ANNEXURE 1

Master of Technology (Computer Science and Engineering)

Course Structure and Syllabus

Semester I

S. No.	Course Name		Credits
1.	Mathematical Foundations for CSE	Core	4
2.	Machine Learning	Core	4
3.	Advanced Computer Networks	Core	4
4.	Advanced Database Management System	Core	4
5.	Advanced Operating System	Core	4

Semester II

S. No.	Course Name		Credits
1	Advanced Algorithms	Core	4
2	Elective-I	Elective	4
3	Elective II	Elective	4
4	Elective III	Elective	4
5	Elective IV	Elective	4

Semester III

S.No.	Course Name		Credits
1	Academic Ethics and Technical Writing	Core	4
2	Research Methodology	Core	4
3	Research Reading and Laboratory	Core	4
4	Seminar	Core	4
5	Minor Dissertation	Core	8

Semester IV

S.No.	Course Name		Credits
1	Major Dissertation	Core	16

List of Electives Courses for M. Tech (CSE)

S.No.	Course Name	Credits
1	Cryptography	4
2	5G and 6G Networks	4
3	Next generation Wireless Networks	4
4	Wireless Communication and Mobile Computing	4
5	Cloud Computing	4
6	Image Processing	4
7	Computer Vision	4
8	Computer Graphics	4
9	Deep Learning	4
10	Big Data Analytics	4
11	Natural language processing	4
12	Artificial Intelligence	4
13	Quantum Computing	4
14	Computer Organization and Architecture	4
15	Web Technology and Services	4
16	Mobile Application Development	4
17	Nonlinear Dynamics	4
18	CAD for VLSI Design	4
19	Embedded Systems	4
20	Detection and Estimation Theory	4
21	Advanced Software Engineering	4
22	Data Communication and Computer Networks	4
23	Data Mining and Knowledge Discovery	4
24	Large Scale Graph Algorithms and Application	4
25	Mobile Ad Hoc Networks	4
26	Multicast Communication	4
27	Network Security	4
28	Object Oriented Software Engineering	4
29	Performance Analysis of Computer Communication Networks	4
30	Swarm Intelligence	4
31	Services Oriented Architecture	4
32	Parallel & Distributed Systems	4
33	Optimization Techniques	4
34	Router and Switch Design and Analysis	4
35	Quantum Communication and Cryptography	4

Syllabus

Core Courses

1. Mathematical foundations for CSE

Introduction to Probability, Random variables; Expectation, Variance, Moment generating function, Characteristic function; Bivariate and multivariate distributions - Joint, marginal and conditional distributions, Covariance, correlation, order statistics; Central limit theorem, Sampling distributions, Theory of Estimation, Maximum likelihood estimation, Testing of Hypotheses; Graphs, Graph isomorphisms, Special graphs; Connectivity, paths and cycles; Planar graphs, Shortest path problems, Graph coloring; Trees, Tree traversal algorithms, Minimum spanning trees; Matrices and their properties (Determinants, Traces, Rank, Nullity) Subspaces, Hyperplanes, Linear Dependence and Span, Basis; Eigenvalues and eigenvectors, Matrix factorizations; Inner products, Distance measures, Projections; Linear programming, Simplex method, Duality in linear programming, Convex optimization and Quadratic programming; Least squares optimization, Unconstrained optimization; Newton method, Gradient descent, Stochastic gradient descent and Conjugate gradient descent methods; Constrained optimization, KKT conditions.

Suggested Readings:

- S. M. Ross, Probability Models, 11th Edition, Academic Press, 2014
- K. S. Trivedi, Probability and Statistics with Reliability, Queuing and Computer Science Applications, 2nd Edition, Wiley, 2004
- K H. Rosen, Discrete Mathematics and Its Applications, McGraw Hill Education, 7th Edition, 2012.
- Gilbert Strang, Introduction to Linear Algebra. 4th ed. Wellesley, MA: Wellesley-Cambridge Press, 2009
- W Forst, D Hoffmann, Optimization-Theory and Practice, Springer-Verlag New York, 2010.

2. Machine Learning

Introduction to various machine learning paradigms and Bayesian decision theory: Introduction to various machine learning paradigms. An overview of Machine learning, Bayesian decision theory. Neural Networks and SVMs: Linear and nonlinear discriminants using Perceptron and multilayer Perceptron, Introduction to Deep Learning-CNNs, Reinforcement learning: Introduction to reinforcement learning, Policy– Evaluation, Model free learning, Policy search, Exploration/Exploitation, Applications to KDD., Learning by training Neural Networks; Support vector machines and different kernel functions, Linear and nonlinear discriminants using Perceptron and multilayer Perceptron.

Unsupervised learning (clustering)& Decision Trees: Unsupervised learning (clustering): Learning from unclassified data. Clustering. Hierarchical Agglomerative Clustering. k-means partitional clustering. Dimension reduction techniques, Inductive learning: ID3, C4.5,C5, Learning Concepts and rules from Examples; Learning by analogy; Learning from observation and discovery; Learning by experimentation. Dimension reduction techniques & Genetic algorithms: PCA, ICA, Genetic Algorithm; Analysis learning

Suggested Readings:

- R. O. Duda, P. E. Hart and D. G.Stork , "Pattern Classification".
- Christopher M. Bishop , "Pattern Recognition and Machine Learning".
- Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani. "An Introduction to Statistical Learning"
- Ethem Alpaydin , "Introduction to Machine Learning" , MIT Press, 2010.
- T.M. Mitchell, Machine Learning McGraw-Hill, 1997.
- S. Marsland, Machine learning: an algorithmic perspective, CRC Press, Taylor and Francis Group, 2015
- Sutton and Barto, "Reinforcement Learning: An Introduction", 2nd Edition, O'Reilly Media, year.

3. Advanced Computer Networks

Computer networks fundamentals, TCP/IP protocol stack model, role and responsibilities of different layers, Recent advances in the protocols, CoAP, MQTT, multipath TCP, transport layer limitations in modern networks, buffer bloat problem, QUIC, SCTP, DCCP protocols, Congestion control algorithms in TCP, CUBIC, TCP New Reno, effect of wireless networks on TCP congestion control algorithms, Ipv6, mobile IP, multicast routing, Software defined networks (SDN), Centralized and Distributed Control and Data Planes, Openflow protocol, SDN controllers, NFV, applications of SDN and NFV in different networks, applications of AI/ML in computer networks Wireshark based live traffic analysis, socket programming, computer networks based mini project, realization of various protocols on Network Simulator 3.

Suggested Readings:

- Computer Networks by A.S. Tanenbaum, Prentice Hall of India.
- Computer Networking: A Top-Down Approach Featuring the Internet by J. Kurose and K.W. Ross, Addison-Wesley.
- Data and Computer Communication by W. Stallings, Prentice Hall of India

4. Advanced Database Management System

Database Approach - System Concepts and Architecture, Database Users; Languages – Relational Algebra, Tuple and Domain Relational Calculus; SQL; Query Processing and Optimization: Steps in Query Processing, Measures of Query Cost, Query Optimization, Transformation of Relational Expressions. Storage Strategies: Indexing, B-Tree, Hashing, Transaction Management - Transaction, ACID properties, Transaction State Diagram, Schedule, 2-PC, Concurrency, Recovery, Deadlock; Database Security: Security vs Integrity, Data Encryption, Access Control, Intrusion detection, SQL injection PL/SQL Concepts: View, Stored Procedures, Database Triggers, Cursors.

