Indian Institute of Space Science and Technology

Department of Space, Govt. of India

Thiruvananthapuram

Curriculum and Syllabus for

M.TECH - DIGITAL SIGNAL PROCESSING

R 2019

(Version -2 June 2021)

[Version 2: Changes (AVD874 and AVD875) added and approved by 11th Academic Council on 04-05-2021]

[Version 1: Approved by Academic Council on 18-9-2019]

COURSE STRUCTURE

SEMESTER I

Code	Course Title	L	T	P	C
AVD611	Advanced Signal Analysis and Processing	3	0	0	3
AVD612	Mathematical Methods for Signal Processing	3	0	0	3
AVD613	Communication Systems I	3	0	0	3
AVD614	Pattern Recognition and Machine learning for data processing	3	0	0	3
E01	Elective - 1	3	0	0	3
AVD632	Digital Image Processing Lab	0	0	1	1
AVD633	Communication Systems Lab	0	0	1	1
Total		15	0	0	17

SEMESTER II

Code	Course Title	L	T	P	C
AVD621	Statistical Signal Processing	3	0	0	3
AVD622	DSP System design	3	0	0	3
AVD623	Communication Systems II	3	0	0	3
AVD624	Computer Vision	3	0	0	3
E02	Elective 2	3	0	0	3
AVD642	Deep learning for visual computing lab	0	0	1	1
AVD641	DSP System design lab	0	0	1	1
AVD643	Innovative design project	0	0	0	1
Total		15	0	2	18

SEMESTER III

Code	Course Title	L	T	P	C
AVD644	Summer Design Project	0	0	0	2
AVD852	Project Work Phase I	0	0	0	15
	Total	0	0	0	17

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	Credits
I	17
II	18
III	17
IV	18
Total	**70**

SEMESTER I

AVD611 Advanced Signal Analysis and Processing (3-0-0) 3 Credits

Review of basic DSP concepts: Transform and their properties -Transform Analysis of LTI system: Phase and Magnitude response of system, Minimum phase, Maximum phase, Allpass - FIR, IIR filter design: design by Windowing, Impulse invariant and Bilinear Transformation - Multirate signal Processing: Interpolation, Decimation, sampling rate conversion, Filterbank design, Polyphase structures - Linear Prediction and Optimum Linear Filters: Adaptive Filter theory : Wiener filters, LMS and RLS, Linear Prediction.

Text Books:

1. Proakis, John G. - Digital signal processing: principles algorithms and applications, Prentice Hall International, 2007.
2. Oppenheim, Alan V - Discrete-time signal processing, Pearson Education India, 2010.
3. Vaidyanathan, Parishwad P - Multirate systems and filter banks, Pearson Education India, 1993.
4. Vaidyanathan, Palghat P- The theory of linear prediction, Morgan and Claypool Publishers, 2008.
5. Simon Haykins. - Adaptive filter theory, Pearson Education India,2001.
6. Monsoon H.Hayes-Statistical digital signal processing and modeling, John Wiley & sons, 1996.

re-requisites:

1. Undergraduate Signals and Systems
2. Undergraduate Digital Signal Processing

Evaluation:

The course will feature two midterm exams and a final exam. Continuous evaluation by class-tests and problem sets.

AVD612 Mathematical Methods for Signal Processing (3-0-0) 3 Credits

Vectors: Representation and Dot products, Matrices: Matrix Multiplication, Transposes, Inverses, Gaussian Elimination, factorization, rank of a matrix, Vector spaces: Column and row spaces, 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, Diagonalization, Hermitian and Unitary matrices, Spectral theorem, Change of basis, Positive definite matrices and singular value decomposition, Linear transformations

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

Evaluation:

The course will feature two midterms and a final exam. There will be continuous evaluation using bi-weekly class tests, problem sets, and programming assignments.

AVD613 Communication Systems I (3-0-0) 3 Credits

Motivating examples of communication systems. Spectrum availability and channels. Channel modelling - baseband and passband channels. Digital modulation schemes for baseband and passband channels. Line coding, Pulse amplitude modulation, Phase modulation, Frequency shift keying, quadrature amplitude modulation. Synchronization, intersymbol interference, and noise in communication systems.

Noise modelling in communication systems - additive white Gaussian noise (AWGN) channels. Signal space concepts: Geometric structure of the signal space, vector representation, distance, norm and inner product, orthogonality, Gram-Schmidt orthogonalization procedure. Optimum receiver for AWGN channels: Optimal detection and error probability for digital signalling schemes. Matched filter and Correlation receiver.

Bandlimited channels and intersymbol interference (ISI). Signal design for bandlimited channels - Nyquist criterion, Partial response signaling. Non ideal bandlimited channels - receivers for channels with ISI and AWGN - ML receiver, its performance. Linear Equalization. Carrier and Symbol synchronization, Carrier recovery and symbol synchronization in signal demodulation, 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.

Text Books

1.Communication systems, Simon Haykin, 4 th edition Wiley, 2001.

