Master of Technology (Data Science)

Course Structure and Syllabus

A student shall have to earn a minimum of 50 credits at the end of II year in order to be eligible for the award of M.Tech. Degree in Data Science.

Semester I

S. No.	Course Name	Credits
1.	Mathematical Foundation for Data Science CS-904	3
2.	Data Structure and Algorithms CS-903	3
3.	Optimization Techniques for Data Science CS-905	3
4.	Big Data Management CS-902	3
5.	Artificial Intelligence and Machine Learning CS-901	3

Semester II

S. No.	Course Name	Credits
1.	Data Visualization CS-906	3
2.	Elective-I	3
3.	Elective II	3
4.	Elective III	3
5.	Elective IV	3

Semester III

S.No.	Course Name	Credits
1	Research Reading and Laboratory CS-907	3
2	Seminar CS-908	3

Semester IV

S.No.	Course Name	Credits
1	Dissertation	14

List of Electives Courses for M. Tech (Data Science) in Semester II

Course	Course
1. Design of Experiments CS-927	25. Computer Vision CS-919
2. Stochastic Modeling And Applications CS-948	26. Digital Image Processing CS-928
3. Regression & Time Series Analysis CS-941	27. Data Warehouse CS-925
4. Computational Intelligence & Applications CS-918	28. Statistical Signal Processing CS-947
5. Speech & Natural Language Processing CS-946	29. Data Compression CS-921
6. Cloud Computing CS-916	30. Cyber Security CS-920
7. Internet of Things CS-932	31 Brain Theory & Neural Networks CS-915
8. Nature Inspired Algorithms CS-936	32. Blockchain Technology CS-914
9. Social Network Analytics CS-944	33. Geo Spatial Informatics CS-930
10. Programming for Data Science CS-940	34. Multicast Communication CS-933
11. Computational Finance CS-917	35. Research Methodology CS-942
12. Bioinformatics CS-913	36. Academic Ethics and Technical Writing CS-911
13. Data Mining & Pattern Recognition CS-922	37. Multimedia Communication CS-935
14. Econometrics CS-929	38. Networking for Big Data CS-937
15. Spatial Data Analysis and GIS CS-945	39. Deep Learning CS-926
16. Big Data Analytics CS-912	
17. Information Theory CS-931	
18. Data Stream Management CS-924	
19. Multimedia and Video Analytics CS-934	
20. Web Mining CS-949	
21. Probabilistic Graphical Models CS-938	
22. Probabilistic Risk Assessment CS-939	
23. Data Security CS-923	
24. Smart Camera & Visual Sensor Networks CS-943	

Syllabus

Semester: I

Compulsory Courses

1. Mathematical Foundation for Data Science

Probability, Statistics and Random Processes: Probability theory and axioms; Random variables; Probability distributions and density functions (univariate and multivariate), Marginal Probability, Conditional Probability, The Chain Rule of Conditional Probabilities; Expectations and moments; Covariance and correlation; Statistics and sampling distributions; Hypothesis testing of means, proportions, variances and correlations; Confidence (statistical) intervals; Correlation functions; White-noise process.

Linear Algebra: Matrices and their properties (determinants, traces, rank, nullity, Linear Dependence and Span etc.); Eigenvalues and eigenvectors; Matrix factorizations; Inner products; Distance measures; Projections; Notion of hyperplanes; half-planes.

Suggested Readings:

1. Strang, Gilbert. Introduction to Linear Algebra. 4th ed. Wellesley, MA: Wellesley-Cambridge Press, February 2009
2. S.M. Ross, Introduction to Probabiltity Models,8th edition. Academic Press,2004
3. Montgomery, D. C. and G. C. Runger (2011). Applied Statistics and Probability for Engineers. 5th Edition. John Wiley & Sons, Inc., NY, USA
4. Cathy O'Neil and Rachel Schutt (2013). Doing Data Science, O'Reilly Media

2. Data Structure and Algorithms

Introduction to C programming, Complexity of Algorithms: Worst case, Average case and Amortized Complexity, Algorithm Analysis, Lists, Stacks and Queues, Trees: Binary Search Trees, AVL Trees, Red-Black Trees, M-way and B Trees, Splay Trees, Hash Tables, Priority Queues: Binary Heap, D-Heaps, Skew Heaps, Binomial Queues, Sorting: Quick sort, Heap Sort, Merge Sort and External Sorting, Bin and Radix Sort, Graphs: Topological Sort, Shortest Path, Network Flow Problem, Minimum Spanning Tree, Algorithm Design Techniques: Greedy Algorithms, Divide and Conquer, Dynamic Programming, Randomized Algorithms, Back Tracking, NP Completeness

Suggested Readings:

1. A. V. Aho, J. E. Hopcraft and J. D. Ullman. "Data Structures and Algorithms", Addison Wesley, 1983
2. M. A. Weiss, "Data Structures and Algorithm Analysis in C", Addison Wesley 2002
3. T. Cormen, C. Leiserson, R. Rivest and C. Stein, "Introduction to Algorithms", Prentice Hall, 2010
4. D. Knuth, "The Art of Computer Programming", Vol I and Vol III, Addison Wesley, 2011

3. Optimization Techniques for Data Science

Unconstrained optimization; Necessary and sufficiency conditions for optima; Newton Method, Jacobian and Hessian Matrices Gradient descent method, Stochastic Gradient descent method and Conjugate Gradient descent method; Constrained optimization, KKT conditions; Introduction to non-gradient techniques; Introduction to least squares optimization; Optimization view of machine learning, Regularization strategies (Parameter Norm Penalties, L2 Parameter Regularization, L1 Regularization), Norm Penalties as Constrained Optimization

Suggested Readings:

1. C. S. Beightler , D. T. Phillips and D. J. Wilde,"Foundations of Optimization", Prentice Hall, 1979
2. E. K. P. Chong and S. H. Zak, "An Introduction to Optimization", John Wiley and Sons, 2013
3. K. Lange, "Optimization", Springer-Verlag, 2004
4. David G. Luenberger (1969). Optimization by Vector Space Methods, John Wiley & Sons (NY)

4. Big Data Management

Introduction to Big Data, Big Data Architecture, Integrated with Big Data Capabilities: storage management, processing, data integration, statistical analysis, large file system, distributed file system, MapReduce. HDFS and Hadoop, Data analysis using statistical methods and visualization, computation predictive analysis of data, Mining of Big data.

