M. Sc. (Computer Science)

CURRICULUM

(w.e.f. 2025-26)

DEPARTMENT OF COMPUTER SCIENCE

Course Structure

SEMESTER I						
Course Type	**Course Code**	**Course Title**	**L**	**T**	**P**	**C**
DSC	CSC411	Parallel and Distributed Computing	3		1	4
DSC	CSC412	Combinatorics and Graph Theory	3		1	4
DSE/GE		From List of Electives of Computer science/Others				4
DSE/GE		From List of Electives of Computer science/Others				4
DSE/GE		From List of Electives of Computer science/Others				4
SEC	CSS411	Research Seminar 1				2
					Total Credits	**22**
SEMESTER II						
Course Type	**Course Code**	**Course Title**	**L**	**T**	**P**	**C**
DSC	CSC461	Advanced Algorithms	3		1	4
DSC	CSC462	Research Methodology	3	1		4
DSE/GE		From List of Electives of Computer science/Others				4
DSE/GE		From List of Electives of Computer science/Others				4
DSE/GE		From List of Electives of Computer science/Others				4
SEC	CSS461	Research Seminar 2				2
					Total Credits	**22**
SEMESTER III						
Course Type	**Course Code**	**Course Title**	**L**	**T**	**P**	**C**
SEC	CSS511	Research Seminar 3	4			4
DSCP	CSP511	Dissertation part 1			18	18

					Total Credits	**22**
SEMESTER IV						
Course Type	**Course Code**	**Course Title**	**L**	**T**	**P**	**C**
DSCP	CSP561	Dissertation part 2			22	22
Total credits 88 for award the degree of M. Sc. in Computer Science					**Total Credits**	**22**

Electives can be taken from list of Electives or MOOC courses approved by authority.

List of Electives:

Course Code	**Course Title**	**L**	**T**	**P**	**C**
CSE101	Big Data Analytics	3		1	4
CSE102	Business Intelligence	3		1	4
CSE103	Introduction to IOT	3		1	4
CSE104	Modeling and Simulation	3		1	4
CSE105	Operation Research	3	1		4
CSE106	Biometrics	3	1		4
CSE107	Computer Vision and Pattern Recognition	3		1	4
CSE108	Digital Image Processing	3		1	4
CSE109	Virtualization and Cloud Computing with AWS	3		1	4
CSE110	Natural Language Processing	3		1	4
CSE111	Introduction to Data Science	3			
CSE112	Digital Marketing	3		1	4

CSE113	Fuzzy Logic	3		1	4
CSE114	Data Mining and Warehousing	3		1	4
CSE115	Digital Signal Processing	3		1	4
CSE116	Probability and Statistical Inference	3	1		4
CSE117	Cryptography and Network Security	3		1	4
CSE118	Advanced Algorithms	3		1	4
CSE119	Information Theory and Coding	3	1		4
CSE120	Machine Learning	3		1	4
CSE121	Neural Networks	3		1	4
CSE122	Mobile Ad-hoc Networks	3		1	4
CSE123	Cloud Architecture	3		1	4
CSE124	Parallel and Distributed Computing	3		1	4
CSE125	Advanced Graph Theory	3	1		4
CSE126	Cyber Forensics	3	1		4
CSE127	Software Defined Networks	3	1		4
CSE128	Evolutionary Algorithms	3		1	4
CSE129	Block chain Technology	3		1	4
CSE130	Quantum Computing	3	1		4
CSE131	Research Methodology	4			4
CSE132	Cloud Security	3	1		4
CSE133	AI-driven Cyber Security	3		1	4

This list may be appended from time to time.

Learning Outcomes

M.Sc. Computer Science

- **PO1.** Communicate computer science concepts, designs, and solutions effectively and professionally.
- **PO2.** Apply computer science theory and software development concepts to produce effective designs and solutions for specific problems.
- **PO3.** Identify, analyze, and synthesize scholarly literature relating to the field of computer science.

Syllabus

(Semester I – Semester IV)

SEMESTER I

CSC411: Parallel and Distributed Computing **L | T | P (3 | 0 | 1)**

Prerequisites: Operating System, Computer Hardware and Networking

Course Outcome: By the end of the course, students should be able to:
CO1. Understand the terminologies in distributed computing
CO2. Understand the different type of Processors, single as well multi-core processors
CO3. Understand the concepts of computational Grids.

Introduction: Parallel Computing Architectures, Paradigms, Issues, & Technologies, architectures, topologies, organizations, Parallel Programming Using Shared Memory, memory coherence, race conditions and deadlock detection, synchronization, multithreaded programming, Parallel Programming using Message Passing, synchronous/asynchronous messaging, partitioning and load-balancing.

Advanced Processors and Interconnects: Multicore Processors and High-bandwidth Networks, Parallel and distributed architectures, Distributed and parallel algorithms, Fundamental problems in parallel and distributed computing, fundamental concepts and reasoning principles for parallel and distributed computer systems.

Distributed Programming Algorithms: Fundamental issues and concepts, synchronization, mutual exclusion, termination detection, clocks, event ordering, locking, CORBA, JavaRMI, Web Services, shared spaces.

Clusters of Computers: Server Clusters, High Availability, and Disaster Recovery, synchronization, fault tolerance, coordination and consensus, Virtual Machines and Virtualized Datacenters.

Peer-to-Peer Computing: P2P systems, Familiarity with concurrent programming primitives (semaphores, locks, monitors), Overlay networks, and Content Distribution.

Computational Grids and Applications: National or global computing Grids and Applications.

Textbooks:
1. M J Quinn, Parallel Programming in C with MPI and OpenMP.
2. AnanthGrama, George Karypis, Vipin Kumar, and Anshul Gupta, Introduction to Parallel Computing, 2nd ed., 2003.
3. David Kirk, Wen-Mei W. Hwu, Wen-meiHwu, Programming Massively Parallel Processors: a hands-on approach, Morgan Kaufmann, 2010.
4. William Gropp, Ewing Lusk, and Anthony Skjellum, Using MPI: Portable Parallel Programming with the Message-Passing Interface, 2nd ed., 1999.
5. Norm Matloff, Programming on Parallel Machines: GPU, Multicore, Clusters and More.
6. K. Hwang and Z. Xu, Scalable Parallel Computing, McGraw-Hill, 1998.

7. G. Coulouris, J. Dollimore, Distributed Systems Concepts and Design, Addison Wesley.
8. Ian Taylor: From P2P to Web Services and Grids, Springer-Verlag, 2005.
9. F. Berman, G. Fox, and T. Hey (Editors), Grid Computing, Wiley, 2003.

Hariri and Parashar, Tools and Environments for Parallel & Distributed Computing, John Wiley, 2004.

CSC412: Combinatorics and Graph Theory **L | T | P (3 | 0 | 1)**

Course Outcome: By the end of the course, students should be able to:
CO1. Solve counting problems using combinatorial principles like permutations, combinations, and generating functions.
CO2. Analyze graph properties such as connectivity, colorings, and matchings using fundamental theorems.
CO3. Apply probabilistic and spectral methods to graph theory problems and randomized algorithms.

Course Outline:

Elementary Concepts in Combinatorics: Basic counting principles, Binomial theorem; Bijective proofs, Combinatorial identities, Permutations of multisets, Multinomial Theorem, Combinations of Multiset, Sterling's Formula, Generalization of Binomial coefficient, Pigeon hole principle and resolution refutation lower bound. Double counting, Matching and Hall's theorem, Inclusion exclusion principle, Inclusion exclusion principle. Solving recurrence relations using generating functions, Partition Number, Catalan Numbers, Sterling numbers of the 2nd kind, Difference Sequences.

Graph Theory: Matchings, Path Cover, Connectivity, Vertex Coloring, Edge Coloring, Other Coloring Problems, Perfect graphs, Planar Graphs, Other special classes of Graphs. Network flow, Introduction to Minor Theory,

The Probabilistic Method: Basics, Markov, Chebishey Inequalities, Lovaz Local Lemma, Linearity of Expectation; The deletion method; The entropy function; Random walks and randomized algorithm for CNF formulas, Random graph.

Spectral Graph theory: Basic properties of graph spectrum; Cheeger's inequality and approximation of graph expansion; Expander graphs and applications to super concentrators and pseudo randomness; Error correcting codes and expander codes; Small set expansion, Unique Games Conjecture and Hardness of approximation.

Additive Combinatorics: Sum product theorem, Szemeredi-Trotter theorem, Kakeya set problem and applications to randomness extractors.

Textbooks:

1. Statys Jukna, Extremal Combinatorics: With Applications in Computer Science, Springer, 2nd ed., 2013.
2. R.P. Grimaldi, B.V. Ramana, Discrete and Combinatorial mathematics – An applied introduction, Pearson Education (2007).
3. Richard A Brnaldi, Introductory Combinatorics, Pearson Education, Inc. (2004).
4. Miklos Bona, Introduction to Enumerative Combinatorics, McGraw Hill (2007).
5. A walk through Combinatorics – An introduction to enumeration and graph theory, World Scientific Publishing Co. Pvt. Ltd. (2006).

6. J.H. Vanlint, R.M. Wilson, A course in Combinatorics, Cambridge University Press.
7. R. Diestel, "Graph Theory", Springer, 2nd ed., 2000.
8. N. Alon and J. Spenser, "Probabilistic Methods", John Wiley and Sons, 2nd ed., 2000.

CSS411-: Research Seminar 1 **L | T | P (0 | 0 | 2)**

Prerequisites: NIL

Course Outcome: By the end of the seminar, students should be able to:
CO1. Understand the concept of research
CO2. Describe and present the literature study and research gaps identified.
CO3. Improving written and communication skills

All the students, will prepare presentation for seminar which includes their research topic and literature survey.

SEMESTER II

CSC461: Advanced Algorithms **L | T | P (3 | 0 | 1)**

Prerequisites: Data structures and algorithms.

Course Outcomes: By the end of the course, students will be able to
CO1. Understand the necessary mathematical abstraction to solve problems.
CO2. Come up with analysis of efficiency and proofs of correctness.
CO3. Comprehend and select algorithm design approaches in a problem specific manner.

Course Outline:

Review of Analysis Techniques, Asymptotic notations; Standard notations and common functions; Recurrences and Solution of Recurrence equations, Master method; Amortized Analysis: Aggregate, Accounting and Potential Methods.

Advanced Data Structures: Red Black Trees, B-Tree, Augmenting Data Structure, Priority Queues, Binomial Heap, Fibonacci Heap, Mergeable Heaps, Data Structure for Disjoint Sets and Union-Find Algorithm.

String Matching Algorithms: Naïve String Matching, Rabin-Karp, String matching with finite automata, Knuth-Morris-Pratt (KMP) Algorithm, Boyer–Moore algorithm.
Number Theoretic Algorithms: Factorization, GCD, Modular Arithmetic, Solving modular linear equations; The Chinese remainder theorem; Powers of an element; RSA cryptosystem; Primality testing; Integer factorization.

Graph Algorithms: Bellman-Ford Algorithm; Single source shortest paths in a DAG; Johnson's Algorithm for sparse graphs; Flow networks and Ford-Fulkerson method; Maximum bipartite matching.

