Department of Applied Mathematics

Defence Institute of Advanced Technology, Pune
(Deemed to be University)
(An Autonomous Organization, Department of Defence R & D)

M. Tech (Data Science)

From the academic year 2020-21

M.Tech. (Data Science)

Introduction: The Department of Applied Mathematics came into existence with the inception of Institute of Armament Studies in 1953 as Faculty of Applied Mathematics. The faculty constituted of three departments: (1) Applied Mathematics (2) Ballistics (3) Statistics. In 1991 the three departments merged into one and named it as Department of Applied Mathematics.

Department of Applied Mathematics offers a two year Interdisciplinary M. Tech. (Modelling & Simulation) programme, and also offers a Doctoral Degree programme in the areas of Applied Mathematics.

The Department faculty members have been actively involved in the research in different fields of applied mathematics such as ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, Numerical Methods and Optimization, Statistics, Probability, Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning.

This MTech. (Data Science) programme is of two years duration where the student undergoes basic training in the subjects(Core and Elective) related to **probability and statistics, inference, regression, optimization, statistical simulation and data analysis, sampling theory (Math and Statistics); management decision analysis, decision models, game theory (IME, Economics), programming, algorithms, operating systems, databases, signal processing, machine learning and data mining techniques of data science (CS, EE). Information Theory (information, entropy, conditional information, coding), Multi-resolution (multirate) signal processing (wavelets, pyramids), ANN, SVM, Projection pursuit Artificial Intelligence and DSS** through classroom teaching in the first and second year. During this period the student is also exposed to various simulation tools and practicals. The second year is the dissertation phase where the student works under the guidance of a recognized guide on a problem related to Data Science. Course curriculum will be updated periodically to keep pace with contemporary technological advancement.

Why Data Science: Data science is concerned with the acquisition, storage, retrieval, processing and finally the conversion of data into knowledge where the quantum of data is very large. Experiments, observations, and numerical simulations in many areas of science and business are currently generating terabytes (2^{40} bytes) of data, and in some cases are on the verge of generating petabytes (2^{50} bytes) and beyond**.** Today we have been witnessing to an exponential growth of the volume of data produced and stored. This can be explained by the evolution of the technology that results in the proliferation of data with different formats from the most various domains (e.g. health care, banking, government or logistics) and sources (e.g. sensors, social networks or mobile devices). Facebook, for example, has an average of 4.75 billion pieces of content shared among friends every day. Business is generating enormous quantities of data that are too big to be processed and analyzed by the traditional Relational Database Management Systems (RDBMSs) and Data Warehouses (DWs) technologies, which are struggling to meet the performance and scalability requirements. Therefore, in the recent years, a new approach that aims to mitigate these limitations has emerged. Companies like Facebook, Google, Yahoo and Amazon etc. are the pioneers in creating solutions as well as recruiting technologies to deal

with these "Big Data" scenarios. Adopting Big Data-based technologies not only mitigates the problems presented above, but also opens new perspectives that allow extracting value from Big Data. Big Data-based technologies are being applied with success in multiple scenarios like in: (1) e-commerce and marketing, the crowds do on the web allow identifying trends that improve campaigns, evaluate personal profiles of a user, so that the content shown is the one he will most likely enjoy; (2) government and public health, allowing the detection and tracking of disease outbreaks via social media or detect frauds; (3) transportation, industry and surveillance, with real-time improved estimated times of arrival and smart use of resources.

Data science is concerned with the acquisition, storage, retrieval, processing and finally the conversion of data into knowledge where the quantum of data is very large. Two current disciplines that have strong overlap with data science are computer science and statistics. An important difference between Data Science and Computer Science is that Data science heavily uses the more continuous aspects of mathematics together with considerable statistics. In order to handle voluminous data (ranging from terabytes to petabytes) in various forms (structured, semi-structured, unstructured formats and from different sources) of different Veracity (managing the reliability and predictability of inherently imprecise data types will be challenging) and its complexity (relationships, hierarchies, and multiple data linkages will have to be connected and correlated), a systematic approach is required before meaningful output expected from the data collected or received.

Basic four steps which are adapted in Data Science are:

- **Data Collection:** Proliferation of smart devices, sensors, web, mobile and social media has led to explosive amount of complex data. To make use of this data, one needs expertise in Internet of Things and Databases to effectively collect and manage such huge volumes of data.
- **Data Processing:** The next step is to convert the raw data into forms that can be scientifically analyzed, which includes data cleaning and transformation. For example, by transforming social network data into graph data, one can use concepts from Graph Theory to analyze social network data. To process huge volumes of data, one needs expertise in Databases, High Performance Computing and mainly Statistics. The data one needs to handle is a heterogeneous mix of different types of data, such as images, videos, text, social networks, etc. To handle these different types of data one needs expertise in areas such as Image and Video Analytics, Information Retrieval, Social Media Analytics, etc.
- **Data Analysis:** The third step is to analyze the processed data using various Statistical, Data Mining and Machine Learning algorithms. Most of the existing data analysis algorithms do not scale to large datasets. As a result, one needs expertise in Statistics, Data Mining and High Performance Computing to design systems that can efficiently analyze large volumes of complex data.
- **Data Product:** The final step is to make decisions from the data analysis and also deliver the analyzed information to the world in the form of various data products. This is often done using data visualization techniques, which are integrated with various smart devices. This step requires expertise in Information Visualization, Databases and Computer Networks.