Suggested Readings:

1. Rajaraman, A., Ullman, J. D., Mining of Massive Datasets, Cambridge University Press, United Kingdom, 2012
2. Berman, J.J., Principles of Big Data: Preparing, Sharing and Analyzing Complex Information, Morgan Kaufmann, 2014
3. Barlow, M., Real-Time Big Data Analytics: Emerging Architecture, O Reilly, 2013
4. Schonberger, V.M. , Kenneth Cukier, K., Big Data, John Murray Publishers, 2013

5. Artificial Intelligence and Machine Learning

Introduction of Artificial Intelligence; Knowledge representation using Predicate Logic, Blind search and search based on heuristics, Search using constraint satisfaction, Adversarial Search, Knowledge representation using Frames and Conceptual Dependency

Introduction of machine learning; Supervised Learning: Nearest-neighbour Method, Linear Regression, Logistic Regression, Artificial Neural Network, Bayesian Classification, Naive Bayes, Support Vector Machine, Decision Trees, Bias-Variance dilemma, Model Selection; Unsupervised learning: K-Means Algorithm, Hierarchical Clustering; Introduction to Reinforcement learning

Suggested Readings:

1. Russell, Stuart, Artificial Intelligence: A Modern Approach, Pearson Edition 2013
2. Mitchell, Machine Learning, McGraw Hill.
3. Marsland, Machine learning: an algorithmic perspective, CRC Press,Taylor and Francis Group.
4. Alpaydin, Introduction to Machine Learning, MIT Press.
5. Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer, 2006

Semester: II

Compulsory Course

1. Data Visualization

Interactive and Dynamic Graphics: Scatter Plots; Brushing and Linked Brushing; Focusing, Zooming; Rotations and Projections; Parallel Coordinate Plots, Andrews Plots; Density Plots; Catagorical Data; Virtual Reality, Interactive 3D Graphics, 3d Representation of Statistical Data; Exploratory Spatial Data Analysis, Application of Interactive and Dynamic Graphics. Applications from Geography, Medicine and Environmental Sciences, Interactive Micromaps, Choropleth maps; Graphical Software; Limitations of Graphics

Suggested Readings:

1. W. S. Cleveland and M. E. McGill, “Dynamic Graphics for Statistics", Woodsworth, 1998
2. J. Blasius and M. Greenacre M, “Visualization of Categorical Data",1998
3. A. P. Buja and P. A. Tukey, Computing and Graphics in Statistics, Springer, 1991
4. J. Symanzik, “Interactive and Dynamic Graphics in Handbook of Computational Statistics (ed) J.E. Gentle, W. Havdle, Y. Mori", Springer, 2004
5. E. R. Tufte, “The Visual Display of Quantitative Information", The Graphics Press, 2001

Elective Courses

2. Elective I (from the list of Elective courses)

3. Elective II (from the list of Elective courses)

4. Elective III (from the list of Elective courses)

5. Electives IV (from the list of Elective courses)

Semester: III

Compulsory Courses

1. Research Reading and Laboratory

This course should be carried out under the supervisor in the area related to dissertation work, as suggested by the supervisor. The research work related to dissertation, including the laboratory work, should be presented to the concerned supervisor. The research reading and laboratory course would be evaluated by the concerned supervisor.

2. Seminar

The Seminar course would include seminars related to the dissertation work. It would be evaluated by a seminar evaluation committee comprising three faculty members. The seminar, as part of the end-semester examination, would finalize the topic of the dissertation.

Semester: IV

1. Dissertation

Student will have to submit the dissertation for evaluation in the school. The dissertation of each student is to be evaluated through viva-voce/presentation in the school conducted by the committee comprising the supervisor and one external expert from outside the university in the related area, as recommended by the special committee of the School and approved by the University.

List of Elective Courses

1. Design of Experiments

Introduction: Guidelines for Designing Experiments, Experiments with a Single Factor, Analysis of Variance, Randomized Blocks, Latin Squares and Related Designs, Factorial Designs: 2^K factorial design, Fractional Factorial Designs- Two level, Three level and Mixed Level Designs, Response Surface Methods: Process Optimization, Response Surface, Mixture Experiments, Robust Designs, Nested and Split plot Designs, Non- normal Responses and Transformations, Analysis of Covariance, Computer Solutions, Factorial Experiments with Covariates (Emphasis will be placed on computational methods in the design of experiments)

Suggested Readings:

1. D. C. Montogomery, "Design and Analysis of Experiments", 5th Edition, John Wiley, 2001
2. T. J. Santner, B. J. Williams and W. I. Notz, "Design and Analysis of Computer Experiments", Springer, 2003
3. G. Taguchi, "System of Expermental Design", Volumes I and II, White Plains, New York, 1987
4. B. P. Zeigler, K. Praehofer and T. G. Kim, "Theory of Modeling and Simulation", 2nd Edition, Academic Press, 2000
5. J. D. Jobson, "Applied Multivariate Data Analysis, Regression and Experimental Design", Springer, 1991
6. Y. Dodge, "Analysis of Experiments with missing data", Wiley, 1985

2. Stochastic Modeling and Applications

Purposes of Stochastic Models: Review of Stochastic Processes, Discrete and Continuous time Markov Chains; Continuous Time Markov Chains: The Kolmogorov equations, Queueing systems, Modeling Neural Activity; Markov Random Fields: Ising Model of Ferromagnetism, Phase Transitions in Markov Random Fields, Likelihood Analysis of the Ising model, Image Analysis; Point Processes: Model of Traffic Patterns, Estimating Second Order Parameters for Stationary Point Processes, Mixed Point Processes, Spatial Point Processes; Brownian Motion and Diffusion: Second Order Processes, A More Realistic Model of Brownian Motion, Introduction to SDE, Likelihood inference for SDE, Wright-Fisher Model and Diffusion; Fractional Brownian Motion: Modeling Internet Traffic, 1/f Noise.

Suggested Readings:

1. P. Guttorp, "Stochastic Modeling of Scientific data", Chapman & Hall, 1995
2. V. G. Kulkarni, "Modeling and Analysis of Stochastic Systems", Chapman & Hall, 1995
3. M. Mitzenmacher, "Eliupfal, Probability and Computing", Cambridge, 2005
4. H. C. Tijms, "Stochastic Modeling and Analysis", Wiley, 1986
5. K. Borovkov, “Elements of Stochastic Modeling", World Scietific, 2003
6. H. Haken, "Synergetics : An Introduction", 3rd Edition, Springer-Verlag, 1993
7. D. J. Bartholomew, "Stochastic Models for Social Processes", 3rd Edition, Wiley, 1982
8. J. Beran, "Statistics for long memory processes", Chapman & Hall, 1994

