimization applications, Sheldon M.Ross. Courier Corporation, 2013.
4. Introduction to stochastic dynamic programming, Sheldon M. Ross. Academic press, 2014.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand probability, stochastic processes (especially Markov chains) and their use in modelling of discrete time stochastic systems
CO2	Understand the theory of Markov decision processes and the problem of controlling discrete time dynamical systems and their formulation as Markov decision problems.
CO3	Implement various methods (such as value iteration and policy iteration) for solving Markov decision processes.
CO4	Design the reinforcement learning framework and apply to fundamental problems of exploration-exploitation dilemma and credit assignment.
CO5	Design, and implement reinforcement learning agents

AVD872 Advanced Deep Learning (3-0-0) 3 Credits

Introduction to neural network and back propagation-Basics of Tensor flow and Keras-details on convolutional neural networks and types of different convolutions-recent topics in recurrent neural networks, LSTM, GRUs-Time series processing-details of transformer networks for text and vision-Instance and semantic segmentation-Generative models, VAE-Deep generative adversarial networks-Model interpretation etc.

Textbooks and References:

1. Deep Learning, Ian Good fellow, Yoshua Bengio and Aaron Courville, ISBN-13:978-0262035613, MIT Press, 2016.
2. Recent peer reviewed journals and conferences.

AVD873 Deep Learning: Theory and Practice (3-0-0) 3 Credits

The perceptron, Feed-forward networks and multi-layer perceptron, Memory based networks like Boltzmann machines, Hopfield networks. State based networks like recurrent neural networks, Long short-term memory networks. Convolutional neural networks, bidirectional networks, concept-based networks used for transfer learning, structural networks for structured prediction, attention-based networks, auto encoders for dimension reduction and embedding, generative adversarial networks, deep Gaussian processes, deep Bayesian nets, deep search models, deep reinforcement learning, deep neural recommenders. non-convex optimization tools for deep networks. Theoretical tools to describe convolutional neural networks and recurrent neural networks. Learning theory for deep neural networks. Several applications covering image analytics, forensic, computer vision, natural language processing, speech processing and data analytics.

Textbooks and References:

1. Deep Learning, Ian Good fellow, Yoshua Bengio and Aaron Courville, ISBN-13:978-0262035613, MIT Press, 2016.
2. Recent journals and conferences in Deep Learning

AVD874 Optimization Methods for Machine Learning (3-0-0) 3 Credits

Introduction (ML applications)-topics in linear system (linear regression)-Basics of gradient descent and its variants (logistic regression)-A detailed understanding of projected gradient (white-box adversarial attack) and proximal gradient (lasso)-Details of conditional gradient (recommendation system)-The sub gradient approach (SVM)-Mirror descent and metric gradient methods-acceleration (total variation denoising)-Smoothing (robust SVM)-optimal transport for machine learning-Alternating (VAE)-

Minimax (adversarial training)-Averaging (GANs)-splitting (federated learning)-Extra gradient (max entropy)-stochastic gradient (Boltzmann machine)-variance reduction (boosting)- derivative-free (black-box adversarial attack).

Textbooks and References:

1. First-order and Stochastic Optimization Methods for Machine Learning, Guanghui Lan, Springer, 2020.
2. Algorithms for Optimization, Mykel J. Kochender fer and Tim A.Wheeler, The MIT Press, 2019.
3. First-Order Methods in Optimization, Amir Beck, SIAM, 2017.

AVD875 Biomedical Signal and Image Processing (3-0-0) 3 Credits

Introduction of Biomedical Signals and Images: ECG, EEG, imaging modalities: Survey of major modalities for medical imaging: ultrasound, X-ray, CT, MRI, PET, and SPECT, MRI, FMRI, various applications.

Fundamentals of Deterministic Signal and Image Processing: Details on data acquisition approaches for biomedical signals-digital filtering for biomedical signals- DTFT: The discrete-time Fourier transform and its properties. FIR filter design using windows. DFT: Discrete Fourier transform and its properties, fast Fourier transform (FFT), overlap-save algorithm, digital filtering of continuous-time signals-Sampling revisited: Sampling and aliasing in time and frequency, spectral analysis-Image processing I: Extension of filtering and Fourier methods to 2-D signals and systems-Image processing II: Interpolation, noise reduction methods, edge detection, homomorphic filtering- Introduction to wavelets, time frequency representation, discrete wavelet transform, pyramid algorithm, comparison of Fourier transform and wavelet transform, Speech analysis–Cepstrum- Homomorphic filtering of speech signals, ECG signal characteristics–EEG analysis..