Suggested Readings:

- R. Elmasri, S. Navathe, Fundamentals of Database Systems, Pearson, Sixth Edition, 2006.
- Silberschatz H., Korth, S. Sudarshan, Database System Concepts, McGraw Hill,
- H G Molina, J. D. Ullman, J Widom, Database Systems: The Complete Book, Pearson, 2008.

5. Advanced Operating System

Centralized Operating Systems: Introduction to kernels, Memory and Process Management and scheduling: Different memory management schemes. Process synchronization: Various mechanisms to ensure the orderly execution of cooperating processes. Virtual memory. Mobile operating system: features, concepts and challenges. Case study: Android OS; Distributed Operating Systems: Concepts and Architectures, Concurrent Processing and Concurrency Control, Distributed Process Management, Distributed File Systems, Current Issues of Modern and Distributed Operating Systems. Selected case studies, such as Amoeba, Chorus, Mach, etc.

Suggested Readings:

- Mukesh Singhal, "Advanced Concept in Operating Systems," Tata McGraw Hill.
- W. Stalling, "Operating Systems: Internals and Design Principles," Pearson.
- Andrew S. Tanenbaum, "Operating Systems: Design and Implementation," Eastern
- Economy edition.
- P.K. Sinha, "Distributed Operating system: Concepts and Design," PHI.
- Maarten van Steen and Andrew S. Tanenbaum, "Distributed Systems," 3rd edition.
- Andrew S. Tanenbaum and Maarten van Steen, "Distributed Systems: Principles and
- Paradigms," 2nd edition.

6. Advanced Algorithms

Fundamental Algorithm Concepts: Divide-and-Conquer, Dynamic Programming, Greedy, Branch-and-Bound, Backtracking; Problem-Solving: Bin Packing, Knapsack, Travelling Salesman Problem; Numerical algorithms: Integer, Matrix and Polynomial Multiplication, Extended Euclid's algorithm, Modular Exponentiation, Primality Testing, Cryptographic Computations. String Matching Algorithms: Suffix arrays, Suffix trees, tries, Rabin-Karp, Knuth Morris-Pratt, Boyer Moore algorithm. Approximation algorithms: Need of approximation algorithms: Introduction to P, NP, NP-Hard and NP-Complete; Deterministic, Non-Deterministic Polynomial time algorithms; Knapsack, TSP, Set Cover, Open Problems.
Randomized algorithms: Introduction, Type of Randomized Algorithms, Quick Sort, Min- Cut, 2-SAT; Game Theoretic Techniques, Random Walks.

Suggested Readings:

- Ellis Horowitz and Sartaj Sahni, Fundamentals of Data Structures, Computer Science Press
- Aaron M. Tenenbaum, Yedidyah Langsam, Moshe J. Augenstein, Data Structures Using C, Pearson Press.
- T. H. Cormen, C. E. Leiserson, R.L. Rivest, C. Stein, Introduction to Algorithms, MIT Press
- Ellis Horowitz and Sartaj Sahni, Fundamentals of Computer Algorithm, Computer Science Press

7. Academic Ethics and Technical Writing

Significance and ways to carry out literature review; Structure and components of a research report, project proposal and research paper; Ethics: definition, moral philosophy, nature of moral judgements and reactions; Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP); Redundant publications: duplicate and overlapping publications, salami slicing; Selective reporting and misrepresentations of data; Publication ethics; Conflicts of interest; Publication misconduct and its identification; Violation of publication ethics, authorship and contributorship; Predatory publishers and journals; Open access and subscription based publications; Online resource to check publisher copyright and self-archiving policies; Journal finder tools; Conflict of interest; Plagiarism and its detection tools; Indexing and citation databases; Impact factor; h-index; g-index; i10 index etc.

Suggested Reading

- Ethics in Science Education, Research and Governance, Edited by K. Muralidhar, A. Ghosh, & A.K. Singhvi. New Delhi: Indian National Science Academy. ISBN: 9788193948217, 2019.
- Research Evaluation Metrics. UNESCO Curriculum for Researchers by U. Kanjilal and A.K. Das, ISBN: 978-92-3-100082-9, 2015.
- Concepts of openness and open access by D.P. Madalli, ISBN: 978-92-3-100079-9, 2015.

8. Research Methodology

Research: meaning, objective and types; Research process; Criteria of good research; Research problem: meaning, necessity to define and techniques involved in defining a research problem; Research design: meaning, need, characteristics and types; Sampling design: implications, steps, selection criteria, characteristics, types and concept of random sample; Measurement techniques: scales, source of errors, sound measurement and techniques of developing measuring tools; Scaling techniques: meaning, classification, various scaling and scale construction techniques; Data collection techniques; Processing and analysis of data: processing operations, elements of analysis, statistics in research and regression analysis; Sampling: need, fundamental terminologies, sampling distributions sampling theories, estimation and sample size; Hypotheses testing: significance, procedure, various parametric tests; Chi-square test, ANOVA and Multivariate analysis techniques.

Suggested Reading

- Research Methodology: Methods and Techniques by C.R. Kothari, ISBN (13): 978-81-224-2488-1, 2nd Edition, 2004.
- Research design: Qualitative, Quantitative, and Mixed Methods Approaches by J.W. Creswell and J.D. Creswell, 5th Edition, 2019.
- Management Research Methodology: Integration of Principles, Methods and Techniques by K. N. Krishnaswamy, M. Mathirajan and Appa Iyer Sivakumar, 1st Edition, 2006.

9. Research Reading and Laboratory

The student will read research papers, and related thesis reports which are relevant to his/her area of work and any other technical or scientific literature which the supervisor may assign for a better understanding of the domain in which the student is pursuing his/her doctoral research work. The evaluation and assessment for this course will be conducted by the supervisor.

10. Seminar

The Seminar course would include seminars related to the dissertation work. This course would be evaluated by a seminar evaluation committee comprising atleast three faculty members.

11. Minor Dissertation

Student would pursue the minor dissertation in the school and submit it to the school for evaluation. The dissertation of each student is to be evaluated, through viva-voce/ presentation, by the minor dissertation evaluation committee of the School.

12. Major Dissertation

Student would pursue the major dissertation in the school and submit it to the school for evaluation. 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 Competent Authority of the University.

Elective Courses

1. Cryptography

Number theory: divisibility, Euclidean algorithm, modular arithmetic, Chinese remainder theorem, Fermat's theorem, Euler's theorem, primality testing; Algebra: groups, rings, fields, polynomial arithmetic, finite fields, AKS algorithm; Symmetric ciphers: Classical ciphers, Steganography, Block ciphers, design principles, DES, Cryptanalysis of DES; AES: structure, transformation functions, key expansion; Pseudorandom Number generators, use of Block ciphers in PNG, stream ciphers, True RNG; Asymmetric ciphers: Principles of public key cryptography, RSA cryptosystem, Cryptanalysis of RSA, Diffie-Hellman key exchange, ElGamal cryptosystem, Elliptic curve cryptography, Lattice based cryptography; Cryptographic applications: Cryptographic hash functions: classical, based on CBC models, MD-5, SHA-1,2,3; Digital signature schemes: principles, ElGamal, Schnorr, ECC, NIST DSA; Message authentication codes: MAC functions, security of MACs, MACs using hash functions and block ciphers.