3. Regression and Time Series Analysis

Basic Regression Model: Computational Techniques for Variable Selection, Regression Models with Multicollinearity and Autocorrelated Errors, ARIMA, ARCH and GARCH Models, VAR Models, Autocorrelation Function and Spectrum of Stationary Processses, White Noise and Colored Noise, Linear Stationary Models, Linear Nonstationary Models Forecasting: Forecast Function and Forecast Weights, Forecasting Autoregressive Processes, Error of Forecast. Seasonal Models, Stochastic Model Building – Model Diagnostics, Transfer Function Models: Identification, Fitting and Checking, Intervention Analysis of Models and Outlier Detection, Aspects of Process Control

Suggested Readings:

1. D. C. Montgomery, E. A. Peck and G. G. Vining, “Introduction to Linear Regression Analysis", 3rd Edition, John Wiley, 2003
2. S. Makridakis, S. C. Wheelwright and R. J. Hyndman, "Forecasting Methods and Application", 3rd edition. John Wiley and Sons, 1998
3. G. E. P. Box, G. M. Jenkins and G. C. Reinsel, "Time Series Analysis - Forecasting and Control", 3rd Edition, Pearson Education, 2004
4. N. R. Draper and H. Smith, “Applied Regression Analysis", 3rd Edition, John Wiley, 2003
5. J. D. Hamilton, “Times Series Analysis", Princeton University Press, 1994
6. C. Chatfield, “The analysis of Time Series", CRC, Chapman and Hall, 2003
7. H. Kantz and T. Schreiber, “Nonlinear Time Series Analysis", 2nd Edition, Cambridge, 2004
8. M. West and J. Harrison, “Bayesian Forecasting", Springer, 1989

4. Computational Intelligence and Applications

Neural Networks: Biological Neuron, Artificial Neuron, General Attributes of Biological Neural Networks and Artificial Neural Networks, Different Learning Paradigms, Specific Models like MLP, SOFM, ART, LVQ, Hopfield Net, Boltzman Machine, Simulated Annealing and Applications; Fuzzy Logic: Motivation, Linguistic Variables and Linguistic Values, Fuzzy Set, Membership Functions, Fuzzy Relation, Operations on Fuzzy Sets and Relations, Approximate Reasoning, Fuzzification, Defuzzification, Fuzzy Rule based Systems, Fuzzy and Possibilistic Clustering and Fuzzy Classification and Applications

Suggested Readings:

1. C. M Bishop, "Neural Network for Pattern Recognition", Oxford University Press, 2014
2. S. Kumar, "Neural Networks", Tata McGraw Hill, 2004
3. H. T. Nguye and E. Walker, "A First Course in Fuzzy Logic", 3rd Edition, 2005
4. George J. Klir, "Fuzzy Sets and Fuzzy Logic: Theory and Applications", Ist Edition, PHI, 2015

5. Speech and Natural Language Processing

Biology of Speech Processing; Place and Manner of Articulation; Word Boundary Detection; Argmax based computations; HMM and Speech Recognition. Morphological Diversity of Languages; Morphology Paradigms; Finite State Machine Based Morphology; Automatic Morphology Learning; Shallow Parsing; Named Entities; Maximum Entropy Models; Random Fields. Theories of Parsing, Parsing Algorithms; Robust and Scalable Parsing on Noisy Text as in Web documents; Hybrid of Rule Based and Probabilistic Parsing; Scope Ambiguity and Attachment Ambiguity resolution. Lexical Knowledge Networks, Wordnet Theory; Indian Language Wordnets and Multilingual Dictionaries; Semantic Roles; Word Sense Disambiguation; WSD and Multilinguality; Metaphors; Coreferences. Sentiment Analysis; Text Entailment; Robust and Scalable Machine Translation; Question Answering in Multilingual Setting; Cross Lingual Information Retrieval (CLIR).

Suggested Readings:

1. D. Manning, "Statistical Foundation of Natural language Processing", MIT Press, 1999
2. A. James, "Introduction to Natural Language Understanding", Addison Wesley, 1991
3. E. Charnaik, "Statitistical Natural Learning", MIT Press, Cambridge, 1993
4. Jurafsky, Dan and Martin, James, Speech and Language Processing, Second Edition, Prentice Hall, 2008.

6. Cloud Computing

Over view of Distributed Computing: Trends of computing, Introduction to Parallel/distributed computing, Grid Computing, Cloud computing, Introduction to Cloud Computing: What's cloud computing, Properties and Characteristics, Service models, Deployment models Components of a computing cloud, Different types of clouds: public, private, hybrid, Delivering services from the cloud, Categorizing service types, Comparing vendor cloud products: Amazon, Google, Microsoft and others, Infrastructure as a Service (IaaS): Introduction to IaaS, Resource Virtualization, Server, Storage, Network, Case studies, Platform as a Service (PaaS): Introduction to PaaS, Cloud platforms and Management, Computation, Storage, Case studies, Software as a Service (SaaS): Introduction to SaaS, Web services, Web 2.0, Web OS, Case studies, Cloud Issues and Challenges: Cloud provider Lock-in, Security.

Suggested Readings:

1. Kai Hwang, Geoffrey Fox, Jack Dongarra, Distributed and Cloud Computing, Elsevier, 2012.
2. Rajkumar Buyya, Christian Vecchiola, and Thamarai Selvi, Mastering Cloud Computing, TMH, 2013.
3. Dan C. Marinescu, Cloud Computing: Theory and Practice, Elsevier, 2013.
4. Barrie Sosinsky, Cloud Computing Bible, Wiley, 2011.

7. Internet of Things

Introduction to the Internet of Things (IoT), Technology and Business drivers for IoT, IoT Architectures and design considerations; IoT paradigms and frameworks; semantics, security, privacy, network and standardization issues; IoT Integration with Cloud technologies, big data, cyber-physical systems, components, network technologies; IoT application and device programming; Data analytics for IoT; Typical IoT applications, Trends and implications; Challenges and Opportunities with IoT.

Suggested Readings:

1. Samuel Greengard, The Internet of Things, MIT Press, 2015
2. Robert Stackowiak , Art Licht , Venu Mantha , Louis Nagode, Big Data and The Internet of Things: Enterprise Information Architecture for A New Age, APress, 2015
3. Peter Waher, Learning Internet of Things, Packt Publishing, 2015
4. Dirk Slama, Frank Puhlmann, Jim Morrish , Enterprise IOT, O'Reilly Publishers, 2015
5. Adrian McEwen, Hakim Cassimally, Designing the Internet of Things, John Wiley and Sons, 2014
6. Vijay Madisetti and Arshdeep Bahga, "Internet of Things (A Hands-on-Approach)", VPT, 2014.
7. Francis daCosta, "Rethinking the Internet of Things: A Scalable Approach to Connecting Everything", 1st Edition, Apress Publications, 2013

8. Nature Inspired Algorithms

Introduction to metaheuritsics, fundamentals of Evolutionary Computation, Genetic Algorithms, Genetic Programming; Evolution Strategies, Components of Evolutionary Computation: Framework, Populations, Selection Operators, Genetic Operators; Introduction to swarm intelligence, Social Behavior as Optimization: Discrete and Continuous Optimization Problems, Swarm Intelligence Techniques: Particle Swarm Optimization, Ant Colony Optimization, Artificial Bees, cuckoo search algorithm etc., Bio-inspired algorithms, modeling and computation with cellular systems, artificial immune system. Introduction to physical algorithms, simulated annealing.