2.Introduction to Communication Systems, Upamanyu Madhow, Cambridge University Press, November 2014.

3.Fundamentals of Digital Communication, Upamanyu Madhow, Cambridge University Press, February 2008.

4.Digital communication, Bernard Sklar, 2nd edition, Pearson Education, 2000.

5.Digital Communication,, John Proakis & Masoud Salehi, 5 th edition, McGrawHill, 2008.

Pre-requisites:

1.Undergraduate probability and random processes

2.Signals and systems, LTI systems and their analysis

Evaluation:

The course will feature two midterm exams and a final exam. Continuous evaluation by class-tests and problem sets.

AVD614	Pattern Recognition and Machine learning for data processing	(3-0-0) 3 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, Backpropagation, 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), Reinforcement Learning (RL) : Markov Decision Processes (MDP), Bellmans Equations, Value Iteration and Policy Iteration, Value Function Approximation, Q-Learning, Application: Advice on structuring an ML project, Evaluation Metrics, Missing data techniques and tracking, Special Topic: Computer Vision. Special Topic: NLP, Special topic: Machine listening and Music Information Retrieval, Special Topic: Speech, Special Topic: Compressive Sensing, Special topics: Array processing, beamforming, independent component analysis, MIMO/SIMO models, under-constrained separation, spectral factorizations.

Textbook

1. Pattern Recognition Machine Learning by C. Bishop, 2010, springer

2. Pattern Classification, 2ed Paperback – 1 January 2007 by Richard Duda, Peter Hart, David Stork, wiley publication

Reference books

1. Machine Learning – A Probabilistic Perspective (Adaptive Computation and Machine Learning series), by kevin murphy, 2012

Course evaluation: 4 Programming assignments 20% (5% each), Term project 20%, Exam 20%, End Sem 40 %.

E01	ELECTIVE I	(3-0-0) 3 Credits

- Refer list of Electives

AVD632		(0-0-1) 1 Credit
	Digital Image Processing Lab	

This course is designed to give the PG students all the fundamentals in 2-D digital image processing with emphasis in image processing techniques, image filtering design and applications.

Following are some list of experiments that student do in the proposed lab

1. Familiarization to Image Processing using python

2. Basic Image Processing operations

3. Histogram Equalization and Image Denoising

4. Edge Detection

5. Image Smoothing

6. Mean shift algorithm

7. Image Transforms

8. Image Filtering in Frequency Domain

9. Canny edge detection algorithm

10. Image Segmentation

11. Watershed algorithm for image segmentation

12. Image Restoration

Prerequisite: Students are expected to have knowledge in linear signals and systems, 1-D Fourier Transform, basic linear algebra, basic probability theory and basic programming techniques; knowledge of Digital Signal Processing is desirable and working knowledge of Matlab/python etc..

Learning outcomes:

a) Knowledge and understanding: Have a clear understanding of the principles the Digital Image Processing terminology used to describe features of images. Have a good understanding of the mathematical foundations for digital manipulation of images; image acquisition; preprocessing; segmentation; Fourier domain processing, compression and analysis. Be able to write programs using Matlab/python language for digital manipulation of images; image acquisition; preprocessing; segmentation; Fourier domain processing; and compression. Have knowledge of the Digital Image Processing Systems. Learn and understand the Image Enhancement in the Spatial Domain. Learn and understand the Image Enhancement in the Frequency Domain. Understand the Image Restoration, Compression, Segmentation, Recognition, Representation and Description.

b) Cognitive skills (thinking and analysis): Be able to use different digital image processing algorithms. Be able to design, code and test digital image processing applications using MATLAB/Python language. Be able to use the documentation for, and make use of, MATLAB/python library. Analyze a wide range of problems and provide solutions related to the design of image processing systems through suitable algorithms, structures, diagrams, and other appropriate methods. Practice self-learning by using the e-courses and web materials.

Communication skills (personal and academic): Display personal responsibility by working to multiple deadlines in complex activities. Be able to work effectively alone or as a member of a small group working on some programming tasks.

Textbooks:

1. R. C. Gonzalez, R. E. Woods. Digital Image Processing. Addison Wesley Longman, Inc., 1992.
2. A. K. Jain. Fundamentals of Digital Image Processing. Prentice-Hall, 1989.
3. Reference Books:
4. R. M. Haralick, L. G. Shapiro. Computer and Robot Vision. Addison-Wesley, 1993.
5. A. Rosenfeld, A. C. Kak. Digital Picture Processing. Addison-Wesley, 1983
6. D. A. Forsyth, J. Ponce. Computer Vision: A Modern Approach. Prentice-Hall, 2003.
7. C. R. Giardina, E. R. Dougherty. Morphological Methods in Image and Signal Processing. Prentice-Hall, Englewood Cliffs, New Jersey, 1988.
8. R. J. Schalkoff. Digital Image Processing and Computer Vision. John Wiley & Sons, Singapore, 1989.
9. V. S. Nalwa. A Guided Tour of Computer Vision. Addision-Wesley, 1993.
10. W. K. Pratt. Digital Image Processing(Second Edition). John Wiley & Sons, New York, 1991.
11. B. K. P. Horn. Robot Vision. MIT Press, Cambridge, 1987.
12. D. H. Ballard, C. M. Brown. Computer Vision. Prentice-Hall, Englewood Cliffs, 1982.
13. G. C. Stockman, L. G. Shapiro. Computer Vision. Prentice-Hall, 2001.
14. R. I. Hartley, A. Zisserman. Multiple View Geometry in Computer Vision. Cambridge University Press, ISBN: 0521623049, 2000.