Probabilistic algorithms; Randomizing deterministic algorithms, Randomized Quicksort, Algorithms for Computational Geometry problems, Convex Hull. Approximation Algorithms, Polynomial Time Approximation Schemes.

Textbooks:

1. T. H Cormen, C E Leiserson, R L Rivest and C Stein: Introduction to Algorithms, 3rded., Prentice-Hall of India, 2010.
2. Kenneth A. Berman, Jerome L. Paul: Algorithms, Cengage Learning, 2002.
3. Ellis Horowitz, Sartaj Sahni, S.Rajasekharan: Fundamentals of Computer Algorithms, 2nded., Universities press, 2007.

CSC462: Research Methodology **L | T | P (3 | 1 | 0)**

Prerequisites: NIL

Course Outcome: By the end of the course, students should be able to:
CO1. Understand the concept of research.
CO2. Understand the concept of data collection and selection for research.
CO3. Understand the applicability of research for public at large.

Introduction to Research Methods in science – Philosophy of Science, Research methods and Creative Thinking, Evolutionary Epistemology, Scientific Methods, Hypotheses Generation and Evaluation, Code of Research Ethics, Definition and Objectives of Research, Various Steps in Scientific Research, Research presentations Types of Research – Research Purposes – Research Design – Survey Research – formulation of scientific problems and hypotheses –selection of methods for solving a scientific problem Case Study Research.

How to perform a literature review – Sampling Methods – Data Processing and Analysis strategies - Data Analysis with Statistical Packages – Statistical Analysis – Hypothesis-testing – Generalization and Interpretation.

Research Reports - Structure and Components of Research Report, Types of Report, Layout of Research Report, Mechanism of writing a research report – Requirements of a good dissertation.

Textbooks:

1. Oates, B.J., (2005). Researching Information Systems and Computing. Sage Publications, UK.
2. Zobel, J. (2004). Writing for Computer Science - The art of effective communication. 2nd ed., Springer, UK.
3. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
4. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International.
5. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology.

CSS461-: Research Seminar 2 **L | T | P (0 | 0 | 2)**

Prerequisites: NIL

Course Outcome: By the end of the seminar, students should be able to:
CO1. Understand the concept of research
CO2. Describe and present the literature study and research gaps identified.
CO3. Improving written and communication skills

All the students, will prepare presentation for seminar which includes their research topic and literature survey.

SEMESTER III

CSS511: Research Seminar 3 **L | T | P (0 | 0 | 4)**

Prerequisites: NIL

Course Outcome: By the end of the seminar, students should be able to:
CO1. Understand the concept of research
CO2. Describe and present the literature study and research gaps identified.
CO3. Improving written and communication skills

All the students, will prepare presentation for research seminar which includes their research topic and literature survey.

CSP511: **Dissertation-Part 1** **L | T | P (0 | 0 | 18)**

Prerequisites: NIL

Course Outcome: By the end of the Dissertation-Part 1, students should be able to:
CO1. Formulate the research objectives
CO2. Design the framework/architecture of the proposed work
CO3. Demonstration of research tools

SEMESTER IV

CSP561: Dissertation-Part 2 **L | T | P (0 | 0 | 22)**

Prerequisites: NIL

Course Outcome: By the end of the Dissertation-Part 2, students should be able to:
CO1. Design and implement the proposed framework/architecture of the proposed work
CO2. Research paper writing and publishing
CO3. Dissertation report

List of Electives:

<u>CSE101: Big Data Analytics</u> **L | T | P (3 | 0 | 1)**

Prerequisites: Programming, Data Structures

Course Outcome: By the end of the course, students should be able to:
CO1: Understand the concept of Big Data and Analytics.
CO2: Understand how to use Big Data in different application areas.
CO3: Understand how to use hadoop and mapreduce.
CO4: Understand the concepts of different methods and techniques used in Big Data.

Course Outline:

Introduction: Big Data and its Importance, Four V's of Big Data, Drivers for Big Data, Introduction to Big Data Analytics, Big Data Analytics applications.

Big Data Technologies: Hadoop's Parallel World, Data discovery, Open source technology for Big Data Analytics, Cloud and Big Data, Predictive Analytics, Mobile Business Intelligence and Big Data, Crowd Sourcing Analytics, Inter- and Trans-Firewall Analytics, Information Management.

Processing Big Data: Integrating Disparate Data Stores, Mapping Data to the Programming Framework, Connecting and Extracting Data from Storage, Transforming Data for Processing, Introduction to MapReduce/Hadoop for analyzing unstructured data, Subdividing Data in Preparation for Hadoop Map Reduce.

HadoopMapReduce: Employing Hadoop Map Reduce, Creating the components of HadoopMapReduce jobs, distributing data processing across server farms, Executing HadoopMapReduce jobs, Monitoring the progress of job flows, The Building Blocks of Hadoop Map Reduce, Distinguishing Hadoop Daemons-Investigating the Hadoop Distributed File System, selecting appropriate execution modes: local, pseudo-distributed, fully distributed.

Advanced Analytics Platform: Real-Time Architecture– Orchestration and Synthesis Using Analytics Engines, Discovery using Data at Rest, Implementation of Big Data Analytics, Big Data Convergence, Analytics Business Maturity Model. HADOOP ECO-SYSTEM: Pig– Installing and Running, Comparison with Databases – Pig Latin – User-Define Functions – Data Processing Operators – Installing and Running Hive– Hive QL – Tables – Querying Data – User-Defined Functions. Fundamentals of HBase and ZooKeeper- IBMInfoSphereBigInsights and Streams. Visualizations– Visual data analysis techniques, interaction techniques; Systems and applications.

Textbooks:

1. Michael Minelli, Michele Chambers, "Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Business", 1sted., Wiley CIO Series, 2013.
2. ArvindSathi, "Big Data Analytics: Disruptive Technologies for Changing the Game", 1sted., IBM Corporation, 2012.
3. Bill Franks, "Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with Advanced Analytics", 1sted., Wiley and SAS Business Series, 2012.
4. Noreen Burlingame, Little Book of Big Data, 2012.
5. Tom White, "Hadoop: The Definitive Guide", 3rded., O'Reilly, 2012.

CSE102: Business Intelligence **L | T | P (3 | 0 | 1)**

Prerequisites: Database Basics, Basics of Programming, Data Structures

Course Outcome: By the end of the course, students should be able to:
CO1: Understand the concept of Data warehouse.
CO2: Understand the concepts of OLAP / OLTP.
CO3: Understand the concepts of Data Mining.

Course Outline:

Business Intelligence: Introduction, Meaning, Purpose and Structure of Business Intelligence Systems. Understanding Multidimensional Analysis Concepts: Attributes, Hierarchies and Dimensions in data Analysis. Understanding Dimensional Data Warehouse: Fact Table, Dimension Tables, Surrogate Keys and alternative Table Structure. What is multidimensional OLAP?

Understanding OLAP: Fast response, Meta-data based queries, Spread sheet formulas. Understanding Analysis Services speed and meta-data. Microsoft's Business intelligence Platform. Analysis Services Tools. Data Extraction, Transformation and Load. Meaning and Tools for the same.

Creating your First Business Intelligence Project: Creating Data source, Creating Data view. Modifying the Data view. Creating Dimensions, Time, and Modifying dimensions. Parent-Child Dimension.

Creating Cube: Wizard to Create Cube. Preview of Cube. Adding measure and measure groups to a cube. Calculated members. Deploying and Browsing a Cube

Advanced Measures and Calculations: Aggregate Functions. Using MDX to retrieve values from cube. Calculation Scripting. Creation of KPI's.

Advanced Dimensional Design: Creating reference, fact and many to many dimensions. Using Financial Analysis Cubes. Interacting with a cube. Creating Standard and Drill Down Actions.

Retrieving Data from Analysis Services: Creating Perspectives, MDX Queries, Excel with Analysis Services

Data Mining: Meaning and purpose. Creating data for data mining. Data mining model creation. Selecting a data mining algorithm. Understanding data mining tools. Mapping Mining Structure to Source Data columns. Using Cube Sources. Configuring Algorithm parameters.

Textbooks:

1. Business Intelligence, Analytics, and Data Science: A Managerial Perspective, Pearson Education

<u>CSE103: Introduction to IoT</u> **L | T | P (3 | 0 | 1)**

Prerequisites: Basics of Networking, Communication, and related protocols

Course Outcome: By the end of the course, students should be able to:

- **CO1:** Understand the foundational concepts and layered architecture of the IoT
- **CO2:** Analyze IoT platforms and service models such as IaaS, SaaS and PaaS
- **CO3:** Understanding of IoT devices, sensors, actuators, and gateways
- **CO4:** Implement real-world industrial applications of IoT

M2M to IoT: IoT Overview: Definition, characteristics, and vision, Evolution: From Machine-to-Machine (M2M) to Internet of Things, Key use cases: Smart homes, smart cities, healthcare, and logistics, Differentiators between M2M and IoT, Industry trends and market landscape.

IoT Architecture & Standards : IoT architectural overview: Key design principles and capabilities, IoT layered architecture (Perception, Network, Middleware, Application layers), Architectural reference models: Functional, Information, and Communication views, Standards and interoperability: IEEE, IETF, ITU, OneM2M, ETSI.

Devices, Gateways & Connectivity : Types of IoT devices: Sensors, actuators, smart objects, Gateways: Functions, types, and communication with cloud, Networking fundamentals: WPAN (Zigbee, BLE), LPWAN (LoRa, NB-IoT), WiFi, 5G, Protocols: MQTT, CoAP, HTTP, AMQP, REST vs. SOAP, Edge vs. Cloud vs. Fog Computing.

Platform Services & Data Management : Everything-as-a-Service (XaaS): IaaS, PaaS, SaaS in IoT, Device and data management platforms (AWS IoT, Azure IoT Hub, Google Cloud IoT), Stream processing, time-series databases, and storage models, Analytics and knowledge extraction: ML and AI in IoT, Role of APIs and middleware in scalable IoT solutions.

IoT Deployment & Real-World Constraints : Deployment models and constraints: Power, bandwidth, latency, cost, Hardware constraints and embedded design basics, Data representation and visualization: Dashboards, Grafana, ThingsBoard, Interaction and control mechanisms: Web, app-based, voice-controlled systems.

Industrial Applications & Case Studies: Industrial Automation, Web of Things, Cloud of Things, Commercial Building Automation, Smart manufacturing, predictive maintenance, connected vehicles, IoT in agriculture, environment monitoring, and healthcare.

Textbooks

1. Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stefan Avesand, Stamatis Karnouskos, David Boyle, “From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence”, 1st Edition, Academic Press, 2014.

References

1 Vijay Madisetti and Arshdeep Bahga, “Internet of Things (A Hands-on-Approach)”, 1stEdition, VPT, 2014.

2. Francis daCosta, “Rethinking the Internet of Things: A Scalable Approach to Connecting Everything”, 1st Edition, Apress Publications, 2013

CSE104: Modeling and Simulation L | T | P (3 | 0 | 1)

Prerequisites: Discrete Mathematics

Course Outcome: By the end of the course, students should be able to understand the concept of:
CO1: Project Planning and System Definition.
CO2: Model Formulation.
CO3: Input Data Collection and Analysis.
CO4: Model Translation, Experimentation and Analysis.