Intelligent techniques for biomedical signal analysis: Blind source separation: Use of principal component analysis (PCA) and independent component analysis (ICA) for filtering. Deep learning for one dimensional biomedical signal analysis. Machine learning methods for biomedical

Image Segmentation and Registration: Image segmentation: statistical classification, morphological operators, connected components. Image registration I: Rigid and non-rigid transformations, objective functions. Image registration II: Joint entropy, optimization methods

Textbooks and References:

1. Two-Dimensional Signal and Image Processing, Lim, J.S., Upper Saddle River, NJ: Prentice Hall, 1989.
2. Mathematics of Medical Imaging, Epstein, C.L. Upper Saddle River, NJ: Prentice Hall, 2003.
3. Signal Processing and Machine Learning for Biomedical, Big Data, Ervin Sejdić.
4. Biomedical Signal Analysis Contemporary Methods and Applications, Fabian J. Theis and Anke Meyer-Bäse.
5. Principles of Medical Electronics and Biomedical Instrumentation, C Raja Rao, SK Guha, Universities Press, 2001.
6. Biomedical Signal Processing: Principles and Techniques, DC Reddy Tata McGraw-Hill Publishing Co. Ltd, 2005.

AVD876 Selected Topics in Computer Vision (3-0-0) 3 Credits

Breakthroughs in computer vision, including object, scene, and activity recognition. Deep learning and statistical techniques. Developments in new research and advances in machine learning, statistical image modeling, sparse coding, graph/information theory, and other methodologies. Surveys of the latest trends in high-level vision in terms of problems and mathematical-theory formulations.

Topics will be from:

- New theory and methodologies in computer vision
- New applications of computer vision
- Societal aspects of computer vision

Textbooks and References:

1. A Guide to Convolutional Neural Networks for Computer Vision, S. Khan, H. Rahmani, S. Shahand, M. Bennamoun.
2. Recent papers from CVPR, PAMI, ICCV etc.

AVD877 Introduction to Intelligent Robotics (3-0-0) 3 Credits

Introduction to the science and design of robots - behavior-based embodied artificial intelligence, kinematics and inverse kinematics, geometric reasoning, motion planning, mapping, and manipulation, dynamics, biologically inspired and biomimetic robotics, distributed robotics and intelligence, and some philosophical questions pertaining to the nature of intelligence in the physical world.

Introduction to Robotics, robotics Motion Control, Probability/Sensing, Basics of Kalman Filters and the invariants, Localization (SLAM,V-SLAM).

Computer Vision for Robotics, Robotic vision sensors and their interfacing, Action and Sensor Modeling.

Behavior Architectures, Planning with Markov Decision Processes (MDPs) Partially Observable Markov Decision Processes (POMDPs), Motion Planning, Sampling Methods in Motion Planning for robotics, Path Planning algorithms for Robots, introduction to Reinforcement Learning for robotic application, Industrial Applications and Social aspects of robotics.

Textbooks and References:

1. Robot Programming, Yoon Seok Pyo, Han CheolCho, Ryu Woon Jung, and Tae Hoon Lim, ROS, ROBOTIS Co., Ltd, 2017.
2. Probabilistic Robotics, Sebastian Thrun, Wolfram Burgard, and Dieter Fox, MIT Press, 2005

AVD878 Algorithm and Architecture for Signal/Image Processing (3-0-0) 3 Credits

Computational characteristics of DSP algorithms and applications; Architectural requirements of DSPs: high throughput, low cost, low power, small code size, embedded applications. Numerical representation of signals-word length effect and its impact. Carry free adders, multiplier. Representation of digital signal processing systems: block diagrams, signal flow graphs, data-flow graphs, dependence graphs; Techniques for enhancing computational throughput: parallelism and pipelining.
Introduction, basic architectural features, DSP computational building blocks, bus architecture and memory, data addressing capabilities, address generation unit, programmability, and program execution, features for external interfacing, VLIW architecture. Basic performance issues in pipelining, simple implementation of MIPS, instruction level parallelism, dynamic scheduling, dynamic hardware prediction, memory hierarchy. Study of fixed point and floating-point DSP architectures.
Analysis of basic DSP Architectures on programmable hardware. Algorithms for FIR, IIR, lattice filter structures, architectures for real and complex fast Fourier transforms, 1D/2D convolutions, Winograd minimal filtering algorithm. FPGA: Architecture, different subsystems, design flow for DSP system design, mapping of DSP algorithms on to FPGA. Examples of digital signal processing algorithms suitable for parallel architectures such as GPUs and multi GPUs. Interfacing: Introduction, Synchronous Serial Interface CODE, ACODEC Interface Circuit, ADC interface.