Two current disciplines that have strong overlap with data science are computer science and statistics. An important difference between Data Science and Computer Science is that Data science heavily uses the more continuous aspects of mathematics together with considerable statistics. Data Science is the combination of statistics, mathematics, programming, problem-solving, capturing data in ingenious ways, the ability to look at things differently, and the activity of cleansing, preparing and aligning the data

Eligibility Criteria for Admission to join in this programme

M. Tech Data Science	The candidate must have a Valid GATE Score and marks / CPI (Cumulative Performance Index), referred to in subsequent section, implies a minimum of 55% marks/SPI of 5.5 (on a 10-point scale) as long as it is at least seven percent higher than the minimum pass marks/CPI from a recognized Institute / University in B. Tech / BE degree in CSE / IT / ECE / ME / AE. OR MSc / MS degree in CS / IT / Mathematics / Physics / Electronics Provided 1) Mathematics is one of the subject at the graduate level and 2) Knowledge in computer programming is desirable

CSE - Computer Science Engineering

IT - Information Technology

AE - Aerospace Engineering

ECE - Electronics & Communication Engineering

ME - Mechanical Engineering

Semester I:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T /P	
1.	AM 603D	Computer Oriented Optimization Methods	3	1	4
2.	AM 604D	Statistical Computing for Data Science	3	1	4
3.	AM 606D	Scientific Computing	3	1	4
4.	AM 607D	Data Structures and Algorithms with C	3	1	4
5.	CE 615A	Intelligent Algorithms	3	1	4
6.	CE 696A	Artificial Intelligence and DSS	3	1	4
		TOTAL	1 8	6	24

Semester II:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 623D	Machine Learning	3	1	4
2.	AM 624D	Data Science: Tools and Techniques	3	1	4
3.	CE 694	Big Data Analysis and Algorithms	3	1	4
4.		Elective I (Department Electives)	3	1	4
5.		Elective II (Open Elective)	3	1	4
6.		Elective III (Open Elective)	3	1	4
		TOTAL	18	6	24

Semester III:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 651D	M. Tech Dissertation - 1	28**		14
		TOTAL	28		14

Semester IV:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 652D	M. Tech Dissertation - 2	28**		14
		TOTAL	28		14

****Contact Hours / week:-**

- ✓ **One credit in Lecture – L (Theory) / Tutorial (T) mean - one contact hour and**
- ✓ **One credit in Practical (P)(Lab session) / Thesis mean -Two contact hours**

List of Electives are given below:

Few of the elective courses are listed below. However, Students are allowed to choose Elective Course(s) from various M. Tech programmes offering by the respective departments which are as per the DIAT PG Course of Study Book / updates of the course curriculum time to time.

Sl. No.	Course Code	Course
	AM 609D	**Data Science: Industrial Perspectives#**
	AM 625D	Image and Video Analytics
	AM 627D	Information Theory and Coding
	AM 628D	Computational Number Theory and Cryptography
	CE 605	Applied Artificial Intelligent Systems
	CE 607	Decision Support Systems
	CE 610	Information Retrieval Systems
	CE 631	Deep Learning
	CE 632	Computer Vision
	CE 688	Game Theory
	CE 690	Parallel & Distributed Systems
	CE 691	Secure Wireless Sensor Networks
	CE 699	Internet of things
	EE 610D	Multiresolution Signal Processing
	AP 618	Advanced Sensors

- ✓ **# This is an audit course which is mandatory for both the semesters of this programme students.**
- ✓ **Evaluation Process: This is a seminar course where specialists will give talk(s) on various verticals like: biology, healthcare, retail governance, physical sciences, e-commerce, climate, supply chains and financial services, manufacturing, hospitality etc. This seminar series will provide the industry or domain specific context for advanced analytics. Summary report of each presentation of the talk given by the expert will be submitted by each student. In addition to this, at the end of the presentation of the expert talk, an exam will be conducted for 10 marks of each talk and a question paper will be set by the expert who has given the talk given to the students. Students will also explore the journal papers, do literature Survey related to this course and give at least one presentations in a month. A total of minimum of 5 presentations by expert talk and each student by 5 talks will be evaluated. A total of 100 marks evaluation will be done to assess the student in this course.**

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 603D	**Computer Oriented Optimization Techniques**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Linear programming: Simplex method, Two-phase method, Big-M method, duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.	
Assignment problem: Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem.	
Classical optimization techniques: Single variable optimization with and without constraints, multi – variable optimization without constraints, multi – variable optimization with constraints – method of Penalty methods Lagrange multipliers, Kuhn-Tucker conditions.	
Numerical methods for optimization: Minimization and maximization of convex functions- Local & Global optimum- Convergence-Speed of convergence. Nelder Mead's Simplex search method.	
Constrained optimization: Constrained optimization with equality and inequality constraints. Kelley's convex cutting plane algorithm - Gradient projection method - Penalty Function methods. Constrained optimization: Lagrangian method - Sufficiency conditions - Kuhn-Tucker optimality conditions- Rate of convergence - Engineering applications Quadratic programming problems-Convex programming problems.	
Unconstrained optimization: One dimensional minimization - Elimination methods: Fibonacci & Golden section search - Gradient methods - Steepest descent method	
Genetic algorithm (GA) : Differences and similarities between conventional and evolutionary algorithms, working principle, reproduction, crossover, mutation, termination criteria, different reproduction and crossover operators, GA for constrained optimization, draw backs of GA	
Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, random population generation, solving differential equations using GP.	

