M. Tech. DATA SCIENCE
Department of Data Science and Computer Applications, MIT Manipal

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PROGRAM STRUCTURE

Year	FIRST SEMESTER						SECOND SEMESTER					
	Sub Code	**Subject Name**	**L**	**T**	**P**	**C**	**Sub Code**	**Subject Name**	**L**	**T**	**P**	**C**
I	MAT 5114	Mathematical Foundation for DS	4	0	0	4	DSE 5251	Deep Learning	4	0	0	4
	DSE 5151	Data Analytics & Visualization	4	0	0	4	DSE 5252	Artificial Intelligence	4	0	0	4
	DSE 5152	Machine Learning	4	0	0	4	DSE ****	Program Elective I	3	0	2	4
	DSE 5153	Data Structures	3	0	2	4	DSE ****	Program Elective II	3	0	2	4
	DSE 5154	Database Technologies	3	0	2	4	DSE ****	Program Elective III	4	0	0	4
	HUM 5151	Research Methodology and Technical Communication	1	0	3	2	*** ****	Open Elective	3	0	0	3
	DSE 5161	Data Analytics & Visualization Lab	0	1	3	2	DSE 5261	Deep Learning Lab	0	0	3	1
	DSE 5162	Machine Learning Lab	0	0	3	1	DSE 5262	Advanced Technologies Lab	0	0	3	1
		Total	**19**	**1**	**13**	**25**		**Total**	**21**	**0**	**10**	**25**
II	**THIRD AND FOURTH SEMESTERS**											
	DSE 6098	Project Work							0	0	0	25
								Total	**0**	**0**	**0**	**25**

LIST OF PROGRAM ELECTIVES:

Sub. Code	Subject Name	Sub. Code	Subject Name
DSE 5001	Design & Analysis of Algorithms	DSE 5013	Enterprise Data Architecture
DSE 5002	Data Communications and Networks	DSE 5014	Quantum Computing
DSE 5003	Cloud Computing	DSE 5015	Internet of Things
DSE 5004	Parallel Programming	DSE 5016	Algorithmic Trading
DSE 5005	Big Data Analytics	DSE 5017	Digital Marketing
DSE 5006	Data Privacy & Security	DSE 5018	Bioinformatics
DSE 5007	Pattern Recognition & Applications		
DSE 5008	Computer Vision		
DSE 5009	Natural Language Processing		
DSE 5010	Business Analytics		
DSE 5011	Finance & Econometrics		
DSE 5012	Health Informatics		

FIRST SEMESTER

MATHEMATICAL FOUNDATIONS FOR DATA SCIENCE [4 0 0 4]

Statistics: Measures of central tendency, measures of dispersion, Correlation coefficient, regression, least squares principles of curve fitting. Probability: Introduction, finite sample spaces, conditional probability, and independence, Baye's theorem, one dimensional random variable, mean, variance. Two and higher dimensional random variables: mean, variance, correlation coefficient. Distributions: Binomial, Poisson, uniform, normal, gamma, Chi-square and exponential distributions, simple problems. Moment generating function, Functions of one dimensional and two-dimensional random variables, Sampling theory, Central limit theorem and applications. Stochastic Process: Markov chains with stationary transition probabilities, properties of transition functions, Stationary distribution of a Markov chain, existence and uniqueness, convergence to the stationary distribution. Methods based on Markov chains for simulation of random vectors. Multivariate Analysis: multivariate normal distribution and its properties, distributions of linear and quadratic forms, tests for partial and multiple correlation coefficients and regression coefficients. Data analytic illustrations. MANOVA Inference on covariance matrices. Classification methods: Discriminant analysis, principal component analysis and factor analysis, Canonical Correlation analysis, Correspondence Analysis, Multidimensional Scaling, Cluster analysis.

References

1. *Meyer P.L. "Introduction to probability and statistical applications", 2nd edn., American Publishing Co*
2. *Hogg and craig , "Introduction to mathematical statistics", 6th Edn,2012, Pearson education, New Delhi.*
3. *William J. Stewart, "Probability, Markov Chains, Queues and Simulation".*
4. *W. Feller: "An Introduction to Probability Theory and its Applications", Vol.-II.*
5. *S. Karlin and H. M. Taylor, "A First Course in Stochastic Processes".*
6. *P. G. Hoel, S. C. Port and C. J. Stone, "Introduction to Stochastic Processes".*
7. *T. W. Anderson, "An Introduction to Multivariate Statistical Analysis"*

DATA ANALYTICS & VISUALIZATION [4 0 0 4]

Steps in Data Analytics Projects, Data Analytics tasks, and methods, Data Gathering and Preparation: Data Formats, Parsing and Transformation, Scalability and Real-time Issues; **Data Cleaning**: Consistency Checking, Heterogeneous and Missing Data, Data Transformation and Segmentation; **Exploratory Analysis**: Descriptive and comparative statistics, Hypothesis testing, **Statistical Inference**. **Association rule mining:** Apriori, FP Growth, Partitioning, measures of pattern interestingness. **Clustering:** Partitioning, Hierarchical, Density based approaches. Recommender Systems, Anomaly Detection. **Visualization**: Visual Representation of Data, Gestalt Principles,

Information Overloads; Creating Visual Representations: Visualization Reference Model, Visual Mapping, Visual Analytics, Design of Visualization Applications; **Classification of Visualization Systems**: Interaction and Visualization Techniques, Visualization of One, Two and Multi-Dimensional Data, Text and Text Documents; **Visualization of Groups**: Trees, Graphs, Clusters, Networks, Software, Metaphorical Visualization; **Visualization of Volumetric Data**: Vector Fields, Processes and Simulations, Visualization of Maps, Geographic Information, GIS systems, Collaborative Visualizations, Evaluating Visualizations; **Recent Trends in Various Perception Techniques:** Various Visualization Techniques, Data Structures used in Data Visualization.

References:

1. Glenn J. Myatt, Wayne P. Johnson, *Making Sense of Data I: A Practical Guide to Exploratory Data Analysis and Data Mining*, 2nd Edition, John Wiley & Sons Publication, 2014.
2. Glenn J. Myatt, Wayne P. Johnson, *Making Sense of Data II: A Practical Guide to Data Visualization, Advanced Data Mining Methods, and Applications*, John Wiley & Sons Publication, 2009.
3. Dr Anil Maheshwari, "Data Analytics Made Accessible, 2021 Edition
4. Jules J., Berman D., *Principles of Big Data: Preparing, Sharing, and Analyzing Complex Information*, (2e), 2013.
5. Matthew Ward and Georges Grinstein, *Interactive Data Visualization: Foundations, Techniques, and Applications*, (2e), A K Peters/CRC Press, 2015.
6. Jurgen Kai-Uwe Brock, *Data Design: The Visual Display of Qualitative and Quantitative Information*, (1e), Consulting Press, 2017.
7. Edward R. Tufte, *The Visual Display of Quantitative Information*, (2e), Graphics Press USA, 2001.
8. Cole Nussbaumer Knaflic, *Storytelling with Data: A Data Visualization Guide for Business Professionals*, (1e), John Wiley and Sons, 2015