Text books and References:

1. Digital Signal Processors, Sen M Kuo, Woon Seng S Gan.
2. Digital Signal Processing and Application with C6713 and C6416 DSK, Rulph Chassaing, Worcester Polytechnic Institute, A Wiley Interscience Publication.
3. Architectures for Digital Signal Processing, Peter Pirsch John Weily, 2007.
4. DSP Processor and Fundamentals: Architecture and Features, Phil Lapsley, JBier, Amit Sohan, Edward ALee; Wiley IEEE Press.
5. VLSI Digital Signal Processing Systems, K.K.Parhi, Wiley, 1999.
6. Principles of Digital Communications System Simulation, Sam Shanmugam, Tranter, Pearson Education, India.

AVD879 Information Theory and Coding (3-0-0) 3 Credits

Information theory: Information – Entropy, information rate, classification of codes, Kraft McMillan inequality, Source coding theorem, Shannon - Fano coding, Huffman coding, Extended Huffman coding - Joint and conditional entropies, mutual information - Discrete memory less channels – BSC, BEC – Channel capacity, Shannon limit. Channel Capacity- AWGN channel, colored noise channel, Wireless Channel-SIMO MISO, MIMO channel, error control coding –Block codes definitions and principles: Hamming weight, Hamming distance, Minimum distance decoding - Single parity codes, Hamming codes, Repetition codes-Linear block codes, Cyclic codes-Syndrome calculation, Encoder and decoder, BCH codes, CRC codes, RS codes, Decoding Techniques for RS codes, LDPC encoder and decoder, Performance analysis of RS and LDPC codes. Polar Codes: polar encoder and decoder, performance analysis of polar codes – Convolution codes: Linear convolution encoders, Structural properties of Convolution codes, Viterbi decoding technique for convolution codes – Soft / Hard decision, concatenation of block codes and convolutional codes, performance analysis, concept of Trellis coded modulation. Turbo Codes: Parallel concatenation, Turbo encoder, Iterative decoding using BCJR algorithm, Performance analysis.

Textbooks and References:

1. Information Theory and Coding, Norman Abramson, McGraw-Hill,1963.
2. Digital Communications, John Proakis & Masoud Salehi, 5th edition, McGraw-Hill, 2008.
3. Introduction to Error Control Codes, S Gravano, Oxford University Press, 2007.
4. The theory of Information theory and coding, Robert Mc Eliece, Cambridge University Press, 2002
5. Error Control Coding: Fundamentals and applications, Shu Lin and Daniel.J. Costello Jr.,Prentice Hall Inc.
6. Theory and Practice of Error Control Coding, R.E. Blahut, MGH.
7. Fundamentals of Error-correcting codes, W.C.Huffman and Vera Pless, , Cambridge University Press.
8. Fundamentals of Convolution Coding, Rolf Johannesson, KamilSh. Zigangirov, Universities Press, India.
9. Digital Communication, Sklar, Pearson Education

AVD880 Multirate Signal Processing (3-0-0) 3 Credits

Introduction- Overview of Sampling and Reconstruction. Oversampling techniques. Fundamentals of Multi-Rate Systems-Basic building blocks–Up sampling, down sampling, aliasing. Sampling rate change and filtering, fractional sampling rate change. Inter connection of multirate DSP blocks, Polyphase decomposition, Noble Identities, efficient implementation of sampling rate conversion. Applications of Multirate DSP in DFT-based Filter banks, Interpolated FIR filter design, Cascaded-Integrator-Comb (CIC) filters, and Trans multiplexers Two channel maximally decimated filter bank, Signal impairments - Aliasing, Magnitude distortion, Phase distortion, Aliasing cancellation. All-pass filters, properties, application in two channel Quadrature mirror filter banks, Perfect reconstruction two-channel FIR filter banks, M-channel QMF banks, Half-band filters, Power complementary filter pairs, M-channel perfect reconstruction filter banks. Application of multi rate DSP in Oversampling A/D and D/A converters, Introduction to wavelets, Discrete-wavelet transform and selected topics.

Textbooks and References:

1. Discrete-Time Signal Processing, Alan V. Oppenheim, Ronald W.Schafer, 3rd edition, Pearson, 2016.
2. Multirate Systems and Filter Banks, P.P.Vaidyanathan, Pearson, 2004.
3. Filter Bank Transceivers for OFDM and DMT Systems, Lin, Phoong & Vaidyanathan, Cambridge University Press, 2011.
4. Multirate digital signal processing: multi rate systems, filter banks, wavelets, Norbert Fliege, Wiley, 1994.
5. Multirate Signal Processing for Communication Systems, Frederic Harris, Prentice Hall, 2004.
6. Digital Signal Processing, Mitra, S.K., 2008, 3rd Edition, McGraw Hill, 2008.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand sampling and reconstruction techniques
CO2	Analyse and implement multi-rate systems in signal processing
CO3	Design, analyse and filter banks for perfect reconstruction