Introduction to System Modeling: The notion of system, model, simulation, Types of simulations, Illustrative examples, Conceptual and computer models, Verification and validation of models, Simulation experiment, Simulation project life cycle, Description of simulation models, Structure vs. behavior models, Classification of tasks solved within the modeling and simulation process, Detailed example introduction: database server as a typical queuing system. Description of discrete-event systems behavior.Modeling of time.The notion of status, event, activity, process and their interdependencies. Object-oriented model design. Simulation time, control of time advancement, event list.Event driven simulation algorithm. Detailed example: implementation of the database server as a queuing system.

Random Numbers in Simulation: Random variables with discrete and continuous probability distribution. Pseudo-random generators.Multiplicative and additive congruential method.Non Uniform random numbers.Testing of pseudo-random generators.Monte Carlo method.Precision.Queueing systems. Entities: queues, service facilities, storages. Properties of input and output stream.Kendall classification of queueing systems. Entity behavior and statistical data sampling during the simulation run.

Markov Model: Discrete and continuous Markov model. Birth-Death processes. Steady-state queueing systems of types M/M/1, M/M/?M/M/m, M/Er/1, Er/M/1 and their variants, Models M/G/1, G/M/1, G/M/m, G/G/1, G/D/1, M+D/D/1.Closed systems and queueing networks, Simulation languages for discrete-event systems. Case study and comparison: Simscript, GPSS, SOL.

Simulation experiments: Preparation and pre-processing of input data. Statistical data collected during the simulation run. Time dependency of statistics.Histograms.Evaluation and interpretation of results.Model validation and verification.Simulation of digital systems. Abstractions levels of digital system description. Models of signals and functions.Structure vs. behavior.Models of components.Models of delays.Digital systems simulators– methods of implementation.Flow of simulation time.Synchronous and asynchronous algorithm of digital systems simulation. Acceleration of simulation run.

Textbooks:

- M. Law, W.D. Kelton, “Simulation, Modeling and Analysis”, McGraw-Hill, 2nded., 1991.
- Frank L. Severance, “System Modeling and Simulation: An Introduction”, Wiley India, 2009.

CSE105: Operation Research **L | T | P (3 | 1 | 0)**

Prerequisites: Basics of mathematics.

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concept of Model Building and analysis.
CO2: Understand the basics of Linear Programming.
CO3: Understand the basics of IOT Architecture.
CO4: Understand the basics of Game Theory and Queing Theory.

Introduction: A quantitative approach to decision making, History and definition of Operations Research, Features of Operations Research Approach, Operations Research Approach to solve a problem, Models and Modelling, Advantages of model building, Methodology, Advantages, Opportunities, Shortcomings, Features and Applications of Operations Research.

Linear programming: Structure of Linear Programming, Advantages Limitations, Application areas of Linear Programming. Mathematical formulations of LP models for product mix problems, graphical and simplex method of solving LP problems, sensitivity analysis, duality.

Transportation and Assignment Problem: Various methods (NWCM, LCM, VAM) of finding initial basic feasible solution and optimal cost.Mathematical model of the Assignment Problem, Hungarian Methods for solving assignment problem, Travelling Salesman Problem.

Network Analysis: Network definition and Network diagram, probability in PERT analysis, project time cost trade off, introduction to resource smoothing and allocation.

Game Theory: Concept of game, two person zero sum game, pure and mixed strategy games, saddle point, dominance method Solution Methods for Games without Saddle point.

Inventory Model: Introduction to inventory control, deterministic inventory model, EOQ model with quantity discount.

Replacement & Maintenance Models: Replacement of items, subject to deterioration of items subject to random failure group vs. individual replacement policies.

Sequencing problem: Johnsons algorithm for n jobs and 2 machines, n jobs and 3 machines, two jobs and m machine problems.

Queuing Theory: Introduction, Concepts relating to queuing systems, basic elements of queuing model, role of Poison & exponential distribution, concepts of birth and death process.The Structure of a Queuing Systems, Performance Measures of a Queuing System, Probability Distribution in Queuing System, Classifications, Solutions of Single Queuing Model Models(M/M/1).

Textbooks:

1. H.A. Taha, "Operations Research: An Introduction", Macmillan, New York, 5^{th}ed., 1992.
2. GovindasamiNaadimuthu and Richard E. Johnson, Schaum's Outline of Theory and Problems of Operations Research.
3. Hillier, Frederick S., Gerald J. Lieberman, “Introduction to Operations Research”, McGraw Hill Book Company New York, 6^{th}ed., 1995.
4. Levin, Richard I., David S. Rubin, Goel P. Stinsin and Everett S. Gardener, “Quantitative

Approaches to Management", McGraw Hill Book Company, New York, 8th ed., 1992.

CSE106: Biometrics **L | T | P (3 | 1 | 0)**

Prerequisites: Basics of Programming, Data Structure

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concept of Biometrics.
CO2: Understand the tools and techniques used in Biometrics. .

Introduction of Biometric traits and its aim, image processing basics, Geometric Transformations, Linear Interpolation, brightness correction, basic image operations, filtering, enhancement, sharpening, edge detection, smoothening, enhancement, thresholding, localization. Fourier Series, DFT, inverse of DFT.

Biometric system, identification and verification. FAR/FRR, system design issues. Positive/negative identification.Biometric system security, authentication protocols, matching score distribution, ROC curve, DET curve, FAR/FRR curve.Expected overall error, EER, biometric myths and misrepresentations.

Selection of suitable biometric.Biometric attributes, Zephyr charts, types of multi biometrics.Verification on Multimodel system, normalization strategy, Fusion methods, Multimodel identification.

Biometric system security and vulnerabilities, circumvention, covert acquisition, quality control, template generation, interoperability, data storage. Recognition systems: Face, Signature, Fingerprint, Ear, Iris etc.

Textbooks:

1. Rafael C. Gonzalez, Richard Eugene Woods, *Digital Image Processing using MATLAB*, 2nd ed., Tata McGraw-Hill Education, 2010.
2. Ruud M. Bolle, SharathPankanti, Nalini K. Ratha, Andrew W. Senior, Jonathan H. Connell,*Guide to Biometrics*, Springer, 2009.
3. Richard O. Duda, David G.Stork, Peter E. Hart,*Pattern Classification*, Wiley, 2007.

CSE107: Computer Vision and Pattern Recognition **L | T | P (3 | 0 | 1)**

Prerequisites: Basics of Linear Algebra, and Mathematics

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concept of supervised and unsupervised learning
CO2: Understand the concept of classification, Clustering, and related tools and techniques.

Depth estimation and Multi-camera views: Perspective, Binocular Stereopsis: Camera and Epipolar Geometry; Homography, Rectification, DLT, RANSAC, 3-D reconstruction framework; Autocalibration. apparel.

Feature Extraction: Edges - Canny, LOG, DOG; Line detectors (Hough Transform), Corners - Harris and Hessian Affine, Orientation Histogram, SIFT, SURF, HOG, GLOH, Scale-Space Analysis- Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT. Image Segmentation: Region Growing, Edge Based approaches to segmentation, Graph-Cut, Mean-Shift, MRFs, Texture Segmentation; Object detection.

Pattern Analysis: Clustering: K-Means, K-Medoids, Mixture of Gaussians, Classification: Discriminant Function, Supervised, Un-supervised, Semi-supervised; Classifiers: Bayes, KNN, ANN models; Dimensionality Reduction: PCA, LDA, ICA; Non-parametric methods.

Motion Analysis: Background Subtraction and Modeling, Optical Flow, KLT, Spatio-Temporal Analysis, Dynamic Stereo; Motion parameter estimation.

Shape from X: Light at Surfaces; Phong Model; Reflectance Map; Albedo estimation; Photometric Stereo; Use of Surface Smoothness Constraint; Shape from Texture, color, motion and edges.

Textbooks:

1. David A. Forsyth, Jean Ponce, Computer Vision: A Modern Approach, 2nded., Pearson.
2. R.C.Gonzalez, M.G.Thomason, Syntactic Pattern Recognition: An introduction.
3. P.A. Devijver, J. Kittler, Pattern Recognition: A Statistical Approach.

4. R.O. Duda, P.E. Hart, Pattern Classification and Scene Analysis, Wiley.

CSE108: Digital Image Processing **L | T | P (3 | 0 | 1)**

Prerequisites: Basics of Linear Algebra, and Mathematics.

Course Outcome: By the end of the course, students should be able to:

CO1:Understand the basics of Image Processing.

CO2:Understand the concept of Image restoration, compression, and Segmentation.

Introduction: Examples of fields that use digital image processing, fundamental steps in digital image processing, components of image processing system. Digital Image Fundamentals– A simple image formation model, image sampling and quantization, basic relationships between pixels.Image enhancement in the spatial domain– Basic gray-level transformation, histogram processing, enhancement using arithmetic and logic operators, basic spatial filtering, smoothing and sharpening spatial filters, combining the spatial enhancement methods.

Image restoration: A model of the image degradation/restoration process, noise models, restoration in the presence of noise-only spatial filtering, Weiner filtering, constrained least squares filtering, geometric transforms, Introduction to the Fourier transform and the frequency domain, estimating the degradation function, Color Image Processing.

Image Compression: Fundamentals, image compression models, error-free compression, lossy predictive coding, image compression standards. Morphological Image Processing– Preliminaries, dilation, erosion, open and closing, hit or miss transformation, basic morphologic algorithms.

Image Segmentation: Detection of discontinuous, edge linking and boundary detection, thresholding, region-based segmentation. Object Recognition– Patterns and patterns classes, recognition based on decision-theoretic methods, matching, optimum statistical classifiers, neural networks, structural methods– matching shape numbers, string matching.

Textbooks:

1. Rafael C. Gonzalez, Richard E. Woods, Steven L. Eddins, "Digital Image Processing using MATLAB", PHI, 2003.
2. Anil K. Jain, "Fundamentals of Digital Image Processing", Prentice Hall, 1989.
3. Digital Image Processing, Rafael C. González, Richard Eugene Woods, Steven L., Pearson, 2010.

CSE109: Virtualization and Cloud Computing with AWS **L | T | P (3 | 0 | 1)**

Prerequisites: Fundamentals of Computers

Course Outcome: By the end of the course, students should be able to:

CO1: Explain the evolution of Cloud Computing and **differentiate** it from traditional computing paradigms.

CO2: Define key terminologies in Cloud Computing and **illustrate** fundamental concepts.

CO3: Describe virtualization techniques and architectures; **demonstrate** virtualization using open-source tools.

CO4: Analyze various cloud platforms and service models; **evaluate** their benefits, limitations, and associated security levels.

CO5: Implement core AWS services to **develop** hands-on skills and practical understanding of cloud computing.