Suggested Readings:

1. De Jong, K.A., Evolutionary Computation – A Unified Approach, Prentice Hall of India, 2006
2. Eiben, A.E., Smith, J.E., Introduction to Evolutionary Computing, Springer-Verlag, 2003
3. Kennedy, J. and Eberhart, R.C., Swarm Intelligence, Morgan Kaufmann Publishers, 2001
4. Bonabeau, E., Dorigo, M. and Theraulaz, G., Swarm Intelligence: From Natural to Artifical Systems, Oxford University Press, 1999
5. Dorigo, M., Stutzle, T., Ant Colony Optimization, MIT Press, 2004
6. Clerc, M., Particle Swarm Optimization, ISTE, 2006
7. Yang, X.S., Nature Inspired Metaheuristic Algorithms, Luniver Press, 2010
8. de Castro, L. N., Timmis, J., Artificial Immune Systems: A New Computational Intelligence Approach, Springer, 2002

9. Social Network Analytics

Background: Review of graph theory, graph isomorphism, types of graph, connectivity, paths and cycles, trees, graph representation, spectral properties of graphs; Introduction: Real world complex networks – technological networks, information networks and social networks, topological properties of networks, network data sets; Social Networks: Strong and weak ties, strength and network structure in large scale data, homophily, tracking link formation in online data; Structure of the web: Hypertext and associative memory, web as a directed graph, link analysis and web search; Network effects: Information cascades, stability, instability and tipping points, power laws and rich – get richer phenomenon; Network dynamics: Modeling diffusion through a network small world phenomenon, epidemics; Case studies: Facebook, LinkedIn, Google Plus and Twitter

Suggested Readings:

1. David Easley and Jon Kleinberg, “Networks, Crowds and Markets”, Cambridge University Press, 2010
2. Kayhan Erciyes, “Complex Networks : An Algorithmic Perspective”, CRC Press, 2015
3. Matthew A. Russell, “Mining the Social Web: Analyzing Data from Facebook, Twitter, LinkedIn and other social media sites”, O'Reilly Media, 2011, ISBN: 978-1-449-38834-8
4. Reza Zafarni, Mohammad Ali Abbasi,Huan Liu, “Social Media Minning”, Cambridge University Press, 2014

10. Programming for Data Science

Python fundamentals, Python data structures, and working with data in Python , program in Python, Python functions, objects, and classes, Python for data analysis

Suggested Readings:

1. Jake VanderPlas, Python Data Science Handbook: Essential Tools for Working with Data, O’Reilly Pub., 2017
2. Wes McKinney, Python for Data Analysis, O’Reilly Pub., 2013

11. Computational Finance

Basic Functional Mathematics- Time Value of Money, Annuities, Yields, Bonds, Bond Price Volatility, Term Structure of Interest rates; Option Basics, Exchange Traded Options, Arbitrage in Option Pricing, Relative Option Prices, Put-Call Parity and its Consequences; Option Pricing Models- Binomial Option Pricing Model, Black- Scholes Formula; Forwards, Futures, Future Options, Forward Contracts; Continuous Time Functional Mathematics- Stochastic Integrals, Black- Scholes Differential Equation, Hedging and Futures, Hedging and Options.

Suggested Readings:

1. Y. D. Lyuu,”Financial Engineering and Computation", Cambridge university, 2002
2. S. M. Ross,”An elementary introduction to mathematical finance", 2nd Edition Cambridge University
3. S. N. Neftci, “Principles of Financial Engineering, Elseveir, 2004
4. P. Wilmont, S. Howison and J. Dewynne, “The Mathematics of Financial Derivatives", Cambridge University, 1995
5. J. Stampfli and V. Goodman, “The Mathematics of Finance: Modeling and Simulation", Thompson, 2001
6. M. J. Miranda and P. L. Fackler, “Applied Computational Economics and Finance", The MIT Press / Pearson Education, 2002
7. R. Bhart and S. Hamori, “Hidden markov models: Application to financial economy", Kluwer, 2004

12. Bioinformatics

Review of Basic Biology (includes Biomolecules, DNA, Protein, Structure of Amino acids), Basic Concepts of Molecular Biology, Sequence Comparison: Comparing Two Sequences, Global Pair wise Sequence Alignment, Multiple Sequence Alignment, Database Search: PAM Matrices, BLAST, FAST, Markov Chain, Hidden Markov Models, Pair wise Alignment, Likelihood and Scoring a Model; Phylogenetic Trees, Probabilistic Approaches, Algorithms for Distance Matrices, Transformational Grammars, RNA Structure Analysis, RNA Secondary Structure Predictions, System Biology Concepts, Computational Models of Regularity Networks, The Search for General Principles

Suggested Readings:

1. W. J. Ewens and G. R. Grant, "Statistical Methods in Bio-Informatics- An Introduction", Springerm, 2004
2. J. Setubal and J. Meidaris, “Introduction to Computational Molecular Biology", Thomson, 2003
3. R. Durbin, S. Eddy, A. Krogh and G. Mitchison, “Biological Sequence Analysis: Probabilistic Models of Proteins and Nueclic Acids”Cambridge University Press, 1998
4. P. Clote and R. Backofen, “Computational Molecular Biology", John Wiley, 2002
5. T. Jiang, Y. Xu and M. Q. Zhang, “Current Topics in Computational Molecular Biology", MIT,

2002
6. J. K. Percus, “Mathematics of Genome Analysis", Cambridge University Press, 2002
7. R. Durrett, “Probability Models for DNA Sequence Evolution", Springer, 2002