AVD882 Wireless Communication (3-0-0) 3 Credits

Introduction to Wireless channel and fading - Rayleigh/Rician fading, Broadband Wireless Channel Modeling: Introduction to LTV Systems, Channel Delay Spread, Coherence Bandwidth, BER Comparison of Wired and Wireless Communication Systems. Introduction to diversity, Multi-antenna maximal ratio combiner, BER with diversity, spatial diversity and diversity order. ISI and Doppler in wireless communications, Doppler spectrum and Jakes model. Spread spectrum: PN Sequences, DSSS with BPSK, Signal space dimensionality and processing gain, Frequency-Hop SS. CDMA-Introduction to CDMA, Multipath diversity, RAKE Receiver. OFDM: Introduction to OFDM, Multicarrier Modulation and Cyclic Prefix, Channel model and SNR performance, OFDM Issues –PAPR, Frequency and Timing Offset Issues, channel estimation. MIMO: Introduction to MIMO, MIMO Channel Capacity, SVD and Eigenmodes of the MIMO Channel, MIMO Spatial Multiplexing – BLAST, MIMO Diversity–Alamouti, OSTBC, MRT, MIMO-OFDM. UWB (Ultra-wide Band): UWB Definition and Features, UWB Wireless Channels, UWB Data Modulation, Uniform Pulse Train, Bit-Error Rate Performance of UWB.

Textbooks and References:

1. Wireless Communications: Principles and Practice, Theodore Rappaport, Prentice Hall.
2. Wireless Communications, Andrea Goldsmith, Cambridge University Press.
3. MIMO Wireless Communications, Ezio Biglieri–Cambridge University Press
4. Modern Wireless Communications, Simon Haykin and Michael Moher, Person Education, 2007
5. Wireless Digital Communications: Modulation and Spread Spectrum Techniques, Kamilo Feher, Prentice-Hall, Inc., 1995.
6. P-Spread Spectrum and CDMA, Principles and Applications, Ipatov Valery, John Wiley& Sons Ltd.
7. MIMO-OFDM wireless communications with MATLAB, Cho,Y.S., Kim,J., Yang,W.Y., & Kang, C.G., John Wiley & Sons, 2010.
8. Fundamentals of Wireless Communications, David Tse and Pramod Viswanath, Cambridge University Press.

AVD883 Multi carrier Communication (3-0-0) 3 Credits

Review of wireless channel characteristics – Multi carrier and OFDM system fundamentals – OFDM system model-Comparison with single carrier-Channel capacity and OFDM–FFT implementation–Power spectrum – Impairments of wireless channels to OFDM signals – Comparison with other multicarrier modulation scheme: MCCDMA. Synchronization in OFDM–Timing and frequency offset in OFDM, Synchronization & system architecture, timing and frequency offset estimation–Pilot and Non pilot based methods, Joint Time & Frequency Offset estimation. Channel Estimation in OFDM systems – Differential and Coherent detection; Pilot symbol aide destination - Block type and Comb type pilot arrangement; Decision directed channel estimation –MMS Estimation using time and frequency domain correlation Clipping in Multicarrier systems–Power amplifier non linearity–Error probability analysis–Performance in AWGN – PAPR properties of OFDM signals – PAPR reduction techniques with signal distortion; Techniques for distortion less PAPR reduction – Selective mapping, Clipping and Filtering, Partial Transmit Sequence, DFT Spreading and Optimization techniques.
OFDM-Index Modulation, generalized frequency division multiplexing (GFDM), filter bank multi-carriers (FBMC) and universal filtered multi-carrier (UFMC), Orthogonal Time Frequency Space modulation (OTFS), Multiple Accesses Techniques–orthogonal frequency division multiple accesses (OFDMA), generalized frequency division multiple accesses (GFDMA), non-orthogonal multiple accesses (NOMA).

Textbooks and References:

1. Multi carrier Digital Communications Theory and Applications of OFDM, Ahmad R.S .Bahai, B.R.Saltz berg, M. Ergen, Second Edition, Springer.
2. OFDM for Wireless Communication, Y.Li.G.Stuber, Springer, 2006.
3. OFDM for Wireless Communication, R.Prasad, Artech House, 2006.
4. Research papers from peer reviewed journals

AVD884 MIMO Signal Processing (3-0-0) 3 Credits

Information theoretic aspects of MIMO: Review of SISO fading communication channels, MIMO channel models, classical and extended channels, frequency selective and correlated channel models, capacity for deterministic and random MIMO channels, capacity of separately correlated and key hole Rayleigh fading MIMO channels, Ergodic and outage capacity, capacity bounds and Influence of channel properties on the capacity.
MIMO Diversity and Spatial Multiplexing: Sources and types of diversity, analysis under Rayleigh fading, Diversity and channel knowledge. Alamouti space time code, MIMO spatial multiplexing. Space time receivers. ML, ZF, MMSE and Sphere decoding, BLAST receivers and Diversity multiplexing trade-off.
Space Time Block Codes: Space time block codes on real and complex orthogonal designs, Code design criteria for quasi-static channels, Orthogonal designs, generalized orthogonal designs, Quasi-orthogonal designs and Performance analysis of Space-time codes over separately correlated MIMO channel.
Space Time Trellis Codes: Representation of STTC, shift register, generator matrix, state-transition

diagram, trellis diagram, Code construction, Delay diversity as a special case of STTC and Performance analysis.