MACHINE LEARNING [4 0 0 4]

Machine Learning Basics: Types of Machine Learning, supervised vs. Unsupervised Learning, Parametric vs. non-parametric models., **Instance Based learning** – k-nearest neighbors, **Simple Regression Models**: Linear, Logistic, Cost functions, Gradient Descent, Batch Gradient Descent, Overfitting, Model Selection, No free lunch theorem, bias/variance trade-off, union and Chernoff bounds, VC dimensions. **Bayesian Models:** Bayesian concept learning, Bayesian Decision Theory, Naïve Bayesian, Laplacian Correction, Bayesian Belief Networks. **Tree Models:** information theory, decision tree induction, tuning tree size, ID3, C4.5, CHAID, Decision Stump. **Support Vector Machines**: kernel functions. **Regression Models**: Ridge and Lasso Regression, GLM and the exponential Family. Bagging algorithm, Random Forests, Grid search and randomized grid search, Partial dependence plots. **Ensembling and Boosting Algorithms**: Concept of weak learners, Adaptive Boosting, Extreme Gradient Boosting (XGBoost). **Artificial Neural Networks**: Perceptron, Back

propagation, Hopfield Network. **Curse of Dimensionality**: Factor Analysis, Principal Component Analysis (PCA), Difference between PCAs and Latent Factors,

References:

1. K. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.
2. G. James, D. Witten, T Hastie, R Tibshirani, An introduction to statistical learning with applications in R, Springer, 2013.
3. J. Han, M. Kamber, J. Pei, Data Mining concepts and techniques, (2e), Morgan Kaufmann-Elsevier, 2011.
4. T. Hastie, R. Tibshirani, J. Friedman, The Elements of Statistical Learning, (2e), Springer, 2009.
5. T. M. Mitchell, Machine Learning, (Indian Edition), MacGraw Hill, 2017.
6. C. Bishop, Neural Networks for Pattern Recognition, Oxford University Press, 2019

DATA STRUCTURES [3 0 2 4]

Abstract data types, linear data structures and their storage representation: stacks, structures, queues, priority queues, and their applications. Pointers and linked storage representation: singly linked list, circular linked list, doubly linked lists, and their application, skip lists. Non-linear data structures: trees, storage representation of binary trees, operations on binary trees: tree traversals, insertion, deletion, searching, trees, applications of trees, AVL trees, Height balanced trees, threaded binary trees, tree traversal algorithms, Persistence and Multidimensional trees, Huffman coding. Dynamic Data structures: 2-3 trees, Red-black trees, heaps, binomial and Fibonacci heaps, priority queues, skip lists, universal hashing. Graphs and algorithms: Breadth first search and Depth First Search, Shortest paths, minimum spanning tree. Dynamic programming and divide-and-conquer, Sorting: selection sort, bubble sort, insertion sort, merge sort, heap sort, quick sort, radix sort. Searching: sequential search, binary search with analysis.

References:

1. *Ellis Horowitz, Sartaz Sahni, S. Rajasekaran, Fundamentals of computer Algorithms, Second edition, University Press (India) Limited, 2008.*
2. *Debasis Samanta, Classic Data structures- 2nd edition, PHI Learning Private Limited, 2010*
3. *Mark Allen Weiss, "Algorithms, Data Structures and Problem Solving with C++", Addison Wesley, 2002.*
4. *Behrouz A. Forouzan, Richard F. Gilberg, Data Structures, A Pseudocode approach Using C, 2e, Cengage, learning India Pvt.Ltd, India, 2009.*

DATABASE TECHNOLOGIES [3 0 2 4]

Introduction Database Systems, Database Languages, Data models, Database architecture. Relational Model, keys, schema diagrams. Entity-Relationship Model, designing ER model,

Reduction ER to Relational schema. Introduction to SQL Data Definition, constraints, importing and loading data, inserting, modification of data, Basic structure of SQL queries, Basic operations, Joins, Nested subqueries, Data Grouping, top-N-Queries, using regular expressions, views.PL/SQL, Cursors, Functions, Procedures, Triggers. Data Warehouse- Basic Concepts, Data Warehousing multi-tiered Architecture, Enterprise Warehouse, Data Mart, Schemas for Multidimensional Data Models, OLAP Operations, A StarNet Query Model for Querying Multidimensional Databases. Data Interchange formats, Understanding XML, constructing XML data from relational results sets, querying XML. Understanding JSON, format, JSON v/s XML, construct JSON data from relational results sets and querying. Unstructured data handling, the emergence of NoSQL, Aggregate model, Four Types of NoSQL Database, scheme less databases, materialized Distribution models-single server, Shading, Master-Slave replication, Peer-to-Peer Replication, combinations, relaxation consistency, Brewer's cap theorem, CRUD operations using MongoDB, Graph Databases, Features, Suitable Use Cases, CRUD operations using Neo4j/MongoDB.

References:

1. *Abraham Silberschatz, Henry Korth, S. Sudarshan, "Database System Concepts", 6th Edition, McGraw Hill, 2010.*
2. *Ramez Elmasri, Shamkant Navathe, "Fundamentals of Database System", 6th Edition, Addison Wesley Publications Co., 2010.*
3. *Pramod J Sadalage, Martin Fowler, "NoSQL Distilled", Addison-Wesley, 1st Edition, 2012.*
4. *Shashank Tiwari, "Professional NOSQL", John Wiley & Sons Inc., 1st Edition, 2011.*
5. *Kyle Banker, Peter Bakkum, Shaun Yerch, Douglas Garrett, Tim Hawkins, "MongoDB in Action", 2nd Edition, Manning Publications, 2016.*
6. *Kristina Chodorow, "MongoDB: The Definitive Guide", O'Reilly publications, 2nd Edition, 2013.*
7. *Peter A. Carter, "SQL Server Advanced Data Types JSON, XML", and beyond, 2018.*
8. *Anders Moller and Michael I Schwartzbach, "Introduction to XML and Web Technologies", Addison-Wesley, 2006*
9. *Tom Marrs, "JSON at Work Practical Data Integration for the Web", O'Reilly publications, 2017.*

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RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION [1 0 3 2]

Mechanics of Research Methodology: Basic Concepts, Types of research, significance of research, research framework case study method, experimental method, sources of data, data collection using questionnaire, interviewing and experimentation. Research formulation: components, selection and formulation of a research problem. Research hypothesis: Criterion for hypothesis construction, Nature

of hypothesis, need for having a working hypothesis, characteristics and types of hypotheses, procedure for hypothesis testing. Sampling methods, Introduction to various sampling methods and their applications. Data analysis: sources of data, collection of data, measurement and scaling technique, different techniques of data analysis. Thesis writing and journal publication: thesis writing, journal and conference papers writing, IEEE and Harvard styles of referencing, effective presentation, copyrights and avoiding plagiarism.