15. O. Faugeras. Three-Dimensional Computer Vision: A Geometric Viewpoint. MIT Press, 1993.

16. R. Kasturi, R. C. Jain. Computer Vision: Principles. IEEE Computer Society Press Tutorial, 1991.

17. W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery. Numerical Recipes in C. (Second Edition) Cambridge University Press, 1992.

18. A. K. Jain, R. C. Dubes. Algorithms For Clustering Data. Prentice-Hall, 1988.

19. R. Gose, R. Johnsonbaugh, S. Jost. Pattern Recognition and Image Analysis. Prentice-Hall, 1996.

20. A. Tucker, D. Small. A Unified Introduction to Linear Algebra: Models, Methods, and Theory. Macmillan Publishing Company, 1989.

AVD633 Communication Systems Lab (0-0-1) 1 Credit

The communication systems lab reinforces the concepts learned in the companion theory course AVD613 - Communication Systems I. The following experiments are done in the lab using simulations and complemented by software defined radio.

1. Introduction to Matlab programming
2. Signals and Systems in Matlab
3. Spectral Analysis in Matlab
4. Filter Design in Matlab
5. Communication over baseband channels
6. Symbol and frame synchronization at baseband
7. Bandlimited baseband channels and ISI
8. Passband communication

Textbooks and References

1.Communication systems, Simon Haykin, 4 th edition Wiley, 2001.

2.Introduction to Communication Systems, Upamanyu Madhow, Cambridge University Press, November 2014.

3.Fundamentals of Digital Communication, Upamanyu Madhow, Cambridge University Press, February 2008.

4.Digital communication, Bernard Sklar, 2nd edition, Pearson Education, 2000.

5.Digital Communication,, John Proakis & Masoud Salehi, 5 th edition, McGrawHill, 2008.

6. Viswanathan M. Simulation of digital communication systems using Matlab. 2013. (Online)

SEMESTER II

AVD621	Statistical Signal Processing	(3-0-0) 3 Credits

Estimation Theory, Maximum Likelihood estimation (MLE): exact and approximate methods (EM, alternating max, etc), Cramer - Rao lower bound (CRLB), Minimum variance unbiased estimation, best linear unbiased estimation, Bayesian inference & Least Squares Estimation , Basic ideas, adaptive techniques, Recursive LS, etc, Kalman filtering (sequential Bayes), Finite state Hidden Markov Models: forward - backward algorithm, Viterbi (ML state estimation), parameter estimation (f - b + EM), 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). Detection Theory: Likelihood Ratio testing, Bayes detectors, Minimax detectors, Multiple hypothesis tests Neyman - Pearson detectors (matched filter, estimator - correlator etc), Wald sequential test, Generalized likelihood ratio tests (GLRTs), Wald and Rao scoring tests, Applications Power Spectrum Estimation - Parametric and Maximum Entropy Methods, Wiener, Kalman Filtering, Levinson - Durban Algorithms Least Square Method, Adaptive Filtering, Nonstationary Signal Analysis, Wigner - Ville Distribution, Wavelet Analysis. Power Spectrum Estimation, model order selection, Prony, Pisarenko, MUSIC, ESPRIT algorithms, least square estimation, cholesky, LDU - OR, SV decomposition. Transversal & reasnic least square lattice filters, Signal Analysis with Higher order Spectra, Array processing, Beam forming, Time - delay estimation

Text Books and References

1. Statistical Signal Processing (Paperback) by Louis Scharf, 1 st edition,

2. Fundamentals of Statistical Signal Processing: Estimation Theory (Vol 1), Detection Theory (Vol 2), .M. Kay's, Prentical Hall Signal Processing Series, 1993

3. Linear Estimation, Kailath, Sayed and Hassibi, Prentical Hall Information and Sciences Series, 1 st edition, 2000.

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, 2 nd edition, Wiley.

6. Monte Carlo Strategies in Scientific Computing, J.S. Liu, Springer - Verlag, 2001.

7. Stochastic Simulation, B.D. Ripley, Wiley, 1987.

AVD622	DSP System design	(3-0-0) 3 Credits

Computational characteristics of DSP algorithms and applications; Architectural requirement 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 issue 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 hardwares. 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 sub-systems, design flow for DSP system design, mapping of DSP alrorithms onto FPGA. Examples of digital signal processing algorithms suitable for parallel architectures such as GPUs and multiGPUs. Interfacing: Introduction, Synchronous Serial Interface CODE, A CODEC Interface Circuit, ADC interface.