Advanced topic in MIMO Spatial modulation, multi user MIMO, and large MIMO or massive MIMO systems- propagation channel models, Channel Estimation in Massive MIMO, Massive MIMO with Imperfect CSI, Multi-Cell Massive MIMO, Pilot Contamination, hybrid beam forming.

Textbooks and References:

1. Fundamentals of Wireless Communication, David Tse and Pramod Viswanath, Cambridge University Press, 2005.
2. Space-Time Coding: Theory and Practice, Hamid Jafarkhani, Cambridge University Press, 2005.
3. Introduction to Space-Time Wireless Communications, Paulraj, R. Nabar and D. Gore, Cambridge University Press, 2003.
4. Space-Time Block Coding for Wireless Communications, E.G. Larsson and P. Stoica, Cambridge University Press, 2008.
5. MIMO Wireless Communications, Ezio Biglieri, Robert Calderbank et al., Cambridge University Press, 2007.
6. MIMO Wireless Networks, B. Clerckx and C. Oestges, lsevier Academic Press, 2nd ed., 2013.
7. Coding for MIMO Communication Systems, T.M. Duman and A. Ghrayeb, John Wiley and Sons, 2007.
8. Multiple-Input Multiple-Output Channel Models, N. Costa and S. Haykin, John Wiley & Sons, 2010.
9. Optimal Combining & Detection, J. Choi, Cambridge University Press, 2010.
10. Large MIMO Systems, A. Chokhalingam and B.S. Rajan, Cambridge University Press, 2014.

AVD885 Adaptive Signal Processing (3-0-0) 3 Credits

Review of correlation matrix and its properties, its physical significance. Eigen analysis of matrix, structure of matrix and relation with its eigenvalues and eigenvectors. Spectral decomposition of correlation matrix, positive definite matrices and their properties and physical significance. Complex Gaussian processes. LMMSE Filters: Goal of adaptive signal processing, some application scenarios, problem formulation, MMSE predictors, LMMSE predictor, orthogonality theorem (concept of innovation processes), Wiener filter, Yule-Walker equation, unconstrained Wiener filter, recursive Wiener filter (using innovation process). Kalman filter, recursions in Kalman filter, extended Kalman filter, comparison of Kalman and Wiener filters. Adaptive Filters-Filters with recursions based on the steepest descent and Newton's method, criteria for the convergence, rate of convergence. LMS filter, mean and variance of LMS, the MSE of LMS and mis adjustment, Convergence of LMS. RLS recursions, assumptions for RLS, convergence of RLS coefficients and MSE. Lattice Filters-Filter based on innovations generation of forward and backward innovations, forward and reverse error recursions. Implementation of Weiner, LMS and RLS filters using lattice filters, Levinson Durbin algorithm, reverse Levinson Durbin algorithm. Tracking performance of the time varying filters –Tracking performance of LMS and RLS filters. Degree of stationarity and mis adjustment, MSE derivations. Applications: System identification, channel equalization, noise and echo cancellation. Applications in array processing, beamforming.

Textbooks and References:

1. Adaptive Filters Theory, S. Haykin. Prentice-Hall.
2. Statistical and Adaptive Signal Processing, Dimitris G. Manolakis, Vinay K. Ingle, Stephan M Krgon, McGraw Hill, 2000
3. Mathematical Methods and Algorithms for Signal Processing, Todd K.Moon, Wynn C.Stirling, Prentice Hall, First edition, 1999.
4. Theory and Design of Adaptive Filters, John.R.Triechler, C.Richard Johnson (Jr), Michael G.Larimore, Prentice Hall India Private Limited, 2004
5. Theory and Design of Adaptive Filters, Bernard Widrow and Samuel D.Stearns

AVD886	Software Defined Radio	(3-0-0) 3 Credits

The need for Software radios and its definition, Characteristics and benefits of Software radio, Design principles of a software radio. Radio Frequency Implementation Issues: Purpose of RF front–end, Dynamic range, RF receiver front
–end topologies, Enhanced flexibility of the RF chain with software radios, Importance of the components to overall performance, Transmitter architectures and their issues, Noise and distortion in the RF chain, ADC & DAC distortion, Pre-distortion, Flexible RF systems using micro-electro mechanical systems.