13. Data Mining & Pattern Recognition

Statistical Pattern Recognition: Introduction to Statistical Pattern Recognition, The Gaussian Case and Class Dependence, Discriminant Functions, Classifier Performance, Risk, and Errors, Supervised Learning Using Parametric and Nonparametric Approaches: Parametric Estimation and Supervised Learning, Maximum Likelihood Estimation, Bayesian Parameter Estimation Approach, Parzen Windows, Linear Discriminant Functions: Linear Discriminant Functions and Decision Surfaces, Generalized Linear Discriminant Functions, Linearly Separable Case, Minimizing the Perceptron Criterion Function, Relaxation Procedures, Minimum Square Error Procedures, Linear Programming Algorithms, Support Vector Machines, Unsupervised Learning and Clustering: Formulation of Unsupervised Learning Problems, Hierarchical Clustering, Partitional Clustering, Density Based Clustering, Learning Vector Quantization, Syntactic Pattern Recognition: Quantifying Structure in Pattern Description and Recognition, Grammar Based Approach and Applications, Elements of Formal Grammar, Recognition of Syntactic Descriptions, Parsing, Graph Based Structural Representations, Neural Pattern Recognition: Neural Network Structures for Pattern
Recognition Applications, Single Layer Perceptron, Multilayer Back propogation Algorithm, Radial Basis Function Network, Hopfield Nets, Kohonen Network

Suggested Readings:

1. R. Schalkoff, "Pattern Recognition Statistical, Structural and Neural Approaches", R. Wiley, 2007
2. R. O. Duda, P. E. Hart and D. G. Stork, “Pattern Classification", 2nd Edition, Wiley
3. E. Gose, R. Johnsonbaugh and S. Jost, "Pattern Recognition and Image Analysis", Prentice Hall, 1996
4. B. D. Ripley and N. L. Hjort, "Pattern Recognition and Neural Networks", Cambridge University Press, 1995
5. C. H. Chen and P. S. Pwang, "Pattern Recognition and Computer Vision", World Scientific, 2005
6. S. Theodoridis and K. Koutroumbas, "Pattern Recognition", 2nd Edition, Academic Press
7. J. Han and M. Kamber, “Data Mining: Concepts and Techniques", Morgan Kaufmann, 2001
8. I. H. Witten and E. Frank, “Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations”Morgan Kaufmann, 1999

14. Econometrics

Pre-requisite: Probability Theory and Statistical Inference (Multivariate), Linear Algebra, Quadratic Forms, Definite Matrices and Classical Regression Models); Data problems in the classical regression Model – Missing observations, Multicollinearity, Measurment Error and Proxy Variables, Regression Diagnostics and Influential Data Points; Nonlinear Regression Models - Loglinear, Logistic and others. Nonlinear Least Squares. Maximum Likelihood Estimation. Asymptotic distribution theory. Parametric Transormations of the Dependent variable - Box-Cox Transformations; Models with Heteroscedasticity and General covariance matrix of error terms with non-zero off diagonal terms- Tests, Estimation and Inference with Generalised Least Squares; Autocorrelated Disturbances: ARIMA, ARCH and GARCH Models; Longitudinal Data and Panel Data Models, Regressions with lagged variables, Logit and Probit Models, Simultaneous Equation Models ; Identification Problem, Estimation Methods - 2SLS, 3SLS, LIML and FIML methods. Forecasting., Structural Equation Models with Latent variables. Censored Regression Models; Bayesian Model Averaging, Flexible Models, Nonparametric and Semi- Parametric Methods

Suggested Readings:

1. W. Greene, “Econometric Analysis", 4th Edition, Prentice Hall, 2000
2. R. S. Pindyck and D. L. Rubinfeld, "Econometric Models and Economic Forecasts", 4th Edition, McGraw-Hill, 1998
3. J. H. Dorfman, "Bayesian Economics through numerical methods", Springer, 1997
4. G. Koop, “Bayesian Econometrics", Wiley, 2003

5. R. Marimon and A. Scott, “Computational methods for the study of dynamic economics", Oxford University Press, 1999
6. K. A. Lawler and A. V. Katos, "Econometrics- A practical approach", Routledge, 2000

15. Spatial Data Analysis and GIS

Introduction review of non-spatial statistics, overview of different types of spatial data Geostatistics: Variograms and covariance functions, fitting variogram functions, kriging, spatial regression, Areal data: Neighborhoods, testing for spatial association, Global and local tests of association, CAR and SAR models, inference, phenomena mapping, Point process data: types of spatial pattern, spatial clustering, GIS conceptual framework, Database, Visualization, Modelling and Analysis, Special topics: Non-stationary Covariance, Bayesian methods, Spatio-temporal modelling, Current Topics

Suggested Readings:

1. O. Schabenberger and C.A. Gotway, "Statistical Methods for Spatial Data Analysis", CRC, 2005
2. T. C. Bailey and A. Gatrell, "Interactive Data Analysis", Longman, 1995
3. S. Fotheringham, A. Stewart, C. Brunsdon and C. Martin, "Quantitative Geography: Perspectives on Spatial Data Analysis", SAGE publication, 2000
4. N. Cressie, "Statistics for Spatial Data", Revised Edition, John Wiley, 1993
5. Manfred M. Fischer and Arthur Getis, “Handbook for Applied Spatial Statistics: Software Tools and Methods, Springer, 2010
6. Alan E. Gelfand, Peter Diggle, Peter Guttorp, and Montserrat Fuentes “Handbook of Spatial Statistics”, CRC Press

16. Big Data Analytics

Introduction to Big Data, Data Mining, Data Analytics, Predictive Analysis and Business Intelligence, Large Scale File System: Distributed File System, MapReduce, HDFS and Hadoop, Mining Big Data, Advanced Data Analytics and Machine Learning, Big Data Streams and Real Time Predictive Analysis, Tools and Visualization, Link Analysis, Web Analytics, Collaborative Filtering, Social Network Analysis, Issues, Challenges and Opportunities with Big Data and its Analytics

Suggested Readings:

1. Rajaraman, A., Ullman, J. D., Mining of Massive Datasets, Cambridge University Press, United Kingdom, 2012
2. Berman, J.J., Principles of Big Data: Preparing, Sharing and Analyzing Complex Information, Morgan Kaufmann, 2014
3. Barlow, M., Real-Time Big Data Analytics: Emerging Architecture, O Reilly, 2013
4. Schonberger, V.M. , Kenneth Cukier, K., Big Data, John Murray Publishers, 2013

17. Information Theory

Uncertainty, Probability, Entropy, Shannon's Measure, Joint Entropy, Mutual Information, Differential Entropy, AEP, Entropy Rates of a Stochastic Process, Markov Chains, Hidden Markov Models, Data Compression, Kraft Inequality, Entropy of English Language, Inference, Sufficient Statistics, Maximum Likelihood and Clustering, Marginalization, Laplaces Method, Model Comparison and Occam's Razor; Maximum Entropy Principle, Maximum Entropy Probability Distributions, Jaynes Concentration Theorem, Applications-Physics, Economics, Statistics. Information in Contingency Tables, Comparison and Fisher's and Maxent Methods of Estimation; Further Applications of Maxent Principle: Pattern Recognition as a Quest for Minimum Entropy, Non-Linear Spectral Analysis, Parametric Entropy Measures: Renyi, Tsallis, Power Laws.