References:

1. *Dr. Ranjit Kumar, Research Methodology: A Step-by-Step Guide for beginners, SAGE, 2005*
2. *Geoffrey R. Marczyk, David DeMatteo & David Festinger, Essentials of Research Design and Methodology, John Wiley & Sons, 2004.*
3. *John W Creswel, Research Design: Qualitative, Quantitative and Mixed Methods Approaches, SAGE 2004*
4. *Suresh C Sinha and Anil K Dhiman, Research Methodology, (2 Vols-Set) Vedam Books, 2006.*
5. *C. R. Kothari, Research Methodology: Methods and Techniques, New Age International Publisher, 2008*

DATA ANALYTICS & VISUALIZATION LAB [0 1 3 2]

Tutorial on tools for Data Analytics & Visualization. Suggested tools are Python, MATLAB, WEKA, R Studio. Experiments with datasets to be defined in lab manual, to implement concepts of data pre-processing, exploratory analysis, comparative statistics, statistical inference, Association and clustering. Creating Visual Representations- Suggested tools are MSExcel, Power BI, Tableau.

References:

1. *Manaranjan Pradhan, U Dinesh Kumar, "Machine Learning using Python", Wiley Publications.*
2. Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, "An Introduction to Statistical Learning with Applications in R", Springer Science, 2017
3. Cole Nussbaumer Knaflic, *Storytelling with Data: A Data Visualization Guide for Business Professionals,* (1e), John Wiley and Sons, 2015.
4. Brian R. Hunt, Ronald L. Lipsman, Jonathan M. Rosenberg, Kevin R. Coombes, John E. Osborn, Garrett J. Stuck, *Guide to MATLAB: For Beginners and Experienced Users*,(2e), Cambridge University Press, 2011.

MACHINE LEARNING LAB [0 0 3 1]

Tutorial on tools for Machine Learning. Python suggested. Experiments with datasets to be defined in lab manual to perform pre-processing and deploy classifiers such as Regression models, Neural Networks, Bayesian, Decision Trees, Support Vector Machines, k-nearest neighbour. Model evaluation using accuracy measures, learning curves, improving classifier performance through ensembling, boosting etc.

References:

1. *Manaranjan Pradhan, U Dinesh Kumar, "Machine Learning using Python", Wiley Publications.*

2. *Hans Peter Langtangen, Python Scripting for Computational Science, (3e), Springer Publishers, 2014*
3. *Naomi R. Ceder, The Quick Python Book, (2e), Manning Publications Co., 2010*
4. *Wesley J. Chun, Core Python Applications Programming, (3e), Prentice Hall Publishers, 2012*
5. *G. James, D. Witten, T Hastie, R Tibshirani, An introduction to statistical learning with applications in R, Springer, 2013.*

SECOND SEMESTER

DEEP LEARNING [4 0 0 4]

Introduction, Neural Network Basics: Multi-layer perceptron, Back propagation algorithm, training procedures, **Shallow Neural Networks:** Review, Gradient descent, and Activation Function **Deep Feed Forward Networks**: Forward and Backward Propagation, Hidden units, architecture design, Dimensionality reduction, learning time. **Regularization for Deep Learning:** Parameter Norm Penalties, Regularization and Under-Constrained Problems, Dataset Augmentation, Noise-Robustness, Bagging and Other Ensemble Methods, Dropout, Adversarial Training. **Optimization for Training Deep Models**: Challenges in Neural Network Optimization. Deep Neural Networks and the Brain**. Convolutional Networks:** convolution operation, pooling Object detection and Face recognition **Sequence Modelling:** Recurrent and Recursive Networks, **Stacked Auto Encoders**: Under complete, Regularized, sparse, de-noising, Monte Carlo Methods. Markov Models, **Hidden Markov models**: evaluation problem, finding the state sequence, HMM as graphical model. **Deep Generative Models**

Boltzmann Machines-the physics, randomness, impact on cognitive learning. Deep Boltzmann Machines, **Deep Belief Networks**-its relationship to Boltzmann Machines, concept of greedy networks, application to drug discovery. **Generative Adversarial Networks, Auto-regressive Networks**. **Practical Methodology:** Performance Metrics, Default Baseline Models, selecting hyper parameters, Debugging Strategies. **Case Studies in:** Large Scale Deep Learning, Computer Vision, Speech Recognition, Economics, Fraud detection, Crime detection.

References:

1. Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning, MIT Press 2016.
2. Alpaydin Ethem, Introduction to Machine Learning, 3rd Edition, PHI Learning Private Limited, 2018.
3. Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.
4. Simon Haykin, Neural Networks and Learning Machines, PHI, 2008
5. Andrew Ng's Notes on Machine Learning from CS229.
6. Rajasekaran S., and Pai G. A. V., Neural Networks, Fuzzy Logic and Genetic Algorithms, PHI Learning, 2010.

ARTIFICIAL INTELLIGENCE [4 0 0 4]

History of AI- Aristotle to the Dartmouth AI Conference. **Foundations of AI**- Philosophy, Mathematics, Psychology, Computing, Linguistics, Neurosciences, Controls, and Economics. **AI Approaches -** Cognitive Modelling. The Turing Test, Rational thinking - Logic. **Computing streams of AI**- NLP, Machine Learning, Knowledge Representation, Automated Reasoning, Computer Vision, and Robotics. **Intelligent Agents and Environments**- the concept of Rationality, Classification,

working of agents, Single and Multi-Agent System, Performance Evaluation of Agents, Architecture of Intelligent Agents. **AI Problems**: Problem Space, Problem analysis. **Problem Solving Techniques;** Heuristic Search, Uninformed Search, Adversarial Search- games, Constraint Satisfaction Problems. **Games:** Optimal decision in games, Alpha Beta Pruning Knowledge based agents, The Wumpus World. **Knowledge and Reasoning, Representation:** Logical Agents, First order logic and inference, Classical Planning. **Propositional logic:** Propositional Theorem Proving, Representation. Classical Planning, Fuzzy Logic. Ontological Engineering, Semantic Web, RDF data models, RDFS, Querying Semantic Web: SPARQL, filters, Ontology and Information Systems, OWL, Ontology Reasoning: Monotonic rules, Rule interchange format, Semantic web rules languages, RuleML. Quantifying Uncertainty, Probabilistic Reasoning, Making Simple & Complex Decisions. **Reinforcement learning**: Passive, Active, Generalization, Policy Search, Markov Decision Process, Bellman equations, value and policy iteration, Linear Quadratic Regulation, Linear Quadratic Guassian, Q-learning, policy search, POMDPs. **Applications:** NLP, Parsing, Machine translation, speech recognition, **Perception:** Image formation, Image Processing, Object Recognition, Robotics: software agents, Hardware, perception, software architectures. **Future of AI:** Cognitive Modeling approach, Layers of Mental Activities, Layered Knowledge Representation, Cognitive Architectures. **Quantum Computing**: Quantum mechanics and its impact, **Brain –Machine Convergence**.