References

1. Sen M Kuo, Woon Seng S Gan, Digital Signal Processors

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, AmitSohan, Edward A Lee; Wiley IEEE Press

5. K. K. Parhi - VLSI Digital Signal Processing Systems - Wiley - 1999

AVD623 Communication Systems II (3-0-0) 3 Credits

Wireless Communications and Diversity: Introduction to 3G/4G Standards, Wireless Channel and Fading, Rayleigh Fading and BER of Wired Communication, BER for Wireless Communication. Introduction to Diversity, Multi-antenna Maximal Ratio Combiner, BER with Diversity, Spatial Diversity and Diversity Order. Broadband Wireless Channel Modeling: Wireless Channel and Delay Spread, Coherence Bandwidth of the Wireless Channel, 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.

Textbook and References:

1. Fundamentals of Wireless Communications – David Tse and Pramod Viswanath, Publisher - Cambridge University Press, 2005.

2. Wireless Communications: Principles and Practice –Theodore Rappaport - Prentice Hall, 1996.

3. Wireless Communications: Andrea Goldsmith, Cambridge University Press, 2005.

4. MIMO Wireless Communications – Ezio Biglieri – Cambridge University Press, 2007

5. Modern Wireless Communications- Simon Haykin and Michael Moher, Person Education, 2007

6. Kamilo Feher-Wireless Digital Communications: Modulation and Spread Spectrum Techniques, Prentice-Hall, Inc., 1995.

7. Ipatov Valery, P- Spread Spectrum and CDMA. Principles and Applications. - John Wiley & Sons Ltd, 2005.

8. Cho, Y. S., Kim, J., Yang, W. Y., & Kang, C. G. MIMO-OFDM wireless communications with MATLAB. John Wiley & Sons.2010.

Pre-requisites:

1.Undergraduate Communication system

2.Undergraduate probability and random processes

Evaluation:

The course will feature two midterm exams and a final exam. Continuous evaluation by class-tests and problem sets.

AVD624	Computer Vision	(3-0-0) 3 Credits

The course is an introductory level computer vision course, suitable for graduate students. It will cover the basic topics of computer vision, and 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.

Prerequisities: Basic Probability/Statistics, a good working knowledge of any programming language (python, matlab, C/C++, or Java), Linear algebra, Vector calculus.

Grading: Assignments and the term project should include explanatory/clear comments as well as a short report describing the approach, detailed analysis, and discussion/conclusion.

Course evaluation: 4 Programming assignments 20% (5% each), Term project 20%, Exam 20%, End Sem 40 %.

Recommended books:

1. Simon Prince, Computer Vision: Models, Learning, and Interface, Cambridge University Press, 2012, cambridge university press

2. Mubarak Shah, Fundamentals of Computer Vision, 1997 , https://www.cse.unr.edu/~bebis/CS485/Handouts/ShahBook.pdf

3. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010

4. Forsyth and Ponce, Computer Vision: A Modern Approach, Prentice Hall, 2002

5. Palmer, Vision Science, MIT Press, 1999,

6. Duda, Hart and Stork, Pattern Classification (2nd Edition), Wiley, 2000,

7.Koller and Friedman, Probabilistic Graphical Models: Principles and Techniques, MIT Press, 2009,

8. Strang, Gilbert. Linear Algebra and Its Applications 2/e, Academic Press, 1980.

Programming: Python will be main programming environment for the assignments. 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)

AVD641	**DSP System design lab**	**(0-0-1) 1 Credit**

This Lab covers Implementation of DSP algorithms in TMS DSP Processors and FPGAs

Introduction to TMS Processor software and Hardware tools and algorithms in C language. Generation of sinusoidal signals, sampling, down sampling, upsampling and interfacing with CODEC and processing using processors Implementation of fast Convolution algorithm (Time domain and FFT) in real time, Power Spectrum Estimation. Digital Filters implementation FIR and IIR, Adaptive Filter implementation, Amplitude Modulation Frequency Modulation implementation, Pseudo-Random Binary Sequences and Data Scramblers, Echo Cancellation, Equalizers, Image Processing using DSP Processor, Introduction to Xilinx FPGA and IDE tools for system development. Hardware architecture for convolution, Filtering, FFT. Application development using DSP and FPGA based design

References

1. Ralph Chassing,Digital Signal Processing and Applications with the Tms320C6713 and Tms320C6416 Dsk, 2nd Ed , John wiley
2. Communication System Design using DSP algorithms with laboratory experiments for the TMS 320C6713 DSK
3. FPGA based System Design by Wayne, Wolf Pearson