Suggested Readings:

1. A. Golan, G. Judge and D. Miller, "Maximum Entropy Econometrics", John Wiley, 1996
2. J. N. Kapur and H. K. Kesavan, "Entropy Optimization Principles with Applications", Academic Press, 1992
3. J. van der Lubbe, “Information Theory", Cambridge University, 1997
4. T. M. Cove and J. A. Thomas, "Elements of Information Theory", Wiley, 1991
5. R. F. Blahut, "Principles and Practice of Information Theory", Addison Wesley, 1988

18. Data Stream Management

Introduction to data streams, overview of streaming applications, architecture of Data Stream Management Systems, issues in data stream management, data models and query semantics for streams, streaming operators and languages, query processing and optimization, algorithmic issues, resource management, multiple and distributed streams, mining and analysis of data streams, streaming applications and systems, security and privacy, stream reduction, data stream management in mobile environments

Suggested Readings:

1. Charu C. Aggarwal, "Data Streams: Models and Algorithms", Springer Verlag, 2007.
2. Joao Gama, "Knowledge Discovery from Data Streams", CRC Press, Taylor and Francis Group, 2010
3. Minos Garofalakis, Johannes Gehrke, Rajeev Rastogi, "Data Stream Management: Processing High-speed Data Streams", Springer Verlag, 2007.
4. Sharma Chakravarthy, Qing Chun Jiang, "Stream Data Processing: Issues and Solutions", Springer Verlag, 2007.
5. Chaudhry Nauman, Shaw Kevin, Abdelguerfi Mahdi, "Stream Data Management", Kluwer Academic Publishers, 2005.

19. Multimedia and Video Analytics

Introduction to multimedia systems. Multimedia compression including fundamentals of compression, text compression, image compression, audio and speech compression, video compression. Multimedia information storage and retrieval including text. Audio, image and video storage and retrieval methods multimedia programming multimedia security. Usability of multimedia.
Basics of image processing, computer vision and machine learning (assuming background in these areas). Video content analysis including: moving object detection and tracking algorithms. Image/video features for human activity detection and recognition in images and video image/video event classification and recognition objects in video counting approaches. Anomaly detection in images and videos multi-camera video analysis. Analyzing videos for video analytics applications such as retail analytics, healthcare, traffic analytics.

Suggested Readings:

1. Richard Szeliski, Computer Vision: Algorithms and Applications, 2010
2. Forsyth & Ponce, Computer Vision: A Modern Approach, Pearson, 2002
3. Rafael C. Gonzalez, Richard Eugene Woods, Digital Image Processing Pearson Education India, 2009.
4. Li , Ze - Nian, Fundamentals of Multimedia, ISBN: 0130618721, Prentice-Hall, 2004.
5. Ramesh Yerraballi, Multimedia Systems Concepts Standards and Practice, PHI, 2004.

20. Web Mining

Data Mining Foundations : Basic concepts in data Mining, Web mining versus Data mining, Discovering knowledge from Hypertext data; An overview of web mining : What is Web mining, Web mining taxonomy, Web mining subtasks, issues, challenges; Web Search and Information Retrieval : Information Retrieval Models, Web Search and IR, Text Mining, , Latent Semantic Indexing, Web Spamming, Clustering and Classification of Web Pages, Information Extraction , Web Content Mining; Web Structure mining: Web as social network , Graph based analysis of web structure, link based ranking of web pages : Page rank and HIT, Short comings of coarse grained models, Enhanced models and techniques; Web usage mining : An introduction to web usage mining, Steps in web usage mining, Web usage mining process, Applications of Web usage mining, Clustering of web pages based on usage; Future of Web mining : Information Extraction, Web mining and Natural Language Processing, Ontology and Semantic Web

Suggested Readings:

1. Bing Liu, Web Data Mining, Springer Publication
2. Somen Chakrabarti, Web mining, Elsevier Publication
3. Grossman, Information Retrieval : Algorithm and Heuristics, Springer
4. Witton Frank, Data Mining , Morgan Kauffan Publishers

21. Probabilistic Graphical Models

Introduction, Probability Theory, Bayesian Networks, Undirected Graphical Models, Local Probabilistic Models, Template-Based Representations, Gaussian Network Models, The Exponential Family, Exact Inference, Inference as Optimization, Particle-Based Approximate Inference, MAP Inference, Inference in Hybrid Networks, Inference in Temporal Models, Learning Graphical Models, Parameter Estimation, Structure Learning in Bayesian Networks, Partially Observed Data, Learning Undirected Models, Causality, Utilities and Decisions, Structured Decision Problems

Suggested Readings:

1. Daphne Koller and Nir Friedman, "Probabilistic Graphical Models: Principles and Techniques", MIT Press.
2. Adnan Darwiche, "Modeling and Reasoning with Bayesian networks".
3. Kevin P. Murp Mhy, "Machine Learning: a Probabilistic Perspective".
4. David J. C. Mackay, "Information Theory, Inference, and Learning Algorithms"
5. Martin J. Wainwright and Michael I. Jordan, "Graphical models, exponential families, and variational inference".

22. Probabilistic Risk Assessment

Concept of risk, objective and scope of risk assessment, probabilistic risk, risk perception and acceptability, Quantitative aspects of risk. Three levels of risk quantification, PRA management, preliminary hazard analysis, HAZOP and HAZAN, FMEA and FMECA analysis, Fault tree Analysis. Digraph and other approaches. Computation of Hazard probability, unavailability and other parameters using fault tree methodology. Monte Carlo Simulation technique, Event tree analysis, identification of initiating events, sequence and scenario development, system analysis, external events and dependent failures and quantification, Accident-consequence Analysis, uncertainty analysis, sensitivity analysis and importance measures, Bayesian approaches. Human Reliability analysis.

Suggested Readings:

1. Mohammad Modarres, "Probabilistic Risk Assessment", Springer
2. Ernest J. Henley and Hiromitsu Kumamoto, Probabilistic Risk Assessment: Reliability Engineering, Design, and Analysis (Henley, Ernest J. Reliability Engineering and Risk Assessment, IEEE Press.
3. M. Stewart and Robert E. Melchers, Probabilistic Risk Assessment of Engineering Systems (Systems Effectiveness), Springer
4. Tim Bedford, Probabilistic Risk Analysis - Foundations and Methods, Cambridge University Press

23. Data Security

Introduction and Objectives, Cryptographic Techniques, Threats, Vulnerabilities, Protection, Access Control, Data Security: Disk Encryption, Mechanisms in Data Security, Authentication, Backup Solutions, Data Masking, Data Erasure, Internal Laws and Standards, Data Breach, Data Theft, Privacy-Preserving Data Mining, information flow control, Wireless Identity Theft.

