Sri Sivasubramaniya Nadar College of Engineering

(An Autonomous Institution, Affiliated to Anna University, Chennai)

Rajiv Gandhi Salai (OMR), Kalavakkam – 603110

Curriculum and Syllabus

Master of Technology

Information Technology

Regulations 2018

Choice Based Credit System (CBCS)

Sri Sivasubramaniya Nadar College of Engineering, Kalavakkam - 603 110
(An Autonomous Institution Affiliated to Anna University Chennai)

REGULATIONS 2018

CHOICE BASED CREDIT SYSTEM

M.TECH. INFORMATION TECHNOLOGY

Program Educational Objectives (PEO)

Technical proficiency
Graduates will apply their technical knowledge and expertise to develop and implement computing technologies for a broad mix of informational purposes of the research /industrial/societal needs.

Professional development
Graduates will continue to grow intellectually and professionally in the dynamic industrial scenarios and Research & Development organizations.

Social responsibility
Graduates will make a positive difference to the society by generating employment and rendering services for the betterment of the society.

Program Outcomes (POs)

1. An understanding of the theoretical foundations and the limits of computing.
2. An ability to apply existing models, techniques, algorithms, data structures, etc. for efficiently solving problems.
3. Understanding and ability to use advanced computing techniques and tools.
4. An ability to design, develop and evaluate existing and new Information technology based systems for novel applications which meet the desired needs of industry and society.
5. An ability to undertake research at the cutting edge of information science and technology & its related areas.
6. An ability to function effectively individually or as a part of a team to accomplish a stated goal.
7. An understanding of professional and ethical responsibility.
8. An ability to communicate effectively with a wide range of audience.
9. An ability to learn independently and engage in life-long learning.
10. An understanding of the impact of IT related solutions in an economic, social and environment context.
11. An ability to observe and examine one's action and to make corrective measures.

Program Specific Outcomes (PSO)

1. Ability to apply analytical methods in evolving technologies.
2. Ability to manage and monitor IT infrastructure and safeguard data and resources.

PEO to PO Mapping

PEO-PO Mapping	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PEO 1	✓	✓	✓	✓	✓					✓	✓
PEO 2		✓	✓	✓	✓	✓	✓		✓	✓	✓
PEO 3		✓		✓		✓	✓	✓		✓	✓

PSO to PO Mapping

PSO-PO Mapping	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PSO 1		✓	✓	✓	✓	✓		✓	✓	✓	✓
PSO 2	✓					✓	✓	✓	✓	✓	✓

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REGULATIONS 2018

CHOICE BASED CREDIT SYSTEM

M.TECH. INFORMATION TECHNOLOGY

CURRICULUM AND SYLLABUS

SEMESTER I

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1.	PCP1176	Advanced Data Structures and Algorithms	PC	3	3	0	0	3
2.	PIF1101	Advanced Data bases and Security	PC	3	3	0	0	3
3.	PIF1176	Agile Software engineering	PC	3	3	0	0	3
4.	PIF1102	Machine Learning Algorithms and Applications	PC	3	3	0	0	3
5.		Professional Elective – I	PE	3	3	0	0	3
6.		Professional Elective – II	PE	3	3	0	0	3
PRACTICALS								
7.	PCP1197	Advanced Data Structures and Algorithms Lab	PC	4	0	0	4	2
8.	PIF1111	Advanced Data bases Lab	PC	4	0	0	4	2
			TOTAL	**26**	**18**	**0**	**8**	**22**

SEMESTER II

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1.	PMA1251	Operations Research	FC	4	4	0	0	4
2.	PIF1201	Smart Sensors and Internet of Things	PC	3	3	0	0	3
3.	PIF1202	Big Data Analytics and Visualization	PC	3	3	0	0	3
4.	PIF1203	Advanced Web Technologies	PC	3	3	0	0	3
5.		Professional Elective - III	PE	3	3	0	0	3
6.		Professional Elective – IV	PE	3	3	0	0	3

PRACTICALS								
7.	PIF1215	Technical Seminar and Report Writing	EEC	2	0	0	2	1
8.	PIF1211	Machine Learning with Python Lab	PC	2	0	0	2	2
9.	PIF1212	Big Data Analytics Lab	PC	4	0	0	4	2
			TOTAL	**27**	**19**	**0**	**8**	**24**

SEMESTER III

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1.	PIF1301	Cyber Security	PC	3	3	0	0	3
2.		Professional Elective – V or Online Course*	PE	3	3	0	0	3
3.		Open Elective - I	OE	3	3	0	0	3
PRACTICALS								
4.	PIF1318	Project Work (Phase I)	EEC	12	0	0	12	6
			TOTAL	**21**	**9**	**0**	**12**	**15**

*** OLC - Online NPTEL courses with the prior approval from the department**

SEMESTER IV

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
PRACTICALS								
1.	PIF1418	Project Work (Phase II)	EEC	24	0	0	24	12
				TOTAL	**0**	**0**	**24**	**12**

Online Course (OLC*):

Students will be permitted to do online courses of maximum six credits (which are provided with certificate after evaluation of the performance) during the entire programme, with the prior approval from the Head of the Department or from the list of courses approved by Head of the Department. On successful completion of the course, the candidate has to submit the copy of the certificate to the Head of the Department. The Head of the Department can form a team of faculty members to recommend the grade to be awarded to the candidate by mapping the score earned by the students and the results can be sent to the Controller of Examinations after the approval of the Head of the Department. On successful completion of online courses of every three credits, the student can get a waiver from doing one Professional Elective or Open Elective.

* OLC - Online NPTEL courses with the prior approval from the Head of the Department

TOTAL NO. OF CREDITS: 73 (22+24+15+12)

PROFESSIONAL ELECTIVES (PE)*
SEMESTER I

ELECTIVE I

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1.	PIF1121	Computer Vision and Image Analysis	PE	3	3	0	0	3
2.	PIF1122	Information Theoretic Learning	PE	3	3	0	0	3
3.	PIF1123	Data warehousing and Data Mining	PE	3	3	0	0	3
4.	PIF1124	Advanced wireless and mobile networks	PE	3	3	0	0	3

PROFESSIONAL ELECTIVES (PE)*
SEMESTER I

ELECTIVE II

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1.	PIF1125	Speech Technology	PE	3	3	0	0	3
2.	PIF1126	Human Computer Interaction	PE	3	3	0	0	3
3.	PIF1127	Security Engineering	PE	3	3	0	0	3
4.	PIF1128	Video Analytics	PE	3	3	0	0	3
5.	PIF1129	Data storage Technologies and Networks	PE	3	3	0	0	3

PROFESSIONAL ELECTIVES (PE)*
SEMESTER II

ELECTIVE III

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1.	PIF1221	Virtualization and Cloud Computing	PE	3	3	0	0	3
2.	PIF1222	Software Testing and Quality Assurance	PE	3	3	0	0	3
3.	PIF1223	Data Visualization	PE	3	3	0	0	3
4.	PIF1233	Natural Language Processing and Information Retrieval	PE	3	3	0	0	3
5.	PIF1224	Information Retrieval and Web Search	PE	3	3	0	0	3
6.	PIF1225	Mobile Application Design and Development	PE	3	3	0	0	3

SEMESTER II

ELECTIVE IV

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1.	PIF1226	High Performance computing	PE	3	3	0	0	3
2.	PIF1227	Nature Inspired Computing	PE	3	3	0	0	3
3.	PIF1228	Reversible Computing	PE	3	3	0	0	3
4.	PIF1229	Soft Computing	PE	3	3	0	0	3
5.	PIF1231	Advances in Operating Systems	PE	3	3	0	0	3
6.	PIF1232	Deep Learning and Neural Networks	PE	3	3	0	0	3

SEMESTER III

ELECTIVE V

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1.	PIF1321	Social Network Analysis	PE	3	3	0	0	3
2.	PIF1322	GPU Architecture and Programming	PE	3	3	0	0	3
3.	PIF1323	Cyber Forensics	PE	3	3	0	0	3
4.	PIF1324	Block Chain Technologies	PE	3	3	0	0	3
5.	PIF1325	Automata Theory and Formal Languages	PE	3	3	0	0	3

OPEN ELECTIVE (OE)
SEMESTER III
Open Electives are Electives from other branches (or) online courses that the student belonging to this curriculum can choose from

OPEN ELECTIVES OFFERED TO OTHER DEPARTMENTS (ODD SEMESTER)

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1.	PIF1941	Speech and Natural Language Processing	OE	3	3	0	0	3

OPEN ELECTIVES OFFERED TO OTHER DEPARTMENTS (EVEN SEMESTER)

Sl. No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
1.	PIF1041	Introduction to Nano Electronics	OE	3	3	0	0	3

SUMMARY

Sl. No.	Subject Area	Credits as per semester				Credits Total	Percentage (%)
		I	II	III	IV		
1	FC		4			4	5.47
2	PC	16	13	3		32	43.84
3	PE	6	6	3		15	20.55
4	OE			3		3	4.11
5	EEC		1	6	12	19	26.03
Total		22	24	15	12	73	100 %

SEMESTER I

PCP1176	ADVANCED DATA STRUCTURES AND ALGORITHMS	L	T	P	C
		3	0	0	3

OBJECTIVES

- To understand the usage of algorithms in computing.
- To learn and use hierarchical data structures and its operations
- To learn the usage of graphs and its applications.
- To select and design data structures and algorithms that is appropriate for problems.
- To study about NP hard and NP Completeness of problems.

UNIT I ROLE OF ALGORITHMS IN COMPUTING 9

Algorithms – Analyzing algorithms – Designing algorithms – Growth of functions: Asymptotic notation – Standard notations and common functions; Recurrences: The substitution method – The recursion-tree method – The master method for solving recurrences

UNIT II HIERARCHICAL DATA STRUCTURES 9

Binary search trees: Basics – Query, Insertion and Deletion; Red-black trees: Properties of Red-black trees – Rotations – Insertion – Deletion; B-Trees: Basic operations on B-Trees; Fibonacci heaps: Structure – Mergeable- heap operations – Decreasing a key and deleting a node; Disjoint-set operations – Disjoint-set forests.