Texts / References Books

1. **Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.**
2. **Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wieley Eastern Ltd.**
3. **Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.**
4. **Introduction to Optimization, 1988, Beale, John Wiley.**
5. **Optimization for Engineering Design – Kalyanmoy Deb, PHI Publishers**
6. **Genetic algorithms in Search, Optimization, and Machine learning – D.E.Goldberg, Addison Wesley Publishers**

7. **Genetic programming: on the programming of computers by means of natural selection- John R. Koza, MIT Press, 1992.**
8. **Genetic Programming Theory and Practice by Rick Riolo, Bill Worzel, Kluwer Academic Publishers**
9. **Genetic Programming: An Introduction, Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, Frank D. Francone, Morgan Kaufmann Publishers**
10. **Multi objective Genetic algorithms - Kalyanmoy Deb, PHI Publisher**
11. **Numerical Methods and Optimization, Hari Arora, S.K. Kataria& Sons**
12. **Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer**
13. **David G Luenberger, .Linear and Non Linear Programming., 2nd Ed, Addison-Wesley.**
    Bazarra M.S., Sherali H.D. & Shetty C.M., Nonlinear Programming Theory and Algorithms, John Wiley, New York, 1979.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 604D	**Statistical Computing for Data Science**	**CORE**	**3**	**0**	**1**	**4**
Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Probability Theory: Sample Spaces- Events - Axioms – Counting - Conditional Probability and Bayes' Theorem – The Binomial Theorem – Random variable and distributions : Mean and Variance of a Random variable-Binomial-Poisson-Exponential and Normal distributions. Curve Fitting and Principles of Least Squares- Regression and correlation.	
Sampling Distributions & Descriptive Statistics: The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling distributions (Chi-Square, t, F, z). Test of Hypothesis- Testing for Attributes – Mean of Normal Population – One-tailed and two-tailed tests, F-test and Chi-Square test - - Analysis of variance ANOVA – One way and two way classifications.	
Tabular data- Power and the computation of sample size- Advanced data handling Multiple regression- Linear models- Logistic regression- Rates and Poisson regression Nonlinear curve fitting	
Density Estimation- Recursive Partitioning- Smoothers and Generalised Additive Models - Survivals Analysis- Analysing Longitudinal Data- Simultaneous Inference and Multiple Comparisons- Meta-Analysis- Principal Component Analysis- Multidimensional Scaling Cluster Analysis	
Introduction to R- Packages- Scientific Calculator- Inspecting Variables- Vectors Matrices and Arrays- Lists and Data Frames- Functions- Strings and Factors- Flow Control and Loops- Advanced Looping- Date and Times.	

Texts / References Books

1. **Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd.**

2. **Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.**
3. **An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.**
4. **All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.**
5. **Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.**
6. **Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Speigel, John Schiller, R Alu Srinivasan, Tata McGraw Hill**
7. **Richard Cotton, "Learning R", O'Reilly, 2013.**
8. **Dalgaard, Peter, "Introductory statistics with R", Springer Science & Business Media, 2008.**
9. **Brain S. Everitt, "A Handbook of Statistical Analysis Using R", Second Edition LLC, 2014.**
10. **Samir Madhavan, "Mastering Python for Data Science", Packt, 2015.**
11. **Sheldon M. Ross,"Introduction to Probability and Statistics for Engineers and Scientists", 4th edition, Academic Press; 2009.**
12. **Paul Teetor, "R Cookbook, O'Reilly, 2011.**
    Mark Lutz ,"Learning Python", O'Reilly,5th Edition,2013

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 606D	**Scientific Computing**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Definition and sources of errors, solutions of nonlinear equations; Bisection method, Newton's method and its variants, fixed point iterations, convergence analysis; Newton's method for non-linear systems; Finite differences, polynomial interpolation; Numerical integration - Trapezoidal and Simpson's rules, Gaussian quadrature; Initial value problems - Taylor series method, Euler and modified Euler methods, Runge-Kutta methods.	
Linear systems – All variants of Gaussian elimination and LU factorization, Cholesky factorization. Linear least-squares problem - Normal equations, rotators and reflectors, QR factorization via rotators, reflectors and Gram Schmidt orthonormalisation, QR method for linear least-squares problems, rank deficient least-squares problems.	
Singular value decomposition (SVD) – numerical rank determination via SVD, solution of least squares problems, Moore- Penrose inverse, low rank approximations via SVD, Principal Component Analysis, applications to data mining and image recognition.	
Eigenvalue Decomposition - Power, inverse power and Rayleigh quotient iterations, Schur's decomposition, unitary similarity transformation of Hermitian matrices to tridiagonal form, QR algorithm, implementation of explicit QR algorithm for Hermitian matrices	

Texts / References Books

1. **L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, Phildelphia, 1997.**
2. **D. S. Watkins, Fundamentals of Matrix Computation, 2nd Edition, Wiley, 2002.**
3. **L. Elden Matrix Methods in Data Mining and Pattern Recognition, SIAM, Philadelphia, 2007**
4. **D. Kincaid and W. Cheney, Numerical Mathematics and Computing, 7th Edn., Cengage, 2013.**
5. **K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edn., John Wiley, 1989.**
6. **L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, 1997.**
7. **D. S. Watkins, Fundamentals of Matrix Computation, 2nd Edn., Wiley, 2002.**