References:

1. Russell S., and Norvig P., Artificial Intelligence A Modern Approach (3e), Pearson 2010.
2. Marvin Minsky, Society of Mind. Simon & Schuster, 1998
3. Marvin Minsky, The Emotion Machine: Commonsense Thinking, Artificial Intelligence, and the Future of the Human Mind. Simon & Schuster, 2007.
4. Rich E., Knight K., Nair S.B., Artificial Intelligence (3e), Tata McGraw Hill, 2008.
5. Grigoris Antoniou, Paul Groth, Frank van vanHarmelen and Rinke Hoekstra, A Semantic Web Primer, MIT Press, 2012.
6. Ray Kurzweil, The Age of Spiritual Machines: When Computers Exceed Human Intelligence, Penguin (USA) , 2000.
7. Douglas R.Hofstadter, Godel, Escher, Bach: An Eternal Golden Braid, Penguin (UK), 2000.

DEEP LEARNING LAB [0 0 3 1]

Tutorial on tools for Machine Learning. Tensorflow, Python-Keras suggested. Experiments with datasets to be defined in lab manual to deploy deep learning algorithms. Case studies or mini projects in topics such as Sentiment Analysis, Anomaly Detection, Recommender Systems.

References:

1. Hans Peter Langtangen, Python Scripting for Computational Science, (3e), Springer Publishers, 2014
2. Naomi R. Ceder, The Quick Python Book, (2e), Manning Publications Co., 2010
3. Ahmed Menshawy, Md. Rezaul Karim, Giancarlo Zaccone , Deep Learning with TensorFlow, Packt Publishing

4. Introduction to Tensorflow, https://www.tensorflow.org/learn

ADVANCED TECHNOLOGIES LAB [0 0 3 1]

A case study based on the standard public dataset/real time data and application of the technologies learnt through all the courses which leads to a research publication.

1. Gathering data
2. Litrature review
3. Defiing a research problem
4. Desgining experiments
5. Implementation and anlaysis of the results
6. Compiling a research paper

PROGRAM ELECTIVES I & II

DESIGN & ANALYSIS OF ALGORITHMS [3 0 2 4]

The role of algorithms in computing, Asymptotic notations and analysis of the growth of the functions, Algorithmic paradigms: Dynamic Programming, Greedy, Divide and conquer, Decrease and Conquer, Transform and Conquer, Space and Time Trade-offs, Back tracking, Branch-and-bound, Asymptotic complexity, Amortized analysis, Graph Algorithms: Shortest paths, Minimum spanning tree, Flow networks; NP-completeness, Approximation algorithms, Polynomial time reduction, Randomized algorithms, Probabilistic analysis of algorithms. Algorithms for optimization of combinatorial optimization problems, Integer Programming and Network Optimization algorithms, Combinatorial problems on Graphs or Networks, Complexity of Problems such as linear programming and the traveling salesman problem. String processing algorithms: KMP algorithm, Boyer-Moore algorithm. Algebraic and number theoretic algorithms: Modular arithmetic, Chinese remainder theory. Internet Algorithms, Compression algorithms, Search engine algorithms, Parallel algorithms: Basic techniques for sorting, searching, merging

References:

1. *T.H Cormen, C.E Leiserson, R.L. Rivest, C. Stein, Introduction to algorithms, Third edition, PHI, 2009.*
2. *Dan Gusfield, "Algorithms on Strings, trees and Sequences", Cambridge, 2005.*
3. *Pardalos, Panos; Du, Ding-Zhu; Graham, Ronald L., Handbook of Combinatorial Optimization, Springer, 2013*
4. *Kleinberg and Tardos, "Algorithm Design", Pearson, 2000*
5. *Anany Levitin, Introduction to The Design And Analysis Of Algorithms, Pearson Education, 2003.*

DATA COMMUNICATIONS AND NETWORKS [3 0 2 4]

Introduction to Data Communication, Connectionless and connection-oriented service, circuit, and packet switching, packet forwarding in computer networks, network access and physical media, ISPs and Internet backbones, delay and loss in packet-switched networks, protocol layers and their service models. LANs, Network service models, routing principles, hierarchical routing, the Internet Protocol (IP), Routing on the internet, Multicasting and Multicast Routing, Introduction to transport layer services, TCP, UDP and SCTP, Principles of congestion control, TCP Congestion control, Client–Server Model, Socket programming

with TCP, socket programming with UDP. SDN Background and Motivation, SDN Data Plane, SDN Control Plane, Controllers. 5 G Networks

References:

1. *Behrouz A. Forouzan, TCP/IP Protocol Suite (3e), Tata McGraw Hill,2012.*
2. *Leon-Garcia and Widjaja, Communication Networks, Tata McGraw Hill, 2010.*
3. *Jean Walrand and Pravin Varayya, High Performance Communication Networks, Harcourt Asia Pvt Ltd., 2010.*
4. *Andrew S. Tanenbaum, Computer Networks (4e), Prentice Hall India, 2012.*
5. *Richard W Stevens, Unix Network Programming, Vol. – I, Pearson Education 2004.*
6. *William Stallings, Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud (1e), Addison-Wesley Professional, 2015.*
7. *Siamak Azodolmolky, Software Defined Networking with OpenFlow, Packt publishing, 2013.*

CLOUD COMPUTING [3 0 2 4]

Introduction to Cloud Computing: NIST Cloud Computing Reference Architecture, Cloud Services models, Cloud Deployment models, Service level agreements, SLA Management in Cloud, Virtualization: Introduction to Virtualization, Implementation Levels, Virtualization Structures, Tools and Mechanisms, Hyper converged Infrastructure, Virtual Machines Provisioning and Migration Services, Services and Service Oriented Architectures, Message-Oriented Middleware, Cloud Programming and Software Environments: MapReduce, Hadoop Library from Apache, Mapping Applications, Programming Support, Features of Cloud and Grid Platforms, Parallel and Distributed Programming Paradigms, Cloud resource management, Introduction to Fog computing. Security in Cloud: Cloud Security Fundamentals, Challenges and Risks, Cloud Computing Security Architecture, Vulnerability Assessment, Data Security and Privacy.

References:

1. *Rajkumar Buyya, James Broberg, Andrzej Goscinski, Cloud Computing Principles and Paradigm, Wiley Publications, 2013.*
2. *Matthew Portnoy Virtualization Essentials, John Wiley and Sons Publication, 2012*
3. *Thomas Erl, Service oriented Architecture, Pearson publications, 2016*
8. *Kant Hiran, Ruchi Doshi, Temitayo Fagbola, Mehul Mahrishi, "Cloud Computing: Master the Concepts, Architecture and Applications with Real-world examples and Case studies", BPB Publications, First Edition, 2019.*
9. *Barrie Sosinsky, "Cloud Computing Bible", Wiley India Edition, 2013.*
10. *Kailash Jayaswal, Jagannath Kallakurchi, Donald J. Houde, Dr. Deven Shah, "Cloud computing black Book", Dream Tech Press, 2014.*

PARALLEL PROGRAMMING [3 0 2 4]

CPU and GPU architectures for parallel computation, Data parallelism and CUDA C, Data parallel execution model, CUDA memories, CUDA resource constraints and their impact on kernel execution performance, Parallel patterns, CUDA prepackaged libraries, Applications, More on CUDA and graphics processing unit computing, An introduction to OpenCL for CUDA programmers.