UNIT III GRAPHS 9

Elementary graph algorithms: Representations of graphs – Breadth-first search – Depth-first search – Topological sort – Strongly connected components; Single-source shortest paths: Bellman-Ford algorithm; Single-source shortest paths in directed acyclic graphs: Dijkstra's algorithm; All-pairs shortest paths: Floyd-Warshall algorithm

UNIT IV ALGORITHM DESIGN TECHNIQUES 10

Greedy Algorithms: The job/event scheduling problem – Minimum-spanning-tree problem; Recursive backtracking: Developing recursive backtracking algorithm – Pruning branches – N-queens problem; Developing dynamic programming algorithms – Subtle points – Decreasing time and space – Longest common subsequence problem, Weighted job/Event Scheduling Problem

UNIT V NP COMPLETE AND NP HARD 8

Reductions and NP – Completeness – Satisfiability – Proving NP-Completeness – 3 Coloring – Bipartite Matching

TOTAL PERIODS: 45

OUTCOMES

Upon the completion of the course the students should be able to

- Design data structures and algorithms to solve computing problems(K3)
- Design algorithms using tree and graph data structure(K3)
- Apply suitable design strategy for problem solving(K3)
- Classify the P and NP type problems(K2)

REFERENCES

1. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, Introduction to Algorithms, Third Edition, Prentice-Hall, 2012 (unit – I, II, III)
2. Jeff Edmonds, How to Think about Algorithms, Cambridge University Press, 2008 (unit – IV, V)
3. Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, Data Structures and Algorithms, Pearson Education, Reprint 2006.
4. Robert Sedgewick and Kevin Wayne, ALGORITHMS, Fourth Edition, Pearson Education.
5. S.Sridhar, Design and Analysis of Algorithms, First Edition, Oxford University Press. 2014.

PIF1101	ADVANCED DATABASES AND SECURITY	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is

- To understand the design of databases.
- To acquire knowledge on parallel and distributed databases and its applications.
- To study the usage and applications of Intelligent databases.
- To study of security issues in Database , Multilevel and Distributed database.
- To understand the emerging databases like Mobile, XML, Cloud and Big Data
    - To formulate a working definition of data base security and administration.

UNIT I PARALLEL AND DISTRIBUTED DATABASES 9

Database System Architectures: Centralized and Client-Server Architectures – Server System Architectures – Parallel Systems- Distributed Systems, Relational algebra and Relational calculus, Parallel Databases: I/O Parallelism – Inter and Intra Query Parallelism – Inter and Intra operation Parallelism – Design of Parallel Systems, Distributed Database Concepts: Distributed Data Storage – Distributed Transactions – Commit Protocols – Concurrency Control – Distributed Query Processing, Case Studies

UNIT II INTELLIGENT DATABASES 9

Active Databases: Syntax and Semantics (Starburst, Oracle, DB2)- Taxonomy- Applications-Design Principles for Active Rules, Temporal Databases: Overview of Temporal Databases TSQL2, Deductive Databases: Recursive Queries in SQL, Spatial Databases: Basics of Geometry and Graph theory for analysis of spatial data- Spatial Data Types - Spatial Relationships- Spatial Data Structures-Spatial Access Methods- Spatial DB Implementation.

UNIT III ENHANCED DATABASES 9

Structured, Semi structured and unstructured data,Native XML databases (NXD), NoSQL, Data Warehousing, Web databases (JDBC, ODBC), Personal databases, Multimedia database-Geography databases, Gnome databases- Knowledge databases.

UNIT IV EMERGING DATABASES 9

Basics of Set Theory, Logical foundations, Semantic databases, Information visualization, Digital libraries, Data grids, Wireless networks and databases, Heterogeneous databases and data integration, Mobile/Disconnected databases,Linear algebra, basics in probability, Cloud Based Databases: Data Storage Systems on the Cloud- Cloud Storage Architectures - Cloud Data Models, Big Data: Introduction to Big Data-Storage-Analysis

UNIT V DATABASE SECURITY **9**

Security and integrity threats, Defence mechanisms, Statistical database auditing & control. Security issue based on granting/revoking of privileges, PL/SQL Security, Locks: Implicit locking- types and levels of locks- explicit locking, Oracles' named Exception Handlers.

TOTAL PERIODS: 45

OUTCOMES

Upon completion of the course, the students will be able to

- To develop skills on databases to optimize their performance in practice.
- To analyze each type of databases and its necessity.
- To design faster algorithms in solving practical database problem.

REFERENCES

1. C.J.Date, A.Kannan, S.Swamynathan, An Introduction to Database Systems , Eighth Edition, Pearson Education, 2006.
2. Carlo Zaniolo, Stefano Ceri, Christos Faloutsos, Richard T.Snodgrass, V.S.Subrahmanian, Roberto Zicari, Advanced Database Systems , Morgan Kaufmann publishers,2006.
3. Henry F Korth, Abraham Silberschatz, S. Sudharshan, Database System Concepts, Sixth Edition, McGraw Hill, 2011.
4. R. Elmasri, S.B. Navathe, Fundamentals of Database Systems, Sixth Edition, Pearson Education/Addison Wesley, 2010.
5. Vijay Kumar, Mobile Database Systems, John Wiley & Sons, 2006.
6. V. S. Subrahmanian, Principles of Multimedia Database Systems, Morgan Kaufmann Publishers, 1998.
7. Michael Gertz and Sushil Jajodia (Editors) , Handbook of Database Security: Applications and Trends , ISBN-10: 387485325. Springer, 2007
8. Osama S. Faragallah, El-Sayed M. El-Rabaie, Fathi E. Abd El-Samie, Ahmed I. Sallam, and Hala S. El-Sayed, Multilevel Security for Relational Databases by; ISBN 978-1-4822-0539-8. CRC Press, 2014.
9. Bhavani Thuraisingham, Database and Applications Security: Integrating Information Security and Data Management, CRC Press, Taylor & Francis Group, 2005.

PIF1176	AGILE SOFTWARE ENGINEERING	L	T	P	C
		3	0	0	3

OBJECTIVES

The student should be able to

- Understand agile software development practices
- Demonstrate Agile development and testing techniques
- Know the benefits and pitfalls of working in an Agile team
- Understand agile development and testing.

UNIT I AGILE METHODOLOGY **9**

Finite State machines and graph theory for advanced SE engineering needs, theories for Agile management: agile software development – traditional model vs. agile model – classification of agile methods – agile manifesto and principles, agile project management: agile team interactions – ethics in agile teams - agility in design – testing, agile documentations, agile drivers, capabilities and values

UNIT II AGILE PROCESSES **9**

Lean production, Agile Processes: SCRUM – Crystal – Feature Driven Development– Adaptive Software Development– Extreme Programming, Method overview: lifecycle – work products, roles and practices

UNIT III AGILITY AND KNOWLEDGE MANAGEMENT **9**

Agile information systems – agile decision making - Earl's schools of KM – institutional knowledge evolution cycle: development – acquisition – refinement – distribution – deployment – leveraging, KM in software engineering: managing software knowledge – challenges of migrating to agile methodologies, agile knowledge sharing: role of story-cards – Story-card Maturity Model (SMM)

UNIT IV AGILITY AND REQUIREMENTS ENGINEERING **9**

Need for formal languages and their use, impact of agile processes in RE: current agile practices – variance, overview of RE using agile, managing unstable requirements, Requirements elicitation: agile requirements abstraction model – requirements management in agile environment – agile requirements prioritization – agile requirements modelling and generation – concurrency in agile requirements generation

UNIT V AGILITY AND QUALITY ASSURANCE **9**

Agile Interaction Design, Agile product development, Agile Metrics: Feature Driven Development (FDD) – Financial and Production Metrics in FDD , Agile approach to Quality Assurance: Test Driven Development – Pair programming– Issues and Challenges, Agile approach to Global Software Development

TOTAL PERIODS: 45

OUTCOMES

At the end the student will be able to

- Explain the importance of interacting with business stakeholders in determining the requirements for a software system.
- Apply iterative software development process
- Apply the impact of social aspects on software development success

REFERENCES

1. Dingsoyr, Torgeir, Dyba, Tore, Moe, Nils Brede (Eds.), ―Agile Software Development, Current Research and Future Directions‖, Springer-Verlag Berlin Heidelberg, 2010
2. David J. Anderson; Eli Schragenheim, ―Agile Management for Software Engineering: Applying the Theory of Constraints for Business Results‖, Prentice Hall, 2003
3. Hazza& Dubinsky, ―Agile Software Engineering, Series: Undergraduate Topics in Computer Science‖, Springer, VIII edition, 2009
4. Craig Larman, ―Agile and Iterative Development: A manager_s Guide‖, Addison-Wesley, 2004
5. Kevin C. Desouza, ―Agile information systems: conceptualization, construction, and management‖, Butterworth-Heinemann, 2007.

PIF1102	MACHINE LEARNING ALGORITHMS AND APPLICATIONS	L	T	P	C
		3	0	0	3

OBJECTIVES

- To introduce the basic concepts and techniques of Machine Learning.

- To enable design and implementation of machine learning solutions to classification, regression, and clustering problems
- To study the concepts of deep learning
- To gain experience of doing independent study and research

UNIT I FUNDAMENTALS 6

Introduction to Machine Learning(ML): utility and applications of ML, Review of Linear Algebra: Matrices and Vectors – Matrix Identities -Matrix Derivatives and Eigen Vectors, Various paradigms of learning, Hypothesis spaces, Inductive bias, PAC learning.

UNIT II SUPERVISED LEARNING 13

Linear Regression: single & multiple variables, Gradient descent, Classification: Logistic regression - Decision Trees, Overfitting & Underfitting, Regularization & Generalization, Bias variance trade-off, VC inequality. Naive Bayes, Neural networks: perceptron - multilayer perceptron - Support Vector Machines - linear and non-linear kernel functions, Case study with California Housing dataset.