Suggested Readings:

- William Stallings, "Cryptography and Network Security - Principles and Practice", Pearson Education India, 7th Edition, 2017T. J. Santner, B. J. Williams and W. I. Notz, "Design and Analysis of Computer Experiments", Springer, 2003
- Jeffrey Hoffstein, Jill Pipher, Joseph H. Silverman, "An Introduction to Mathematical Cryptography", Springer, 2014
- Johannes Buchmann, "Introduction to Cryptography", Springer, 2004

2. 5G and 6G Networks

Introduction to 5G Technology :Advancements in 4G technologies and Foundation of 5G technologies, 5G Requirements, 5G candidate technologies, key drivers of 5G, New spectrum for 5G, 5G Standardization, 5G Use Cases, 5G Architecture, 5G NR Protocol Stack, 5G NR

Numerologies and Overall Transmission Structure.5G NR based V2X Communications in ITS-Role of V2X Communications (Vehicle to Everything Communications) in ITS (Intelligent Transportation Systems, ITS Spectrum, V2X Uses Cases, ITS Protocol Stacks, Cellular V2X (C-V2X), Communications modes of C-V2X, C-V2X Architecture, Resource Allocation in C-V2X. 5G NR based Open Radio Access Networks (ORAN)-.ORAN Architecture, ORAN open interfaces, Near-RT RIC, xApps, and control of the RAN, Non-RT RIC and orchestration framework, AI/ML workflows in ORAN, ORAN use cases, ORAN development and standardisation, Implementation of ORAN framework in NS3.5G NR in Unlicensed Spectrum-Unlicensed Spectrum for NR, Technology Components for Unlicensed Spectrum, Channel Access in Unlicensed Spectra, Downlink Data Transmission, Uplink Data Transmission, Downlink Control Signaling, Uplink Control Signaling, Initial Access Foundation of 6G Technologies - Network evolution beyond 5G, Targets of 6G technologies, features, and capabilities of 6G, 6G use cases, 6G requirements, timeline, 6G standardization, India's initiatives for 6G, Bharat 6G mission updates of 6G development, Interworking of terrestrial and non-terrestrial networks.

Suggested Readings:

- Erik Dahlman, Stefan Parkvall, Johan Skold, "5G NR: The Next Generation Wireless Access Technology", Elsevier, 2016.
- Sassan Ahmadi, "5G NR Architecture, Technology, Implementation, and Operation of 3GP New Radio Standards", Elsevier, 2018.
- M. H. C. Garcia et al., "A Tutorial on 5G NR V2X Communications," in IEEE Communications Surveys &Tutorials, vol. 23, no. 3, pp. 1972-2026, 2021. https://doi.org/10.1109/COMST.2021.3057017

3. Next generation Wireless Networks

Introduction to Wireless Networks: History of wireless networks, types of wireless networks, modern wireless networks, scope and use cases, challenges in wireless networks, wireless MAC layer protocols, mobility, basics of wireless communications and networks. 802.11 Wireless LAN-Characteristics of WLAN, Adhoc and infrastructure based WLAN networks, DCF, PCF, applications and use cases of WLAN, goals of different Wi-Fi standards, IEEE 802.11a, b, g, n, p, ac, ah, ax, bd, be. Cellular Networks: Fundamentals of cellular networks, uses cases and applications, history of cellular networks, scope of next generation cellular networks, 2G, 3G, 4G, 5G, 6G. Modern Wireless Technologies- Convergence of Wi-Fi and Cellular technologies, NFV and SDN based wireless networks, application of AI/ML in wireless networks, IEEE 802.15.4, IoT based technologies, NB-IoT, 6Lowpan, LORA, BLE, vehicular networks, V2X communications, visible light communications. Network Simulator 3 (NS-3): Introduction to NS3, types of different network simulators, realising the scenarios of different wireless networks in NS-3, NS-3 based projects.

Suggested Readings:

- Martin Sauter, From GSM to LTE: An Introduction to Mobile Networks and Mobile Broadband, Wiley Publications
- Jochen Schiller, Mobile communications, Perason Education, 2nd edition.
- Anil K. Rangisetti, Advanced Network Simulations Simplified: Practical guide for wired,
- Wi-Fi (802.11n/ac/ax), and LTE networks using ns-3, Packet Publishing.

4. Wireless Communication and Mobile Computing

Mobile radio systems, Paging systems, cordless telephone system, cellular telephone system, Cellular Concept: Frequency reuse, channel assignment, hand off, Interference and cell splitting,

sectoring, Improving Coverage and capacity in Cellular systems. Propagation modeling: Outdoor/ Indoor Propagation models, Small scale Multipath propagation- Rayleigh fading, Ricean Fading, Nakagami fading, Shadowing, lognormal shadowing fading model, outage probability, coverage estimation under shadowing, and multipath fading. Wireless Networks 802.11, frequency-hopping, encoding and modulation, MAC Layer Protocol Architecture Multiple access with collision avoidance protocol, Virtual Carrier-Sensing, DCF Protocol, PCF Operation. Mobility: challenges, limits and connectivity, mobile TCP, mobile IP and cellular IP in mobile computing.

Suggested Readings:

- Rappaport, Wireless communications: principal and practice, Pearson ed.
- Matthew s. Gast, 802.11 wireless networks, o'reilly
- Andrea Goldsmith, Wireless communication, cambridge university press ed.
- Jochen Schiller, Mobile communications, phi/person edu., 2 nd ed.,

5. 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:

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

6. Image Processing

Digital image fundamentals: basics of visual perception, image acquisition, image sampling and quantization, pixel relationships, Intro. to mathematical tools used in DIP, etc. Intensity transformation and spatial filtering: gamma correction, histogram equalization and matching, spatial convolution, filter masks, image sharpening, Gabor filters, Intro. to bilateral filtering (supplement) etc. Color image processing: Color models, color transformations, color corrections, processing of color images, etc. Filtering in the frequency domain: Fourier transform of 2-D signals and sampling, the DFT in 1-D and 2-D and properties, image smoothing and sharpening in the frequency domain, frequency domain features, etc. Basics of Fourier Imaging, 2-D DSP topics based on additional textbooks: wavelets and filter-banks, 2-D filter design, etc. Image restoration and reconstruction: mean and order statistics filters, image degradation estimation, Wiener filtering, Intro. To regularization-based restoration (supplement). Morphological image processing: Basic operations on binary images such as: dilation, erosion, opening and closing, various applications of morphological filters, image segmentation: Edge detection and linking, thresholding, region-based segmentation, clustering and super pixels,

morphological watershed segmentation, etc. Graduate projects can start at this point; more topics are listed next but not all of them will be covered. feature extraction: binary image feature, region features, texture features, corner detection, etc.