Overview of Computing Paradigm: History with overview of Computing Paradigm, Cluster Computing, Grid Computing, Distributed Computing, Utility Computing, Cloud Computing versus Traditional Computing

Introduction to Cloud Computing: Introduction to Cloud Computing, Different Perspectives on Cloud Computing, Characteristics, Different Stakeholders in Cloud Computing, Cloud NIST Reference Architecture

Service Level Agreements (SLAs), Total cost of ownership (TCO), Benefits and limitations of Cloud Computing, Open Challenges

Virtualization: Introduction & need of Virtualization, Definition & types of Hypervisors, Characteristics of Virtualized Environments, Virtualization and Cloud Computing, System calls & Ring Privileges, Machine Reference Architecture, Xen Hypervisor Architecture, Pros and Cons of

Virtualization, case studies: Installation of VMware Workstation in on-premise machine and creating VMs, hosting the website on local server

Cloud Computing Architecture: Traditional Computing Architecture-Client-Server Architecture, Peer to Peer Architecture, OpenStack-based Cloud Computing Architecture, Cloud Reference Architecture: Service Models Perspective- Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS), Deployment Models- Public Cloud, Private Cloud, Hybrid Cloud, Community Cloud

Cloud Security: Introduction, Cloud Security Issues such as Application-level Security, Network Level Security, Data-level Security, Virtualization Security, Identity Management & Access Control

AWS Cloud Services: Creating an account in AWS, Implementation of AWS Cloud Services: Launching EC2 instance and configuring security rules, accessing the VM from remote machine via PuTTy/ssh, Hosting the Website on cloud server, Load Balancing and Autoscaling, Building Amazon Machine Images (AMI), Monitoring Cloud Services using CloudWatch, AWS RDS etc.

Text Books:

1. Raj Kumar Buyya, Mastering the Cloud Computing,MacGraw Hill Education (India), 2013
2. Tim Mather, SubraKumaraswamy, ShahedLatif: Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance
3. J.R. ("Vic") Winkler: Securing the Cloud
4. Haley Beard, Cloud Computing Best Practices for Managing and Measuring Processes for On-demand Computing, Applications and Data Centers in the Cloud with SLAs, Emereo Pty Limited, July 2008.

Reference Books:

1. Michael Miller, Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online, Que Publishing, August 2008.
2. David Chisnall, The Definitive Guide to Xen Hypervisor, Prentice Hall; Reprint edition (9 November 2007)

<u>CSE110: Natural Language Processing</u> L | T | P (3 | 0 | 1)

Prerequisites: Programming and Data Structure

Course Outcomes: By the end of the course, students will be able to

- CO1: Learn basics of speech and text processing.
- CO2: Understand sequential modeling and algorithms.
- CO3: Understand parsing and ambiguity resolution.

CO4: Understand multilinguality and associated applications.

Course Outline:

Biology of Speech Processing; Place and Manner of Articulation; Word Boundary Detection; Argmax based computations; HMM and Speech Recognition.

Words and Word Forms: Morphology fundamentals; Morphological Diversity o f Indian Languages; Morphology Paradigms; Finite State Machine Based Morphology; Automatic Morphology Learning; Shallow Parsing; Named Entities; Maximum Entropy Models; Random Fields.

Theories of Parsing, Parsing Algorithms; Constituency Parsing, Dependency Parsing, Robust and Scalable Parsing on Noisy Text as in Web documents; Hybrid of Rule Based and Probabilistic Parsing; Scope Ambiguity and Attachment Ambiguity resolution.

Lexical Knowledge Networks, Wordnet Theory; Indian Language Wordnets and Multilingual Dictionaries; Semantic Roles; Word Sense Disambiguation; WSD and Multilinguality; Metaphors; Coreferences.

Text summarization, Text classification, Sentiment Analysis; Text Entailment; Robust and Scalable Machine Translation; Question Answering in Multilingual Setting; Cross Lingual Information Retrieval (CLIR).

Textbooks:

1. James Allen, "Natural Language Understanding", Pearson Education, 2nd ed., 2003.
2. Charniack, Eugene, Statistical Language Learning, MIT Press, 1993.
3. C. Manning and S. Heinrich, Foundations of Statistical Natural Language Processing, MIT Press, 1999.
4. Radford, Andrew et. al., Linguistics: An Introduction, Cambridge University Press, 1999.
5. L.M. Ivansca, S.C. Shapiro, "Natural Language Processing and Language Representation".
6. Jurafsky, Dan and Martin, James, Speech and Language Processing, Second Edition, Prentice Hall, 2008.
7. T. Winograd, "Language as a Cognitive Process", Addison-Wesley.

<u>CSE111: Introduction to Data Science</u> **L | T | P (3 | 0 | 1)**

Prerequisites: Basics of engineering mathematics, python programming, and databases

Course Outcome: By the end of the course, students should be able to:
CO1. Understand the evolution of Data Science.
CO2. Understand the applicability of Data Science in various fields.
CO3. Understand the basics of Data Visualization and recommendation Systems.

Introduction: Introduction to Data Science, Big Data, Statistical Inference–Populations and samples, Statistical modeling, Probability Distributions, Fitting a Model, Intro to Python, Numerical Programming in Python – NumPy and Panda, Exploratory Data Analysis– Data Analysis (Data

Visualization, Data Wrangling) of EDA, Case Study:Capstone Project on EDA.

Machine Learning:
Basics of Machine Learning, Regression - (Linear Regression, Bias Variance Tradeoff, Regularized Linear Regression, Cross Validation and Hyper Parameter Tuning), Case Study:Project implementation on Regression.
Classification Algorithms - (Logistic Regression, Decision Tree, Ensemble Decision Tree), Case Study:Project implementation on Classification.
Non-Linear Algorithms - (K-Nearest Neighbors, Naive Bayes Classifier, Support Vector Machine, Neural Networks, Handling Class Imbalance, Anomaly Detection, General Modelling Techniques, Principle Component of Analysis), Case Study:Project implementation on Non-Linear.
Unsupervised Algorithms - (K-means Clustering, Hierarchical Clustering, Clustering Analysis), Case Study:Project implementation on Unsupervised.

Advance Topic:
Natural Language Processing - (Introduction to NLP, Topic Modelling)
Recommender System - (Collaborative Filtering, Content Based Filtering)
Time Series Analysis - (Introduction to Time Series Analysis, Modelling a Time Series Problem)
Case Study: Capstone Project on Advance Machine Learning.

Textbooks:

1. Cathy O'Neil, Rachel Schutt, Doing Data Science: Straight Talk from the Frontline, O'Reilly, 2014.
2. Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2005.
3. David Barber, Bayesian Reasoning and Machine Learning, Cambridge University Press, 2012.

CSE112: Digital Marketing **L | T | P (3 | 0 | 1)**

Prerequisites: Basics of Computer Fundamentals, Social Media platform.

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concepts of Digital Marketing.

CO2: Understand the SEO/SMO/ SMM / Back Linking, and related concepts theoretically and practically.

An Introduction to Digital Marketing, Digital Marketing basics (Online Payments, Disability Web Access, Surveys & Forms, Affiliate & Voucher Marketing, Crowdsourcing).

Search Engine Optimization: Understanding Search Engine, Search Engine Result Pages, Search Behavior, On-Page Optimization, Off-Page Optimization,

Digital Display Advertising, Online Advertising, Social Media Marketing (Facebook &LinkedIn), Mastering Google (AdWords Advertising, Analytics & Applications).

Micro Blogging, Twitter, Copywriting for The Web, Social Media & Mobiles, Mobile Marketing, Email

Marketing, Video & Audio (Podcasting) Marketing, Strategic & Action Planning.

Textbooks:

1. Ian Dodson, "The Art of Digital Marketing", Wiley, 2016.

References:

1. A Beginner's Textbook for Digital Marketing online book.

<u>CSE113: Fuzzy Logic</u> **L | T | P (3 | 0 | 1)**

Prerequisites: Discrete Mathematics

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the evolution of Fuzzy Logic.

CO2: Understand the concept of Fuzzy Arithmetic and Control System.

Introduction to Soft Computing: Evolution of Computing, Soft Computing Constituents– From Conventional AI to Computational Intelligence.

Fuzzy Sets and Uncertainty: Uncertainty and information, fuzzy sets and membership functions, chance versus fuzziness, properties of fuzzy sets, fuzzy set operations.

Fuzzy Relations: Cardinality, operations, properties, fuzzy cartesian product and composition, fuzzy tolerance and equivalence relations, forms of composition operation. Fuzzification and Defuzzification: Various forms of membership functions, fuzzification, defuzzification to crisp sets and scalars.

Fuzzy Logic and Fuzzy Systems: Classic and fuzzy logic, approximate reasoning, Natural language, linguistic hedges, fuzzy rule based systems, graphical technique of inference. Development of membership functions: Membership value assignments: intuition, inference, rank ordering, neural networks, genetic algorithms, inductive reasoning.

Fuzzy Arithmetic and Extension Principle: Functions of fuzzy sets, extension principle, fuzzy mapping, interval analysis, vertex method and DSW algorithm. Fuzzy Optimization: One dimensional fuzzy optimization, fuzzy concept variables and casual relations, fuzzy cognitive maps, agent based models.

Fuzzy Control Systems: Fuzzy control system design problem, fuzzy engineering process control, fuzzy statistical process control, industrial applications.

Textbooks:

1. T. J. Ross, "Fuzzy logic with Engineering Applications", 3rd ed. McGraw-Hill, 2011.
2. H. J. Zimmermann, "Fuzzy set theory and its applications", Springer, 4thed., 2006.
3. George J. Klir and Bo Yuan, "Fuzzy Sets and Fuzzy Logic-Theory and Applications", Prentice Hall, 1995.
4. Klir, G. and Yuan, B., "Fuzzy Set and Fuzzy Logic: Theory and Applications", Prentice Hall, 2002.
5. T. Terano, K. Asai, and M. Sugeno, "Fuzzy systems theory and its applications", 1 ed. San Diego, CA: Academic press, 1992.
6. Jyh-Shing Roger Jang, Chuen-Tsai Sun, EijiMizutani, "Neuro-Fuzzy and Soft Computing",

Prentice-Hall of India, 2003.

CSE114: Data Mining and Warehousing **L | T | P (3 | 0 | 1)**

Prerequisites: Basics of Database

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the Data Mining basics and knowledge Discovery in Database.

CO2: Understand the pattern identification and knowledge recognition.

CO3: Understand the basics of classification, clustering and their related techniques.

Evolution of database technology: Introduction to data warehousing and data mining, difference between operational databases and data warehouses.

Data warehouse architecture & design: Data warehousing Components, building a Data warehouse, Mapping the Data warehouse to multiprocessor architecture, DBMS Schema as for Decision Support, Data Extraction, Clean up and Transformation tools, Metadata.

Data mining: Data Pre-processing & Data Mining Primitives Data Pre-processing, Data cleaning, Data Integration and Transformation, Data reduction, Discretization and Concept Hierarchy Generation, Data Mining primitives, Languages and System Architectures, Concept Description: characterization and Comparison, Analytical Characterization, Mining Class Comparison.