AVD642 Deep learning for visual computing lab (0-0-1) 1 Credit

In this lab we will cover various aspects of Deep Learning for visual computing for example classifying images into categories or detecting and distinguishing persons. As we have seen in the recent time, Deep Learning research has led to breakthroughs in the fields of computer vision, nlp and other areas of science and technology; in certain problems, the performance of current methods based on this technology is similar or even better than that of humans – a novelty in Computer Vision. The objective of this lab is to provide in depth knowledge to this exciting branch of machine learning. Familiarization with the current state-of-the-art in deep learning methods for computer vision. Familiarization with state-of-the-art software frameworks for deep learning. Implementation and, if applicable, extension of a deep learning method in computer vision; done in teams

Following are some list of experiments that student do in the proposed lab

1. Harris Corner Detection
2. Transformations
3. CNN using Tensorflow
4. Image Stitching
5. SIFT
6. RNN
7. Stereo Matching
8. Object Detection Using Faster RCNN
9. Visual Object Tracking

Prerequisite: Solid programming skills in C/C++ or Python or Lua

Books

1. Deep Learning for Computer Vision: Expert techniques to train advanced neural networks using TensorFlow and Keras, publisher Packt Publishing, 2018, packtpub.com

2. Goodfellow, Y, Bengio, A. Courville, “Deep Learning”, MIT Press, 2016. S. Haykin, “Neural Networks and Learning Machines”,3e,Pearson, 2008.

E02	ELECTIVE II	(3-0-0) 3 Credits

- Refer list of Electives

DEPARTMENT ELECTIVE COURSES

Sl. No	Course Code	Course Name
1	AVD861	Speech Signal Processing and Coding
2	AVD862	Information Theory and Coding
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	VLSI Signal Processing
9	AVD870	Deep Learning for Computational data sciences
10	AVD871	Applied Markov Decision Processes and Reinforcement Learning
11	AVD872	Internet of Things

12	**AVD873**	**Machine Learning for signal processing**
13	**AVD874**	**Radar Signal Processing**
14	**AVD875**	**Topics in Reinforcement Learning**

ELECTIVE COURSES

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

Syllabus

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.

Text Books

Same as Reference

References

Digital Processing of Speech Signals Pearson Education, L.R. Rabiner and R.W. Schafer, Delhi, India, 2004

Discrete - Time Processing of Speech Signals, J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis, Wiley - IEEE Press, NY, USA, 1999.

Human and Machine, D. O'Shaughnessy, Speech Communications: Second Edition, University Press, 2005.

Discrete time processing of speech signals, T. F. Quatieri, Pearson Education, 2005.

Fundamentals of speech recognition, L. R. Rabiner, B. H. Jhuang and B. Yegnanarayana Pearson Education, 2009.

AVD862 Information Theory and Coding (3-0-0) 3 Credits

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 memoryless channels – BSC, BEC – Channel capacity, Shannon limit. 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 – CRC Convolutional codes – code tree, trellis, state diagram - Encoding – Decoding: Sequential search and Viterbi algorithm – Principle of Turbo coding, LDPC codes

Text Books

Same as Reference

References

Information Theory and Coding, Norman Abramson, McGrawHill ,1963

Digital Communications,John Proakis & Masoud Salehi, 5 - th edition McGrawHill, 2008.

Introduction to Error Control Codes, S Gravano, Oxford University Press 2007

The theory of Information theory and coding , Robert McEliece, Cambridge University press, 2002

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 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.

Text Books

Same as Reference

References

Neural Fuzzy Systems, Chin - Teng Lin & C. S. George Lee, Prentice Hall PTR,2000.

Fuzzy Sets and Fuzzy Logic, Klir & Yuan, PHI, 1997.

Neural Networks, S. Haykin, Pearson Education, 2ed, 2001.

Genetic Algorithms in Search and Optimization, and Machine Learning, D. E. Goldberg, Addison - Wesley, 1989.

Neural Networks, Fuzzy logic, and Genetic Algorithms, S. Rajasekaran & G. A. V. Pai, PHI.

Neuro - Fuzzy and Soft Computing, Jang, Sun, & Mizutani, PHI.

Learning and Soft Computing, V. Kecman, MIT Press, 2001.

Rough Sets, Z. Pawlak, Kluwer Academic Publisher, 1991.

Intelligent Hybrid Systems, D. Ruan, Kluwer Academic Publisher, 1997.

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

Image Formation Models, Monocular imaging system, Orthographic & Perspective Projection , Camera model and Camera calibration , Binocular imaging systems Image Processing and Feature Extraction , Image representations (continuous and discrete), Edge detection, Motion Estimation , Regularization theory, Optical computation , Stereo Vision , Motion estimation , Structure from motion Shape Representation and Segmentation , Deformable curves and surfaces , Snakes and active contours , Level set representations , Fourier and wavelet descriptors

• Medial representations , Multiresolution analysis Object recognition , Hough transforms and other simple object recognition methods , Shape correspondence and shape matching , Principal component analysis, Shape priors for recognition

Text Books

Same as Reference

References

Computer Vision - A modern approach, D. Forsyth and J. Ponce, Prentice Hall ,2002

Introductory Techniques for 3D Computer Vision, by E. Trucco and A. Verri, Publisher: Prentice Hall,1998.