Suggested Readings:

- Fundamentals of Digital Image processing by A. K. Jain, Pearson Education
- Digital Image Processing by R. C. Gonzalez and R. E. Woods, Pearson Education

7. Computer Vision

Feature Detection, Description, Correspondence and Alignment: Introduction and Overview, Light, Image Formation, Filtering, Edge Detection, Feature Detection, Harris Corner Detection, Invariance and Blob Detection, Feature Descriptors and Matching, Image Transformations, Image Alignment, RANSAC, Hough Transform, etc. Perspective and 3D Geometry: Camera Models, Single-view Geometry and Calibration, Image Stitching, Epipolar Geometry, Stereo, Structure from Motion, etc. Recognition and Learning: Intro to Recognition, Viola-Jones Face Detection, Bag-of-Words Model, Convolutional Neural Networks. Advanced topics: Image Classification, Object Detection, Segmentation, Image Generation, etc.

Suggested Readings:

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

8. Computer Graphics

Input devices, Video display devices, Area filling algorithms with irregular boundaries, Cohen-Sutherland and Cyrus-Beck line clipping algorithms, Basic 2-dimensional and 3-dimensiona geometric transformations, Homogeneous coordinate system, Parallel projection, Isometric projection and its construction, Perspective projection, Hidden surface elimination algorithms, Basic illumination models, Gouraud and Phong surface rendering models, Representation of curves and surfaces.

Suggested Readings:

- Computer Graphics; Principles and practice; Second Edition in C; J. D. Foley, A. Van Dam, S. K. Feiner and J. F. Hughes; Addison Wesley, 1997.
- Computer Graphics - C version; D. Hearn and M. P. Baker; Pearson Education, 2004.
- Computer Graphics - OpenGL version; D. Hearn and M. P. Baker; Pearson Education.
- Mathematical elements for Computer Graphics; 2nd edn.; D. F. Rogers and J. A. Adams; McGraw-Hill International. Edn., 1990.
- Computer Graphics using OpenGL; 2nd edn.; F. S. Hill Jr.; Pearson Education, 2003.
- The OpenGL Reference Manual - The Bluebook, Version 1.4, Fourth Edition, Addison-Wesley.
- The OpenGL Programming Guide - The Redbook, Version 2, Fifth Edition, Addison-Wesley.

- OpenGL Programming Guide, 6th. Edition, Pearson Education, Shreiner, Woo, Neider, Davis, 2008

9. Deep Learning

Machine Learning: features, weights, Artificial Neural Network, loss function, cost function, ANN: forward propagation; Backpropagation, Stochastic Gradient Descent, Batch gradient descent, mini batch gradient descent, Optimisers: Momentum, RMSProp, Adam, Deep Learning Experiments: Datasets, training-validation testing set, Evaluation measures: accuracy, precision, recall, f-measure; Model Improvement: Overfitting vs underfitting, Bias vs Variance, Regularization: L1, L2 regularization, Dropout, Early stopping, Data normalization, Batch normalization, Hyper parameter Tuning: random, coarse to fine, Network architecture search. Imbalance data problem, Data Augmentation in image: Cropping, Flipping, Rotation, Brightness, Contrast, Color Augmentation, Saturation, Convolutional Neural Networks: convolution, striding, padding, pooling, Alexnet Architecture, Image classification (ImageNet Challenge), Well known CNN architectures VGG16&19, Residual Block, Resnet50, 1x1 convolution, XceptionNet, EfficientNet, Transfer learning ; Object Detection: setup problem and cost function, well known datasets, Evaluation measure: Average precision, Mean average precision, Two stage detector, single stage detector, RCNN, Fast RCNN, Faster RCNN, SSD, YOLO1-4, RetinaNet, EfficientDet, Image Segmentation: setup problem and cost function, various dataset, Semantic segmentation, Instance segmentation, Evaluation measure: IoU/Jacard Index, Dice score, Mean pixel accuracy, Segnet, Unet, Mask R-CNN; Generative Learning, Variational Auto-encoders, Generative Adversarial Neural Networks, GL Applications: Image generation, font generation, video generation, anime face/celebrity face generation, Deep Reinforcement Learning, Markov decision Processing, Exploration vs Exploitation, Value Iteration vs Policy Iteration, RL Applications: Robotics, gaming, Ad Targeting, recommendation system, decision making, Model optimization for Deployment, Pruning, Quantization and binarization, Transferred or Compact Convolutional Filters, Knowledge distillation.

Suggested Readings:

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

10. Big Data Analytics

Data Analytics - Types – Phases - Quality and Quantity of data – Measurement: Exploratory data analysis - Business Intelligence. Big Data and Cloud technologies: Introduction to HADOOP: Big Data, Apache Hadoop, MapReduce - Data Serialization - Data Extraction - Stacking Data - Dealing with data. Introduction to data visualization – Data visualization options – Filters – Dashboard development tools – Creating an interactive dashboard. Machine learning – Modeling Process – Training model – Validating model – Predicting new observations –Supervised learning algorithms – Unsupervised learning algorithms, Data Science Ethics – Doing good data science – Owners of the data - Valuing different aspects of privacy - Getting informed consent - The Five Cs – Diversity – Inclusion – Future Trends.

Suggested Readings:

- Davy Cielen, Arno D. B. Meysman, Mohamed Ali, Introducing Data Science,Manning Publications Co., 1st edition, 2016.
- Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, An Introduction to

Statistical Learning: with Applications in R, Springer, 1st edition, 2013.

- Bart Baesens, Analytics in a Big Data World: The Essential Guide to Data Science and its Applications, Wiley.
- D J Patil, Hilary Mason, Mike Loukides, Ethics and Data Science, O' Reilly, 1st edition, 2018

11. Natural Language Processing

Characteristics of Natural language – ambiguity, incompleteness, imprecision; Linguistic Essentials – Part of speech, Lexicography, morphology, Phrase structure grammar, theory, Semantics and pragmatics; Grammatical frameworks – Chomsky hierarchy, X-bar theory, LFG, Unification grammar; Knowledge Representations – Frames, Scripts, Conceptual graphs; Applications of Statistical Techniques - Word Sense Disambiguation, Lexical Acquisition, Markov Model for Part-of-speech tagging, Probabilistic CFG; Named Entities; Theories of Parsing, Parsing Algorithms - probabilistic and shallow parsing; Scope Ambiguity and Attachment Ambiguity resolution. Lexical Knowledge Networks, Wordnet Theory; Semantic Roles; Word Sense Disambiguation; Metaphors; Coreferences. Sentiment Analysis; Text Entailment; Robust and Scalable Machine Translation; Word vector embeddings, RNNs in language models, Vanishing gradient problem, Sequence to Sequence learning, Attention, Augmented RNNs, Transformers, Pretraining, Question Answering systems, Natural Language generation.

Suggested Readings:

- Manning D. Statistical Foundation of Natural language Processing, MIT Press, 1999.
- James A. Introduction to Natural Language Understanding, Addison Wesley, 1991.
- Harris M.D. Natural Language Processing, Benjamin/Cumming, 1991

12. Artificial Intelligence

Overview of AI: Foundations, history and sate of art; Problem Solving: Search, Game playing; Knowledge Representation and Reasoning: First Order Logic, building knowledge-bases, Logic based Reasoning Systems, Semantic Networks, Frames; Uncertainty and Reasoning, Bayesian networks, Demster-Shafer theory, Fuzzy Sets; Planning; Machine Learning: learning from observations, Artificial Neural Networks, Reinforcement learning; Intelligent Agents; Natural Language Processing; Robotics.