Suggested Readings:

1. Stinson D., Cryptography, Theory and practice, CRC Press, Boca Raton.
2. Dorothy Elizabeth Robling Denning, Cryptography and Data Security, publisher Addison-Wesley, 1982
3. Brent Mullins, Data Security Complete Certification Kit, Publisher Emereo Publishing company, May 2016
4. Stallings, William, Computer Security: Principles and Practices, Pearson Education Limited, 2015.

24. Smart Camera & Visual Sensor Networks

Basics of image sensors and processing, computer vision and visual sensor networks, Calibration of smart camera networks, Camera network tracking and re-identification, Visual analytics in a smart camera network, Data association in visual sensor network, Distributed camera networks, Collaborative sensing and analysis in visual sensor networks.

Suggested Readings:

1. Richard Szeliski, Computer Vision: Algorithms and Applications , 2010, Springer, 2.Forsyth & Ponce, Computer Vision: A Modern Approach, Pearson, 2002
3. Rafael C. Gonzalez, Richard Eugene Woods, Digital Image Processing Pearson Education India,2009
4. B. Bhanu, C. Ravishankar, A. Roy-Chowdhury, H., Distributed Video Sensor Networks

25. Computer Vision

Introduction to vision; Camera models; Camera calibration; Multi-view geometry and reconstruction; Edge/ Feature extraction; Correspondence and tracking; 3D structure/ motion estimation; shape from X techniques; Recognition, scene and activity interpretation, video analysis.

Suggested Readings:

1. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2011
2. Richard Hartley and Andrew Zissermann, Multi-view Geometry in Computer Vision, 2nd Edition
3. Forsyth and Ponce, Computer Vision: A Modern Approach, Prentice Hall

26. Digital Image Processing

Elements of visual perception, Arithmetic, Logical, Geometric operations, Convolution, Correlation, Spatial Domain Filtering, Image Transforms and Filtering in the Frequency domain, Image Restoration, Image Compression, Wavelet based Image Compression, Morphological Image Processing, Image Segmentation, Color Models and Relationship Between Different Models, Digital Image Watermarking, Steganography, Medical Imaging

Suggested Readings:

1 R C Gonzalez , R E Woods, Digital Image Processing, 3rd Edition, Pearson Education.
2 A K Jain, Fundamentals of Digital image Processing, Prentice Hall of India.
3 K R Castleman, Digital Image Processing, Pearson Education.
4 Schalkoff, Digital Image Processing and Computer Vision, John Wiley and Sons.

27. Data Warehousing

Data Warehouse Definition, Perspectives of DW, Dimensional Modelling, OLAP functions, MDX query language, Architecture, Representation, Design Process, Mapping ER to Star schema, Metadata, ETL- Extraction, Transformation and Loading, Data warehousing to Mining; Data Mining Methodologies - Association Rule Mining , Classification and Prediction, Cluster Analysis; Modern Topics. Practical: Executing MDX queries on SQL Server

Suggested Readings:

1. Inmon W.H., Building the Data Warehouse, Wiley, Fourth Edition, 2005
2. Ponniah P., Data Warehousing Fundamentals : A Comprehensive Guide for IT Professionals, John Wiley and Sons, Second Edition,2010
3. Anahory S. and Murray D., Data Warehousing in the Real World, Addison-Wesley, First Edition, 1997
4. Han J. and Kamber M., Data Mining : Concepts and Techniques, Morgan Kaufmann, Third Edition, 2011

28. Statistical Signal Processing

Discrete-Time Processing, Random Variables, Stochastic Signals, Estimation Theory, Signal Models, Autocorrelation, Spectral Estimation, Joint Signal Analysis, Coherence Analysis, Time-Frequency Analysis, Linear Estimation, Optimum FIR Filters, Linear Prediction, Optimum IIR Filters, Optimum Linear Filter Applications, State Space Models, Kalman Filter, Extended Kalman Filter, Least-Squares Estimation, Practical Modeling, Autoregressive Models.

Suggested Readings:

1. Robert M. Gray and Lee D. Davisson, An Introduction to Statistical Signal Processing, 2004 ,Cambridge University Press.
2. Mandyam D. Srinath, P.K. Rajasekaran, R. Viswanathan, Introduction to Statistical Signal Processing with Applications, Prentice Hall, 1995

29. Data Compression

Compression Techniques, Lossless Compression, Lossy Compression, Mathematical Preliminaries for Lossless Compression, Huffman Coding, Arithmetic Coding, Dictionary Techniques, The Shannon–Fano and Huffman coding techniques, The JPEG compression algorithm, Fractal compression techniques, Mathematical Preliminaries for Lossy Coding, Scalar, Vector, Quantization, Differential Encoding, video compression.

Suggested Readings:

1. Khalid Sayood, Introduction to Data Compression, Morgan Kaufmann Publishers, 3ed, 2006
2. Wade, Graham, "Signal coding and processing", 2nd edition. Cambridge University Press, 1994

30. Cyber Security

Cyber Security Fundamental, Basic Cryptography, the Internet. Cyber Crimes, Types Cyber Crimes, Defense and Analysis Techniques: Cryptographic Mechanism, Authentication, Confidentiality, Integrity, Digital Signature, and Key Distribution Technique, Cyber Forensic and Law, Cyber Security Initiatives in India and World.

Suggested Readings:

1. James Graham Richard Howard Ryan Olson, "Cyber Security Essentials", CRC Press, 2011.
2. Thomas J. Mowbray, Cybersecurity: Managing Systems, Conducting Testing and Investigating Intrusions, Wiley, 2014
3. Alfred Basta , Nadine Basta , Mary Brown , Ravinder Kumar, "Cyber Security And Cyber Laws, Cengage", 2018
4. Stinson D., "Cryptography, Theory and practice ", CRC Press, Boca Raton, FA 2005.

31. Brain Theory and Neural Networks

Introducing the Neuron, Basic properties of Neurons, receptors and effectors, Neural models, Dynamics and adaptation: Neural networks, Dynamic systems, Self-organization and co-operativity, Learning in artificial neural networks, computability and complexity, Connectionism, Psychology, Linguistics, and Artificial Intelligence. Biological neurons and networks, detection and classification of extracellular action- potential recordings, information theoretic analysis of neural data, identification of non- linear dynamics in neural population activity. State-space modeling of neural spike train and behavioral data, neural decoding, statistical pattern recognition and machine learning in brain-computer interfaces.