Robot Vision, by B. K. P. Horn, McGraw - Hill,1986.

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

The course focuses on 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, Emphasis will be on the family of MPEG 1/2/4 (Moving Picture Experts Group), H.26x (x = 1, 2, 3), JPEG/JPEG - LS/JPEG2000 (Joint Photographic Experts Group), JBIG 1/2 (Joint Binary Image Group), H.264/MPEG - 4 Part 10 AVC (Advanced Video Coding) and the emerging H.265 standard (HEVC). Other standards such as WMV - 9 (Windows Media Video) of Microsoft and AVS China (Advanced Video Standard) and their similarities/differences with H.264 will also be presented, also audio coding AC3, AAC, AAC + SBR, G.72x–series, MPEG - 1, 2, 4 audio. Course will be supplemented with ftp/web sites, software, standards documents, test sequences etc. Industry worldwide is very active in developing products (software/hardware) based on these standards with emphasis on the latest standard H.264. Some of these are digital TV, HDTV, HD - DVD, set - top - box, handheld devices with multimedia capabilities, digital cameras, camcorders, electronic games, IPTV, video streaming, iPods etc. Motion Estimation : Matching Criteria, Generalised Matching, Generalised 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

Text Books

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

References

Same as Textbooks

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

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 correlates 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, mosaicing, 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

Laboratory : Introductory training in scripting and Vizard software demo on modeling. There will be lab exercises given to students for better understanding of the course.

Project : Two projects will be given to students that need to be simulated using python/c/opengl/vrml etc.

1. The first project is a short individual project that will focus on creating a simple VR environment to get everyone familiar with the available software and give you a sense of the scope of the projects that you can create.

2. The second project will focus on creating a more complicated virtual world. This second project can either be done as individuals or in groups of two. Groups of two are responsible for CLEARLY delineating each persons role in the project

Text Books

Information Not Available

References

A hitchhikers Guide to Virtual Reality, by Karen McMenemy, Stuart Ferguson, A.K.Peter's, 2007

Vizard Teacher in a Book from Vizard, 2008

IEEE conferences and Journals on Graphics, VR and computer vision.

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 - k NN approaches.Dimensionality reduction, data normalization. Regression, and time series analysis. Linear discriminat functions. Fishers 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

Text Books

Same as Reference

References

1. Pattern classification, Duda and Hart, John Wiley and sons ,2001.

2. Machine learning, T M Mitchel, McGraw Hills 1997 Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer, 2006.

AVD868 VLSI Signal Processing (3-0-0) 3 Credits

Introduction to Digital Signal Processing ; Need of VLSI DSP algorithms. Introduction to VLSI Technology and DSP Technology requirements; main DSP Blocks and typical DSP Algorithms. Number Representation: Fixed point Representation Floating point Representation; Binary Adders; Binary Multiplier; Binary Dividers; Floating point Arithmetic Implementation: CORDIC architectures; Multiply Accumulator unit ; Computation of Special functions using MAC cells. Redundant arithmetic, redundant number representations , carry free radix 2 addition and subtraction . Hybrid radix 4 addition. Radix 2 hybrid redundant multiplication architectures , data format conversion. Redundant to nonredundant converter. Numerical strength reduction. Transformations for retiming. Folding and unfolding DSP programs. Bit level arithmetic structures - parallel multipliers, interleaved floor plan and bit plan based digital filters. Bit serial multipliers. Bit serial filter design and implementation. Canonic signed digit arithmetic, Distributed arithmetic. Synchronous pipelining and clocking styles, clock skew and clock distribution in bit level pipelined VLSI designs. Parallel FIR filters. Pipelining of FIR filters. Parallel processing. Pipelining and parallel processing for low power FIR filters. Pipeline interleaving in digital filters. Pipelining and parallel processing for IIR filters. Low power IIR filter design using pipelining and parallel processing, Pipelined adaptive digital filters. Systolic Array Architectures and fast convolution algorithms. Round off noise and its computation. State variable description of digital filters, Round off noise computation using state variable description. Scaling using slow - down, retiming and pipelining.

Text Books

Same as Reference

References

1.VLSI Digital Signal Processing Systems - Design and Implementation, Keshab K. Parhi, Wiely, 2010

2. High - Performance VLSI Signal Processing – Innovative Architectures and Algorithms, Systems Design and Applications, K. J. Ray Liu, IEEE Press, 1998

3. System Design with SystemC, Thorsten Grotker, et al,Kluwer Academic Publishers, 2002

4. Digital Signal Processing with Field Programmable Gate Arrays, U Meyer Baese Springer 2009

5. FPGA - based Implementation of Signal Processing Systems, Roger Woodset al ,2008

6. Design of Analog - Digital VLSI Circuits forTelecommunication and Signal Processing, Jose E. France, Yannis Tsividis, Prentice Hall, 1994

AVD870 Deep Learning for Computational data sciences (3-0-0) 3 Credits

Prerequisite: Linear algebra, Probability and interest in programming

Description: Deep learning methods are now prevalent in the area of machine learning, and are now used invariably in many research areas. In recent years it received significant media attention as well. The influx of research articles in this area demonstrates that these methods are remarkably successful at a diverse range of tasks. Namely self driving cars, new kinds of video games, AI, Automation, object detection and recognition, surveillance tracking etc.