Suggested Readings:

- Knight, Kevin, Rich, Elaine, Nair, B., artificial Intelligence, Tata McGraw-Hills, 2008
- Russell, Stuart, Artificial Intelligence: A Modern Approach, Pearson Edition 2013
- Winston, P.H. Artificial Intelligence, Pearson, 2002

13. Quantum Computing

Linear algebra and the dirac notation: Overview, Computers and the Strong Church–Turing Thesis, The Circuit Model of Computation, A Linear Algebra Formulation of the Circuit Model, Reversible Computation, A Preview of Quantum Physics, Quantum Physics and Computation, The Dirac Notation and Hilbert Spaces, Dual Vectors, Operators, The Spectral Theorem, Functions of Operators, Tensor Products, The Schmidt Decomposition Theorem, Some Comments on the Dirac Notation. Qubits and the framework of quantum mechanics: The State of a Quantum System, Time-Evolution of a Closed System, Composite Systems, Measurement, Mixed States and General Quantum Operations, Mixed States, Partial Trace, General Quantum Operations. A quantum model of computation: The Quantum Circuit Model, Quantum Gates, 1-

Qubit Gates, Controlled-U Gates, Universal Sets of Quantum Gates, Efficiency of Approximating Unitary Transformations, Implementing Measurements with Quantum Circuits. Superdense coding and quantum teleportation: Superdense Coding, Quantum Teleportation, An Application of Quantum Teleportation. Probabilistic Versus Quantum Algorithms, Phase Kick-Back, The Deutsch Algorithm, The Deutsch–Jozsa Algorithm, Simon's Algorithm. Algorithms with superpolynomial speed-up: Quantum Phase Estimation and the Quantum Fourier Transform, Error Analysis for Estimating Arbitrary Phases, Periodic States, GCD, LCM, the Extended Euclidean Algorithm, Eigenvalue Estimation, Finding-Orders, The Order-Finding Problem, Some Mathematical Preliminaries, The Eigenvalue Estimation Approach to Order Finding, Shor's Approach to Order Finding, Finding Discrete Logarithms, Hidden Subgroups, More on Quantum Fourier Transforms, Algorithm for the Finite Abelian Hidden Subgroup Problem, Related Algorithms and Techniques. Algorithms based on amplitude amplification: Grover's Quantum Search Algorithm, Amplitude Amplification, Quantum Amplitude Estimation and Quantum Counting, Searching Without Knowing the Success Probability, Related Algorithms and Techniques.

Suggested Readings:

- Paul Kaye, Raymond Laflamme, and Michele Mosca, An Introduction to Quantum Computing, Oxford University Press (2007).
- Eleanor Rieffel and Wolfgang Polak, A Gentle Introduction to QUANTUM COMPUTING, MIT USA

14. Advance Computer Organization and Architecture

Basic functional blocks of a computer: CPU, memory, input-output subsystems, control unit. Instruction set architecture of a CPU: registers, instruction execution cycle, RTL interpretation of instructions, addressing modes, instruction set. Data representation: signed number representation, fixed and floating-point representations, character representation. Computer arithmetic: integer addition and subtraction, ripple carry adder, carry look-ahead adder, multiplication techniques (shift-and-add, Booth multiplier, carry save multiplier), division techniques (non-restoring and restoring techniques, floating-point arithmetic). CPU control unit design: hardwired and micro-programmed design approaches. Memory system design: semiconductor memory technologies, memory organization. Peripheral devices and their characteristics: input-output subsystems, I/O transfers (program-controlled, interrupt-driven, and DMA), privileged and non-privileged instructions, software interrupts, and exceptions. Performance Enhancement Performance enhancement techniques: pipelining (basic concepts, throughput, speedup, pipeline hazards), memory organization (memory interleaving, hierarchical memory organization, cache memory, cache size vs block size, mapping functions, replacement algorithms, write policy).

Suggested Readings:

- Computer Organization and Design, 4th Ed, D. A. Patterson and J. L. Hennessy.
- Computer Architecture, Berhooz Parhami, 2019.
- Computer Organization and Design: The Hardware/Software Interface, MorganKaufmannD. A. Patterson, J. L. Hennessy, 2016.
- Computer Organization and Architecture: Designing for Performance, Pearson Education. W. Stallings, 2022.

15. Web Technology and Services

Internet Overview- Networks - Web Protocols — Web Organization and Addressing - Web Browsers and Web Servers,URL - Domain Name – Client-side and server-side scripting. HTML5 – Form elements, Input types and Media elements, CSS3. Client side processing and scripting: JavaScript Introduction –Functions – Arrays – DOM, Built-in Objects, Event handling, Validation- AJAX - JQuery. XML Basics – XSL, XSLT, XML Schema, Introduction to Servlets, Servlet Life Cycle, Form Data handling, Client Request and Server Response, Cookies Handling and Session Tracking, Introduction to JSP, Implicit object, Directive handling, Introduction to JDBC – Connections – Internal Database Connections – Statements – Results Sets - Prepared Statements - Callable Statements. Advanced technologies: Introduction to JS frameworks, Angular JS, Microsoft Technologies: ASP.NET, API and Web services, Content management System: WordPress.

Suggested Readings:

- Esposito Dino "Modern Web Development: Understanding Domains, Technologies, And User Experience", Microsoft Press, 1st edition, 2016.
- Randy Connolly and Ricardo Hoar "Fundamentals of Web Development",Pearson, 1st edition, 2016.
- N. P. Gopalan and J. Akilandeswari "Web Technology: A Developer's Perspective", PHI, 1st edition, 2014.

16. Mobile Application Development

History of Mobile-Mobile ecosystem, Mobile Information Architecture, Mobile Design, Types of mobile application, Brief discussion on Java Programming, API levels, Introduction to Android and IOS-Architecture, components and features. Tools for App development, creating your first project- Layouts, Views and Resources, Text and Scrolling Views, Activity Lifecycle and Saving State. Views-Text View, Edit Text Button, Radio Button, Check Box, Toggle, Switch, Chip, Time Picker, Date Picker, API-Components Basics: Activities, Services, Broadcast Receivers, Content Providers. Activities and Implicit Intents, User Input Controls Menus, Selection components (Grid View, List View, Spinner), Adapters, Custom Adapters, Complex UI components, Creating custom and compound Views. Notifications- Toast, Dialogs, Status bar Notifications. Android-Shared Preferences, Android File System- Internal storage, External storage, SQLite, IOS: local Storage and session Storage, Client-Side Database.

Suggested Readings:

- App Programming Guide for iOS-Apple developer - 2014 Apple Inc
- Paul Deitel,Harvey Deitel,Android for programmers an app-driven approach Deiteldeveloper series, Abbey Deitel,Michael Morgano-2012 Pearson Education, Inc.