References:

1. *David B. Kirk and Wen mei W. Hwu, Programming Massively Parallel processors A Hands on Approach (3e), Morgan Kaufman, 2016.*
2. *Tolga Soyata, "GPU Parallel Program Development Using CUDA", CRC Press, 2018.*
3. *Bhaumik Vaidya, Hands-On GPU-Accelerated Computer Vision with OpenCV and CUDA: Effective techniques for processing complex image data in real time using GPUs (1e), Packt Publishing, 2018.*
4. *John Cheng, Max Grossman, and Ty McKercher, Professional CUDA C Programming, John Wiley & Sons, Inc.2014.*
5. *Shane Cook, CUDA Programming: A developer's guide to parallel computing with GPUs (1e), Morgan Kaufman, 2013.*
6. *CUDA C Programming Guide, Version 4.2, NVDIA corporation, 2012.*

BIG DATA ANALYTICS [3 0 2 4]

Introduction to Big Data: Evolution, Structuring, Elements, Big Data Analytics, Distributed and Parallel Computing for Big Data, Hadoop, Cloud Computing and Big Data, In-memory Computing Technology for Big Data, Big Data Stack, Virtualization and Big Data, Hadoop: Ecosystem, Hadoop Distributed File System (HDFS), MapReduce: MapReduce Framework, Optimizing MapReduce Jobs, MapReduce Applications, Understanding YARN architecture, HBase, Exploring Hive, Analyzing Data with Pig, Using Oozie, Introduction to Mahout, Role of HBase in Big Data Processing, RHadoop: Data Analysis Using the MapReduce Technique in RHadoop, Spark: Core Concepts, Spark's Python and Scala shells, Programming with RDD: RDD Operations, Passing Functions to Spark, Common Transformations and Actions, Mining Data Streams: Streams Concepts, stream Data Model and Architecture, Stream Computing, Filtering Streams, Estimating Moments, Decaying Window, Real time Analytics Platform (RTAP) Applications, Case studies: Real Time Sentiment Analysis, Stock Market Predictions.

References:

1. *Vignesh Prajapathi, Big Data Analytics with R and Hadoop, Packt Publishing, 2013.*
2. *Holden Karau, Andy Konwinski,Patrick Wendell,Matei Zaharia, Learning Spark: Lightning-Fast Big Data Analysis,1st Edition, O'Reilley Media Inc, 2015.*

3. *Michael Minnelli, Michele Chambers, Big Data Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses, Wiley India Pvt. Ltd., 2013.*
4. *Arvind Sathi, Big Data Analytics, MC Press, LLC, 2012.*

DATA PRIVACY & SECURITY [3 0 2 4]

Introduction to Data Privacy, types of privacy attacks, Data linking and profiling, access control models, role-based access control, privacy policies, their specifications, privacy policy languages, privacy in different domains-medical, financial, etc. Mathematical model for comparing real-world data sharing practices, computing privacy and risk measurements. Demographics and Uniqueness. Protection Models-Null-map, k-map, Wrong map. Survey of Techniques-Protection models (null-map, k-map, wrong map), Disclosure control, Inferring entity identities, entry specific databases. Computation systems for protecting delimited Data-Min Gen, Datafly, Mu-Argus, k-Similar. Introduction to Security: The OSI Security Architecture, Security Attacks, Services and Mechanisms, Model for Network Security, Introduction to cryptography, Symmetric Encryption, Substitution ciphers, Stream ciphers, Data Encryption Standard, Number theory, Advance Encryption Standard Public-key cryptography, Digital Signatures, Cryptographic Hash Functions, Message Authentication and Confidentiality, Key Distribution and Authentication, Transport Layer Security, Wireless Network Security, E-mail Security, IP Security, Security Management Systems, Intrusion Prevention and Detection Systems. Security protocols, Secure Socket Layer (SSL), Intruders and Viruses, Firewalls

References:

1. *Ronald Leenes , Rosamunde van Brakel , Serge Gutwirth , De Hert, Paul, Data Protection and Privacy: The Age of Intelligent Machines (Computers, Privacy and Data Protection), Hart Publishing (December 28, 2017)*
2. *B. Raghunathan, The Complete Book of Data Anonymization: From Planning to Implementation, Auerbach Pub, 2016.*
3. *L. Sweeney, Computational Disclosure Control: A Primer on Data Privacy Protection, MIT Computer Science, 2017*
4. *William Stallings, Cryptography and Network Security: Principles and Practice, 7th Edition, Pearson Education, 2017.*
5. *William Stallings, Network Security Essentials: Applications and Standards, 6th Edition, Pearson Education, 2014.*
6. *B. A. Forouzan, Cryptography & Network Security, Tata Mc Graw Hill.*

PATTERN RECOGNITION & APPLICATIONS [3 0 2 4]

Introduction: Definitions of data sets for Pattern Recognition (PR), Different paradigms of PR, Representations of Patterns and Classes, Metric and Non-metric proximity measures, Applications of PR, Feature extraction and feature selection: Feature extraction, different approaches to feature selection, Feature ranking. Statistical Decision Making: Introduction, Bayes theorem, multiple features,

conditionally independent features, decision boundaries, the leaving-one-out technique, characteristic curves, estimating the composition of populations. Naïve Bayes classifier, Bayesian Belief Networks, Supervised and unsupervised Classification: Introduction to supervised and unsupervised classifications, Classification in High dimension, Random forests, SVM classifications. Introduction to clustering, clustering large datasets and combination of classifiers.

References:

1. *Devi V. S, Murthy M. N, Pattern Recognition: An Introduction, Universities Press, Hyderbad. 2011.*
2. *Earl Gose, Richard Johnsonbaugh and Steve Jost, Pattern Recognition and Image Analysis, Prentice Hall of India, 2003.*
3. *R.D. Duda, P.E. Hart and D.G. Stork, Pattern Classification, 2nd Edition, John Wiley Inc., 2001.*

COMPUTER VISION [3 0 2 4]

Overview of image processing systems, image formation and perception, continuous and digital image representation, image quantization, image contrast enhancement, histogram equalization, 2D signals and systems, sampling, linear and nonlinear operations. Mathematical modelling and techniques for image and signal analysis. Image transforms, image degradation models: blurs and noise models, estimation of signal and noise, restoration methods, image registration. Image enhancement techniques, unsharp masking and high-boost filtering. Image segmentation: image thresholding, region-based segmentation methods, region growing, region merging & splitting, active contour models and advanced algorithms. Edge detection, features and fitting, feature descriptors, resizing, image compression, Visual bag of words, motion analysis, geometric camera models, object identification, image classification, motion tracking, robot vision. colour image processing, imaging geometry, applications of image processing to various imaging systems.