The proposed course aims at introducing the foundations of Deep learning to various professionals who are working in the area of automation, machine learning, artificial intelligence, mathematics, statistics, and neurosciences (both theory and applications).

This is proposed course to introduce Neural networks and Deep learning approaches (mainly Convolutional Neural networks) and give few typical applications, where and how they are applied. The following topics will be explored in the proposed course.

We will cover a range of topics from basic neural networks, convolutional and recurrent network structures, deep unsupervised and reinforcement learning, and applications to problem domains like speech recognition and computer vision.

Prerequisites: a strong mathematical background in calculus, linear algebra, and probability & statistics, as well as programming in Python and C/C++. 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 Autoencoders

3. Unsupervised deep learning:

Autoencoders for Representation Learning and MLP Initialization

4. Stacked, Sparse, Denoising Autoencoders and Ladder Training

5. Cost functions, Learning Rate Dynamics and Optimization

6. Introduction to Convolutional Neural Networks (CNN) and LeNet

7. Convolutional Autoencoders and Deep CNN (AlexNet, VGGNet)

8. Very Deep CNN architecture for Classification (GoogLeNet, ResNet, DenseNet)

9. Computational Complexity and Transfer Learning of a Network

10. Object Localization (RCNN) and Semantic Segmentation

11. Generative Models with Adversarial Learning

12. Recurrent Neural Networks (RNN) for Video Classification

13 Deep reinforcement learning

14 NLP/Vision Application

Textbook

The required textbook for the course is

■ Ian Goodfellow, Yoshua Bengio, Aaron Courville. Deep Learning.

Other recommended supplemental textbooks on general machine learning:

■ Duda, R.O., Hart, P.E., and Stork, D.G. Pattern Classification. Wiley-Interscience. 2nd Edition. 2001.

■ Theodoridis, S. and Koutroumbas, K. Pattern Recognition. Edition 4. Academic Press, 2008.

■ Russell, S. and Norvig, N. Artificial Intelligence: A Modern Approach. Prentice Hall Series in Artificial Intelligence. 2003.

■ Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995.

■ Hastie, T., Tibshirani, R. and Friedman, J. The Elements of Statistical Learning. Springer. 2001.

■ Koller, D. and Friedman, N. Probabilistic Graphical Models. 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.

References and textbooks:

1. Richard S. Sutton and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018.

2. Dimitri P. Bertsekas, Dynamic programming and optimal control. Vols. I and II, Athena scientific, 2005.

3. Sheldon M. Ross. Applied probability models with optimization applications. Courier Corporation, 2013.

4. Sheldon M. Ross. Introduction to stochastic dynamic programming. Academic press, 2014.

Pre-requisites:

1. Undergraduate Probability and Random Processes

2. Programming background in Matlab and Python

Evaluation:

The course will feature two midterms and a final exam. Continuous evaluation will be through two programming mini-projects (3 weeks long), assignments, and class-tests.

AVD872 Internet of Things (3-0-0) 3 Credits

Evolution of the Internet and Big Data. Introduction to the Internet of Things. The Internet protocol stack. IPv4 and IPv6. TCP and UDP. 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 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.

References

1. Soldatos, John –Editor, Building blocks for IoT analytics internet-of-things analytics, River publishers, 2017.

2. Perry Lea, Internet of Things for Architects: Architecting IoT solutions by implementing, Packt Publishing Limited, 2018.

3. Kamal, Internet of Things, McGraw Hill Education, 2017

4. C. Siva Ram Murthy and B. S. Manoj, Ad hoc Wireless Networks: Architectures and Protocols, Prentice Hall PTR, New Jersey, May 2004.Raj .

5. Relevant research publications.

AVD873 Machine Learning for signal processing (3-0-0) 3 Credits

“Deep Learning” and "Machine Learning" systems are conquering all the AI tasks, ranging from language understanding, and speech and image recognition, to machine translation, planning, and even game playing and autonomous driving. As a result, gaining an expertise in deep learning/ML is a mandatory requirement now a days in many advanced academic settings for building a research career , as well as in the industrial job market.

In this course objective is to learn about the basics of deep neural networks and machine learning, and their applications to various AI tasks specifically to text, speech images and videos. A student who enrolls for this course would expected to gain significant familiarity with the subject, and believed to be able to use these techniques in some real world applications to benefit society at large. It is also expected that. they will witness the recent developments that are happening in this area and they will be in position to follow the current literature on the recent topics to extend their knowledge through further study.