8. **D. Kincaid and W. Cheney, Numerical Analysis: Mathematics of Scientific Computing, 3rd Edn., AMS, 2002.**
K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edn., John Wiley, 1989.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 607D	**Data Structures and Algorithms with C**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Preliminaries: Concept & notation, common operation on data structures, algorithm complexity, time space trade-off between algorithm, physical & logical representation of different data structures. Arrays: Arrays defined, representing arrays in memory, Various operation (traversal, insertion, deletion), Multidimensional arrays, Sequential allocation, Address calculation, Sparse arrays. List: Simple Array Implementation of Lists, Linked Lists, Doubly Linked Lists, Circularly Linked list. Stack: Stack Model, Implementation of Stacks, Applications of Stacks.	
Queue: Queue Model, Array Implementation of Queues, Applications of Queues. Trees: Implementation Of Trees, Tree Traversal with an application, Binary Trees-Implementation, Expression trees, Binary Search Tree, Binary Search Trees, Various Operations On BST- Make Empty, Find, Find Min and Find Max, Insert, Delete, Average-Case Analysis, AVL Trees- Single Rotation , Double Rotation, B-trees. Hashing: Definition, Hash Function, Separate Chaining, Open Addressing- Linear Probing, Quadratic Probing, Double Hashing, Rehashing, Extendible Hashing.	
Priority Queues: Model, Simple Implementation, Binary Heap-Structure Property, Heap Order Property, Basic Heap Operation, Application Of Priority Queues- The Selection Problem, Event Simulation, Heap Sorting: Preliminaries, Insertion Sort- Algorithm, Analysis Of Insertion Sort, Shell sort- Analysis Of Shell sort, Heapsort- Analysis Of Heapsort, Merge sort- Analysis Of Merge sort, Quicksort- Picking theb Pivot, Partitioning Strategy, Small Arrays, Analysis Of Quicksort, Bucket Sort.	
Graphs: Definitions, Representation Of Graphs, Topological Sort, Shortest Path Algorithms- Unweighted Shortest Paths, Dijkstra's Algorithm, Graph With Negative Edge Costs, Acyclic Graphs, All- Pairs Shortest, Minimal Spanning Tree- Prim's Algorithm, Kruskal's Algorithm, Application Of Depth First Search- Undirected Graphs, Biconnectivity, Euler Circuits, Directed Graphs. Algorithm Design Techniques: Greedy Algorithms- A Simple Scheduling Problem, Huffman Codes, Divide And Conquer Running Time Of Divide and Conquer Algorithms, Closets-Points Problem, The Selection Problem	

Texts / References Books

1. **Mullis Cooper: Spirit of C: Jacob Publications**

2. **Yashwant Kanetkar: Let us C: BPB**
3. **Gotterfied B.: Programming in C: Tata McGraw Hill**
4. **Jean Paul Tremblay & Paul G. Sorenson: An Introduction to Data Structures with Applications: Tata McGraw Hill.**
   Robert L. Kruse: Data Structures & Program Design: PHI

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 609D	**Data Science: Industrial Perspectives**	**Audit - Compulsory**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING / AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
This is a seminar course where specialists will give talk(s) on various verticals like: biology, health, governance, physical sciences, e-commerce, climate, supply chains and finance etc. This seminar series will provide the industry or domain specific context for advanced analytics. This will include the following topics: ➢ Industry/domain overview description, history, challenges faced, key players, industry trends. ➢ Key business processes (marketing, financial, sales, logistics, order fulfilment, procurement, executive reporting, customer facing). ➢ Key data elements for each major business process and systems of record. Critical metrics (KPI) for each business process and the definitions. Sources/location of the data, typical errors in data. ➢ Benchmarking information sources. ➢ Signal and noise in system information relevance. ➢ Classes of users and associated metrics/information needed/questions asked or would like to ask.. Potential for new apps. ➢ Historical access to information and impacts. ➢ Impact of social media, text analysis, web and other sources of information. Timeliness of data/information. ➢ Predictive Vs historical analysis (customer segmentation, churn etc).	

Subject domains / industry

- Politics/elections required reading http://fivethirtyeight.com/ Nate Silvers book (signal and the noise), invite party strategists from major parties. Crowd sourced analytics (www.kaggle.com).
- Healthcare invite CFO/CMO from AIIMS, Apollo and/or other large hospitals to discuss metrics for hospital operation including financial, operational and medical procedures efficacy.
- Supply chain management invite VP/Operations/Logistics from auto companies, Flipkart/Amazon to discuss supply chain analytics and issues.
- Weather/climate change National weather bureau chief.
- Agriculture Industry think tanks re crop yields, weather patterns, evolving trends.
- Corporate - HR, Finance, Sales, Marketing, Web marketing, IT.
- Customer services/ support.