Suggested Readings:

1. Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems, P. Dayan and L. F. Abott, MIT Press, 2001.
2. Statistical Signal Processing for Neuroscience and Neurotechnology, Edited K. G. Oweiss, Elsevier 2010.

3. The handbook of Brain Theory and Neural Networks, Edited M.A. Arbib, MIT Press, 2006.
4. Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting, E. M. Izhikevich, MIT Press, 2010.

32. Blockchain Technology

Introduction to Blockchain, How Blockchain works, Blockchain vs Bitcoin, Practical applications, public and private key basics, pros and cons of Blockchain, Myths about Bitcoin. Blockchain Architecture, versions, variants, use cases, Blockchain vs shared Database, Introduction to cryptocurrencies, Types, Applications, Concept of Double Spending, Hashing, Mining, Proof of work, Introduction to Merkel tree, Privacy, Payment verification, Resolving Conflicts, Creation of Blocks, Introduction to Ethereum, Advantages and Disadvantages, Ethereum vs Bitcoin, Introduction to Smart contracts, usage, application, working principle, Law and Regulations, Case Study.

Suggested Readings:

1. Lewis, Antony. The basics of bitcoins and blockchains: An introduction to cryptocurrencies and the technology that powers them. Mango Media Inc., 2018.
2. Mahankali, Srinivas. Blockchain: The Untold Story: From birth of Internet to future of Blockchain. BPB Publications, 2019.
3. Singhal, Bikramaditya, Gautam Dhameja, and Priyansu Sekhar Panda. Beginning Blockchain: A Beginner's Guide to Building Blockchain Solutions. A press, 2018.
4. Wattenhofer, Roger. The science of the blockchain. CreateSpace Independent Publishing Platform, 2016.

33. Geo Spatial Informatics

Introduction to Geo informatics – Remote Sensing and Geospatial data, GIS; Physics of Remote Sensing, Sensors (Passive, active) and Satellites, Photogrammetry; Geospatial Data models (data structures), Digital Image Processing techniques in Remote Sensing; Geospatial data Processing, Spatial statistics, Spatial/temporal analysis and data mining: feature extraction, Supervised-Semisupervised-unsupervised classification; Applications of Geospatial informatics.

Suggested Readings:

1. J.R. Jensen, Introductory Digital Image Processing: A Remote Sensing Perspective, 3rd Edition, Pearson Prentice Hall, 2005
2. George Joseph, Fundamentals of Remote Sensing, University Press, 2003
3. I. Heywood, S. Cornelius and S. Carver, An Introduction to Geographical Information Systems, Dorling Kinderseley India, 2006
4. H.J. Miller and Jiawei Han, Geographic Data Mining and Knowledge Discovery, 2nd Edition, CRC Press, 2009
5. R.A. Schowengerdt, Remote Sensing: Models and Methods for Image Processing, 2nd Edition, Academic Press, (imprint of Elsevier), 2020

34. Multicast Communication

Introduction, Application, Characteristics, Backbone Architecture, Video data generation, Group based Video Applications, Routing Algorithm, Group Dynamics, Routing between domains, IP group, Group in transport protocols, address allocation, Group LANs, Reliable group, Congestion control, Data Analysis, Security issues.

Suggested Readings:

1. Morgan Kaufmann, Ralph Wittmann, Martina Zitterbart, Multicast Communication: Protocols, Programming, and Applications, Edition 2000, Academic Press, USA.
2. Kennet Miller, Multicast Networking and Application, AW publication, 2008.
3. David Makofske, Kevin Almeroth, Multicast sockets: Practical Guide for Programmers, Edition 2003, Elsevier, USA.

35. Research Methodology

Science and Research, Verification Vs. Falsification, Objectivity: Facts, theory and concepts, Basic Steps for doing Research, Formulation of Research Problem, Scientific method Vs Arbitrary Method, Deductive and Inductive Reasoning, Error Analysis and Accuracy, Descriptive Statistics, Probability, Random Variables, Sampling distribution and Probability Distribution, Hypothesis Testing, Regression Analysis, Multivariate Analysis.

Suggested Readings:

1. Michael P. Marder, Research Methods for Science, Cambridge University Press, 20111.
2. C. Radhakrishna Rao, Statistics and Truth, CSIR, 1989.
3. Sheldon M Ross, Introduction to Probability and Statistics for Engineers and Scientists, Elsevier, 2010.
4. Day RA, How To Write and Publish a Scientific Paper, Cambridge University Press, London, 1992.
5. Latour, B. and Woolgar., Laboratory Life: The Construction of Scientific Facts, 2nd Edition, Princeton: Princeton University Press, 1986

36. Academic Ethics and Technical Writing

Significance of literature review, Writing scientific report, structure and components of research report, revision, writing project proposal, writing a Research Paper, Citation counting and Impact factor, Science citation index (SCI)/ Science citation index Expended (SCI-E), H-index, Academic Ethics and Plagiarism, Intellectual Property Rights and Patent law.

Suggested Readings:

1. P. Oliver, *Writing Your Thesis,*New Delhi:Vistaar Publications, 2004.
2. Gregory, *Ethics in Research*, Continuum, 2005.

37. Multimedia Communication

Introduction to Multimedia, Fundamental Concepts of Multimedia Data types : Image, Audio, Video and Animation; Compression Technology, Multimedia Communication and delivery, Content management and retrieval, Distributed multimedia Systems.

Suggested Readings:

1. Ze-Nian Li and M. S. Drew, Fundamentals of Multimedia, Pearson Education, 2004.
2. K. R. Rao, Z. S. Bojkovic and Dragorad A. Milovanovi, Multimedia Communication Systems: Techniques, Standards, and Networks, Prentice Hall

38. Networking for Big Data

Networking theory and design for Big Data, networking security for Big Data, and platforms and systems for Big Data applications, virtual machine placement problem, network configuration and flow scheduling for Big Data applications, Throughput and bandwidth efficiency for big data, energy efficiency and service resiliency

Suggested Readings:

1. Shui Yu, Xiaodong Lin , Jelena Misic , Xuemin (Sherman) Shen , Networking for Big Data , Chapman and Hall/CRC; 1st Edition (August 3, 2015)
2. José M. F. Moura, Big Data over Networks, Cambridge University Press, 2016

39. Deep Learning

Introduction – Deep Feedforward Networks – Regularization – Optimization of Deep Learning – Convolutional Networks – Recurrent and Recursive Network, long-short term memory – Applications of Deep Learning.

Suggested Readings:

1. John D. Kelleher , Deep Learning (The MIT Press Essential Knowledge series) Paperback – Illustrated, 2019
2. Andrew Trask, Deep Learning 1st Edition, Manning Pub. 2019.