Association Rules & Mining Association Rule Mining: Mining of Single dimensional Boolean association rules, Constraint based association Mining Classification and prediction: Basic issues regarding classification and prediction, Classification by Decision Tree, Bayesian classification, Prediction, Classifier accuracy.

Cluster Analysis: Basic issues, clustering using partitioning methods, Hierarchical methods, Density based methods, Grid based methods and model based methods, Algorithms for outlier analysis.

Textbooks:

1. Ralph Kimball, "The Data Warehouse Life Cycle Toolkit", John Wiley & Sons Inc., 1998.
2. Alex Berson, S.J. Smith, "Data Warehousing, Data Mining & OLAP", TMH, 1997.
3. W.H. Inmon, "Building the Data Warehouse", Wiley India, 2011.

CSE115: Digital Signal Processing **L | T | P (3 | 0 | 1)**

Prerequisites: Digital Electronics

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the evolution of Signals and their processing.

CO2: Understand the basics of Discrete-Time Signals, and related techniques.

CO3: Understand the use of Fast Fourier Transformation

Introduction: Signals, systems and signal processing, classification of signals, elements of digital signal processing system, concept of frequency in continuous and discrete time signals, Periodic Sampling, Frequency domain representation of sampling, Reconstructions of band limited signals from its samples, general applications of DSP.

Discrete-Time Signals and Systems: Discrete-Time Signals, Discrete-Time Systems, LTI Systems, Properties of LTI Systems, linear convolution and its properties, Linear Constant Coefficient Difference equations. Frequency domain representation of Discrete-Time Signals & Systems, Representation of sequences by Discrete Time Fourier Transform (DTFT), Properties of DTFT and correlation of signals, Fourier Transform Theorems.

The Z-transform and Analysis of Linear Time Invariant System: Z-Transform, Properties of ROC for Z-transform, Inverse Z-transform methods, Z-transform properties, Analysis of LTI systems in time domain and stability considerations. Frequency response of LTI system, Relationship between magnitude & phase, all pass systems, inverse systems, Minimum/Maximum phase systems, systems with linear phase. Structures for Discrete Time Systems: Block Diagram and signal flow diagram representations of Linear Constant-Coefficient Difference equations, Basic Structures of IIR Systems, Transposed forms, Direct and cascade form Structures for FIR Systems, Effects of Co-efficient quantization.

Filter Design Techniques: Design of Discrete-Time IIR filters from Continuous-Time filters-Approximation by derivatives, Impulse invariance and Bilinear Transformation methods; Design of FIR filters by windowing techniques, Illustrative design examples of IIR and filters. Discrete-Fourier Transform: Representation of Periodic sequences: The discrete Fourier series and its Properties Fourier Transform of Periodic Signals, Sampling the Fourier Transform, The Discrete-Fourier Transform, Properties of DFT, Linear Convolution using DFT.

Fast Fourier Transform: FFT-Efficient Computation of DFT, Goertzel Algorithm, radix2 and radix 4 Decimation-in-Time and Decimation-in-Frequency FFT Algorithms. Architecture of DSP Processors–Harward architecture, pipelining, Multiplier-accumulator (MAC) hardware, architectures of fixed and floating point (TMSC6000) DSP processors.

Textbooks:

1. Alan V. Oppenheim, Ronald W. Schafer, “Digital Signal Processing”, Pearson, 1sted., 2015.
2. Sanjit K. Mitra, “Digital Signal Processing: A Computer-based Approach”, McGraw-Hill, 4thed., 2013.
3. Andreas Antoniou, “Digital Filters: Analysis, Design, and Applications”, TMH, 2nded., 2001.

CSE116: Probability and Statistical Inference **L | T | P (3 | 1 | 0)**

Prerequisites: Mathematics

Course Outcomes: By the end of the course, students will be able to

- **CO1:** Understand the concept of random variables and various discrete and continuous distributions.
- **CO2:** Apply probability distributions and central limit theorem to solve problems.
- **CO3:** Understand data properties using various statistical measures.
- **CO4:** Estimate population parameter (point and confidence interval) using statistical

techniques.

Course Outline:

Probability and Randomness, Random Experiment, Sample Space, Random Events, Probability Definition– Axiomatic definition, Frequency Definition. Conditional probability, Independent events, Bayes' theorem and related problems. Expectation, Standard deviation, Variance, Co-variance, Pearson's coefficient, Chebyshev's inequality

Discrete random variables, Probability mass function, Cumulative distribution function and distributions – Bernoulli, Binomial, Geometric, Negative Binomial, Poisson. Poisson approximation of Binomial distribution.

Continuous random variables, Probability density function and distributions – Uniform, Exponential, Gamma, Normal. Normal approximation of Binomial distribution.

Central Limit Theorem, Law of large numbers (Weak law); Random variables simulation, Monte-Carlo methods.

Population and Sample, simple statistics – mean, median, percentiles, quartiles, mode, standard deviation, variance; Statistical Inference: parameter estimation – maximum likelihood, estimation of standard errors. Confidence Intervals estimation.

Hypothesis Testing, Type I and Type II errors, Z-tests, T-tests, P-value, F-distribution and F-tests.

Textbooks:

1. Sheldon Ross, "A First Course in Probability", 9th ed., Pearson Education, 2013.
2. Vijay K. Rohatgi, A. K. Md. EhsanesSaleh, "An Introduction to Probability and Statistics", 2nded., Wiley, 2008.
3. Michael Baron, "Probability and Statistics for Computer Scientists", 2nd ed, CRC Press.

References:

1. Trevor Hastie, Robert Tibshirani, Jerome Friedman, "The Elements of Statistical Learning: Data Mining, Inference, and Prediction", Springer, 2nded., 2017.
2. Vijay K. Rohatgi, "Statistical Inference", 2003.
3. Bradley Efron, Trevor Hastie, "Computer Age Statistical Inference: Algorithms, Evidence and Data Science", Cambridge University Press, 2016.

CSE117: Cryptography and Network Security **L | T | P (3 | 0 | 1)**

Prerequisites: Basic Knowledge of Algebra and Computer Networks

Course Outcome: By the end of the course, students will be able to:

CO1: Understand the evolution of Cryptography.

CO2: Understand the different types of Authentication and messages.

CO3: Understand the basics of web and system security.

Introduction to cryptography: Private key cryptography, Conventional Encryption models, Classical encryption techniques, Substitution cipher, Transposition cipher, Cryptanalysis, Stereography, Stream and block ciphers, Modern block cipher: principles, Shannon's theory of confusion and diffusion, Feistel structure, DES, Strength of DES, Triple DES, AES, IDEA, Key distribution, Diffie-Hellman algorithm, Public key cryptography, RSA algorithm, Elliptic curve cryptography, Elgamal cryptosystem.

Message Authentication and Hashing: Authentication requirements, Message Digest Algorithms-MD4, MD5, Hash functions, Security of hash functions, Message Authentication Codes (MAC), Secure hash algorithm (SHA). Digital Signatures: Digital Signatures, Authentication protocols, Digital signature standards.

Authentication Applications: Kerberos and X.509, Public Key Infrastructure (PKI), Concept of Digital Certificate, Types of PKI, Electronic mail security-pretty good privacy (PGP), S/MIME. IP Security: Architecture, Authentication header, encapsulating security payloads, combining security associations, key management.

Web and System Security: Secure socket layer (SSL), Transport layer security, Secure electronic transaction (SET). System Security: Intruders, Intrusion Detection System, Password Management, Viruses and related threats, Distributed Denial of Service Attacks, Firewalls, Firewall design principles, Trusted systems.

Textbooks:

1. William Stallings, Cryptography and Network Security: Principles and Practice, Pearson Education, 6thed., 2013.
2. B. Forouzan, Cryptography and Network Security, TMH, 2nded., 2010.
3. AtulKahate, Cryptography and Network Security, TMH, 7thed., 2013.
4. Johannes A. Buchmann, Introduction to Cryptography, Springer, 2nded., 2009.
5. Alfred J. Menezes, Paul C. van Oorschot, Scott A. Vanstone, "Handbook of Applied Cryptography", CRC Press, 1996.

<u>CSE118: Advanced Algorithms</u> **L | T | P (3 | 0 | 1)**

Prerequisites: Basic knowledge of Data structures and algorithm design.

Course Outcomes: By the end of the course, students will be able to

- **CO1:** Understand the necessary mathematical abstraction to solve the problems.
- **CO2:** Come up with an analysis of efficiency and proof of correctness.
- **CO3:** Comprehend and select algorithm design approaches in a problem specific manner.

Course Outline:

Asymptotic notations; Standard notations and common functions; Review of Analysis Techniques, Recurrences and Solution of Recurrence equations, Master method; Amortized Analysis: Aggregate, Accounting and Potential Methods.

Advanced Data Structures: B-Tree, Red Black Trees, Augmenting Data Structure, Priority Queues, Binomial Heap, Fibonacci Heap, Mergeable Heaps, Data Structure for Disjoint Sets and Union-Find Algorithm.

String Matching Algorithms: Naïve String Matching, Rabin-Karp, String matching with finite automata, Knuth-Morris-Pratt (KMP) Algorithm, Boyer–Moore algorithm.

Number Theoretic Algorithms: Factorization, GCD, Modular Arithmetic, Solving modular linear equations; The Chinese remainder theorem; Powers of an element; RSA cryptosystem; Primality testing; Integer factorization.

Graph Algorithms: Bellman-Ford Algorithm; Single source shortest paths in a DAG; Johnson's Algorithm for sparse graphs; Flow networks and Ford-Fulkerson method; Maximum bipartite matching.

Probabilistic algorithms: Randomizing deterministic algorithms, Randomized Quicksort, Algorithms for Computational Geometry problems, Convex Hull. Approximation Algorithms, Polynomial Time Approximation Schemes.

Textbooks:

1. T. H Cormen, C E Leiserson, R L Rivest and C Stein: Introduction to Algorithms, 3rd ed., Prentice-Hall of India, 2010.
2. Kenneth A. Berman, Jerome L. Paul: Algorithms, Cengage Learning, 2002.
3. Ellis Horowitz, Sartaj Sahni, S.Rajasekharan: Fundamentals of Computer Algorithms, 2nd ed., Universities press, 2007.

CSE119: Information Theory and Coding **L | T | P (3 | 1 | 0)**

Prerequisites: Basics of Fourier Transformation, calculus

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the evolution of Information Theory.

CO2: Understand the concepts of different types of code such as Linear Block code, Cyclic Codes, Convolutional Codes.

Information Theory: Uncertainty, Information, Entropy: characterization and related properties, Huffman codes, Robustness of coding techniques, Discrete Memoryless Channel, Mutual Information, Channel Capacity, Shannon's Theorems, Fundamental theorem of information theory, Gaussian Channel, Limits to Communication.

Linear Block Codes: Groups, Fields and Vector Spaces, Construction of Galois Fields of Prime Order, Syndrome Error Detection, Standard Array and Syndrome Decoding, Hamming Codes.

Cyclic Codes: Polynomial Representation of Codewords, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes.