- Website analytics - Google.
- Financial Services Chief Marketing Officers/CEO to discuss customer analytics, services, service quality, innovation, profitability.
- Energy prospecting ONGC, Chevron, BP.
- Security communications, RAW, National Security agencies.
- Entertainment - movie/show launches.
- Retail Hindustan Lever, Proctor & Gamble, Godrej.
- Telecom Airtel, BSNL, Vodafone

Education Teach for India, UNICEF, Gates Foundation.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 623D	**Machine Learning**	**CORE**	**3**	**0**	**1**	**4**
Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Introduction - Definitions – Theoretical- Definitions – Applied Practice- Well-posed learning problems, designing a learning system, Perspectives and issues in machine learning	
Concept learning and the general to specific ordering – Introduction, A concept learning task, Concept learning as search, Find-S: finding a maximally specific hypothesis, Version spaces and the candidate elimination algorithm, Remarks on version spaces and candidate elimination, Inductive bias	
Evaluation Hypotheses – Motivation, Estimation hypothesis accuracy, Basics of sampling theory, A general approach for deriving confidence intervals, Difference in error of two hypotheses, Comparing learning algorithms	
Bayesian learning – Introduction, Bayes theorem, Bayes theorem and concept learning, Maximum likelihood and least squared error hypotheses, Maximum likelihood hypotheses for predicting probabilities, Minimum description length principle, Bayes optimal classifier, Gibbs algorithm, Naïve Bayes classifier, An example learning to classify text, Bayesian belief networks The EM algorithm.	
Graphical and sequential models- Bayesian networks- conditional independence Markov random fields-inference in graphical models- Belief propagation- Markov models- Hidden Markov models- decoding states from observations- learning HMM parameters.	
Computational learning theory – Introduction, Probability of learning an approximately correct hypothesis, Sample complexity for Finite Hypothesis Space, Sample Complexity for infinite Hypothesis Spaces, The mistake bound model of learning	
Instance-Based Learning- Introduction, k -Nearest Neighbour Learning, Locally Weighted Regression, Radial Basis Functions, Case-Based, Reasoning, Remarks on Lazy and Eager Learning (Passive vs Active learning, V-C dimension). Clustering Methods-Partitioned based Clustering - K-means- K-medoids; Hierarchical Clustering - Agglomerative- Divisive- Distance measures; Density based Clustering - DBScan; Spectral clustering.	
Types of Machine Learning –Supervised –Unsupervised – Reinforcement-Decision Tree learning. **Neural networks**- the perceptron algorithm- multilayer perceptron's- back propagation nonlinear regression- multiclass discrimination- training procedures- localized network structure - dimensionality reduction interpretation.	

Texts / References Books

1. **Tom M. Mitchell, Machine Learning –- MGH**

2. **Stephen Marsland , Machine Learning: An Algorithmic Perspective, Taylor & Francis (CRC)**
3. **William W Hsieh, , Machine Learning Methods in the Environmental Sciences, Neural Networks, Cambridge Univ Press.**
4. **Richard o. Duda, Peter E. Hart and David G. Stork, pattern classification, John Wiley & Sons Inc., 2001.**
5. **Chris Bishop, Neural Networks for Pattern Recognition, Oxford University Press, 1995**
6. **Charles Dierbach, Introduction to computer science using Python a computational problem solving focus, John-Wiley & Sons, 2012.**
7. **T. Hastie, R. Tibshirani and J. Friedman, "Elements of Statistical Learning", Springer, 2009.**
8. **E. Alpaydin, "Machine Learning", MIT Press, 2010.**
9. **K. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.**
10. **C. Bishop, "Pattern Recognition and Machine Learning, Springer", 2006.**
11. **Shai Shalev - Shwartz, Shai Ben-David, "Understanding Machine Learning: From Theory to Algorithms", Cambridge University Press, 2014.**

John Mueller and Luca Massaron, "Machine Learning For Dummies", John Wiley & Sons, 2016.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 601	**Data Science: Tools and Techniques**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Programming Language: Introduction to Python, Programming Interfaces, Spyder, Python script file, Print Message to Standard Output, variables and data types, Reading Input from console, Type Conversion, Arithmetic Operators and Conditions	
Control Flow - Relational Operators, if…else statement , if…else if…else statement, Logical operators, While Loops, break and continue statement, Loops with else statement, pass statement, Python for loop, Range Function,	
Lists: Creating List, Accessing elements from List, Inserting and Deleting Elements from List, List Slicing, Joining two list, Repeating sequence, Nested List, Built-in List Methods and Functions, Searching elements in List, Sorting elements of List	
Python Data Structures: Python Set, Creating Set, Adding/Removing elements to/from set , Python Set Operations : Union, Intersection, Difference and Symmetric Difference, Python Tuple, Creating Tuple, Understanding Difference between Tuple and List, Accessing Elements in Tuple, Python Dictionary, Creating Dictionary, Accessing / Changing / Deleting Elements in Dictionary	
Data Pre-processing Numpy and Pandas: Numpy**,** Creating Numpy array, Numpy data type, Accessing Elements in Numpy, Element wise calculations, Vectorized Operation, Numpy Subsetting, Built-in Methods of Numpy, Array creation Methods: arange, linspace, eye, Numpy 2D Array, 2D Array Indexing, Matrix Calculations	
Pandas: Reading Files, Writing Files, Loading Data with Pandas, Selecting Specific Columns, Selecting rows using labels: loc, Selecting rows using position: iloc, Adding and Removing rows and Columns, Filtering Data Frames, Importing Data from csv Files, Missing Data Handling, OnHot Encoder, Label Encoding, Data Splitting, Training Data, Importance of Test Data.	
Built-in Dictionary Methods and Functions: Data Analytics**,** Data preprocessing, Analyzing data, Handling missing data, Applying Machine learning techniques to analyze data. **Functions:** Defining Functions in Python, Function Argument, Single Parameter	