References:

1. *Rafael C. Gonzalez & Richard E. Woods, "Digital Image Processing", Addison-Wesley, 2nd edition, 2002.*
2. *Henri Maitre, "Image Processing",first edition, Wiley, 2008. T.F. Chan, J.H. Shen, "Image processing and analysis", SIAM,First edition, 2005.*
3. *L. Shapiro, G. Stockman, "Computer Vision", Prentice Hall, 2001.*
4. *Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1992.*

NATURAL LANGUAGE PROCESSING [3 0 2 4]

Basics of Finite State Automata, Knowledge in Speech and Language Processing, Ambiguity, Models and Algorithm. Survey of English Morphology, Finite-State Morphological Parsing, Building a Finite-State Lexicon, FSTs for Morphological Parsing, Lexicon-Free FSTs. Words and sentence tokenization,

Detecting and Correcting Spelling Errors. Case study: Normalizing Text, Segmentation. N-Grams, Unsmoothed N-Grams, Smoothing, Interpolation, and Backoff. English Word Classes, Tag-sets for English, Part-of-Speech Tagging, The Noisy Channel Model for Spelling. Case study: Automatic Tagging. Constituency, Some Grammar Rules for English, The Penn Treebank project, Dependency Grammar. Parsing with Context Free Grammars, CKY algorithm, Statistical Parsing.

References:

1. *J.E.Hopcroft, R.Motwani & J.D.Ullman , Introduction to Automata Theory Languages, and Computation, (3rd Edition) , Pearson Education.*
2. *Daniel Jurafsky & James H. Martin, Speech and Language Processing, (2e), Pearson, 2009.*
3. *Steven Bird, Ewan Klein and Edward Loper, Natural Language Processing with Python, (1e), O'Reilly Media, 2009*
4. *Akshar Bharati, Rajeev Sangal and Vineet Chaitanya, Natural Language Processing: A Paninian Perspective, Prentice-Hall of India, New Delhi, 1995*
5. *Steven Bird, Ewan Klein, Edward Loper, Natural Language Processing with Python – Analysing Text with natural language toolkit, O'Reilly Media, 2009*
6. *Chris Manning, Hinrich Schutze, Foundations of Statistical Natural Language Processing, MIT Press, Cambridge, 1999*

BUSINESS ANALYTICS [3 0 2 4]

Data-Analytic Thinking for Business: The Ubiquity of Data Opportunities, Data Science as a strategic asset, data analytic thinking, Business Enterprise and its functions, Enterprise Applications – ERP, CRM, MIS. Difference between Business Intelligence and Business Analytics. **Database systems for Business**: OLTP and OLAP systems for business overview and architecture overview. **Business Problems and Data Science Solutions using CRISP-DM Approach**: Business Understanding, preparation, modeling, evaluation, deployment. **Performance Metrics in Analytics -** Key performance Indicators (KPIs), KPI based balanced score card, KPIs on Dashboards. **Project Management -** Project Management, phases, tools, techniques and methodologies in project management, Agile Framework and Scrum Approach. **Quality Management -** quality management philosophy, concepts and tools, Statistical Quality Control methods, Lean and Six Sigma, SERVQUAL model of service quality. **Case studies** – Human Capital Analytics, IT Analytics, Sales and Marketing Analytics, Analytics in telecom, Retail, healthcare, financial markets, social media, sports and other related business fields.

References:

1. *Prasad, R, N. and Acharya, Seema (2016) Fundamentals of Business Analytics. Wiley India Pvt, Ltd, New Delhi*
2. *Provost and Fawcett (2013). Data Science for Business, O'Reilly*
3. *Shmueli, Patel, and Bruce (2009) Data Mining for Business Intelligence, Concepts, Techniques and Applications. Wiley*
4. *Clifford F. Gray, Erik W. Larson, Gautam V. Desai (2014) - Project Management - Tata McGraw Hill*

5. Schwaber Ken (2004). Agile project management with scrum, WP Publishers and Distributors, Bangalore
6. Sridhar Bhatta (2015). Total Quality Management, concepts and cases-Himalaya Publishing House.

FINANCE & ECONOMETRICS [3 0 2 4]

Basic Economics: Nature and significance, Micro & macro differences, Law of demand and supply, Elasticity & equilibrium of demand & supply. Time value of money, Interest factors for discrete compounding, Nominal & effective interest rates, basics of investment and consumption function. **Mathematics of Finance:** Present and future worth of single, Uniform gradient cash flow. Bases for comparison of alternatives, Present worth amount, Capitalized equivalent amount, Annual equivalent amount, Future worth amount, Capital recovery with the return, Rate of return method. **Financial Investment Companies:** Mutual fund companies, types of mutual funds, Calculation of Net Asset Values, Venture Capital Companies, Investment and Merchant Banking companies. **Accounting:** Concept of Financial Accounting, Difference between financial, cost and management accounting, Depreciation of fixed assets: Physical & functional depreciation, Straight-line depreciation, Declining balance method of depreciation, Sum-of-the years digits method of depreciation, Sinking fund and service output methods, basics of cost accounting methods – Job costing and Process costing, Cost sheet format and its uses. **Financial Statements:** Introduction to balance sheet and profit & loss statement. Basic financial ratios. **Financial Econometrics:** Nature of Econometrics and Economic Data. Regression Model, General Linear Model, Auto regressive and distributed Lag Models, Simultaneous Equation Models. Multi-collinearity and Heteroscedasticity, autocorrelation, Qualitative and Limited Dependent Variables Models, Simultaneous Equation Models: Estimation Methods, Panel Data Regression Models and Time Series Econometrics

References:

1. *Prasanna Chandra., Fundamentals of Financial Management, Tata Mc-Graw Hill Companies, New Delhi, 2005.*
2. James L Riggs, David D Bedworth and Sabah U Randhawa., Engineering Economics, Tata McGraw – Hill Publishing Company Ltd, New Delhi, 2004.
3. T. Ramachandran., Accounting and Financial Management, Scitech Publications Pvt. Ltd. India, 2001.
4. Eugene F. B. & Joel F. H., Fundamentals of Financial Management, th 12 ed., Cengage Learning Publisher, 2009.
5. Johnston,J, Econometric Methods, McGraw-Hill Book Co., New York.
6. Maddala, G.S, Econometrics, McGraw-Hill Book Co., New York, 3rd Rd.
7. Gujarathi, D.N, Basic Econometrics, Fourth Edition, Tata McGraw-Hill, New Delhi.

MEDICAL IMAGE PROCESSING [3 0 2 4]

Review of signals, systems & transforms; 2D signals & systems; Medical Imaging: Imaging modalities and their applications; Computed tomography (CT): mathematical basis, the Radon transform & the central slice theorem; Image reconstruction from projections: the Direct Fourier Method, convolution back projection (CBP) algorithm, Algebraic Reconstruction Techniques (ART); reconstruction from fan-beam projections; Extension to 3D – cone-beam CT, spiral CT. Tomosynthesis; X-rays: utility, generation and detection; X-ray CT systems. Emission CT: principles, Positron emission tomography (PET); attenuation correction in ECT; Ultrasound in clinic: benefits/risks, Basics of Ultrasound - review, Ultrasound imaging; Contrast enhanced ultrasound imaging; Motion artifacts in ultrasound imaging. Clutter filtering; elastography, plane wave imaging; Magnetic resonance imaging: Principles of data-generation, resolving the tissues, resolving the spatial locations, and extension to 2D. Resolution & Field of View; Data sampling and the concept of bandwidth.