UNIT III ENSEMBLE LEARNING 7

Model selection, feature selection, feature extraction, Factor analysis, Principal Component analysis, Ensemble learning: bagging - random forests - boosting – adaboost, stacking combining classifiers, KNN, Case study with Adult dataset.

UNIT IV OTHER PARADIGMS AND ISSUES IN ML 7

Unsupervised learning: Clustering - k-means - hierarchical - Gaussian Mixture Models, Case study with Breast Cancer dataset, Reinforcement learning, Design, analysis and evaluation of ML experiments, Practical advice on ML algorithms, imbalanced data, outliers, missing values etc.

UNIT V DEEP LEARNING 2

Deep learning: deep feed forward networks - Convolutional Networks - Recurrent Networks - LSTM, Deep Unsupervised learning: autoencoders, Case study using CIFAR10/ MNIST/Intl. Airline Passengers.

TOTAL PERIODS: 45

OUTCOMES

By the end of the course, students should

- Explain Machine Learning algorithms and their limitations.
- Apply common Machine Learning algorithms in practice and implement them.
- Relate current research papers on Machine Learning and Deep Learning, and understand the issues raised by current research.

REFERENCES

1. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.
2. Ethem Alpaydin, Introduction to Machine Learning, MIT Press, Prentice Hall of India, Third Edition 2014.
3. Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar Foundations of Machine Learning, MIT Press, 2012.
4. Tom Mitchell, Machine Learning, McGraw Hill, 3rd Edition,1997. 4. Charu C. Aggarwal, Data Classification Algorithms and Applications , CRC Press, 2014.
5. Deep Learning, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press, 2016

PCP1197	ADVANCED DATA STRUCTURES AND ALGORITHMS LAB	L	T	P	C
		0	0	4	2

OBJECTIVES

- To learn advanced tree and graph structures.
- To learn the need for heap and disjoint set representations.
- To understand algorithm design techniques and apply suitable techniques for problems.

Suggested Programming Languages

- C, Java or Python

LIST OF EXERCISES

1. Insertion sort and merge sort with complexity analysis
2. Application of binary search trees
3. Red-Black Trees
4. Min heaps, Fibonacci heaps
5. Disjoint sets
6. Application of graph traversals – BFS and DFS
7. Single source Shortest Path Algorithms (e.g. Dijkstra's and Bellman Ford algorithms)
8. All-pairs Shortest Path Algorithms: (e.g. Floyd's algorithm)
9. Dynamic programming (e.g. Longest common subsequence, 0/1 Knap-sack)
10. Recursive backtracking (e.g. N-Queen's problem)
11. Greedy technique (e.g. Job/event scheduling, Minimum spanning tree)
12. Mini project: For a given application, identify and solve using suitable data structures and design techniques

TOTAL PERIODS: 60

OUTCOMES

After the completion of this course, students will be able to

- Build basic data structures and sorting algorithms (K4).
- Build algorithms using tree and graph structures (K3).
- Design and develop efficient algorithms for problems, using algorithm design techniques (K3).

PIF1111	ADVANCED DATABASES LAB	L	T	P	C
		0	0	4	2

OBJECTIVES

The primary objectives of this course are

- To understand the concepts of DBMS.
- To familiarize with SQL queries.
- To write stored procedures in DBMS.
- To learn front end tools to integrate with databases.

EXPERIMENTS IN THE FOLLOWING TOPICS

1. Data Definition, Manipulation of Tables and Views, Database Querying – Simple queries, Nested queries, Sub queries and Joins.
2. Triggers, Transaction Control.
3. Embedded SQL, Database Connectivity with Front End Tools High level language extensions - PL/SQL Basics, Procedures and Functions.
4. Active Databases, Deductive Databases.

5. Distributed and Parallel Transactions and Query Processing.
6. Mobile Database Query Processing.
7. Multimedia Database for Image and Video Processing.
8. Spatial and Temporal Databases.
9. XML Databases and No SQL Database Storage and Retrieval.
10. Ontology creation with Protégé.

TOTAL PERIODS: 60

OUTCOMES

Upon completion of this course, the student should be able to

- Design and Implement databases.
- Formulate complex queries using SQL.
- Design and Implement applications that have GUI and access databases for backend connectivity

SEMESTER II

PMA1251	OPERATIONS RESEARCH	L	T	P	C
		4	0	0	4

OBJECTIVES

The primary objective of this course is

- to introduce and familiarize OR approaches in optimization
- to introduce the basic concepts and tools in optimization
- to explore the advanced concepts vertically to get clear understanding and
- to apply the concepts in engineering and scientific applications.

UNIT I INTRODUCTION TO OPERATIONS RESEARCH 12

Introduction of Operations Research - Operations Research Techniques and Tools-General mathematical formulation of LPP- Graphical Methods to solve LPP- Some Exceptional Cases

UNIT II LINEAR PROGRAMMING 12

Simplex Method - The Simplex Algorithm- Big M method- Variants of simplex method-Two Phase Method

UNIT III INTEGER PROGRAMMING AND TRANSPORTATION PROBLEM 12

Integer programming: Branch and bound method- Transportation and Assignment problems - Travelling salesman problem

UNIT IV PROJECT SCHEDULING 12

Project network -Diagram representation – Floats - Critical path method (CPM) – PERT- Cost considerations in PERT and CPM

UNIT V QUEUING MODELS 12

Introduction, Queuing Theory, Operating characteristics of a Queuing system, Constituents of a Queuing system, Service facility, Queue discipline, Single channel models, multiple service channels.

TOTAL PERIODS: 60

OUTCOMES

After completing this course, students should demonstrate competency in the following topics

- Analyze a problem,
- Formulate and solve problems in any engineering field using operations research principles

TEXT BOOK

1. Hamdy A Taha, Introduction to Operations Research, Prentice Hall India, 9 th Edition, Third Indian Reprint 2010

REFERENCES

1. J.K.Sharma, Operations Research Theory and applications, Macmillan, 5th Edition, 2013.
2. Hiller F.S, Liberman G.J, Introduction to Operations Research, 9th Edition McGrawHill Inc. , 2009.
3. Jit.S.Chandran, Mahendran P. Kawatra, KiHoKim, Essentials of Linear Programming, Vikas Publishing House Pvt.Ltd. New Delhi, 1994.
4. Philip D.T. and Ravindran A., Operations Research, John Wiley, 1992.

PIF1201	SMART SENSORS AND INTERNET OF THINGS	L	T	P	C
		4	0	0	4

OBJECTIVES

The primary objectives of this course are

- To understand the key concepts in sensors and IOT
- To understand the architecture of sensors to be used in the IOT applications.
- To understand the concepts and issues involved in designing low power protocols for IOT.
- To make the students to know about the different domains of applications for IOT.

UNIT I INTRODUCTION TO SENSORS AND IOT 9

ADC and DAC: Introduction-Role in IOT, Transducer and Sensors: Overview-Different Environmental Parameters-Measurement and Monitoring-Need for measurement and monitoring of Environmental parameters- Effects of adverse parameters for the living being, IOT: Introduction-Different entities/components involved- introduction to Graph theory concepts – Direct acyclic graph

UNIT II SENSOR ARCHITECTURE AND FABRICATION 9

Sensors:Working Principles-Different types-Selection of Sensors for Practical Applications. Introduction of Different Types of Sensors such as Capacitive, Resistive, Surface Acoustic Wave for Temperature, Pressure, Humidity, Toxic Gas- Architecture of Smart Sensors: Important components- Importance and Adoption of Smart Sensors- Fabrication of Sensor and Smart Sensor: Electrode, Silicon Technology: Usefulness of Silicon Technology in Smart Sensor And Future scope of research in smart sensor

UNIT III IOT ARCHITECTURE **9**

IOT Architecture: M2M high-level ETSI architecture - IETF architecture for IoT - OGC architecture - IoT reference model - Domain model - information model - functional model - communication model - IoT reference architecture-

UNIT IV DIFFERENT PROTOCOLS IN IOT **9**

Protocol: Standardization for IoT – Efforts – M2M and WSN Protocols – SCADA and RFID Protocols – Unified Data Standards – Protocols – IEEE 802.15.4 – BACNet Protocol – Modbus– Zigbee Architecture – Network layer – 6LowPAN - CoAP – Security- Design and development of Security and Privacy protocols related to IOT.

UNIT V DESIGN AND DEVELOPMENT OF IOT BASED STSTEMS **9**

Mathematical and numerical modelling of smart city including smartphone real-world and mobile networks, optimization methods, mathematics modelling for smart Grid with Cloud computing, numerical analysis for security and emergencies in IoT**,** Raspberry Pi:Building IOT with RASPERRY PI- IoT Systems - Logical Design using Python – IoT Physical Devices & Endpoints - IoT Device -Building blocks -Raspberry Pi -Board - Linux on Raspberry Pi - Raspberry Pi Interfaces -Programming Raspberry Pi with Python - Other IoT Platforms - Arduino.-Building an IOT application using Android of Things-Case Studies: IOT for home automation-IOT for industrial automation-.IOT for weather monitoring-IOT for Health Care.

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should be able to

- Apply the concepts of sensor for interfacing with the environment.
- Evaluate the performance of different types of applications for performance.
- Develop new IOT protocols by doing some minor changes.
- Apply the different architectural features of Embedded systems for IOT application design.
- Apply the concepts for sensors and IOT for health care applications.

TEXTBOOKS

1. Arshdeep Bahga, Vijay Madisetti, Internet of Things – A hands-on approach, Universities Press, 2015
2. Dieter Uckelmann, Mark Harrison, Michahelles, Florian (Eds), Architecting the Internet of Things, Springer, 2011.

REFERENCES

1. Honbo Zhou, The Internet of Things in the Cloud: A Middleware Perspective, CRC Press, 2012.
2. Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stamatis, Karnouskos, Stefan Avesand. David Boyle, From Machine-to-Machine to the Internet of Things - Introduction to a New Age of Intelligence, Elsevier, 2014.
3. Olivier Hersent, David Boswarthick, Omar Elloumi, The Internet of Things – Key applications and Protocols, Wiley, 2012.