17. Nonlinear Dynamics

History of dynamics, importance of being nonlinear, formulation of dynamics using differential equations, state space representation, brief introduction of chaos and fractals. Flow along a line, fixed points and stability, impossibility of oscillations in one dimensional motion, concept of bifurcation: saddle node bifurcation, trans-critical bifurcation, pitchfork bifurcation, examples of bifurcations: laser threshold, insect outbreak. Introduction to two dimensional linear systems, definition and examples, classifications of linear systems, phase portraits, fixed point and linearization, conservative and reversible systems. Concept of limit cycles, ruling out closed orbits, Poincare-Bendixson theorem, applications: weakly nonlinear oscillators, relaxation oscillators, bifurcations revisited. Introduction to chaos, example of a chaotic waterwheel, simple properties of the Lorentz system, concept of strange attractor and chaos.

Suggested Readings:

- S. Strogatz, Nonlinear Dynamics and Chaos. Reading, MA: Addison-Wesley, 1994.

ISBN: 9780201543445.

- M. Lakshmanan, and S. Rajasekar, Nonlinear Dynamics: Integrability, Chaos and Patterns, Springer Verlag, 2003.

18. CAD for VLSI Design

Introduction to VLSI Design: Overview of VLSI technology, VLSI design flow, challenges. Verilog/VHDL: introduction and use in synthesis, modeling combinational and sequential logic, writing test benches. Logic synthesis: two-level and multilevel gate-level optimization tools, state assignment of finite state machines. Basic concepts of high-level synthesis: partitioning, scheduling, allocation and binding. Technology mapping. Synthesis of reversible logic circuits: Basic concepts of reversible circuits and synthesis. Exact, Transformation-based synthesis, and ESOP-based synthesis methods. Physical design and Verification. Review of MOS/CMOS fabrication technology. VLSI design styles: full-custom, standard-cell, gate-array and FPGA. Physical design automation algorithms: floor-planning, placement, routing, compaction, design rule check, power and delay estimation, clock and power routing, etc. Special considerations for analog and mixed-signal designs.

Suggested Readings:

- Principles of CMOS VLSI Design, Systems Perspective, 1993. Neil H. E. Weste and Kamran Eshraghian.
- Basic VLSI Design, Prentice Hall of India, 1995. Douglas A Pucknell and Kamran Eshraghian.
- CMOS VLSI Design: A Circuits and Systems Perspective, Pearson Education, 2015. Neil H. E. Weste and David Money Harris.
- Contemporary logic design, Addison-Wesley Pub, 2005. R.H. Katz and Gaetano Borriello.
    - Verilog VHDL synthesis: a practical primer, 1998. J. Bhasker.
- Algorithms for VLSI physical design automation, Kluwer Academic Publishers, 1995. N.A. Sherwani.Digital VLSI systems design, Springer, 2007. S. Ramachandran.

19. Embedded Systems

Basics of computer architecture and the binary number system: Basics of computer architecture, Computer languages, RISC and CISC architectures, Number systems, Number format conversions, Computer arithmetic, Units of memory capacity. Introduction to Embedded systems: Application domain of embedded systems, Desirable features and general characteristics of embedded systems, Model of an Embedded System, Microprocessor vs Microcontroller, Example of a Simple embedded system, Classification of Scum : 4/8/16/32 Bits, History of embedded systems, Current trends. Embedded Systems – The hardware point of view: Micro-controller Unit(MCU), Memory for embedded systems, Low power design, Pull-up and pull-down resistors. Sensors and Actuators: Sensors, Analog to Digital Converters, Actuators. Examples of Embedded Systems: Mobile Phone, Radio frequency identification(RFID), Biomedical Applications, Wireless sensor networks(WISENET), Robotics. Automated design of Digital IC's : History of integrated circuit(IC) design, Types of Digital IC's, ASIC design, ASIC design: the complete sequence; Real – time Operating Systems: Real-time tasks, Real-time systems, Types of Real-time tasks, Real-time operating systems, Real- time scheduling algorithms, Rate Monotonic Algorithm, The Earliest deadline first algorithm, Qualities of a Good RTOS. Hardware Software Co-design and Embedded Product development lifestyle management: Hardware Software Co-design, Modeling of Systems, Embedded Product Development Lifecycle Management, Lifestyle Models. Embedded Design: A Systems Perspective: A typical Example, Product Design, The Design Process, Testing, Bulk Manufacturing. Internet of Things: Sensing and Actuation From Devices, Communication Technologies, Multimedia Technologies, Circuit Switched Networks, Packet Switched

Networks.

Suggested Readings:

- Lyla B. Das, Embedded Systems: An Integrated Approach, Pearson
- Raj Kamal, Embedded Systems Architecture, Programming and Design, Tata Mcgraw Hill

20. Detection and Estimation Theory

Introduction: Review of Gaussian Variables and Processes; Problem Formulation and Objective of Signal Detection and Signal Parameter Estimation in Discrete-Time Domain.

Statistical Decision Theory: Bayesian, Min-Max, and Neyman-Pearson Decision Rules, Likelihood Ratio, Receiver Operating Characteristics, Composite Hypothesis Testing, Locally Optimum Tests, Detector Comparison Techniques, Asymptotic Relative Efficiency.

Detection of Deterministic Signals: Matched Filter Detector and its Performance; Generalized Matched Filter; Detection of Sinusoid with Unknown Amplitude, Phase, Frequency and Arrival Time, Linear Model. Detection of Random Signals: Estimator-Correlator, Linear Model, General Gaussian Detection, Detection of Gaussian Random Signal with Unknown Parameters, Weak Signal Detection.

Estimation of Signal Parameters: Minimum Variance Unbiased Estimation, Fisher Information Matrix, Cramer-Rao Bound, Sufficient Statistics, Minimum Statistics, Complete Statistics; Linear Models; Best Linear Unbiased Estimation;

Maximum Likelihood Estimation, Invariance Principle; Estimation Efficiency; Bayesian Estimation: Philosophy, Nuisance Parameters, Risk Functions, Minimum Mean Square Error Estimation, Maximum Aposteriori Estimation.

Suggested Reading

- Detection, Estimation and Modulation Theory: Part I, II, and III by H. L. Van Trees, John Wiley, NY, 1968.
- An Introduction to Signal Detection and Estimation by H. V. Poor, Springer, 2/e, 1998.
- Fundamentals of Statistical Signal Processing: Estimation Theory by S. M. Kay, Prentice Hall PTR, 1993.
- Fundamentals of Statistical Signal Processing: Detection Theory by S. M. Kay, Prentice Hall PTR, 1998.

21. Advanced Software Engineering

Overview of Software Engineering, Methods of Analysis and Design of Software Systems: Structured and Object Oriented, Coding Standards and Guidelines, Theoretical Foundation of Testing: Coverage Criterions, Software Testing Techniques and Strategies, Software Debugging; Software Project Metrics and Estimation Techniques: Empirical, Heuristic and Analytical Techniques; Software Project Planning and Scheduling: PERT and CPM; Software Project Crashing; Software Reliability Metrics and Models, Software Availability, Software, Risk and Configuration Management; Software Reuse and Re-engineering; CASE Tools and Support; Software Quality Assurance.