Structure and Properties of Convolutional Codes: Convolutional Encoder Representation, Tree, Trellis, and State Diagrams, Distance Properties of Convolutional Codes, Punctured Convolutional Codes and Rate Compatible Schemes.

Decoding of Convolutional Codes: Maximum Likelihood Detection, The Viterbi Algorithm, Automatic Repeat Request Strategies: Basic Techniques, Hybrid ARQ.

Textbooks:

1. J. A. Thomas and T. M. Cover: Elements of information theory, Wiley, 2006.
2. J. H. van Lint: Introduction to Coding Theory, 3rd ed., Springer, 1998.
3. F. J. MacWilliams and N.J. Sloane: Theory of Error Correcting Codes, Parts I and II, 1977.
4. D. Stinson: Combinatorial Designs: Constructions and Analysis, Springer, 2003
5. P. J. Cameron and J. H. van Lint: Designs, Graphs, Codes and their Links, Cambridge University Press, 2010.
6. C. Fragouli and E. Soljanin: Network Coding Fundamentals, Now Publisher, 2007.

<u>CSE120: Machine Learning</u> **L | T | P (3 | 0 | 1)**

Prerequisites: Understanding of Basic Mathematics concepts in Linear Algebra, Calculus, Discrete Mathematics, Probability and statistics theory, Programming skills (commonly python).

Course Outcome: By the end of the course, students should be able to:
CO1: Understand the basic ideas behind supervised learning algorithms and analyze the various supervised learning techniques.
CO2: Understand the basic ideas behind unsupervised learning algorithms and analyze the various supervised learning techniques.
CO3: Understand and apply different estimation techniques.
CO4: Design the learning algorithm models for real world problems, optimize the models and evaluate the models using different performance metrics.

Course Outline:

Supervised learning: Artificial Neural Network, classifying with k-Nearest Neighbour classifier, Support vector machine classifier, Decision Tree classifier, Naive Bayes classifier, Bagging, Boosting, Improving classification with the AdaBoost meta-algorithm.

Unsupervised learning: Grouping unlabeled items using k-means clustering, Association analysis with the Apriori algorithm, efficiently finding frequent item sets with FP-growth. PCA (Principal components analysis), ICA (Independent components analysis);
Forecasting and Learning theory: Predicting numeric values: regression, Linear Regression, Logistic regression, Tree-based regression. Bias/variance tradeoff, Union and Chernoff/Hoeffding bounds, Vapnik– Chervonenkis (VC) dimension, Worst case (online) learning.

Reinforcement learning and control: Markov decision process (MDP), Bellman equations, Value iteration and policy iteration, Linear quadratic regulation, Linear Quadratic Gaussian, Q-learning, Value function approximation, Policy search, Reinforce, POMDPs.

Textbooks:

1. Alex Smola, S.V.N. Vishwanathan, “Introduction to Machine Learning”, Cambridge
University Press, 2008.

2. K. Murphy, “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012.
3. Ethem Alpaydin, "Introduction to Machine Learning", The MIT Press, 2nd Edition., 2009.
4. Tom M. Mitchell, "Machine Learning", Tata McGraw-Hill Education, 2017.

<u>CSE121: Neural Networks</u> **L | T | P (3 | 0 | 1)**

Prerequisites: basic understanding of statistics, mathematics, and machine learning concepts.

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the evolution of Neural Networks.

CO2: Understand the basics of ANN.

CO3: Understand the concepts of backpropagation networks, Competitive Learning, and Neuro-Fuzzy Learning.

Introduction to Neural Networks: Humans and Computers, Organization of the Brain, Biological Neuron, Features, structure and working of Biological Neural Network, Biological and Artificial Neuron Models, Characteristics of ANN, Comparison of BNN and ANN, Models of neuron, Hodgkin-Huxley Neuron Model, Integrate-and-Fire Neuron Model, Spiking Neuron Model, McCulloch-Pitts Model, Perceptron, Adaline model, Basic learning laws, Topology of neural network architecture, Historical Developments, Potential Applications of ANN.

Basic functional units of ANN for pattern recognition tasks: Basic feedforward, Basic feedback and basic competitive learning neural network. Pattern association, pattern classification and pattern mapping tasks. Linear responsibility X-OR problem and solution. Analysis of pattern mapping networks summary of basic gradient search methods. Pattern storage networks, stochastic networks and simulated annealing, Boltzmann machine and Boltzmann learning.

Backpropagation Networks: Architecture of feed forward network, single layer ANN, multilayer perceptron, back propagation learning, input, hidden and output layer computation, backpropagation algorithm, applications, selection of tuning parameters in BPN, Numbers of hidden nodes, learning. Activation & Synaptic Dynamics– Introduction, Activation Dynamics models, Synaptic Dynamics models, Stability and Convergence, Recall in Neural Networks.

Competitive Learning Neural Networks: Components of CL network, pattern clustering and feature mapping network, ART networks, Features of ART models, character recognition using ART network.

Applications of ANN– Pattern classification, Recognition of Olympic games symbols, Recognition of printed Characters, Neocognitron– Recognition of handwritten characters, NETTALK.

Neuro-Fuzzy Modeling: Adaptive Neuro-Fuzzy Inference Systems, Coactive Neuro-Fuzzy Modeling– Classification and Regression Trees, Data Clustering Algorithms, Rulebase Structure Identification, Neuro-Fuzzy Control, Case studies.

Textbooks:

1. L. Fausett, “Fundamentals of Neural Networks: Architectures, Algorithms & Applications”, Prentice-Hall,1994.
2. James A. Freeman and David M. Skapura, “Neural Networks Algorithms, Applications, and

Programming Techniques”, Pearson, 2003.
3. B. Yegnanarayana, “Artificial Neural Networks”, PHI, 2006.
4. Rajasekaran, Pai “Neural networks, Fuzzy Logic and Genetic Algorithms: Synthesis and Applications”, PHI, 2011.
5. Stephen I. Gallant, “Neural Network Learning & Expert Systems”, MIT Press, 1995.
6. John Hertz, Anders Krogh, Richard G. Palmer, “Introduction to the theory of Neural Computation”, Addison-Wesley, 1991.
7. J.-S.R. Jang, C.-T. Sun, E. Mizutani, “Neuro-Fuzzy and Soft Computing”, Pearson, 1996.

Haykin, S., Neural Networks - A Comprehensive Foundation, 2nd ed., Macmillan, 1999.

CSE122: Mobile Ad-hoc Networks **L | T | P (3 | 0 | 1)**

Prerequisites: basic understanding of wireless, network devices, and networking protocols.

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the MAC addresses and related protocols .

CO2: Understand the basics of Transport Layer.

CO3: Understand the concepts of Routing.

Introduction: Ad-hoc Networks– Definition, Characteristics, Features, Application, Characteristics of Wireless Channel, Ad-hoc Mobility Models– Indoor and Outdoor Models. Medium Access Protocols, MAC Protocols, Design Issues, Goals and Classification, Contention Based Protocols– With Reservation, Scheduling Algorithms, Protocols Using Direction Antennas. IEEE Standards– 802.11a, 802.11b, 802.11g, 802.15.HIPERLAN.

Network Protocols: Routing Protocols– Design Issues, Goals and Classification, Proactive vs. Reactive Routing, Unicast Routing Algorithms, Multicast Routing Hierarchical Routing, Quos Aware Routing.

End-End Delivery and Security: Transport Layer– Design Issues, Classification, Ad-hoc Transport Protocols. Security Issues in Ad-hoc Network– Issues and Challenges, Network Security Attacks, Secure Routing Protocols.

Cross Layer Design and Integration of Ad-hoc for 4G: Cross Layer Design– Need for Cross Layer Design, Cross Layer Optimization, Parameter Optimization, Techniques, Cross Layer Cautionary Perspective. Integration of Ad-hoc with Mobile IP Networks. Mesh Networks, Vehicular Area Networks. Ad Hoc On-Demand Distance-Vector Protocol– Properties, Unicast Route Establishment, Multicast Route Establishment, Broadcast, Optimizations and Enhancements.

Link Reversal Routing: Gafni-Bertsekas Algorithm, Lightweight Mobile Routing Algorithm, Temporally Ordered Routing Algorithm, Preserving Battery Life of Mobile Nodes, Associativity Based Routing, Effects of Beaconing on Battery Life, Research Paper on Recent Trends in MANET.

Textbooks:

1. C-K Toh, “Ad Hoc Mobile Wireless Networks: Protocols and Systems”, Pearson, 1st ed., 2007.
2. C. Siva Ram Murthy, B. S. Manoj, “Ad Hoc Wireless Networks: Architectures and Protocols”, Prentice Hall, 2004.

3. Stefano Basagni, Marco Conti, Silvia Giordano, Ivan Stojmenovic, "Mobile Ad Hoc Networking", Wiley, 2010.
4. AzzedineBoukerche, "Algorithms and Protocols for Wireless, Mobile Ad Hoc Networks", Wiley-Blackwell, 2008.
5. Yi Pan, Yang Xiao, "Ad Hoc and Sensor Networks", Nova Science Publishers, 2005.

Carlos de MoraisCordeiro, Dharma PrakashAgrawal, "Ad Hoc and Sensor Networks: Theory and Applications", World Scientific, 2ndед., 2013.

<u>CSE123: Cloud Architecture</u> **L | T | P (3 | 0 | 1)**

Prerequisites: Nil

Course Outcome: By the end of the course, students should be able to:

- **CO1:** Differentiate SMP and MPP architectures
- **CO2:** Describe the concepts of parallel computing, hardware architecture and levels of parallelism
- **CO3:** Analyze various distributed computing models and message based communications
- **CO4:** Explain and Implement virtualization concepts
- **CO5:** Analyze Openstack cloud architecture with attack surfaces.

Fundamentals: *Evolution of cloud computing, Key characteristics and benefits, Cloud service models: IaaS, PaaS, SaaS, Cloud deployment models: Public, Private, Hybrid, Community, layered cloud architecture, architectural design challenges*

Computer Clusters for Scalable Computing: Clustering for Massive Parallelism. Computer Clusters and MPP Architectures. Design Principles of Computer Clusters. Cluster Job and Resource Management.

Principles of Parallel Computing: Eras of Computing, Parallel vs. Distributed Computing, Elements of Parallel Computing, What is Parallel Processing?, Hardware Architectures for Parallel Processing, Approaches to Parallel Programming, Levels of Parallelism, Laws of Caution, **Distributed Computing :** Elements of Distributed Computing, General Concepts and Definitions, Components of a Distributed System, Architectural Styles for Distributed Computing, Models for Inter-Process Communication, Technologies for Distributed Computing, Remote Procedure Call, Distributed Object Frameworks, Service Oriented Computing

Virtualization Architecture: Implementation Levels of Virtualization, Virtualization of CPU, Memory and I/O Devices, Virtualization in Multi-core processor, physical versus virtual cluster

Design of Cloud Computing Platforms: Design architecture of Cloud Platforms: OpenStack, attack surface of cloud architecture and security tools

Textbooks:

1. Kai Hwang, Jack Dongarra, and Geoffrey C. Fox 2011, Distributed and Cloud Computing: From Parallel Processing to the Internet of Things: Clusters, Grids, Clouds, and the Future Internet,

Morgan Kaufmann.