PIF1202	BIG DATA ANALYTICS AND VISUALIZATION	L	T	P	C
		3	0	0	3

OBJECTIVES

The Student should be made to

- Be exposed to big data
- Learn the different ways of Data Analysis
- Be familiar with data streams
- Learn the mining and clustering
- Be familiar with the visualization

UNIT I INTRODUCTION TO BIG DATA 8

Introduction to Big Data Platform – Challenges of conventional systems – Web data – Evolution of Analytic scalability, analytic processes and tools, Analysis vs reporting – Modern data analytic tools, Statistical concepts: Sampling distributions, statistical inference, prediction error, Inferential statistics – Hypothesis testing

UNIT II DATA ANALYSIS 12

Regression modeling, Multivariate analysis, Analysis of Variance (ANOVA), Bayesian modeling, inference and Bayesian networks, Support vector and kernel methods, Analysis of time series: linear systems analysis, nonlinear dynamics – Rule induction – Neural networks: learning and generalization, competitive learning, principal component analysis and neural networks; Fuzzy logic: extracting fuzzy models from data, fuzzy decision trees, Stochastic search methods

UNIT III MINING DATA STREAMS 8

Introduction to Streams Concepts – Stream data model and architecture – Stream Computing, Sampling data in a stream – Filtering streams – Counting distinct elements in a stream – Estimating moments – Counting oneness in a window – Decaying window – Realtime Analytics Platform(RTAP) applications, Case studies: real time sentiment analysis, stock market predictions

UNIT IV FREQUENT ITEMSETS AND CLUSTERING 9

Mining Frequent itemsets – Market based model – Apriori Algorithm – Handling large data sets in Main memory – Limited Pass algorithm – Counting frequent itemsets in a stream, Clustering Techniques: Hierarchical – K- Means – Clustering high dimensional data – CLIQUE and PROCLUS – Frequent pattern based clustering methods – Clustering in non-euclidean space – Clustering for streams and Parallelism, Supervised learning: Ensemble method- Random Forest

UNIT V FRAMEWORKS AND VISUALIZATION 8

MapReduce – Hadoop, Hive, MapR – Sharding – NoSQL Databases – S3 – Hadoop Distributed file systems, Visualizations: Visual data analysis techniques, interaction techniques; Systems and applications

TOTAL PERIODS: 45

OUTCOMES

The student should be made to

- Apply the statistical analysis methods.
- Compare and contrast various soft computing frameworks.
- Design distributed file systems.

- Apply Stream data model.
- Use Visualisation techniques

TEXT BOOKS

1. Michael Berthold, David J. Hand, Intelligent Data Analysis, Springer, 2007.
2. Anand Rajaraman and Jeffrey David Ullman, Mining of Massive Datasets, Cambridge University Press, 2012.
3. Holmes, Dawn E, Big data: a very short introduction, Oxford University Press, 2017.

REFERENCES

1. Bill Franks, Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with advanced analystics, John Wiley & sons, 2012.
2. Glenn J. Myatt, Making Sense of Data, John Wiley & Sons, 2007
3. Pete Warden, Big Data Glossary, O'Reilly, 2011.
4. Jiawei Han, Micheline Kamber, Data Mining Concepts and Techniques, Second Edition, Elsevier, Reprinted 2008.
5. Richard Cotton, Learning R – A Step-by-step Function Guide to Data Analysis, O"Reilly Media, 2013.
6. Michael Minelli, Michelle Chambers, and Ambiga Dhiraj, Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses, Wiley, 2013.
7. P. J. Sadalage and M. Fowler, NoSQL Distilled: A Brief Guide to the Emerging World of Polyglot Persistence, Addison-Wesley Professional, 2012.
8. Hastie, Trevor, et al., The elements of statistical learning. Vol. 2. No. 1. New York: Springer, 2009.

PIF1203	ADVANCED WEB TECHNOLOGIES	L	T	P	C
		2	0	1	3

OBJECTIVES

The primary objective of this course is to

- Understand the fundamentals of MVVM framework
- Learn and apply Java script libraries and framework
- Design Single Page Applications
- Design Progressive Web Applications
- Learn functional web application development
- Learn to design, develop and test secure web applications.
- Understand the web performance intricacies

UNIT I INTRODUCTION 6

MVVM architecture, Using Javascript libraries and frameworks : jQuery- selectors- attributes, events-effects , creating asynchronous request and response using AJAX, jQuery and JSON, Bootstrap : grid-typography- tables-forms-theme-support for media-filters

UNIT II SINGLE PAGE APPLICATIONS(SPA) 6

Single Page Applications(SPA) : Introduction, Expressions and Data Biding-Number and String Expressions-Object Binding-Expressions, Working with Arrays, Forgiving Behavior , Understanding Data binding, directives, Controllers, Filters, forms:Working with Select and Options-Input Validations-Form Events-Custom Model update triggers-Custom Validations, modules, services, Routing : Routing in a Single-Page Application-Creating HTML Templates - Routing Options-Configuring Route Provider

UNIT III PROGRESSIVE WEB APPLICATIONS(PWA) 6

Introduction to progressive web app architectures, Service worker, working with fetch API, promises-audit a web app for PWA features using light house, IndexedDB, responsive design , migrating an existing site to PWA, building offline support, gulp, push notification, Introduction to the Payment Request API, Integrating Analytics in applications

UNIT IV FUNCTIONAL STYLE 6

Overview, Functional Vs OOP styles, Best practices, First-class functions, Array functions: Map-Filter-Reduce, Callbacks, Lambdas, Closures, Pseudo classical Inheritance Vs functional inheritance, module pattern, Chaining functions/methods, Composition, Immutability, Memorization, Partial application, Recursion

UNIT V WEB PERFORMANCE MODELING 6

Introduction: response time- service times- service demands- service times in network and routers- web page download time- queues and contention, Client side models:no cache proxy server case- the performance model - computing service demands- using a cache proxy server, Server-side models: single web server- the performance model- computing service demands- mirrored web servers

UNIT VI LABORATORY COMPONENT 30

Web application design using bootstrap, JSON, jQuery, AJAX, using React to create interactive UIs, develop single page applications, develop progressive web applications using Vue.js, develop functional web applications, Develop a MEAN stack application, Deploying application on Heroku web server.

TOTAL PERIODS: 60

OUTCOMES

After completing this course, students should demonstrate competency in the following topics

- Use bootstrap framework to design web pages
- Implement Single Page Applications
- Use Express framework to develop web applications
- Design a web page applying functional programming concept
- Analyze web performance

WEB RESOURCES

1. Progressive Web Application - https://developers.google.com/web/ilt/pwa/
2. React js-https://reactjs.org/

REFERENCES

1. Brad Green, Shyam Seshadri, AngularJS, Up and Running Enhanced Productivity with Structured Web Apps, O'Reilly Media 2014.
2. Anto Aravinth, Beginning Functional JavaScript Functional Programming with JavaScript Using EcmaScript 6 1st ed, Apress, 7 March 2017.
3. Alex Banks and Eve Porcello, Learning React: Functional Web Development with React and Redux 1st Edition, O'Reilly Media, 27 April 2017
4. Stoyan Stefanov, React Up & Running: Building Web Applications, O'Reilly Media, 1 edition, 14 July 2016
5. Simon Holmes, Getting MEAN with Mongo, Express, Angular, and Node, Manning Publications, first edition,2019.
6. Menasce, Daniel A., and Virgilio AF Almeida , Capacity Planning for Web Services: metrics, models, and methods. Upper Saddle River, NJ: Prentice Hall PTR, 2002.

PIF1211	MACHINE LEARNING WITH PYTHON LAB	L	T	P	C
		0	0	4	2

OBJECTIVES

- To learn the fundamentals and practice Python codes for Data Science.
- To understand and implement machine learning algorithms using public datasets

Each student has to work individually on assigned lab exercises. Lab sessions could be scheduled as one contiguous four-hour session per week or two two-hour sessions per week. There will be about 10 exercises in a semester. All implementations would be carried out in Python. Exercises are designed to cover the following topics:

LIST OF EXERCISES

Lab (Indicative List of Experiments (in the areas of)

1. Python fundamentals and scripts for Data Science
2. Implement Decision Tree learning
3. Implement Logistic Regression
4. Implement classification using Multilayer perceptron
5. Implement classification using SVM
6. Implement Adaboost
7. Implement Bagging using Random Forests
8. Implement K-means Clustering to Find Natural Patterns in Data
9. Implement Hierarchical clustering
10. Implement K-mode clustering

TOTAL PERIODS: 60

OUTCOMES

Upon Completion of this course, the students will be able to

1. Build simple python codes for Data Science
2. Build Machine Learning algorithms using datasets available in public repositories

PIF1212	BIG DATA ANALYTICS LAB	L	T	P	C
		0	0	4	2

OBJECTIVES

The student should be made to

- To analyse data using linear models
- To analyse data using machine learning techniques such as SVM / Decision tree classification and clustering
- To analyse stream data
- To implement MapReduce programs for processing big data

LIST OF EXPERIMENTS

1. Install, configure and run Hadoop and HDFS
2. Implement word count / frequency programs using MapReduce
3. Implement Linear and logistic Regression
4. Implement Apriori Algorithm
5. Implement SVM / Decision tree classification techniques
6. Implement clustering techniques

7. Visualize data using any plotting framework
8. Implement an real time application to study data value chain.

OUTCOMES

After completing this course, the student will be able to

- Apply data mining techniques and methods to large data sets.
- Experiment big data using Hadoop framework.
- Build and apply linear and logistic regression models.
- Analyze data with machine learning methods.
- Analyze graphical data analysis.

PIF1301	CYBER SECURITY	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to make students understand

- Difference between threat, risk, attack and vulnerability.
- How threats materialize into attacks.
- Where to find information about threats, vulnerabilities and attacks.
- Typical threats, attacks and exploits, and the motivations behind them.