Suggested Readings:

- Pressman, R., Software Engineering – A Practitioner's approach, Sixth Edition,McGrawHill International Edition.
- Ghezzi, C., Jazayeri, M., Mandrioli, D., Fundamentals of Software Engineering, Second Edition, Pearson Education.
- Peters, J.F., Pedreyz, W., Software Engineering - An Engineering Approach, John Wiley and Sons. Sommerville, I., Software Engineering, Sixth Edition, Pearson Education.
- Taha, H.A., Operations Research – An Introduction, Seventh Edition, Pearson Education.

22. Data Communication and Computer Networks

Data Communication – Analog and digital communications, Channel characteristics, modulation, encoding schemes; Error Detection and correction, Flow control, multiplexing switching, Multiple access techniques, Routing – shortest path algorithms, routing protocols, virtual path routing, Network Protocols – IP, TCP, UDP, FTP, SMTP, etc, Performance Evaluation – Queuing models, Traffic model – deterministic and stochastic

Suggested Readings:

- Leon Garcia and Indra Widjaja, Communication Networks: Fundamental Concepts and Key Architecture, 2 nd ed., Tata McGraw-Hill, 2004
- Anurag Kumar, D. Manjunath and Joy Kuri, Communication Networking: An analytical approach, Elsevier, 2004.
- Dimitri Bertsekas and Robert Gallager, Data Networks, 2 nd ed., PHI, 2001.
- Thomas G. Roberttazzi, Computer Networks and Systems, 3 rd ed. Springer, 2002

23. Data Mining and Knowledge Discovery

Concepts of data mining and knowledge discovery: Input – concepts, instances, attributes; Knowledge representation of outputs; Data mining methodologies – classification, prediction, regression, association, clustering, outlier analysis, Advanced data mining models – Machine learning: incremental learning, reinforcement learning, genetic algorithms, neural networks, intelligent agents based learning; Soft Computing: Concepts and ML models using Fuzzy set theory and Rough set theory. Applications of data mining in complex data: world-wide web, Streams, Scientific, spatial Current topics

Suggested Readings:

- Han, J. and Kamber, M., Data Mining: Concepts and Techniques, Morgan Kaufmann,2e, 2007.
- .Witten, Ian H. and Frank Eibe, Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations. Morgan Kaufmann, 2e,2005.
- Tan, P., Kumar, V. and Steinbach, M., Introduction to Data Mining, Pearson Education Inc. 2007
- Hand, David, Mannila Heikki and Smyth Padheaic, Principles of Data Mining, PrenticeHall India, 2004 (Indian reprint)
- Thuraisingham, B., Data Mining: Technologies, Techniques, Tools, and Trends, CRC Press, 1999

24. Large Scale Graph Algorithms and Application

Introduction and Application of Large-scale Graph, Characteristics, Complex Data Sources-Social Networks, Simulations, Bioinformatics; Categories- Social, Endorsement, Location, Co-occurrence graphs; Basic and Advanced Large-scale Graph Analysis- List Ranking, Link

Analysis, Page Ranking Algorithms; Distributed Computation for Massive Data Sets- Spectral, Modularity-based Clustering, Random Walks; Large Graph Representation and Implementation V-Graph Representation, MapReduce, Surfer, GraphLab; Advanced Topics-Power Law Distribution, Game-Theoretic Approach, Rank Aggregation and Voting Theory, Recommendation Systems, Social network analysis: case study - Facebook, LinkedIn,Google+, and Twitter.

Suggested Readings:

- Social and Economic Networks by Matthew O. Jackson (Nov 21, 2010)
- Stanley Wasserman, Katherine Faust "Social Network Analysis Methods and Applications" (Structural Analysis in the Social Sciences) 1995
- Tanja Falkowski "Community Analysis in Dynamic Social Networks" 2009
- Ladislav Novak, Alan Gibbons, "Hybrid Graph Theory and Network Analysis" Cambridge Tracts in Theoretical Computer Science 2009.
- Eric D. Kolaczyk, "Statistical Analysis of Network Data Methods and Models" Springer Series in Statistics 2009.
- Akihito Hora, Nobuaki Obata Quantum Probability and Spectral Analysis of Graphs"

25. Mobile Ad Hoc Networks

Fundamentals of Wireless Communication Technology – Radio Propagation Mechanisms Multiple Access Techniques, Characteristics of wireless Channel. Ad Hoc Networks – Definition, Application, challenges, Traffic profile, and challenges, Media Access protocols Topology-based routing; Position-based routing, Mobility and location Management, Transport Protocols, Energy Conservation Issues QoS, Security issue, Simulation of protocols

Suggested Readings:

- C. Siva Ram Murthy and B.S. Manoj, Ad Hoc Wireless Networks – Architecture and Protocols, Pearson Education, 2004 (Low price edition)
- C.K. Toh, Ad hoc Mobile Wireless Networks – Protocols and Systems, Prentice Hall, 2002.
- Ivan Stojmenovic (ed), Handbook of Wireless Networks and Mobile Computing, John Wiley, 2002

26. Multicast Communication

Introduction, Application, Characteristics, Multicast Backbone Architecture, Multicast Routing, Basic Routing Algorithm, Group Dynamics, Multicast routing between domains, IP multicast, Multicast in transport protocols, address allocation, Multicast LANs, Reliable Multicast, Congestion control, Security issues.

Suggested Readings:

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

27. Network Security

Introduction, Security goals, attacks, services and mechanisms, cryptography and steganography, Symmetric Key cipher-substitution ciphers, Transposition ciphers, stream and block ciphers, Modern block ciphers, Modern stream ciphers, DES and AES, Elliptic curve cryptosystems, RSA, Message integrity, Digital signature, Public key distribution, IPSec, SET,

ESP, PGP, SSL, Security in wireless**.**

Suggested Readings:

- Stallings, Cryptography and Network Security: Theory and practice, JohnWiley, 2013
- Behrouz A. Forouzan, Cryptography and Network security, Tata Mcgraw Hill 2010.
- Bible Eric Cole, Ronald L.Krutz, Network security, Welley 2009.
- Stinson D., Cryptography, Theory and Practice, CRC Press, Boca Raton, FA 2005.

28. Object Oriented Software Engineering

Object Oriented Concepts; Modeling with UML; Analysis - Object Model, Dynamic Model; System Design - Addressing Design Goals; Object Design; Reusability - Introduction to Design Patterns; Mapping Models to Code; Testing Techniques - Unit, Integration and System Testing

Suggested Readings:

- Bruegge B. and Dutoit A.H., Object-Oriented Software Engineering, Using UML, Patterns, and Java, 3rd Edition, Prentice-Hall, 2010
- Booch G., Rumbaugh J and Jacobson I., The Unified Modeling User Guide, Addison Wesley
- Longmen, 2nd Edition, 2005.
- Gamma, et al., Design Patterns, Elements of Reusable Object Oriented Software", Addison
- Wesley, Ist Edition,1994.
- Craig Larman, Applying UML and Patterns - An Introduction to Object-Oriented Analysis and Design and Iterative Development, Prentice Hall, 3rd Edition, 2008

29. Performance Analysis of Computer Communication Networks

Role of Modeling and Analysis, Examples of Performance Modeling, Analytic Models, Elements of Stochastic process, Poisson Process, Basic Queuing models, M/M/1; M/M/∞; M/G/ ∞; M/M/m; M/M/m/m Queues with Product formula. Cell and Burst scale Traffic Models: Round trip time distribution, PING data, Markov modulated Poisson Process, Long Range Dependence, Heavy Tail Distribution. Traffic Control: Admission Control, Effective, Bandwidth, Statistical Multiplexing gain, Access Control: Leaky bucket System. Multi access Modelling: Slotted ALOHA Markov chain, Diffusion Approximation Approach, CSMA, Congestion Control, Window Control, Modelling TCP, Window Size, TCP Window Dynamics.