2. RajkumarBuyya 2013, Mastering Cloud Computing: Foundations and Applications Programming, First Ed., Morgan Kaufmann Waltham, USA.

3. Dan C. Marinescu., Cloud computing, Elsevier/Morgan Kaufmann Boston.

4. San Murugesan (Editor), Irena Bojanova (Editor) 2015, Encyclopedia on Cloud Computing, First Ed., Wiley-Blackwell

5. NIST 2013, Cloud Computing Synopsis and Recommendations, CreateSpace Independent Publishing Platform.

CSE124: Parallel and Distributed Computing **(L | T | P (3 | 0 | 1)**

Prerequisites: Operating System, Computer Hardware and Networking

Course Outcome: By the end of the course, students should be able to:

- **CO1:** Understand the terminologies in distributed computing
- **CO2:** Understand the different type of Processors, single as well multi-core processors
- **CO3:** Understand the concepts of computational Grids.

Introduction: Parallel Computing Architectures, Paradigms, Issues, & Technologies, architectures, topologies, organizations, Parallel Programming Using Shared Memory, memory coherence, race conditions and deadlock detection, synchronization, multithreaded programming, Parallel Programming using Message Passing, synchronous/asynchronous messaging, partitioning and load-balancing.

Advanced Processors and Interconnects: Multicore Processors and High-bandwidth Networks, Parallel and distributed architectures, Distributed and parallel algorithms, Fundamental problems in parallel and distributed computing, fundamental concepts and reasoning principles for parallel and distributed computer systems.

Distributed Programming Algorithms: Fundamental issues and concepts, synchronization, mutual exclusion, termination detection, clocks, event ordering, locking, CORBA, JavaRMI, Web Services, shared spaces.

Clusters of Computers: Server Clusters, High Availability, and Disaster Recovery, synchronization, fault tolerance, coordination and consensus, Virtual Machines and Virtualized Datacenters.

Peer-to-Peer Computing: P2P systems, Familiarity with concurrent programming primitives (semaphores, locks, monitors), Overlay networks, and Content Distribution.

Computational Grids and Applications: National or global computing Grids and Applications.

Textbooks:

1. M J Quinn, Parallel Programming in C with MPI and OpenMP.
2. AnanthGrama, George Karypis, Vipin Kumar, and Anshul Gupta, Introduction to Parallel Computing, 2nd ed., 2003.
3. David Kirk, Wen-Mei W. Hwu, Wen-meiHwu, Programming Massively Parallel Processors: a hands-on approach, Morgan Kaufmann, 2010.
4. William Gropp, Ewing Lusk, and Anthony Skjellum, Using MPI: Portable Parallel Programming with the Message-Passing Interface, 2nd ed., 1999.
5. Norm Matloff, Programming on Parallel Machines: GPU, Multicore, Clusters and More.
6. K. Hwang and Z. Xu, Scalable Parallel Computing, McGraw-Hill, 1998.
7. G. Coulouris, J. Dollimore, Distributed Systems Concepts and Design, Addison Wesley.
8. Ian Taylor: From P2P to Web Services and Grids, Springer-Verlag, 2005.
9. F. Berman, G. Fox, and T. Hey (Editors), Grid Computing, Wiley, 2003.
10. Hariri and Parashar, Tools and Environments for Parallel & Distributed Computing, John Wiley, 2004.

<u>CSE125: Advanced Graph Theory</u> **L | T | P (3 | 1 | 0)**

Prerequisites: Discrete Mathematics.

Course Outcomes: By the end of the course, students will be able to

- **CO1:** Know important classes of problems in graph theory.
- **CO2:** Formulate and prove fundamental theorems on graphs.
- **CO3:** Acquire in-depth knowledge of covering, connectivity and coloring problems in graphs.

Course Outline:

Graphs, Types, Isomorphism, Paths, Cycles, Vertex degrees and Counting, Euler and Hamilton graphs, minors, topological minors.

Matching and covering: vertex cover, edge cover, path cover, Gallai-Millgram and Dillworth's theorem, dominating sets, independent sets, matching, maximum matching, Hall's theorem, Tutte's theorem, k-factor graphs.

Connectivity: vertex connectivity, edge connectivity, blocks, 2-connected, 3-connected graphs and their structures, Menger's theorem.

Coloring and Planarity: vertex coloring, Brook's theorem, line graphs and edge coloring, Vizing's theorem, upper bounds on chromatic numbers, structure of k-chromatic graphs, color-critical graphs, planar graphs.

Special classes of graphs, perfect graphs, chordal graphs, interval graphs; basics of spectral graph theory, eigenvalues and graph parameters, strongly regular graphs.

Spectral Graph theory: Basic properties of graph spectrum; Cheeger's inequality and approximation of graph expansion; Expander graphs and applications to super concentrators and pseudo randomness;

Error correcting codes and expander codes; Small set expansion, Unique Games Conjecture and Hardness of approximation.

Textbooks:

1. Statys Jukna, Extremal Combinatorics: With Applications in Computer Science, Springer, 2^{nd}ed., 2013.
2. R.P. Grimaldi, B.V. Ramana, Discrete and Combinatorial mathematics – An applied introduction, Pearson Education (2007).
3. Richard A Brnaldi, Introductory Combinatorics, Pearson Education, Inc. (2004).
4. Miklos Bona, Introduction to Enumerative Combinatorics, McGraw Hill (2007).
5. A walk through Combinatorics – An introduction to enumeration and graph theory, World Scientific Publishing Co. Pvt. Ltd. (2006).
6. J.H. Vanlint, R.M. Wilson, A course in Combinatorics, Cambridge University Press.
7. R. Diestel, "Graph Theory", Springer, 2^{nd} ed., 2000.
8. N. Alon and J. Spenser, "Probabilistic Methods", John Wiley and Sons, 2^{nd} ed., 2000.

<u>CSE126: Cyber Forensics</u> **L | T | P (3 | 1 | 0)**

Prerequisites: Cyber Security, and Cryptography

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concepts of Cyber Forensics.

CO2: Understand the concepts of Data Forensics, E-Mail Forensics and Steganography.

History of Forensics: Computer Forensic Flaws and Risks, Rules of Computer Forensics, Legal issues, Digital Forensic Principles, Digital Environments, Digital Forensic Methodologies.

Computer Crime: Introduction to Traditional Computer Crime, Traditional problems associated with Computer Crime. Introduction to Identity Theft & Identity Fraud.Types of CF techniques, Incident and incident response methodology, Forensic duplication and investigation.

Preparation for IR: Creating response tool kit and IR team, Forensics Technology and Systems, Understanding Computer Investigation, Data Acquisition, Evidence Collection: Processing Crime and Incident Scenes, Working with Windows and DOS Systems, Computer Forensics Tools: Software/ Hardware Tools.

Data Forensics: Recovering deleted files and deleted partitions, deleted file recovery tools, deleted partition recovery tools, data acquisition and duplication, data acquisition tools, hardware tools, backing up and duplicating data.

E-Mail Forensics and Steganography: Forensics Acquisition, Processing Local mail archives, Processing server level archives, classification of steganography, categories of steganography in Forensics, Types of password cracking.

Validating Forensics Data: Data Hiding Techniques, Performing Remote Acquisition, Network

Forensics, Email Investigations, Cell Phone and Mobile Devices Forensics

Textbooks:

1. Kevin Mandia, Chris Prosise, “Incident Response and Computer Forensics”, Tata McGraw Hill, 2006.
2. Peter Stephenson, “Investigating Computer Crime: A Handbook for Corporate Investigations”, Sept 1999.
3. Anthony Reyes, Jack Wiles, “Cybercrime and Digital Forensics”, Syngress Publishers, Elsevier 2007.
4. John Sammons, “The Basics of Digital Forensics”, Elsevier 2012
5. Linda Volonins, Reynaldo Anzaldua, “Computer Forensics for dummies”, Wiley Publishing 2008.
6. Nelson, Phillips, Enfinger, Steuart, “Computer Forensics and Investigations”, Cengage Learning, 2008.
7. R.Vacca, “Computer Forensics”, Firewall Media, 2005.
8. Richard E. Smith, “Internet Cryptography”, Pearson Education, 3rded., 2008.
9. Marjie T. Britz, “Computer Forensics and Cyber Crime: An Introduction”, Pearson Education, 1sted., 2012.

CSE127: Software Defined Networks **L | T | P (3 | 1 | 0)**

Prerequisites: Basics of Operating System

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concepts of Network Visualization.

CO2: Understand the concepts of Control Plane, Data Plane, and Data Center Network.

Introduction: History and Evolution of Software Defined Networking (SDN)**,** Separation of Control Plane and Data Plane, IETF Forces, ActiveNetworking. Control and Data Plane Separation: Concepts, Advantages andDisadvantages, the Open Flow protocol.

Network Virtualization: Concepts, Applications, Existing Network Virtualization Framework (VMWare and others), Mininet based examples.

Control Plane: Overview, Existing SDN Controllers including Floodlight and Open Daylight projects. Customization of Control Plane, Switching and Firewall Implementation using SDN Concepts.

Data Plane: Software-based and Hardware-based; Programmable Network Hardware. Programming SDNs: Northbound Application Programming Interface, Current Languages and Tools, Composition of SDNs.Network Functions Virtualization (NFV) and Software Defined Networks: Concepts, Implementation and Applications.

Data Center Networks: Packet, Optical and Wireless Architectures, Network Topologies. Use Cases of SDNs: Data Centers, Internet Exchange Points, Backbone Networks, Home Networks, Traffic Engineering. Use Cases and Looking Forward.

Textbooks:

1. SDN: Software Defined Networks, an Authoritative Review of Network Programmability Technologies, By Thomas D. Nadeau, Ken Gray Publisher: O'Reilly Media, 2013.
2. Software Defined Networks: A Comprehensive Approach, by Paul Goransson and Chuck Black, Morgan Kaufmann, 2014, eBook.
3. Paul Göransson, Chuck Black, Software Defined Networks: A Comprehensive Approach, Elsevier, 2014.
4. Thomas D. Nadeau, SDN: Software Defined Networks, 1st ed., O'reilly.
5. SiamakAzodolmolky, "Software Defined Networking with Open Flow", Packt Publishing, 2013.

Fei Hu, "Network Innovation through Open Flow and SDN: Principles and Design", CRC Press, 2014.

CSE128: Evolutionary Algorithms **L | T | P (3 | 0 | 1)**

Prerequisites: Programming

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concepts of Genetic Algorithm.
CO2: Understand the concept of Swarm Optimization.
CO3: Understand the concepts of Differential Evolution, and Genetic Programming.

Genetic Algorithms: Historical development, GA concepts – encoding, fitness function, population size, selection, crossover and mutation operators, along with the methodologies of applying these operators. Binary GA and their operators, Real Coded GA and their operators

Particle Swarm Optimization: PSO Model, global best, Local best, velocity update equations, position update equations, velocity clamping, inertia weight, constriction coefficients, synchronous and asynchronous updates, Binary PSO.