References:

1. *R.C Gonzalez and R.E. Woods, Digital Image Processing, (4e), Pearson Education Inc., 2017.*
2. *A.K. Jain, Fundamentals of Digital Image Processing, Prentice- Hall, 1989, Fourth Indian Reprint.*
3. *A.C. Kak and M. Slaney, Principles of Computerized Tomographic Imaging, SIAM's Classics in Applied Mathematics, Philadelphia, SIAM, 2001.*
4. *Kline Jacob, Handbook of Biomedical Engineering, Academic Press, 1988.*
5. *Carol M. Rumack, Deborah Levine, Diagnostic Ultrasound, (5e), Elsevier, 2017*

HEALTH INFORMATICS [3 0 2 4]

Introduction to Health care and Information Technology-HealthCare Data – Types of HealthCare Data – HealthCare Databases & Applications – Healthcare Informatics Vs Clinical Informatics-EMR, HER and EPR. Interoperability Standards in Healthcare – Introduction to healthcare standards-need for such standards-HL7-Digital Image Communication in Medicine (DICOM)- Picture Archival and Communication System (PACS)- Clinical Document Architecture (CDA)- Integrating the Healthcare Enterprise . Imaging Systems in Healthcare – Imaging Modalities- Xray, CT, MRI, US- Radiology Information Systems-PACS. Ethics in Healthcare – Protected Healthcare Information-HIPPA-Mobile in Healthcare. Clinical Data Interchange Standards Consortium (CDISC). Telehealth-Telemedicine-Tele Radiology-Data Compression Techniques- IT for rural healthcare. Drug development life cycle, Basics of Drug discovery process, Overview of Clinical Trials, Analytics in Pharmaceutical Industry, Clinical Trails and drug development.

References:

1. *Health Informatics: An Interprofessional Approach - Ramona Nelson and Nancy Staggers.*
2. *Healthcare Informatics - WIlliam Hanson - McGraw-Hill Education.*

3. *"Principles of Medical Imaging" by K. Kirk Shung, Michael B. Smith, Benjamin M.W. Tsui*
4. *"Digital Imaging and Communication in Medicine(DICOM)" by Oleg S Pianykh, Springer.*
5. *"HIMSS Dictionary of Healthcare Information Technology Terms, Acronyms and Organizations", Second Edition, HIMSS, ISBN 13978-1-938904-03-5*
6. *"Telemedicine and Telehealth 2.0: A Practical Guide for Medical Providers and Patients" by Victor Lyuboslavsky, Paperback.*
7. *"Textbook of Healthcare Ethics" 2nd Edition Erich H. Loewy, M.D. , Roberta Springer Loewy, Ph.D. University of California, Davis School of Medicine Sacramento, California, Kluwer Academic Publishers New York.*

PROGRAM ELECTIVES III

ENTERPRISE DATA ARCHITECTURE [4 0 0 4]

Enterprise Architecture- Overview, core elements, Structure of enterprises. Introduction to Enterprise Data Architecture (EDA). Developing an EDA- structured vs. unstructured data, analysis and planning approaches, data governance, security, privacy, value and risk, implementation methodology, components and artifacts, Developing Current Architect Views, Repository and Support Tools. Data Quality Management – Concepts and Implementation. Enterprise Data models - performance requirements and rendering, performance testing and monitoring; Disaster Recovery strategies, Fault Tolerance and Recovery, data-sharding, de-duplication in-memory computing, Effective Metadata modeling, design, and management. Enterprise Architectural frameworks – Open-Source Frameworks, MEGAF, India Enterprise Architecture (IndEA), National Institute of Standards and Technology (NIST), IndiaStack, Praxeme. TOGAF framework – modular structure, content framework, extended guidance, architectural styles. Application architecture- Open-source components, API, and micro-services, building UX layer. Hardware for EDA- Data warehousing, Enterprise Big Data Storage Models, , Cloud and edge-computing, Polyclouds and data interchange, Case studies. Mini project on creating a EDA for a specific enterprise using open-source technologies.

References:

1. *Andy Graham, The Enterprise Data Model: A framework for enterprise data architecture, Koios Associates Ltd, 2nd edition, 2012 .*
2. *Charles D. Tupper, Data Architecture: From Zen to Reality, Morgan Kaufmann, 1 edition, 2011.*
3. *Len Silverston, The Data Model Resource Book, Volume 1and 2: A Library of Universal Data Models for All Enterprises, Wiley, Revised edition, 2001.*
4. *https://dama.org/content/body-knowledge , DAMA-DMBOK: Data Management Body of Knowledge.*
5. *John Ladley, Data Governance: How to Design, Deploy and Sustain an Effective Data Governance Program , Morgan Kaufmann, 1st edition, 2012.*
6. *Scott A. Bernard , An Introduction to Enterprise Architecture, AuthorHouse, 3rd edition.*
7. *https://www.opengroup.org/togaf, TOGAF, The Open Group*

QUANTUM COMPUTING [4 0 0 4]

Introduction, Fundamental concepts. Quantum bits, Quantum computation, Quantum algorithms, Quantum Information, Introduction to Quantum Mechanics, Liner algebra, Postulates of quantum mechanics, Quantum Computation, Quantum circuits, Controlled operations, Measurement, Universal quantum gates, The Quantum Fourier Transform, The quantum Fourier transform, Phase estimation, Applications, Quantum Search Algorithms, Quantum counting, Speeding up the solution of NP-

Complete problems, Quantum Information, Classical noise and Markov processes, Quantum Operations, Quantum Error Correction, The Shor code, Theory of quantum error correction, Entropy and Information, Shannon entropy, Basic properties of entropy, Von Neumann entropy, Quantum Information Theory, Distinguishing quantum states and the accessible information, Data compression, Classical information versus noisy quantum channels, Quantum information versus noisy quantum channels, Entanglement as a physical resource, Quantum cryptography.

References:

1. *Michael A Nielsen, and Isaac L. Chuang "Quantum Computation & Quantum Information", (10e), Cambridge University Press, 2011.*
2. *F. Benatti, M. Fannes, R. Floreanini, and D. Petritis, "Quantum Information, Computation and Cryptography" Springer, 2010.*
3. *Mika Hirvensalo, "Quantum Computing", (2e), Springer-Verlag New York, 2004.*
4. *Jozef Gruska, "Quantum Computing", McGraw Hill, 1999.*
5. *Phillip Kaye, Raymond Laflamme and Michele Mosca, "An Introduction to Quantum Computing", Qxford University Press, 2006.*

INTERNET OF THINGS [4 0 0 4]

Introduction to internet of things, IoT in global context, Design Principles, IoT Technology Fundamental- Devices and gateways, Local and wide area networking, Data management, Business processes in IoT, IoT reference Architecture, IoT Domain Model, Functional Model. Information Model, Communication Model, Deployment and Operational View, IoT Prototyping- Prototyping Embedded Devices, Electronics, Sensors, Actuator, Embedded Computing Basics, Arduino, Raspberry Pi, BeagleBone Black, IoT Use Cases - Industrial Automation, Smart Home, Smart City, Commercial Building Automation.