Suggested Readings:

- M. N. O. Sadiku, S. M. Musa, Performance Analysis of Computer Networks, Springer, 2013.
- I. Kaj, Stochastic Modeling in Broadband Communications Systems, SIAM, 2002
- H. Kobayashi, B. L. Mark, System Modeling and Analysis, Foundations of System Performance Evaluation, Pearson Prentice Hall, 2009.
- M.H. Balter, Performance Modeling and Design of Computer Systems, Cambridge Univ. Press , 2013.

30. Swarm Intelligence

Introduction to Models and Concept of Computational Intelligence, Social Behavior as Optimization: Discrete and Continuous Optimization Problems, Classification of Optimization Algorithms, Evolutionary Computation Theory and Paradigm, Swarm and Collective

intelligence, Swarm Intelligence Techniques: Particle Swarm Optimization, Ant Colony Optimization, Artificial Bees and Firefly Algorithm etc., Hybridization and Comparisons of Swarm Techniques, Application of Swarm Techniques in Different Domains and Real World Problems.

Suggested Readings:

- Engelbrecht, A.P. Computational Intelligence: An Introduction, Second Edition, John
- Wiley and Sons, 2007.
- Kennedy, J. and Eberhart, R.C., Swarm Intelligence, Morgan Kaufmann Publishers, 2001
- Bonabeau, E., Dorigo, M. and Theraulaz, G., Swarm Intelligence: From Natural to Artifical Systems, Oxford University Press, 1999
- Dorigo, M., Stutzle, T., Ant Colony Optimization, MIT Press, 2004
- Parsopoulos, K.E., Vrahatis, M.N., Particle Swarm Optimization and Intelligence:Advances and Applications, Information Science Reference, IGI Global, 2010
- Clerc, M., Particle Swarm Optimization, ISTE, 2006 7. Nature Inspired MetaheuristicAlgorithms, Xin-She Yang, Luniver Press, 2010

31. Services Oriented Architecture

SOA Fundamentals - definition, characteristics; Architecture; Evolution; Web Service; Web Service Composition - Orchestration and Choreography; Interoperability; WS*, Metadata; Security; XML Technology - name-spaces, schema, well-formed XML documents; WSDL - name spaces, Abstract and Concrete Models; Universal Description, Discovery and Integration (UDDI), SOAP (messaging framework); Composition Languages - BPEL and CDL 19 | 23.

Suggested Readings:

- Thomas Erl, Service Oriented Architecture (SOA) : Concepts, Technology and Design, Prentice Hall, 2008 2. Newcomer E. and Lomow G, Understanding SOA with Web
- Services, Addison Wesley, 2004
- http://www.w3.org/xml
- http://www.w3.org/TR/wsdl
- http://docs.oasis-open.org/wsbpel/2.0/OS/wsbpel-v2.0-OS.html
- http://www.w3.org/TR/ws-cdl-10/

32. Parallel & Distributed Systems

Introduction to Parallel and Distributed Systems, Classification, Various Speedup Laws, Interconnection Network Architecture, Algorithms On Parallel/Distributed Machine, PRAM Model, EREW, ERCW, CREW, CRCW Algorithms, Sorting Networks 0-1 Principle, Bitonic Sorter, Merger, Sorter, Distributed Systems, Interprocess Communication, Message Passing Communication, Distributed Coordination, Physical And Logical Clocks, Distributed serverless computing

Suggested Readings:

- K Hwang, Advanced Computer Architecture, TMH, 2011
- M.J. Quinn, Parallel Computing, Mc-Graw Hill, 1994
- T. H. Cormen, Algorithms, PHI, 2009
- A. S. Tanenbaum, Distributed System, Pearson Education, 2002

33. Optimization Techniques

Mathematical preliminary, Linear programming, Simplex method, Duality in linear programming, Convex optimization and quadratic programming, least squares optimization, Unconstrained optimization problems, Nonlinear constrained optimization, Problems with equality constraints, Problems with inequality constraints, Application of mathematical programming in machine learning.

Suggested Readings:

- S. Chandra, Jayadeva, A. Mehra, Numerical Optimization with Applications, Alpha Science International Ltd, 2008.
- I Griva, S. G. Nash, A Sofer, Linear and Nonlinear Optimization, Society for Industrial Mathematics, 2008.
- W Forst, D Hoffmann, Optimization—Theory and Practice, Springer-Verlag New York, 2010.

34. Router and Switch Design and Analysis

Basics of computer networks, TCP/IP protocol stack, switching, switching and bridging, interconnecting LANs, learning switches, spanning trees, switches vs routers, buffer sizing, routing, interdomain and intradomain routing, routing algorithms and protocols, RIP, OSPF, BGP, IP addressing, classless interdomain, longest prefix match, NAT, IPv6, IPv4 to IPv6, IPv6 routing table entries, router design, basic router architecture, crossbar switching, scheduling and fairness, max-min fairness, router as DHCP server, SNMP, traffic engineering, measuring, modelling and controlling traffic, Queuing Models, SDN, Programming of SDN, router attacks and security, Firewall, DNS security.

Suggested Readings:

- Computer Networks by A.S. Tanenbaum, Prentice Hall of India.
- Computer Networking: A Top-Down Approach Featuring the Internet by J. Kurose and K.W. Ross, Addison-Wesley.
- Anurag Kumar, D. Manjunath and Joy Kuri, Communication Networking: An analytical approach, Elsevier, 2004.
- I. Kaj, Stochastic Modeling in Broadband Communications Systems, SIAM, 2002

35. Quantum Communication and Cryptography

Introduction to quantum communication: quantum. Networks, difference between classical and quantum networks, overview of the current quantum networks deployed, Photon polarization: Maxwell's equations, applications of polarization in quantum networks, Composite quantum networks, Nonlinear and Quantum Optical Sources, CASCADE Algorithm, Quantum entanglement and teleportation, experimental quantum teleportation, no cloning theorem, Information Theory, Components from Broadband QKD (Quantum Key Distribution) and Implementation, Review of classical cryptography, quantum public key encryption, digital hash functions, key exchange protocols, MACs, quantum error correcting codes.

Suggested Readings:

- Daniel J. Rogers, Broadband Quantum Cryptography, Springer International Publishing, 2020
- Thomas Vidick, Stephanie Wehner, Introduction to Quantum Cryptography, Cambridge University Press, 2023
- Federico Grasselli, Quantum Cryptography: From Key Distribution to Conference Key Agreement, Springer International Publishing, 2021

- Ramona Wolf, Quantum Key Distribution: An Introduction with Exercises, Springer International Publishing, 2021
- Daniel J. Bernstein, J. Buchman, E. Dahmen, Post-Quantum Cryptography