UNIT I INTRODUCTION TO CYBER SECURITY 9

Computer Security: Threats- Vulnerabilities- Controls- Attacks, Privacy: Identification- Authentication, Countermeasure, Digital forensics, Number systems: Number theory- Prime numbers- logics and combinatorics, Basic cryptography

UNIT II ATTACKER TECHNIQUES 9

Tunneling and fraud techniques, Threat infrastructure, Exploitation: Techniques to gain a foothold - Misdirection, Reconnaissance and disruption methods, Malicious codes: Self-replicating codes - Evading detection and elevating privileges - Stealing information and exploitation

UNIT III DEFENSE AND ANALYSIS TECHNIQUES 9

Memory forensics: Importance - Capabilities - Framework - Dumping physical memory - Installing and using volatility - Finding hidden process - Volatility analyst pack, Honeypots, Malicious code naming and automated analysis system – DNS , Firewalls

UNIT IV INTRUSION DETECTION 9

Network vs. Host based detection, Anatomy and process, Network based and host based intrusion detection systems: Architecture - Detection engine - Operational concept - Benefits and challenges, Detection mechanism, Signatures, Traffic analysis, Intrusion detection

UNIT V CYBERCRIME 9

Nature and scope, Classification, Social engineering, Internet hacking and cracking, Flooding, Software piracy, Phishing, Online frauds and offenses, Identity theft

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should demonstrate competency in the following topics

- Apply security principles in the application layer.
- Explain computer forensics.
- Use forensics tools.
- Analyze and validate forensics data

TEXTBOOKS

1. Charles P. Pfleeger and Shari Lawrence Pfleeger, Analyzing Computer Security – A threat/vulnerability / Counter measure approach, Pearson, New Delhi, 2014.
2. James Graham, Richard Howard and Ryan Olson, Cyber Security Essentials, CRC Press, USA, 2011.

REFERENCES

1. Paul E Proctor, The Practical Intrusion Detection Handbook, Prentice Hall, USA, 2007.
2. Bernadette H Schell and Clemens Martin, Cybercrime, ABC – CLIO Inc, California, 2004.
3. Vivek Sood, Cyber Law Simplified, Tata McGraw Hill, New Delhi, 2008.

PROFESSIONAL ELECTIVES (PE)

SEMESTER I

ELECTIVE I

PIF1121	COMPUTER VISION AND IMAGE ANALYSIS	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to

- To review image processing techniques for computer vision
- To understand shape and region analysis
- To understand Hough Transform and its applications to detect lines, circles, ellipses
- To understand three-dimensional image analysis techniques
- To understand motion analysis
- To study some applications of computer vision algorithms

UNIT I IMAGE AND IMAGE PROCESSING **9**

Images in the Spatial Domain, Images in the Frequency Domain, Operators: Point - Local - Global, Three Procedural Components, Classes of Local Operators, Advanced Edge Detectors

UNIT II IMAGE AND MOTION ANALYSIS **9**

Basic Image Topology, Geometric 2D Shape Analysis, Image Value Analysis, Detection of Lines and Circles, 3DMotionand2DOpticalFlow, Algorithms: Horn–Schunck - Lucas–Kanade - BBPW, Performance Evaluation of Optical Flow Results

UNIT III SEGMENTATION, CAMERA COORDINATES, CALIBRATION **9**

Image Segmentation: Mean-Shift, Image Segmentations as an Optimization Problem, Video Segmentation and Segment Tracking, Cameras: Coordinates – Calibration

UNIT IV 3D SHAPE RECONSTRUCTION AND STEREO MATCHING **9**

Surfaces, Structured lighting, Stereo Vision, Photometric stereo method, Matching, Data, Cost, and Confidence, dynamic programming matching, and Belief propagation matching, Third eye technique

UNIT V FEATURE DETECTION AND OBJECT DETECTION **9**

Invariance, Features, and Sets of Features, Examples of Features, Tracking and Updating of Features, Localization, Classification, and Evaluation, Ada Boost, Random Decision Forests, Pedestrian Detection

TOTAL PERIODS: 45

OUTCOMES

Upon completion of the course, the student should be able to

- Demonstrate fundamental image processing techniques required for computer vision
- Demonstrate shape analysis
- Apply boundary tracking techniques
- Apply 3D vision techniques
- Demonstrate motion related techniques
- Develop applications using computer vision techniques

TEXT BOOK

1. Reinhard Klette, Concise Computer Vision: An Introduction into Theory and Algorithms, Springer, 2014

REFERENCES

1. Simon J. D. Prince, Computer Vision: Models, Learning, and Inference, Cambridge University Press, 2012.
2. D. A. Forsyth, J. Ponce, Computer Vision: A Modern Approach, Pearson Education, 2003.
3. Mark Nixon and Alberto S. Aquado, Feature Extraction & Image Processing for Computer Vision, Third Edition, Academic Press, 2012.
4. R. Szeliski, Computer Vision: Algorithms and Applications, Springer 2011.
5. E. R. Davies, Computer & Machine Vision, Fourth Edition, Academic Press, 2012.

PIF1122	INFORMATION THEORETIC LEARNING	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to

- Learn random variables
- Understand Shannon's and Renyi's entropies
- Understand entropy minimization and correntropy maximization
- Understand entropy-based classification and clustering

UNIT I INTRODUCTION TO PROBABILITY THEORY 9

Review of Probability Theory: Probability Measure - Conditional Probability - Probability Distribution

UNIT II INTRODUCTION TO ENTROPY AND DIVERGENCE ` 9

Information Theory: Entropy - Relative Entropy - Mutual Information - Relationship Between Entropy and Mutual Information - Chain Rules for Entropy

UNIT III RENYI'S ENTROPY AND DIVERGENCE 9

Renyi's Entropy: Quadratic Renyi's Entropy Estimator, Renyi's Divergence and Mutual Information, Quadratic Divergences and Mutual Information

UNIT IV MINIMUM ERROR ENTROPY AND MAXIMUM CORRENTROPY 9

Adaptive filter: Linear - Nonlinear, Error Entropy Criterion for Adaptation, Minimum Error Entropy Algorithm, Correntropy: Maximum Correntropy, Information potential

UNIT V APPLICATIONS IN IMAGE PROCESSING AND CLUSTERING 9

Information Theoretic Clustering: Differential Clustering Using Renyi's Entropy - Graph-Theoretic Clustering with entropy and correntropy, Distance between two images based on probability - mean square error - Kullback-Leibler divergence; Image classification

TOTAL PERIODS: 45

OUTCOMES

Upon completion of the course, the student should be able to

- Explain and estimate information theory metrics, entropy, cross entropy and correntropy
- Use entropy to design adaptive systems
- Use entropy based algorithms in image processing
- Develop machine learning algorithms based on entropy and correntropy

TEXT BOOK

1. Jose. C. Principe, "Information Theoretic Learning", Springer, 2010

REFERENCES

1. Thomas Cover, Joy Thomas, "Elements of Information Theory" , Wiley Interscience, 2nd Edition, 2006.
2. Ran He, Baogang Hu, Xiaotong Yuan, Liang Wang, Robust Recognition via Information Theoretic Learning, Springer, 2014.
3. Daniel G. Silva, Denis G. Fantinato, Jˆanio C. Canuto, Leonardo T. Duarte, Aline O. Neves, Ricardo Suyama, Jugurta Montalv˜ao and Romis Attux, " An Introduction to Information

Theoretic Learning, Part I: Foundation", Journal Of Communications And Information Systems, Vol. 31, No. 1, pp. 69-80, 2016.
4. Daniel G. Silva, Denis G. Fantinato, Jˆanio C. Canuto, Leonardo T. Duarte, Aline O. Neves, Ricardo Suyama, Jugurta Montalv˜ao and Romis Attux, " An Introduction to Information Theoretic Learning, Part II: Applications", Journal Of Communications And Information Systems, Vol. 31, No. 1, pp. 81-91, 2016.
5. Silverman B W, Density Estimation for Statistics and Data Analysis, Chapman & Hall/CRC, 1996.

PIF1123	DATA WAREHOUSING AND DATA MINING	L	T	P	C
		3	0	0	3

OBJECTIVES

- To expose the students to the concepts of Data warehousing Architecture and Implementation
- To Understand Data mining principles and techniques and Introduce DM as a cutting edge business intelligence
- To learn to use association rule mining for handling large data
- To understand the concept of classification for the retrieval purposes
- To know the clustering techniques in details for better organization and retrieval of data
- To identify Business applications and Trends of Data mining

UNIT I DATA WAREHOUSE **9**

Data Warehousing - Operational Database Systems vs. Data Warehouses – Multidimensional Data Model - Schemas for Multidimensional Databases – OLAP Operations – Data Warehouse Architecture – Indexing – OLAP queries & Tools

UNIT II DATA MINING & DATA PREPROCESSING **9**

Introduction to KDD process – Knowledge Discovery from Databases - Need for Data Preprocessing– Data Cleaning – Data Integration and Transformation – Data Reduction – Data Discretization and Concept Hierarchy Generation

UNIT III ASSOCIATION RULE MINING **9**

Introduction - Data Mining Functionalities - Association Rule Mining - Mining Frequent Itemsets with and without Candidate Generation - Mining Various Kinds of Association Rules - Constraint Based Association Mining

UNIT IV CLASSIFICATION & PREDICTION **9**

Classification vs. Prediction – Data preparation for Classification and Prediction – Classification by Decision Tree – Bayesian Classification – Rule Based Classification – Classification by Back Propagation – Support Vector Machines – Associative Classification – Lazy Learners – Other Classification Methods – Prediction – Accuracy and Error Measures – Evaluating the Accuracy of a Classifier or Predictor – Ensemble Methods – Model Section.

UNIT V CLUSTERING **9**

Cluster Analysis: Types of Data in Cluster Analysis, Categorization of Major Clustering Methods: Partitioning Methods - Hierarchical methods – Density-Based Methods – Grid-Based Methods – Model-Based Clustering Methods, Clustering High Dimensional Data, Constraint Based Cluster Analysis, Outlier Analysis.