Functions, Function Returning single Values, Functions with multiple parameter, Function that return Multiple Values, Functions with Default arguments, Named arguments, Scope and Lifetime of Variables, Global specifier	
Data Visulization With MatplotLib: Introduction to Matplotlib, Basic Plotting with Matplotlib, Line Plot on Example DataSet, Exploring the plot Options, Other types of Plots, Bar Plot, Pie Plot, Histograms	
Regression for data analysis: Introduction to regression and Classification, Types of Classification, Simple Linear regression Intuition, Sci kit Learn Library, Hands on Lab on Simple Linear Regression, Performance Evaluation **Regression and Classification Part 2** : Multivariable Linear regression, Hands on Example on Multivariable LR, Performance Evaluation, Improving the Performance, Backward Elimination method, Other types of Regression Models, Performance Evaluation of different Regression Models	
Classification in Machine Learning : Classification Introduction, K-Nearest Neighbours, Decision Tress, Naïve Bayes algorithm, Support Vector Machine, Introducing Correlation Matrix	
Deep Learning: Deep Learning Introduction, Deep learning methods, Supervised Deep learning, Unsupervised deep learning	
Artificial Neural Networks(ANN): Introduction to ANN, Practical use cases of ANN, Understanding Neural Networks, Hidden Layers, Activation Functions-(Relu, Soft max), Feed forward and Backward Propagation, Introducing Keras and Tensor flow for Neural Network, Hands on Example on ANN to understand above concepts (defining the input layers, creating hidden layers, Activation function usage, Output Layer), Understanding the network training, Module loss, Validation loss calculation, Performance Improvement by introducing Dropout layer.	
CNN in Computer Vision application: Image Processing introduction, Types of Images, Importing and exporting images, Visualizing Images in Python, Image filtering, Data Augmentation, Hands-on Laboratory to understand CNN better"Tagging Images into different labels", Padding in CNN, Batch Normalization, Confusion Matrix, Mini project Building CNN model to recognize the handwritten digit, Saving the Models, Using Pre-trained Models, Recurrent Neural Networks.	

Texts / References Books

1. **Samir Madhavan, Mastering Python for Data Science, Packt Publishing, 2015**
2. **Sebastian Raschka Python Machine Learning, Packt Publishing, 2015**
3. **H. Bhasin, Python Basics, Mercury Learning And Information, 2019**
4. **Magnus Lie Hetland, Beginning Python, Apress, 2015**
5. **Nikhil Ketkar, Deep Learning withPython, Apress, 2017**
6. **Peter Norton, Alex Samuel, David Aitel, Eric Foster-Johnson, Leonard Richardson, Jason Diamond, Aleatha Parker, Michael Roberts Beginning Python, Wiley Publishing, 2005**
7. **Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, Packt Publishing, 2008.**
8. **Programming Python, Mark Lutz, O'Reilly Media, 2010.**
9. **Programming in Python 3: A Complete Introduction to the Python Language, Mark Summerfield, Addison-Wesley, 2010**
10. **Practical programming: An introduction to computer science using Python, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf, 2009.**
11. **Core Python Programming, 2nd Edition, Wesley Chun, Prentice Hall, 2006.**
12. **Core Python Applications Programming, Wesley J Chun, Prentice Hall, 2012**
13. **Programming Computer Vision with Python: Tools and algorithms for analyzing images, Jan Erik Solem, O'Reilly Media, 2012**
14. **Convolutional Neural Networks in Python, Lazy Programmer. Kindle Edition**
    Neural Network Projects with Python, James Loy, Packt Publishing

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 625D	**Image and Video Analytics**	**ELECTIVE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Digital Image Fundamentals: Introduction – Origin –Steps in Digital Image Processing – Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – Image Sensing and Acquisition – Image Sampling and Quantization – Relationships between pixels.	
Image Enhancement: Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening Spatial Filtering – Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters.	
Image Restoration: Noise models – Mean filters – Order Statistics – Adaptive filters – Band reject – Band pass – Notch – Optimum notch filtering – Inverse Filtering – Constrained Least Square Filtering – Wiener filtering.	
Morphological image processing: Dilation, Erosion, Opening, Closing, Applications to; Boundary extraction, Region filling, Extraction of connected components.	
Image Compression: Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding –Bit – Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding –Wavelet Coding – Compression Standards – JPEG2000.	
Image Segmentation and Representation: Segmentation – Detection of Discontinuities – Edge Linking and Boundary detection – Region based segmentation; Representation – Boundary descriptors – Simple Descriptors – Shape numbers –Regional descriptors – Simple and Topological Descriptors – Introduction to Image Processing Toolbox – Practice of Image Processing Toolbox – Case studies–Various Image Processing Techniques. Object recognition: Decision-theoretic methods. SVM, feature selection methods, feature extraction methods, Maximum Output Information (MOI) for joint selection and classifier training.	
Colour models and Transformations – Image and Video segmentation - Image and video demonising- Image and Video enhancement- Image and Video compression. Object detection and recognition in image and video - Texture models Image and Video classification models- Object tracking in Video	

Texts / References Books

1. **Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall.**

2. **Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing.**
3. **Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.**
4. **Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.**
5. **Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.**
6. **Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.**
7. **Rick Szelisk, "Computer Vision: Algorithms and Applications", Springer 2011.**
8. **Jean-Yves Dufour, "Intelligent Video Surveillance Systems", Wiley, 2013.**
9. **Caifeng Shan, Fatih Porikli, Tao Xiang, Shaogang Gong, "Video Analytics for Business Intelligence", Springer, 2012.**