Multirate signal processing in SDR –Sample rate conversion principles, Polyphase filters, Digital filter banks, Timing recovery in digital receivers using multi rate digital filters.
Digital generation of signals - Introduction, Comparison of direct digital synthesis with analog signal synthesis, Approaches to direct digital synthesis, Analysis of spurious signals, Spurious components due to periodic jitter, Band pass signal generation, Performance of direct digital synthesis systems, Hybrid DDS – PLL Systems, Applications of direct digital synthesis, Generation of random sequences, ROM compression techniques.

Smart antennas -Introduction, Vector channel modeling, Benefits of smart antennas, Structures for beam forming systems, Smart antenna algorithms, Diversity and Space time adaptive signal processing, Algorithms for transmit STAP, Hardware implementation of smart antennas, Array calibration, Digital Hardware Choices- Key hardware elements, DSP processors, FPGAs, Power management issues.

Object oriented representation of radios and network-networks, Object–Oriented-Programming, Object brokers, Mobile application environments, Joint Tactical radio system.

Case studies in software radio design-, JTRS, Wireless Information transfer system, SDR-3000 digital transceiver sub system, Spectrum Ware, Brief introduction to Cognitive Networking.

Textbooks and References:

1. Software Radio: A Modern Approach to Radio Engineering, Jeffrey Hugh Reed, Prentice Hall Professional, 2002.

2. Software-Defined Radio for Engineers, Travis F. Collins, Robin Getz, Di Pu, and Alexander M. Wyglinski, Artech House, 2018
3. RF and DSP for SDR, Tony J Rouphael, Elsevier Newnes Press, 2008.
4. RF and Baseband Techniques for Software Defined Radio, P.Kenington, Artech House, 2005

AVD887	**Internet of Things**	**(3-0-0) 3 Credits**

Evolution of the Internet and Big Data. Introduction to the Internet of Things (IoT). The Internet protocol stack. IPv4 and IPv6. TCP and UDP. DNS and the IoT Protocol stack, Layers in the Internet of Things. Sensing and Actuator Layer, Network Layer, and Application Layer. Wireless Sensor Networks. Communication Technologies for the Internet of Things. CoAP, MQTT and HTTP Protocols for IoT. Data aggregation and fusion. Operating Systems for IoT. Contiki OS, Tiny OS, and other IoT OSs. Databases for the Internet of things. Data mining for the Internet of Things. Block chain design for the Internet of Things. Approaches of Big data analytics for IoT. Security issues and solutions in IoT. Applications of the Internet of Things. IoT for assisted living. Case studies of IoT. Internet of Medical Things. Introduction to the Digital Twins.

Textbooks and References:

1. Building blocks for IoT analytics internet-of-things analytics, Soldatos, John–Editor, River publishers, 2017.
2. Internet of Things for Architects: Architecting IoT solutions by implementing packet, Perry Lea, Publishing Limited, 2018.
3. Internet of Things, Raj Kamal, McGraw Hill Education, 2017
4. Wireless Networks: Architectures and Protocols, C. Siva Ram Murthy and B. S. Manoj, Ad hoc, Prentice Hall PTR, New Jersey, 2004.
5. Internet of Things, B.S. Manoj, Trivandrum, 2022.
6. Relevant research publications.

AVD888	**Complex Networks**	**(3-0-0) 3 Credits**

Graph Theory Preliminaries. Introduction to Complex Networks. Centrality Metrics. Community Detection in Complex Networks. Random Networks. E-R random networks. Properties of Random Network. Real-world examples of random networks. Small- World Networks. Creation of Deterministic Small- World Networks. Anchor Points in a String Topology Small- world Network. Routing in Small-World Networks. The capacity of small-world Networks. Scale-Free Networks. Characteristics of Scale-Free Networks. Real-world examples of Scale-free networks. Preferential Attachment-based Scale-Free Network Creation. Greedy Decision-based Scale-Free Network Creation. Social Networks. Algorithms for social networks. Applications of social network analysis. Small-World Wireless Mesh Networks. Architectures and protocols for small-world wireless mesh networks, Small World Wireless Sensor Networks. Energy efficiency design in small- world wireless sensor networks. Signal processing over complex networks. Other relevant topics in Complex Networks.

Textbooks and References:

1. Complex Networks: A Networking and Signal Processing Perspective, B.S.Manoj, Abhishek Chakraborty, and Rahul Singh, Pearson, NewYork, 2018.
2. The Structure of Complex Networks, Ernesto Estrada, Oxford University Press (Reprint edition), 2016.
3. Networks: An Introduction, Mark Newman, OUP Oxford; First edition, 2010.
4. Graph Spectra for Complex Networks, Pietvan Mieghem, Cambridge University Press, 2012.