Differential Evolution: DE as modified GA, generation of population, operators and their implementation.

Genetic programming (GP): Steps in GP, individual representation, initial population, tree creation methods, fitness assessment, individual section methods, GP operators, GP parameters

Introduction to parallel genetic programming, distributed genetic programming, parallel distributed GP.

Textbooks:

1. Gen, M. and Cheng, R. "Genetic Algorithms and Engineering Design", Wiley, New York.
2. David E. Goldberg, "Genetic Algorithm in Search, Optimization and Machine Learning".
3. Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, Frank D. Francone, "Genetic programming: An introduction– On the Automatic Evolution of Computer Programs and its Applications", Morgan Kauffman.

CSE129: Blockchain Technology L | T | P (3 | 0 | 1)

Prerequisites: Cryptography, Distributed Networks

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concepts of Blockchain.
CO2: Understand the concept of Decentralization.
CO3: Understand the concept of Bitcoin, Ethereum, and Hyperledger.

Introduction to Blockchain: Definitions of blockchains, The history of blockchain, Generic elements of a blockchain, Features of a blockchain, Applications of blockchain technology, Types of blockchain, Benefits and limitations of blockchain.

Decentralization: Decentralization using blockchain, Methods of decentralization, Routes to decentralization, Blockchain and full ecosystem decentralization, Smart contract, Decentralized organizations, Platforms for decentralization.

Cryptography and Technical Foundations: Cryptographic primitives, Asymmetric cryptography, Public and private keys, Hash functions, Secure Hash Algorithms (SHAs), Merkle trees, Patricia trees ,Distributed hash tables (DHTs) ,Digital signatures.

Bitcoin: Bitcoin definition, Bitcoin Transactions, Bitcoin Blockchain, Bitcoin payments, Bitcoin limitations, Other crypto currency**:** Namecoin, Litecoin, Zcash.

Ethereum: Ethereum clients and releases,The Ethereum stack, Ethereum blockchain ,Currency (ETH and ETC) ,Forks, Gas ,The consensus mechanism, Elements of the Ethereum blockchain, Precompiled contracts, Mining , Applications developed on Ethereum.

Hyperledger: Hyperledger as a protocol, Hyperledger Fabric, Sawtooth lake, Corda Architecture ,State objects 376 Transactions ,Consensus , Flows , Components.

Textbooks

1. Mastering Blockchain – Imran Bashir, Packt Publishing.
2. Drescher, D. (2017). Blockchain basics: A non-technical introduction in 25 steps. Apress Media LLC.

References

1. Building Blockchain Projects-Narayan Prusty, Packt Publishing.

CSE130: Quantum Computing L | T | P (3 | 1 | 0)

Prerequisites: NIL

Course Outcome: By the end of the course, students should be able to:

CO1: Understand the concepts of Quantum computing.

CO2: Understand the concept of Quantum physics, Circuits, and Algorithms.
CO3: Understand the concepts of Noise detection and correction.

Introduction to Quantum Computation: Quantum bits, Bloch sphere representation of a qubit, multiple qubits. 10 5 Noise and error correction: Graph states and codes, Quantum error correction, fault-tolerant computation.

Background Mathematics and Physics: Hilber space, Probabilities and measurements, entanglement, density operators and correlation, basics of quantum mechanics, Measurements in bases other than computational basis.

Quantum Circuits: single qubit gates, multiple qubit gates, design of quantum circuits.

Quantum Information and Cryptography: Comparison between classical and quantum information theory. Bell states. Quantum teleportation. Quantum Cryptography, no cloning theorem.

Quantum Algorithms: Classical computation on quantum computers. Relationship between quantum and classical complexity classes. Deutsch's algorithm, Deutsch's-Jozsa algorithm, Shor factorization, Grover search.

Noise and error correction: Graph states and codes, Quantum error correction, fault-tolerant computation.

Textbooks

1. Nielsen M. A., Quantum Computation and Quantum Information, Cambridge University Press. 2002

2. Benenti G., Casati G. and Strini G., Principles of Quantum Computation and Information, Vol. I: Basic Concepts, Vol II: Basic Tools and Special Topics, World Scientific. 2004

3. Pittenger A. O., An Introduction to Quantum Computing Algorithms

CSE131: Research Methodology **L | T | P (4 | 0 | 0)**

Prerequisites: NIL

Course Outcome: By the end of the course, students should be able to:
CO1: Understand the concept of research.
CO2: Understand the concept of data collection and selection for research.
CO3: Understand the applicability of research for the public at large.

Introduction to Research Methods in science – Philosophy of Science, Research methods and Creative Thinking, Evolutionary Epistemology, Scientific Methods, Hypotheses Generation and Evaluation, Code of Research Ethics, Definition and Objectives of Research, Various Steps in Scientific Research, Research presentations

Types of Research – Research Purposes – Research Design , Survey Research , formulation of scientific problems and hypotheses , selection of methods for solving a scientific problem Case Study Research.

How to perform a literature review – Sampling Methods – Data Processing and Analysis strategies - Data Analysis with Statistical Packages – Statistical Analysis – Hypothesis-testing – Generalization and Interpretation.

Research Reports - Structure and Components of Research Report, Types of Report, Layout of Research Report, Mechanism of writing a research report – Requirements of a good dissertation.

Textbooks:

1. Oates, B.J., (2005). Researching Information Systems and Computing. Sage Publications, UK.
2. Zobel, J. (2004). Writing for Computer Science - The art of effective communication. 2nd ed., Springer, UK.
3. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
4. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International.
5. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology.

CSE132 Cloud Security **L | T | P (3 | 1 | 0)**

Prerequisites: Virtualization and Cloud Computing with AWS/ Cloud Architecture

Course Outcomes: By the end of the course, students will be able to:

- **CO1:** Understand the characteristics in terms of the systems, protocols and mechanisms in Cloud
- **CO2:** Comprehend the security & privacy issues with reference to Cloud Computing
- **CO3:** Identify the vulnerabilities, threats and attacks in Cloud Environment and the defense mechanisms
- **CO4:** Examine intrusion detection systems and approaches in Cloud Computing
- **CO5:** Implement open-source attacking and security tools

COURSE OUTLINES:

Introduction to Cloud Computing: History and Underlying Technologies, Definitions & Characteristics, Cloud Deployment Models, Cloud Service Platforms, Challenges Ahead

Introduction to Cloud Security: Definition, vulnerabilities and need of Cloud Security, Cloud Security Concepts: Multi-tenancy, Virtualization, Data Outsourcing, Trust Management, Metadata Security, Cloud Security Standards, CSA Cloud Reference Model, NIST Cloud Reference Model

Cloud Security & Privacy Issues: Introduction, Cloud Security goals: Confidentiality, Integrity, Availability, Authentication, Authorization, Auditing, Access Control, Cloud Security Issues: Application Level, Application Level, Virtualization Level, Data security, Identity management and access control, Improper cryptographic keys management, Service level agreement (SLA), Regular audit and compliances, Cloud and CSP Migration, SLA, Hardware issues, Security Requirements for Privacy, Privacy issues in Cloud

Threat Model, Attacks, Defense Systems and Security Technique: Threat Model and Taxonomy of Cloud Attacks, Virtual Machines-level Attacks, Virtual Machine Monitor-Level Attacks, Peripheral - Level Attacks, Virtual Storage-Level Attacks, Tenant Network-Level Attacks, Case studies on attack dataset

Classification of Intrusion Detection Systems in Cloud: Evolution of Cloud-Intrusion Detection System (IDS), TVM-based IDS, VMM-based IDS, Network-based IDS, Distributed IDS, Research Challenges

Intrusion Detection Techniques in Cloud: Taxonomy of Intrusion Detection Techniques in Cloud, Misuse Detection, Anomaly Detection, Virtual Introspection-based, Hypervisor Introspection-based, Hybrid Techniques

Tools & Case Studies: Overview of Tools (Attack/Security) in Cloud, Network-Level Attack Tools, VM-Level Attack Tools, VMM Attack Tools, Network Security Tools, VM Security Tool, VMM Security Tools, Case Study of LibVMI : A Virtualization-Specific Tool

Virtual Machine Introspection and Hypervisor Introspection: Virtual Machine Introspection (VMI):VM Hook based, VM-State Information based, Hypercall verification based, Guest OS kernel debugging based, VM interrupt analysis based, Hypervisor Introspection (HVI): Nested Virtualization, Code Integrity Checking using hardware-support, Memory Integrity Checking using Hardware/Software Support, Revisiting the VMM Design, VM-Assisted Hypervisor Introspection

BOOKS:

1. Cloud Security: Attacks, Techniques, Tools and Challenges, Published by Preeti Mishra, Emmanuel S. Pilli, R. C. Joshi by Taylor and Francis 2022
2. Cloud Security and Privacy by Tim Mather, Subra, Shahed Latif (Publ. Orielly Media), 2009

Reference Books:

1. Mastering Cloud Computing by Raj Kumar Buyya,Vecchiola & Selvi (Published by Mc Graw Hill Education Pvt. Ltd) – 2013
2. Securing the Cloud By Vic (J.R.) Winkler 1st edition , 2011

<u>CSE133 AI-driven Cyber Security</u> **L | T | P (3 | 0 | 1)**

Prerequisites: Fundamentals of Computer, Problem solving concepts

Course Outcomes: By the end of the course, students will be able to:

CO1: Understand the fundamentals of cyber security, including key concepts, attack types, and real-world case studies.

CO2: Explain and Analyze OWASP Top 10 vulnerabilities
CO3: Understand applications of AI in intrusion detection systems, email filtering, and firewall
CO4: Develop and evaluate AI/ML models for malware detection and network anomaly monitoring using real-world datasets and performance tuning techniques.

COURSE OUTLINES:

Unit 1: Introduction to Cyber Security: Cyber Security overview, Importance of Cyber Security, Today's Digital World, Recent Cyber Attacks, Types of Attacks, Impact of Attacks, Security Objectives, Introductory Quiz

Unit 2: Layers and Application Security: Cyber Security Myths, What Needs to be Secured, Security Layers, Basics of Application Security, OWASP Top 10 Overview, Global landscape of cyber threats

Unit 3: AI in Cyber Security: What, Why, How of AI in Cyber Security, AI applications in modern cyber defense

Unit 4: Network Security using AI/ML: What, Why, How of Network Security, Introduction to Network Security, Network Anomaly Datasets, Preparing Network Anomaly Dataset, Classification algorithm for Network Monitoring, Improving ML Algorithms with Hyperparameter Optimization, Quiz on Network Security and ML

Unit 5: Malware Detection using AI/ML: What, Why, How of Malware Detection, Types of Malware, Traditional Malware Detection Systems, Loading and Analyzing Malware Datasets, Preparing Datasets for ML, Training ML-based Malware Detection Systems, Improving ML Algorithms with Hyperparameter Optimization, Quiz on Malware Detection and ML

Text Book:

Qureshi, B. (2023). *AI in Cybersecurity: Securing the Digital Frontier*. Amazon Kindle Direct Publishing.