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 627D	**Information Theory and Coding**	**ELECTIVE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Information Theory: Uncertainty, Information, Entropy, Discrete Memoryless Channel, Mutual Information, Channel Capacity, Shannon's Theorems, Gaussian Channel, Limits to Communication	
Linear Block Codes: Groups, Fields and Vector Spaces, Construction of Galois Fields of Prime Order, Syndrome Error Detection, Standard Array and Syndrome Decoding, Hamming Codes	
Cyclic Codes: Polynomial Representation of Code words, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes	
Structure and Properties of Convolutional Codes: Convolutional Encoder Representation, Tree, Trellis, and State Diagrams, Distance Properties of Convolutional Codes, Punctured Convolutional Codes and Rate Compatible Schemes	
Decoding of Convolutional Codes: Maximum Likelihood Detection, The Viterbi Algorithm	
Automatic Repeat Request Strategies: Basic Techniques, Hybrid ARQ	
Introduction to Cryptography: History. Overview of cryptography, Simple classical cryptosystems, Cryptanalysis **Perfect Secrecy:** Information theoretic security, One time pad **Secret and Public Key Encryption**: Description of DES, Description of AES (advanced encryption standard), Trapdoor Function, The RSA Algorithm	

Texts / References Books

1. **Jorge Castiñeira Moreira, Patrick Guy Farrell , Essentials of Error-Control Coding, John Wiley, 2006. ISBN: 978-0-470-02920-6**
2. **G. A. Jones and J. M. Jones, "Information and Coding Theory," Springer, ISBN 1-85233-622-6, 3rd Edition.**
3. **John F. Dooley, History of Cryptography and CryptanalysisCodes, Ciphers, and Their Algorithms, Springer, 2018, ISBN 978-3-319-90442-9**
4. **Maria Welleda Baldoni, Ciro Ciliberto, Giulia Maria Piacentini Cattaneo, Number Theory, Elementary Cryptography and Codes, Springer, 2009, ISBN 978-3-540-69199-0**

5. **Jorge Castiñeira Moreira, Patrick Guy Farrell, Essentials of Error-Control Coding, John Wiley & Sons Ltd, 2006, ISBN-13 978-0-470-02920-6**
6. **Hideki Imai, Essentials of Error-Control Coding Techniques, Academic Press, Inc., 1990, ISBN 0-12-370720-X**
7. **Dominic Welsh, Codes and Cryptography, Oxford Science Publications, 1988**
8. **T. M. Cover, J. A, Thomas, "Elements of information theory," WielyInterscience,2nd Edition, 2006**
9. **R. W. Hamming, "Coding and information theory," Prentice Hall Inc., 1980.**
10. **Robert M. Gray, Entropy and Information Theory, 2ndEdition, Springer, 2011, ISBN 978-1-4419-7969-8**

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 628D	**Computational Number Theory and Cryptography**	**ELECTIVE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Introduction: Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon's Theory, Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem	
Number Theory: **Divisibility:** Representations of Integers, Computer Operations with Integers, Complexity of Integer Operations, Divisibility, Prime Numbers, The Fundamental Theorem of Arithmetic, Sieve of Eratosthenes, The Distribution of Primes, Greatest Common Divisor, Euclidean Algorithm, Mersenne Numbers, Fermat Numbers, Perfect numbers **Congruence:** Congruences, Congruence Applications, Linear Congruences, The Chinese Remainder Theorem, Theorems of Fermat and Euler- Fermat, Wilson's Theorem, Pseudo Primes, Carmichael Numbers, The Euler Phi-Function, The Sum and Number of Divisors, Quadratic Residue, Quadratic Reciprocity. Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Quadratic Reciprocity Law, **Inter Factorization and Primality Testing Algorithms:** Complexity of Number Theoretic Algorithms, Fermat's Factorization, Kraitchik's Improvement, Trial division, Pollard Rho Algorithm, p-1 method, CFRAC method, quadratic sieve method, elliptic curve method. **Primality testing algorithms:** Fermat test, Miller-Rabin test, Solovay-Strassen test, AKS test.	
Computing discrete logarithms over finite fields: Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method, index calculus methods, linear sieve method, Coppersmith's algorithm.	
Representation of finite fields: Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Prime and extension fields, representation of extension fields, polynomial basis, primitive elements, normal basis, optimal normal basis, irreducible polynomials. Binary Fields and their application in Cryptosystems	

Elliptic Curve Cryptography: Introduction to Elliptic Curves, The elliptic curve group, elliptic curves over finite fields, Schoof's point counting algorithm, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.	