TOTAL PERIODS: 45

OUTCOMES

Upon Completion of the course, the students will be able to

- Store & Preprocess voluminous data for online processing
- Apply the association rules for mining the data
- Design and deploy appropriate classification techniques
- Demonstrate clustering of the high dimensional data for better organization of the data
- Discover the knowledge imbibed in the high dimensional system
- Build Multidimensional Intelligent model from typical system

- Evaluate various mining techniques on complex data objects

REFERENCES

1. Jiawei Han and Micheline Kamber, Data Mining Concepts and Techniques Second Edition, Elsevier, Reprinted 2008.
2. K.P. Soman, ShyamDiwakar and V. Ajay, Insight into Data mining Theory and Practice, Easter Economy Edition, Prentice Hall of India, 2006.
3. G. K. Gupta, Introduction to Data Mining with Case Studies, Easter Economy Edition, Prentice Hall of India, 2006.
4. Berson, Alex & Smith, Stephen J, Data Warehousing, Data Mining, and OLAP, TMH Pub. Co. Ltd, New Delhi, 2012
5. Pang-Ning Tan, Michael Steinbach and Vipin Kumar, Introduction to Data Mining, Pearson Education, 2007
6. Prabhu, Data Warehousing, Phi Learning Private Limited, New Delhi, 2012, ,
7. Ponniah Paulraj, Data Warehousing Fundamentals, John Wiley & Sons, New Delhi, 2011
8. Marakas, George M, Modern Data Warehousing, Mining, and Visualization, Pearson Education, 2011.

PIF1124	ADVANCED WIRELESS AND MOBILE NETWORKS	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to

- To get familiar with key concepts of wireless networks, standards, technologies and their basic operations
- To learn how to design and analyse various medium access protocols
- To learn how to implement low power and future mobile networks.
- The students should get familiar with the wireless/mobile market and the future needs and challenges.

UNIT I WIRELESS NETWORKING 9

Wireless Networking:: Overview and Introduction - OFDM and 802.11 (WiFi) Physical layer - Multi-antenna systems and MIMO - Overview of 802.11n/ac PHY including beamforming - CSMA/CA and WiFi MAC overview-Wide bandwidth channel access techniques (802.11n/ac) - Energy efficiency and rate control - Power Control- Mathematical Modeling for Network Selection in Heterogeneous Wireless Networks - Mathematical Simulation of Indoor Wireless Networks - framework to learn graph theory using simple wireless network models

UNIT II MOBILE AND WEARABLE SENSING 9

Smartphone/wearable sensors: Blocks of Smartphone- Overview-Accelerometer-gyroscope-magnetometer,Smartphone:Orientation-Heading detection - Activity recognition, Healthcare: Identifying human activities and context through sensors - Health monitoring and fitness tracking,Wearables: Overview:- Wrist-worn wearables- Gesture and remote interaction, Sensor fusion in body-area networks

UNIT III MULTI-GIGABIT WIRELESS NETWORKS 9

Next generation (5G) wireless technologies: Upper Gigahertz and Terahertz wireless communications - Millimeter wave networking - Directionality and beamforming - Mobility and signal blockage, IEEE 802.11ad (60 GHz WLAN): MAC and PHY layer overview – MAC and PHY layer protocols, Visible light communication: High-speed networking using LEDs-IEEE 802.15.7 PHY and MAC overview -Sensing through visible light - Visible light indoor localization and positioning

UNIT IV INDOOR LOCALIZATION AND RF SENSING 9

Localization: Smartphone localization - WiFi fingerprinting - protocols and challenges - Non-WiFi localization -Device-free sensing with radio frequency-Mining wireless PHY channel state information -Device-free localization and indoor human tracking - Activity and gesture recognition through RF.

UNIT V LOW POWER AND FUTURE MOBILE NETWORKING 9

Mobile Networking: Backscatter communication-Radio Frequency Identification (RFID) technology overview - Energy harvesting tags and applications, IOT protocol:Overview - CoAP and MQTT - IPv6 networking in low-power PANs (6LoWPAN) - Drone networking - Multi-UAV networks, architectures and civilian applications - Communication challenges and protocols for micro UAVs - Connected and autonomous cars - Wireless technologies for Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications - Automotive surrounding sensing with GHz and THz signals

TOTAL PERIODS: 45

OUTCOMES

At the end of the course, the students will be able to

- Explain the different terminologies used in mobile and wireless networking.
- Design networks that will use low power techniques.
- Explain the concepts and principles involved in the design of future networks.

REFERENCES

1. Theodore S.Rappaport, Wireless Communications: Principles and Practice, Prentice Hall
2. Matthew Gast, 802.11n: A Survival Guide, O'Reilly Media, 2012
3. Matthew Gast, 802.11ac: A Survival Guide, O'Reilly Media, 2013
4. Pei Zheng et al., Wireless Networking Complete, Morgan Kaufmann, International Publishing AG 2017.
5. Andrea Goldsmith, Wireless Communications, Cambridge University Press, 2007.

PROFESSIONAL ELECTIVES (PE)

SEMESTER I

ELECTIVE II

PIF1125	SPEECH TECHNOLOGY	L	T	P	C
		3	0	0	3

Pre-requisites: Digital Signal Processing (UG-level)

OBJECTIVES

- To make the students understand the basic parameters that can be estimated from time- and frequency-domain
- To introduce the important features that can be used to build any speech-based system
- To introduce the basic concepts behind building a speech recognition system
- To introduce some of speech-based classifications tasks
- To introduce the fundamentals of text-to-speech synthesizer, and to make them understand the state-of-art TTS engines

UNIT I TIME - AND FREQUENCY-DOMAIN ANALYSIS OF SPEECH 10

The mechanism of speech production, Classification of speech sounds, Digital models for speech signals, The sampling theorem, Time-domain parameters:Short-term energy andmagnitude - Zero-crossing rate - Autocorrelation function, Pitch estimation using autocorrelation function, Frequency-domain parameters: Fourier transform - Short-time speech analysis – Windowing - Time- and frequency-resolution -Wide- and narrow-band spectrograms – Formant estimation

UNIT II CEPSTRAL AND LINEAR PREDICTION COEFFICIENTS 9

Cepstrum: Definition - Computation of cepstrum - Formant and pitch estimation - Computation of mel-frequency cepstral coefficients,Linear predictive analysis: Principle - autocorrelation method - Pitch estimation using linear prediction error signal -Formant estimation using LPC - Computation of LPCC

UNIT III AUTOMATIC SPEECH RECOGNITION 10

Template training methods, Template adaptation to new talkers, Hidden Markov models (HMM): Discrete-time Markov process - Extensions to HMM - Three basic problems of HMM - types of HMM, Large vocabulary speech recognition:Subword speech units -Subword unit models -Context-dependent subword units -Language models, Connected digit recognition system – a case study

UNIT IV SPEAKER RECOGNITION 8

Verification vs Recognition - Recognition techniques - Distinguishing features - System design, Language and Accent identification, Speaker recognition by humans, GMM-based speaker identification system – a case study.

UNIT V TEXT-TO-SPEECH SYNTHESIS 8

Principles of speech synthesis, Synthesizer methods: Basic principles of Unit-selection approach and HMM-based speech synthesis, Synthesis of intonation, Speech synthesis for different speakers, Evaluation of TTS systems

TOTAL PERIOD: 45

OUTCOMES

At the end of the course, the students will be able to,

- Explain the usefulness of different parameters that can be estimated from the speech signal.
- Build a simple connected digit speech recognition system.
- Derive useful features from a given speech signal for building speech based applications.
- Build a simple waveform concatenation-based synthesizer, and to design the power of statistical parametric (HMM-based) synthesizer.

TEXTBOOKS

1. Lawrence R. Rabiner and Ronald W. Schafer, Digital Processing of Speech Signals, Pearson, 2003.
2. Lawrence R.Rabiner, Biing-HwangJuang, and B.Yegnanarayana, Fundamentals of Speech Recognition, Pearson, 2008.
3. Douglas O'Shaughnessy, Speech Communication: Human and Machine, Universities Press, 2001.

REFERENCES

1. Thomas F. Quatieri, Discrete-Time Speech Signal Processing – Principles and Practice, Pearson Education, 2006.
2. Ben Gold and Nelson Morgan, Speech and Audio Signal Processing, Processing and Perception of Speech and Music, John Wiley & Sons, 2006.
3. John Makhoul, Linear Prediction: A Tutorial Review, Proceedings of the IEEE, Vol. 63, Issue 4, Apr. 1975, pp. 561 – 580.
4. Heiga Zen, Keiichi Tokuda, Alan W. Black, Statistical Parametric Speech Synthesis, Speech Communication, Vol. 51, Issue 11, Nov. 2009, pp. 1039 - 1064.

PIF1126	HUMAN COMPUTER INTERACTION	L	T	P	C
		3	0	0	3

OBJECTIVES

- To know how to analyze and consider user's need in the interaction system
- To understand various interaction design techniques and models
- To understand the theory and framework of HCI
- To Understand and analyze the cognitive aspects of human – machine interaction

UNIT I INTRODUCTION **9**

Foundation: Human, Computer, Interaction, Paradigms, What is HCI, Components, Cognitive Framework: Perception and Representation, Attention and Memory Constraint, Knowledge and Mental Model, Interface Metaphors, Input, Output

UNIT II DESIGN PROCESS **9**

Interaction Styles, Interaction Design Basics, HCI in the Software Process, Design Rules, Designing Windowing Systems, User Support and On-Line Information, Designing for Collaborative Work and Virtual Environments, Principles and User-Centred Design, Methods for User-Centred Design

UNIT III IMPLEMENTATION AND EVALUATION PROCESS **9**

Implementation issues, Implementation Support, Evaluation techniques, Universal Design, User Support

UNIT IV MODELS **9**

Cognitive models, Communication and collaboration models, Models of the system, Modeling Rich Interaction

UNIT V APPLICATIONS **9**

Socio – organization issues and stakeholder requirements, Ubiquitous Computing, Context – aware User Interfaces, Hypertext, multimedia and the World Wide Web

TOTAL PERIODS: 45

OUTCOMES

Upon Completion of the course, the students will be able to:

- Develop good design for human machine interaction system
- Analyze the user's need in interaction system
- Design new interaction model to satisfy all types of customers
- Evaluate the usability and effectiveness of various products
- Apply interaction techniques for systems

REFERENCES

1. Alan Dix, Janet Finlay, Gregory D. Abowd, Russell Beale, Human Computer Interaction, Third Edition, Pearson Education, 2004
2. Dix, Finlay, Abowd and Beale. Human – Computer Interaction, Second edition, Prentice Hall,1998
3. J. Preece, Y. Rogers, H. Sharp, D. Benyon, S. Holland and T. Carey, Human – Computer Interaction, Addison Wesley, 1994
4. John M. Carrol, Human Computer Interaction in the New Millenium, Pearson Education, 2002

5. Hollan, James, Edwin Hutchins, and David Kirsh, Distributed Cognition: Toward a New Foundation for Human-Computer Interaction Research, ACM Transactions on Computer-Human Interaction, 7(2):174-196, 2000.