References:

1. *McEwen A., Designing the Internet of Things, Wiley, 2014*
2. *Holler J., From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence, Academic Press, 2014.*
3. *Francis daCosta, Rethinking the Internet of Things: A Scalable Approach to Connecting Everything, Apress Publications, 2013*
4. *Pethuru R., The Internet of Things: Enabling Technologies, Platforms, and Use Cases, CRC Press, 2017*
5. *Vijay M., Internet of Things (A Hands-on-Approach), Universities Press, 2014*
6. *Daniel M., Building the Internet of Things with IPv6 and MIPv6: The Evolving World of M2M Communications, Wiley, 2013.*

ALGORITHMIC TRADING [4 0 0 4]

Basic Trading strategies- Discretionary, Algorithmic Trading, Hybrid. Algorithmic vs. High-Frequency/Low Latency Trading. **Industry Overview**- Alternatives, Hedge Funds, Commodity Trading Advisor Funds, Quant Funds. Tracking Funds, Tracking Benchmarks, Basic Portfolio Strategies. **Mathematics for algorithmic trading**- Prediction of prices, Risk calculation, Capital Allocation, locking in Options & Futures **Review of Time Series, Capital Allocation, Momentum, Options, and futures**- trend, seasonal, cyclical, and irregular components, white noise, Brownian motion, Auto covariance, autocorrelation and criteria. ARIMA models, Autoregressive Models, Moving Average Models, ARMA Models. Box-Jenkins method, characteristic polynomials, Sharpes and Skewness, Stationary vs. Non-stationary processes, criteria (AIC, BIC) for model choice, Cross Validation, Bootstrap and Stochastic Differential Equations (SDE)s., Kalman Filters. **Algorithmic Trading Basics**- Back testing, Automated Execution, Momentum, Mean Reversion, Carry, Value, Basic Portfolio Strategies, Over fitting. **Mean Reversion Strategies** - Mean Reversion of Stocks, ETFs, Currencies and Futures, Timescales/horizons associated with MR, Momentum and Value, Volume and Mean Reversion Liquidity, Unit Root Tests, Augmented Dickey Fuller Tests. KPSS Tests, Variance Ratio Tests. Co-integration and Johansen Test. **Momentum/Trend Following**- properties and tradeoffs, Inter-day and Intraday Momentum Strategies, Risk Management. Skewness over horizon results, momentum modelling. **Filters, change points** - sequential binary segmentation, switching Kalman filters, Carry, Value, P vs. Q-measure. **Over fitting**- p-hacking, lack of reproducibility, holdout over fitting. Adjusted Sharpe Ratios. Multiple Hypothesis Testing – Holm-Bonferroni. BHY adjustments. ML for Algorithmic trading, pitfalls, and future opportunities. **Case Studies**: Introduction to Quantopian, Mini project using open-source technologies to build and test simple algorithmic models

References:

1. Earnest Chan, *Algorithmic Trading: Winning Strategies and Their Rationale*, John Wiley & Sons , 1st edition, 2013.
2. Ernie Chan, *Quantitative Trading: How to Build Your Own Algorithmic Trading Business*, John Wiley & Sons;, 1 edition , 2008
3. Rishi K. Narang, *Inside the Black Box: The Simple Truth about Quantitative Trading*, John Wiley & Sons , 1st edition, 2009.
4. Barry Johnson, *Algorithmic Trading and DMA: An introduction to direct access trading strategies*, 4Myeloma Press, 2010.
5. David J. Leinweber, Theodore R. Aronson, *Nerds on Wall Street: Math, Machines and Wired Markets* , John Wiley & Sons, 1st edition, 2009.
6. Alex Kuznetsov, *The Complete Guide to Capital Markets for Quantitative Professionals (McGraw-Hill Library of Investment and Finance)* . McGraw-Hill Education, 1 edition, 2006.

DIGITAL MARKETING [4 0 0 4]

Introduction: Online Market space- Opportunities for building Brand, Digital eco system and channels, Market and customer segmentation, Digital Marketing Strategy Components, Combining digital and traditional media. Search Engine Optimization: How Search Engine works, SEM components, PPC advertising with Google ad words, Display Advertisement. Search Engine Optimization: SEO success factors (On-Page and Off-Page Techniques), Google analytics. Display Advertising: Real time bidding, Executing display advertising, E-commerce Models. Social Media Marketing: Social Media Channels. Facebook, Twitter, Linkedin, Instagram, other Soc. Media channels. Leveraging social media for brand conversations and buzz, Successful /benchmark social media campaigns. Social Media Marketing: Promoting/advertising brand in social media, Social Media Feedback, Measuring Social media impact. E- Mail Marketing: Types of E- Mail Marketing, Email Automation, Lead Generation, Integrating Email with social media and Mobile, Digital Marketing for B2B, Measuring and maximizing email campaign effectiveness. Online Reputation Management: Combining digital and traditional media, Power of social media, Monitoring SM, Proactive and reactive reputation management. Creating a Digital Marketing Strategy: Elements of strategy, Operational aspects of strategy, Digital Marketing plans. Mobile Marketing: Mobile Inventory/channels, Location based, Context based, Coupons and offers, Mobile Apps, Mobile Commerce, SMS Campaigns, Profiling and targeting. Web Analytics and Channel Attribution Strategies: Social Media Analytics, Website Analytics, Channel attribution model.

References:

1. *Maity, Moutusy (2017), Internet Marketing: A Practical Approach in the Indian Context, Oxford University Press (ISBN: 9780199469550)*
2. *Richard Gay, Alan Charlesworth and Rita Esen (2013), Online Marketing- a customer led approach, Oxford University Press, New York. 3. Alan Charlesworth (2014), Digital Marketing: A Practical Approach*
3. *Avinash Kaushik, Web Analytics 2.0 (2009): The Art of Online Accountability*

BIOINFORMATICS [4 0 0 4]

Introduction to Bioinformatics, Central Dogma of Biology, Digital Code of Life, Database Sequence Search & Alignment, The evolutionary basis of Sequence Alignment, The Modular Nature of Proteins, Optimal Alignment Methods, Substitution Scores and Gap Penalties, Statistical Significance of Alignments, Structure File Formats; Visualizing Structural Information, Motifs and Pattern, Protein Structure Prediction, Searching for Trees, Rooting Trees, Evaluating Trees and Data, Phylogenetic Software, Phylogenetics on the Web, Some Simple Practical Considerations. Introduction to Genomics, Genome Annotation, Comparative Genomics, Genome Compression.

References:

1. *Arthur M. Lesk. Introduction to Bioinformatics, Oxford University Press, 2002.*
2. *Stuart M. Brown. BIOINFORMATICS: A biologists guide to biocomputing and the internet, NYU Medical Center, 2000*