AVD889	Graph Theory	(3-0-0) 3 Credits

Introduction to Graphs and their applications. Finite and infinite graphs. History of graph theory. Paths and Circuits. Isomorphism, sub graphs. Walks, paths, and circuits. Hamiltonian paths and circuits. Trees and Fundamental Circuits. Cut-Sets and Cut-Vertices. Connected and disconnected graphs and components. Directed Graphs. Euler graphs. Operations on graphs. Graph-Theoretic Algorithms and Computer Programs. Applications of Graph theory in operations research. Distributed graph algorithms for computer networks. Complex networks. Regular networks, random networks, small-world networks, and scale-free networks. Advanced graph theory concepts.

Textbooks and References:

1. Graph Theory with Applications to Engineering and Computer Science, Narsing Deo, PHIL earning Private Limited, New Delhi, 2010.
2. Complex Networks: A Networking and Signal Processing Perspective, B.S.Manoj, Abhishek Chakraborty, and Rahul Singh, Pearson, NewYork, USA, 2018.
3. Introduction to graph theory, Robin Wilson, Noida Pearson Education 1996.
4. Pearls in graph theory a comprehensive introduction, Nora Hartsfield, NewYork, 1990.
5. Schaum's outline of theory and problems of Graph theory, V.K.Balakrishnan, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 2004.
6. Distributed Graph Algorithms for Computer Networks (Compute Communications and Networks), Kayhan Erciyes, Springer, 2013

AVD890	Wireless Mesh Networks	(3-0-0) 3 Credits

Introduction: Introduction and overview of Wireless Mesh Networks, Evolution of Wireless Mesh Networks, Pros and Cons of WMNs, Architectural issues in Wireless Mesh Networks, Capacity of Wireless Mesh Networks, Layer-wise Protocol, Propagation models for WMNs, and Design issues in Wireless Mesh Networks.

Layer-wise Protocols and Protocol Design: MAC layer protocols for Wireless Mesh Networks, Network layer protocols for Wireless Mesh Networks, and Transport layer protocols for Wireless Mesh Networks.

Recent advances on WMNs: 5GWireless Mesh Networks, Design issues for satellite mesh networks, Design issues for Wide Area Wireless Mesh Networks, Resource allocation problems in Wireless Mesh Networks, Hybrid wireless mesh networks, and Layer-wise open research problems on protocol design for Wireless Mesh Networks.

Textbooks and References:

1. Wireless Networks, C.Siva Ram Murthy and B.S.Manoj, Adhoc Prentice Hall PTR, New Jersey, 2004.
2. Wireless Mesh Networking: Architectures, Protocols, and Standards, Yan Zhang, Jijun Luo, and Honglin Hu, Auerbach Publications, 2006.
3. Wireless Mesh Networks, Ian Akyildiz and Xudong Wang, John Wiley & Sons, 2009.
4. Guide to Wireless Mesh Networks, Sudip Misra, Subhas Chandra Misra, Isaac Woungang, Springer, 2010.
5. Relevant research publications and lecture notes from the instructor.

AVD891 Radar Signal Processing (3-0-0) 3 Credits

Basic radar definitions; radar equation; receiver noise; probability of detection and signal-to-noise ratio; receiver band width; target cross-section and cross-section fluctuations with statistical description of RCS; antenna coverage and gain; system losses.

Signal Models for Radar: Amplitude models, range equation and its distributed target forms, Clutter: signal to clutter ratio, temporal and spatial correlation of clutter, compound models for RCS; Noise model and signal to noise ratio; spatial model: variation with angle, variation with range, projections, multipath, spectral models.

Types of Radar: CW, FMCW and multiple-frequency CW radars; MTI: delay line cancelers; transversal filters; low, medium, and high-PRF radars; staggered PRF; multiple PRF ranging; digital MTI; Doppler filter bank and its generation; Reflection of radar waves; Tracking radars: conical scan radar; error signal of conical-scan radar; mono pulse radars; error signal of amplitude comparison mono pulse

Radar detection as hypothesis Testing: Neyman-Pearson detection rule, likelihood ratio test; threshold detection of radar signals: non-coherent integration of non-fluctuating targets, Albersheim and Shnidaman equations; Binary integration.

Phased array and Imaging radar: Phase array working and feed systems; Introduction to Beam forming: conventional beam forming, adaptive beam forming.

Synthetic aperture radars (SAR) and pulse compression techniques; SAR Fundamentals: cross range resolution in Radar, synthetic aperture viewpoint, Strip map SAR Data Characteristics: Strip map SAR Geometry, Strip map SAR dataset; Strip map SAR Image Formation Algorithm, Introduction of Polarimetric and Interferometric SAR and its principle, Remote sensing applications of radars.