PIF1127	SECURITY ENGINEERING	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to

- Understand the cryptographic techniques
- Learn the application of security for various domains
- Understand the defense mechanisms
- Develop secure systems

UNIT I SECURITY ENGINEERING 9

Introduction to concepts of Linear Algebra, Elementary probability, Abstract Algebra, Number Theory, Information Theory and Matrices, Security Engineering, Usability and Psychology, Protocols, Access Control, Cryptography

UNIT II MULTILEVEL SECURITY 9

Distributed Systems, Economics, Multilevel Security, Multilateral Security, Banking and Bookkeeping

UNIT III PROTECTION MECHANISMS 9

Physical Protection, Monitoring and Metering, Nuclear Command and Control, Security Printing and Seals, Biometrics

UNIT IV API SECURITY 9

Physical Tamper Resistance, Emission Security, API Security, Electronic and Information Warfare Telecom System Security.

UNIT V NETWORK DEFENSE 9

Network Attack and Defense, Copyright and DRM, The Bleeding Edge, Terror, Justice and Freedom, Managing the Development of Secure Systems, System Evaluation and Assurance.

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should demonstrate competency in the following topics:

- Evaluate elementary defense requirements of an application.
- Evaluate security levels of the defense mechanisms
- Apply security mechanisms for various applications.

TEXTBOOK

1. Ross Anderson, Security Engineering, John Wiley & Sons, 2008

REFERENCE

1. Kannan and Chithra Selvaraj, Bank of the Future, Minimizing Technological Risks: Maximizing Returns, Wolters Kluwer publications, 2018.
2. William Stallings, Network Security Essentials: Applications and Standards, Prentice Hall, 4th edition, 2010.
3. Schneier, Bruce. Applied Cryptography, Second Edition, John Wiley & Sons, 1996.
4. William Stallings, Network Security Essentials: Applications and Standards, Prentice Hall, 4th edition, 2010.
5. Michael T. Goodrich and Roberto Tamassia, Introduction to Computer Security, Addison Wesley, 2011.

PIF1128	VIDEO ANALYTICS	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to

- Know the fundamental concepts of big data and analytics
- Learn various techniques for mining data streams
- Acquire the knowledge of extracting information from surveillance videos
- Learn Event Modelling for different applications
- Understand the models used for recognition of objects in videos

UNIT I INTRODUCTION TO BIG DATA & DATA ANALYSIS 9

Introduction: Big Data Platform – Challenges of Conventional systems – Web data - Evolution of Analytic scalability- analytic processes and tools- Analysis Vs Reporting, Data Analysis: Modern data analytic tools - Regression Modeling- Bayesian Modeling- Rule induction

UNIT II MINING DATA STREAMS 9

Stream concepts: Stream data model and architecture – Stream Computing- Sampling data in a Stream- Filtering Streams- Counting distinct elements in a Stream, Estimating moments, Counting oneness in a window, Decaying window, Real time Analytics platform(RTAP) applications

UNIT III VIDEO ANALYTICS 9

Introduction: Video Basics - Fundamentals for Video Surveillance- Scene Artifacts, Object Detection and Tracking: Adaptive Background Modelling and Subtraction- Pedestrian Detection and Tracking- Vehicle Detection and Tracking- Articulated Human Motion Tracking in Low-Dimensional Latent Spaces

UNIT IV BEHAVIOURAL ANALYSIS & ACTIVITY RECOGNITION 9

Event Modelling: Behavioural Analysis, Human Activity Recognition: Complex Activity Recognition- Activity modelling using 3D shape, Video summarization, shape based activity models, Suspicious Activity Detection

UNIT V HUMAN FACE RECOGNITION & GAIT ANALYSIS 9

Introduction: Overview of Recognition algorithms – Human Recognition using Face - Face Recognition from still images - Face Recognition from video - Evaluation of Face Recognition Technologies, Human Recognition using gait: HMM Framework for Gait Recognition - View Invariant Gait Recognition - Role of Shape and Dynamics in Gait Recognition

TOTAL PERIODS: 45

OUTCOMES

Upon completion of the course, the student should be able to:

- Demonstrate big data platform and its analysis techniques
- Design efficient algorithms for mining the data from large volumes
- Demonstrate surveillance videos for analytics
- Design of optimization algorithms for better analysis and recognition of objects in a scene
- Model a framework for Human Activity Recognition

REFERENCES

1. Anand Rajaraman and Jeffrey David Ullman, Mining of Massive Datasets, Cambridge University Press, 2012
2. Michael Berthold, David J.Hand, Intelligent Data Analysis, Springer, 2007
3. Rama Chellappa, Amit K.Roy-Chowdhury, Kevin Zhou.S, Recognition of Humans and their Activities using Video, Morgan&Claypool Publishers, 2005
4. Yunqian Ma, Gang Qian, Intelligent Video Surveillance: Systems and Technology, CRC Press (Taylor and Francis Group), 2009
5. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010

PIF1129	DATA STORAGE TECHNOLOGIES AND NETWORKS	L	T	P	C
		3	0	0	3

OBJECTIVE

- To provide learners with a basic understanding of storage media types, technologies, storage architecture, enterprise data storage and management and the mathematical modeling of storage devices.

UNIT I MATHEMATICS ESSENTIALS 9

Numerical Linear Algebra Basics, Storage models: modeling using linear and polynomial regression, Stochastic analysis of storage devices, Queuing models of storage devices, Modeling storage device performance prediction

UNIT II STORAGE MEDIA AND TECHNOLOGIES 9

Storage Media: Magnetic - Optical and Semiconductor Media, Techniques for read/write Operations: Issues and Limitations, Positioning in the Memory Hierarchy, Hardware and Software Design for Access, Performance issues

UNIT III LARGE STORAGES 9

Large Storages: Hard Disks-Networked Attached Storage: Scalability issues – Networking issues

UNIT IV ARCHITECTURE 9

Storage Architecture, Storage Partitioning, Storage System Design, Caching, Legacy Systems

UNIT V STORAGE AREA NETWORKS 9

Storage Area Networks: Hardware and Software Components, Storage Clusters/Grids, Storage QoS: Performance – Reliability – Security issues, Recent Trends related to Copy data management, Erasure coding, Software defined storage appliances

TOTAL PERIODS: 45

OUTCOMES

After completing this course, the student should be able to be

- Explain Storage Media Technologies.
- Explain Storage Architecture
- Demonstrate Virtualization Technologies, Storage Area Networks.
- Explain mathematical modeling of storage devices.

TEXT BOOK

1. Franklyn E. Dailey Jr., The Complete Guide to Data Storage Technologies for Network-centric Computing Paperback–Import, First Edition, Computer Technology Research Corporation, 1997.

REFERENCES

1. Nigel Poulton, Data Storage Networking: Real World Skills for the CompTIA Storage+ Certification and Beyond Paperback – Import, Sybex, 2014.
2. Datta B.N , Numerical Linear Algebra and Applications-Paperback, Second Edition, Prentice Hall India Learning Private Limited, 2010.
3. M.E. Gomez, V. Santonja, A new approach in the analysis and modeling of disk access patterns, in the proceedings of IEEE International Symposium on Performance Analysis of Systems and Software. ISPASS, 2000.

4. Georgia Sakellari, George Loukas, A survey of mathematical models, simulation approaches and testbeds used for research in cloud computing, Simulation Modelling Practice and Theory, pp. 1-12, 2013.

PROFESSIONAL ELECTIVES (PE)

SEMESTER II

ELECTIVE III

PIF1221	VIRTUALIZATION AND CLOUD COMPUTING	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to

- To understand the mathematical concepts related to platforms.
- To discuss the management of complex virtual environments.
- To gain knowledge on the concept of virtualization that is fundamental to cloud
- To understand the various governance in cloud computing tools.
- To gain knowledge of multi cloud and cloud applications.

UNIT I INTRODUCTION 12

Optimization problem: Linear optimization - Sequential optimization, Classical optimization techniques for task allocation and scheduling: methodology of optimization - Case study on resource allocation - task scheduling

UNIT II VIRTUAL MANAGEMENT 9

Virtual management techniques, Methodology: key performance metrics - CPU - memory, network - Virtual Machine, Application performance bottlenecks: Virtualized environment - Enabling Technologies - System Models for Cloud Computing: management- Scalability- Performance - QoS - Benefits- Challenges – Implementation risk

UNIT III CLOUD STORAGE OPTIMIZATION 9

Storage strategy, Governance, Security and regulations, Designing secure solutions: the considerations - implementations involved - Virtualized Securing storage - Security auditing - SIEM - Global storage management locations – scalability - operational efficiency - Global storage distribution, Policy based information management: Metadata attitudes - file systems or object storage

UNIT IV MULTI CLOUD STRATEGIES 6

Cloud Analysis: Cloud - Hybrid Cloud - Multi-Cloud - Multi-Cloud offers - Multi-Cloud Capabilities - Features of Multi-Cloud Data Control - Benefits of Multi-Cloud Data Control - multi-cloud storage - Multi-Cloud applications, Case study: Multi-Cloud controller (Zenko)

UNIT V CLOUD COMPUTING APPLICATIONS 9

Business drivers for cloud computing: Managed services - disaster recovery - Flexible operation, Cloud computing as utility: Reason for organizations choose the cloud - Expenditure reduction - Degrease operational expenses - Improve desktop support - improve accessibility, Cloud deployment: Considerations - decisions - role multitenant shared cloud hosting - Cloud mode model selection criteria - security issues and solution - Scientific Data Management in the Cloud.