Tentative Syllabus for the course

Introduction: Representing text, Sounds and Images

text, speech, image, and video. Signal processing for feature extraction: for Text (BoW), Speech (LPC, Mel-frequency Cepstral coefficients, STFT and Wavelet features), Images (HoG, BoVW, FV), Videos (BoVW).--- 3 weeks

Basics of Pattern recognition: Generative models (GMMs);

Discriminative models (Support vector Machines and Neural Networks (NNs)); principal component analysis, ----2 weeks

Introduction to deep learning: The perceptron/multli-layer perceptron

Hebbian learning, Training a neural network Perceptron learning rule

Empirical Risk Minimization Optimization by gradient descent

Back propagation, Calculus of back propagation----2 weeks

Convergence in neural networks, Rates of convergence

Loss surfaces Learning rate and data normalization, RMSProp, Adagrad, Momentum, Convolutional Neural Networks (CNNs)

Weights as templates Translation invariance, Training with shared parameters

Arriving at the convolutional model----2 weeks

Recurrent Neural Networks (RNNs), Back propogation through time

Bidirectional RNNs, Exploding/vanishing gradients, Long Short-Term Memory Units (LSTMs) Autoencoders and dimensionality reduction

Representation learning---2 weeks. Generative Adversarial Networks (GANs)

Hopfield Networks, Energy functions

Reinforcement Learning :

Markov Reward Process Markov Decision Process

Bellman Expectation Equation, Actions Optimal Policies---3 weeks

Key references

1. Deep Learning By Ian Goodfellow, Yoshua Bengio, Aaron Courville Online book, 2017

2. Neural Networks and Deep Learning By Michael Nielsen Online book, 2016

3. Deep Learning with Python By J. Brownlee

4. Deep Learning Step by Step with Python: A Very Gentle Introduction to Deep Neural Networks for Practical Data Science By N. D. Lewis

5. "Pattern Recognition and Machine Learning", C.M. Bishop, 2nd Edition, Springer, 2011.

6. "Machine Learning for Audio, Image and Video Analysis", F. Camastra, Vinciarelli, Springer, 2007. link http://www.dcs.gla.ac.uk/~vincia/textbook.pdf

AVD874 Radar Signal Processing (3-0-0) 3 Credits

Fundamentals of radar systems - propagating EM waves in space and time, Doppler shift, Range equation, system structure. Signal Models - Radar cross-section of targets and clutter, multipath, statistical signal models, Swerling models, advanced (compound) statistical signal models for clutter, convolutional models in range and angle, frequency-domain models. Waveforms - The ambiguity function, Basic waveforms: simple pulse, LFM, coherent pulse train, Coded waveforms: frequency, phase (biphase, Costas), MCW, step-frequency - Optimum waveforms for time delay, velocity, acceleration measurements - Measurement accuracy, Cramer-Rao bounds.

Doppler processing, Optimal Detection- Neyman-Pearson detection and the likelihood ratio, threshold detection, targets in Gaussian noise, coherent and noncoherent integration; binary integration, Optimal detectors for non-Gaussian interference, CFAR

Textbooks:

1. Richards, Mark A. Fundamentals of radar signal processing. Tata McGraw-Hill Education, 2005.

2. De Maio, Antonio, and Maria Sabrina Greco. Modern radar detection theory. SciTech Publishing Inc, 2015.

3. Mahafza, Bassem R. Radar signal analysis and processing using MATLAB. CRC Press, 2016.

AVD875 Topics in Reinforcement Learning (2-0-0) 2 Credits

Module 1: Mathematical foundations (12 lectures): Relevant topics from probability and stochastic processes, dynamic programming, background on Markov decision processes, partially observable Markov decision processes, Stochastic approximation theory.

Module 2: Topics in reinforcement learning (18 lectures): Sample complexity, Exploration-Exploitation in reinforcement learning, Bandits and Regret analysis, Rollout and policy improvement, Policy gradient methods, Value function approximation, Behavioural cloning, Apprenticeship learning, Inverse reinforcement learning, Multiagent and distributed reinforcement learning, Statistical learning theory, Generalization bounds, Mean field approaches, Optimization methods for approximate dynamic programming.

References:

1.Sutton, Richard S., and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018.

2.Dimitri P. Bertsekas, Dynamic programming and optimal control. Vol. 1. No. 2. Belmont, MA: Athena scientific, 1995.

3.Dimitri P. Bertsekas - Reinforcement learning and optimal control, (Draft textbook), Athena Scientific, 2019.

4.Dimitri P. Bertsekas and John N. Tsitsiklis - Neuro-Dynamic Programming, Athena Scientific, 1996.

5.Anurag Kumar - Discrete time stochastic processes: Lecture Notes (available online)

Pre-requisites:

1.Probability and Random Processes

2.Linear algebra

3.Programming background

4.Basics of reinforcement learning or instructor consent