Texts / References Books

1. **J. Katz and Y. Lindell, Introduction to Modern Cryptography, 2nd Edition, Chapman & Hall/CRC, 2008**
2. **Abhijit Das, Computational number theory, Chapman and Hall/CRC., 2018**
3. **N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.**
4. **I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, John Wiley & Sons, Inc 2006.**
5. **L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.**
6. **J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.**
7. **D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.**
8. **J. Pipher, J. Hoffstein and J. H. Silverman , An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.**
9. **G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.**
10. **R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.**
11. **Song Y. Yan: Number Theory for Computing, Springer-Verlag, Second Edition,2002.**
12. **T. H. Cormen, C. E. Leiserson, and R. L. Rivest: Introduction to Algorithms, Second Edition, Prentice Hall of India, 1994.**
13. **K. Rosen: Elementary Theory of Numbers, Fifth Edition, Addison Wesley, 2004.**
14. **D. M. Bressoud: Factorization and Primality Testing, Springer-Verlag, 1989.**
15. **V. Shoup, A computational introduction to number theory and algebra, Cambridge University Press**
16. **M. Mignotte, Mathematics for computer algebra, Springer-Verlag.**
17. **I. Niven, H. S. Zuckerman and H. L. Montgomery, An introduction to the theory of numbers, John Wiley**
18. **J. von zur Gathen and J. Gerhard, Modern computer algebra, Cambridge University Press.**
19. **R. Lidl and H. Niederreiter, Introduction to finite fields and their applications, Cambridge University Press.**
20. **A. J. Menezes, Applications of finite fields, Kluwer Academic Publishers**
21. **J. H. Silverman and J. Tate, Rational points on elliptic curves, Springer International Edition.**
22. **D. R. Hankerson, A. J. Menezes and S. A. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag**
23. **A. Das and C. E. Veni Madhavan, Public-key cryptography: Theory and practice, Pearson Education Asia**

    H. Cohen, A course in computational algebraic number theory, Springer-Verlag

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
EE 610D	**MULTIRESOLUTIONAL SIGNAL PROCESSING**	**ELECTIVE**	**3**	**0**	**1**	**4**
Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Electronics Engineering**	**10**	**10**	**10**	**20**	**70**

Course Contents	No of hours
Introduction to Multiresolution Analysis: Vector Spaces – Properties– Dot Product – Basis – Dimension, Orthogonality and Orthonormality – Relationship Between Vectors and Signals – Signal Spaces – Concept of Convergence – Hilbert Spaces for Energy Signals- Fourier Theory: Fourier series expansion, Fourier transform, Short time Fourier transform, Time-frequency analysis, Definition of Multi Resolution Analysis (MRA) – Haar Basis – instruction of General Orthonormal MRA – Wavelet Basis for MRA – Continuous Time MRA Interpretation for the DTWT – Discrete Time MRA – Basis Functions for the DTWT – PRQMF Filter Banks.	
Advanced DSP Techniques: Matrix factorizations and least squares filtering, optimal linear filter theory, classical and modern spectral estimation, adaptive filters, and optimal processing of spatial arrays, Multirate signal processing, Multirate digital signal processing, Decimation, interpolation, sampling rate conversion, filter design and implementation for multirate conversion, sampling rate conversion by an arbitrary factor, applications of multirate signal processing.	
Wavelet Transform Techniques: Definition and Properties – Concept of Scale and its Relation with Frequency – Continuous Wavelet Transform (CWT) – Scaling Function and Wavelet Functions (Daubechies Coiflet, Mexican Hat, Sinc, Gaussian, Bi Orthogonal)– Tiling of Time – Scale Plane for CWT. DISCRETE WAVELET TRANSFORM Filter Bank and Sub Band Coding Principles – Wavelet Filters – Inverse DWT Computation by Filter Banks – Basic Properties of Filter Coefficients – Choice of Wavelet Function Coefficients – Derivations of Daubechies Wavelets – Mallat's Algorithm for DWT – Multi Band Wavelet Transforms Lifting Scheme- Wavelet Transform Using Polyphase Matrix Factorization – Geometrical Foundations of Lifting Scheme –Lifting Scheme in Z –Domain	
Advanced Transform Techniques for MSP: Frequency for signal and image analysis, spatial frequency components, Signal/image restoration using the Fourier domain, Homomorphic filtering, Heisenberg plane, Huff transform, Examples of the Windowed FT, Gabor Transform in Heisenberg space, ACT, DCT, Hilbert transform, PC: from signals to images, Fuzzy logic for signal/image/video processing, applications of MSP in machine learning, Machine Learning for Sensors and Signal Data.	
MSP implementations in FPGA: Digital Signal Processing Designing for FPGA Architectures, filter designs, IP implementations, real-time MSP architecture implementations, high-speed signal recording, handling and processing, MAC engine implementations, speech, image and video processing, Implementations of DSP hardware technologies, DSP arithmetics, FIR and IIR digital filters, Multirate signal processing, Fourier transforms, and Adaptive filters, hybrid designs.	

Texts / References Books

1. **Moon & Stirling, Mathematical Methods and Algorithms for Signal Processing, Prentice Hall, 2000. ISBN 9780201361865 (required)**
2. **Adaptive Filter Theory by Simon Haykin, Prentice Hall, 2002 Neural and Adaptive Systems by Jose Principe et al, Joh Wiley & Sons, 2000.**
3. **Wavelets and Subband Coding by Martin Vetterli and JelenaKovacevic, Prentice Hall, 2007. Notes and papers**
4. **Discrete-Time Signal Processing by A. V. Oppenheim and R. W. Schafer, 3rd Edition, 2014.**
5. **Digital Signal Processing: A Computer-based Approach by S. K. Mitra, 4th Edition, 2013.**
6. **Multirate Systems and Filter Banks by P. P. Vaidyanathan, 1st Edition, 1993 (1st Pearson Impression in 2006).**
7. **http://firasaboulatif.free.fr/index_files/gaidaa%20book/Digital%20Signal%20Processing/Multirate%20Filtering.pdfv**
8. **http://www.doiserbia.nb.rs/img/doi/0353-3670/2007/0353-36700703437R.pdf**

9.	**https://reality.ai/machine-learning-for-sensors-and-signal-data/** **https://freevideolectures.com/course/3042/advanced-digital-signal-processing**