Textbooks and References:

1. Fundamentals of Radar Signal Processing, Mark A. Richards, McGraw Hill.
2. Radar Design Principles: Signal Processing and The Environment, Fred E. Nathanson, 2nd Edition,

1999, PHI.
3. Introduction to Radar Systems, M.I. Skolnik, 3rd Edition, 2001, TMH.
4. Radar Signals, N. Levanon and E. Mozeson, Wiley-Blackwell, 2004.
5. Processing of SAR Data: Fundamentals, Signal Processing, Interferometry A. Hein, Springer, 2010.
6. Introduction to Radar Systems, M.I. Skolnik, Tata McGraw Hill, 2010.
7. Radar Principles, P. Z. Peebles, Wiley, 2007.
8. Radar Principles, Peyton Z. Peebles, Jr., 2004, John Wiley.
9. Radar Signal Processing and Adaptive Systems, R. Nitzberg, Artech House, 1999.

AVD892 Case Studies In Signal Processing (3-0-0) 3 Credits

Linear Prediction and its application - Modelling Time Series Data, Sigma-Delta Modulation, LPC in Speech Processing, Wireless Channel Prediction for Feedback Communication.
Applications of Kalman Filter: OFDM Channel estimation, tracking a moving/Flying object using Radar, Lidar data and optical images, alpha-beta and alpha-beta-gamma trackers, State of Charge estimation of a Li-Ion Battery. Sensor fusion.
Applications of Wiener and Adaptive Filters: Deconvolution problem, Noise cancellation, System Identification.
Applications of Monte Carlo methods: importance sampling, MCMC, particle filtering, applications in numerical integration (MMSE estimation or error probability computation) and in numerical optimization (e.g. Annealing).
Applications Power Spectrum Estimation - Parametric and Maximum Entropy Methods, model order selection, MUSIC, ESPRIT algorithms.
Applications of Wavelets-Preprocessing of Biomedical Signals, Images and Speech. Applications to Data Forecasting: Long term and short term forecasting.
Optimal Stopping Problems: Signal Modeling and its applications: Shank, Prony, Pisarenko Methods for estimating the parameters during transients. Application of Array Processing Algorithms to Radars and MIMO Communications: Beam Forming, MUSIC, ESPRIT, Matrix Pencil algorithms
Time Delay estimation

Textbooks and References:

1. Recent peer reviewed journals and conferences

AVD893 Machine Learning For Digital Communication (3-0-0) 3 Credits

Introduction and fundamentals of machine learning: Basics of supervised/unsupervised/reinforcement learning, Revision of probability and statistics revision, Revision of linear algebra, Fundamentals of numerical optimization, Machine learning for wireless communications, Machine learning for physical layer design Linear Modeling: A Least Squares Approach, Linear modeling Generalization and over fitting, Regularized least squares Wireless application - MIMO zero-forcing receiver design Linear Modeling: A Maximum Likelihood Approach, Errors as noise– thinking generatively, Maximum likelihood, Bias-variance trade-off, Effect of noise on parameter estimates, Wireless application - MIMO MMSE receiver design The Bayesian Approach to Machine Learning: Exact posterior, Marginal likelihood, Hyper parameters, Bayesian Inference: Non-conjugate models, Point estimate– MAP solution, Laplace approximation, wireless application - Massive MIMO channel estimation Classification: Probabilistic classifiers– Bayes classifier, logistic regression, Non Probabilistic classifiers-K-nearest neighbors, Discriminative and generative classifiers, Wireless application - Detection in digital communication systems sparse kernel machines, Support vector machines (SVM), Sparse Bayesian learning (SBL),Wireless application, SVM for beam forming and data detection in millimeter wave systems, SBL for channel estimation in massive MIMO Clustering: General Problem, K-means clustering, Gaussian mixture models (GMM), EM algorithm –MAP estimates, Bayesian mixture models, Wireless application - Clustering for massive MIMO system using K means and GMM Principal components analysis and latent variable models, General Problem, K-means clustering, Gaussian mixture models (GMM),EM algorithm – MAP estimates, Bayesian mixture models, Wireless application - Clustering for massive MIMO system using K means and GMM Principal components analysis and latent variable models, General Problem, Latent variable model Variational Bayes Probabilistic model for PCA, Wireless application - Variational Bayes for massive IoT device detection Gaussian Processes, Gaussian Processes for regression Gaussian Processes for classification Deep Learning for Wireless Communications Deep Learning Based MIMO Communications, Deep Reinforcement Learning for Dynamic Multi channel Accessing wireless networks, Deep Reinforcement Learning Auto encoder with Noisy Feedback.

Textbooks and References:

1. Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer, 2009.
2. Machine Learning - A Probabilistic Perspective, Kevin P Murphy, MIT Press, 2012.