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should demonstrate competency in the following topics:

- Demonstrate the optimization and task scheduling in cloud.
- Apply the concept of virtualization in the cloud computing
- Analyze the optimal storage delivery models of cloud computing

- Develop the cloud based application using tools.
- Apply the multi cloud applications.

TEXT BOOK

1. Kai Hwang, Geoffery C. Fox and Jack J. Dongarra, Distributed and Cloud Computing: Clusters, Grids, Clouds and the Future of Internet, First Edition, Morgan Kaufman Publisher, an Imprint of Elsevier, 2012.

REFERENCES

1. S.S. Rao, Engineering Optimization: Theory and Practice, New Age International P) Ltd.,New Delhi, 2000.
2. Danielle Ruest, Nelson Ruest, Virtualization: A Beginner‟s Guide, McGraw-Hill Osborne Media, 2009.
3. Gaurav Somani, Scheduling and Isolation in Virtualization, VDM Verlag Dr. Müller [ISBN: 978-3639295139], Muller Publishers, Germany, Sept. 2010.
4. Kai Hwang, Geoffrey C Fox, Jack G Dongarra, Distributed and Cloud Computing, From Parallel Processing to the Internet of Things, Morgan Kaufmann Publishers, 2012.
5. Tim Mather, Subra Kumaraswamy, and ShahedLatif,Cloud Security and Privacy, O‟Reilly Media, Inc.,2009.
6. Greg Schulz, Cloud and Virtual Data Storage Networking, Auerbach Publications [ISBN: 978-1439851739], 2011.
7. Di Nitto, E., Matthews, P., Petcu, D., Solberg, A, Model-Driven Development and Operation of Multi-Cloud Applications, The MODAClouds Approach Springer 2017.

PIF12222	SOFTWARE TESTING AND QUALITY ASSURANCE	L	T	P	C
		3	0	0	3

OBJECTIVES

The student should be able to

- Know what is software and the usage of different types of Softwares.
- Know the Quality Metrics of various Softwares.
- Know the methodologies in making Software.
- Test the product finally to check the product Quality.

UNIT I INTRODUCTION 9

Introduction to Software Quality: Challenges – Objectives, Quality Factors, Components of SQA, Contract Review, Development and Quality Plans, SQA Components in Project Life Cycle, SQA Defect Removal Policies, Reviews

UNIT II TESTING METHODOLOGIES 9

Basics of Software Testing – Test Generation from Requirements, Finite State Models ,Combinatorial Designs, Statistics to reduce number of test cases: Test Selection- Minimization and Prioritization for Regression Testing**,** Test Adequacy, Assessment and Enhancement

UNIT III TEST STRATEGIES 9

Testing Strategies: White Box and Black Box Approach – Integration Testing – System and Acceptance Testing – Performance Testing – Regression Testing - Internationalization Testing – Ad-hoc Testing – Website Testing – Usability Testing – Accessibility Testing

UNIT IV TEST AUTOMATION AND MANAGEMENT 9

Test plan, Management, Execution and Reporting, Software Test Automation, Automated Testing tools, Hierarchical Models of Software Quality, Configuration Management, Documentation Control.

UNIT V SQA IN PROJECT MANAGEMENT 9

Project progress control, costs, quality management standards, project process standards, management and its role in SQA, SQA unit

TOTAL PERIODS: 45

OUTCOMES

At the end of this course, the students should be able to:

- Analyze the product Quality.
- Use various testing methods.
- Assess Quality standards.

REFERENCES

1. Aditya Mathur, ―Foundations of Software Testing‖, Pearson Education, 2008
2. Alan C Gillies, ―Software Quality Theory and Management‖, Cengage Learning, Second Edition, 2003.
3. Daniel Galin, ―Software Quality Assurance – from Theory to Implementation‖, Pearson Education, 2009
4. Robert Furtell, Donald Shafer, and Linda Shafer, Quality Software Project Management, Pearson Education Asia, 2002.
5. Ron Patton, ―Software Testing‖ , Second Edition, Pearson Education, 2007

6. Srinivasan Desikan, Gopalaswamy Ramesh, ―Software Testing – Principles and Practices‖, Pearson Education, 2006
7. Yogesh Singh, Software Testing, Cambridge University Press, 2012

PIF1223	DATA VISUALIZATION	L	T	P	C
		3	0	0	3

OBJECTIVES

- To understand the basic and advanced techniques of information visualization and scientific visualization
- To learn key techniques of the visualization process
- To understand visual perception, the visualized data and the actual visualization, interaction and distorting techniques

UNIT I INTRODUCTION TO DATA VISUALIZATION 9

Introduction of visual perception - visual representation of data - Gestalt principles - information overloads

UNIT II VISUAL MAPPING OF DATA 9

Creating visual representations - visualization reference model - visual mapping - visual analytics, Design of visualization applications.

UNIT III VISUALIZATION TECHNIQUES 9

Classification of visualization systems, Interaction and visualization techniques misleading, Visualization of one, two and multi-dimensional data, text and text documents.

UNIT IV VISUALIZATION OF LARGE DATA 9

Visualization: groups - trees- graphs- clusters- networks- software, Metaphorical visualization: Visualization of volumetric data - vector fields - processes and simulations, Visualization of maps - geographic information, GIS systems, collaborative visualizations, Evaluating visualizations

UNIT V MODERN VISUALIZATION 9

Recent trends in various perception techniques - various visualization techniques - data structures used in data visualization

TOTAL PERIODS: 45

OUTCOMES

On successful completion of this course, students will be able to:

- Design a process to develop visualization methods and visualization systems, and methods for their evaluation
- Design and process the data for visual mapping and the visualization
- Explain large-scale abstract data

REFERENCES

1. Ward, Grinstein, Keim, Interactive Data Visualization: Foundations, Techniques, and Applications. Natick : A K Peters, Ltd, 2010
2. E. Tufte, The Visual Display of Quantitative Information, Graphics Press, 2001
3. Scott Murray, Interactive Data Visualization for the Web, 2nd Edition, 2017
4. Tamara Munzner, Visualization Analysis & Design, AK Peters Visualization Series,1st Edition, 2014
5. Manuel Lima, Visual Complexity: Mapping Patterns of Information, 2013

PIF1233	NATURAL LANGUAGE PROCESSING AND INFORMATION RETRIEVAL	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to make the student

- Learn the language models
- Understand the levels of knowledge in language processing
- Explore the learning algorithms for text processing
- Understand the NLP applications

UNIT I OVERVIEW AND LANGUAGE MODELING 9

Origins and challenges of NLP, Knowledge in Language Processing, NLP Applications. Language Modeling: Language and Grammar, Grammar-based Language Models – Lexical Functional Grammar, Government and Binding, Statistical Language Model – N-gram Model, Smoothing Techniques.

UNIT II WORD LEVEL AND SYNTACTIC ANALYSIS 9

Word Level Analysis: Regular Expressions, Survey of Morphology, Word and Sentence Tokenization, Stemmer, Spelling Error Detection and correction, Word classes, Part-of-Speech Tagging, HMM POS Tagging, Tree bank. Syntactic Analysis: Constituency, Context-free Grammar, Dependency Grammar, Parsing - top-down, bottom-up, ambiguity, Early algorithm, CYK, Probabilistic CFG, Probabilistic CYK Parsing.

UNIT III SEMANTIC ANALYSIS AND DISCOURSE PROCESSING 9

Semantic Analysis: Meaning Structure of Language, Slot-filler Representation, Lexical Semantics - word senses, relations, WordNet, Word Sense Disambiguation - Dictionary-based, Supervised, Semi-Supervised, Word Similarity - thesaurus-based, distributional similarity. Discourse Processing: Reference Resolution, Anaphora Resolution Algorithms, Co-reference Resolution.

UNIT IV CLASSIFICATION AND CLUSTERING 9

Text Classification: Naïve Bayes, K-Nearest Neighbour. Clustering: Flat Clustering – K-means, Expectation Maximization, Hierarchical Clustering, Dense Vectors – Single Value Decomposion, Latent Semantic Analysis, Embeddings - Skip-gram, CBOW.

UNIT V MACHINE TRANSLATION, IR AND IE 9

Machine Translation: Problems in Machine Translation, Classical MT, Statistical MT, Seq2Seq Model. Information Retrieval: Boolean, Vector Space, Probabilistic Models, Evaluation of IR. Information Extraction: Named Entity Recognition, Relation Detection.

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should demonstrate competency in the following topics:

- Explain the language models (K2)
- Explain levels of knowledge in language processing (K2)
- Apply learning algorithms for text processing (K3)
- Apply NLP techniques to MT, IR and IE systems(K3)

TEXTBOOK

1. Daniel Jurafsky and James H Martin, Speech and Language Processing: An introduction to Natural Language Processing, Computational Linguistics and Speech Recognition, 2nd Edition, Prentice Hall, 2008.

REFERENCES

1. Tanveer Siddiqui, U.S. Tiwary, Natural Language Processing and Information Retrieval, Oxford University Press, 2008.
2. Christopher D. Manning, Hinrich Schutze, Foundations of Statistical Natural Language Processing, MIT Press, 1999.
3. Nitin Indurkhya, Fred J. Damerau, Handbook of Natural Language Processing, 2nd Edition, CRC Press, 2010.
4. NLTK – Natural Language Tool Kit - http://www.nltk.org/

PIF1224	INFORMATION RETRIEVAL & WEB SEARCH	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objectives of this course are

- To understand the basics of information retrieval with pertinence to modeling, query operations and indexing
- To get an understanding of machine learning techniques for text classification and clustering.
- To understand the various applications of information retrieval giving emphasis to web search

UNIT I INTRODUCTION 8

Motivation, Basic Concepts, Practical Issues, Retrieval Process: Boolean Retrieval, Architecture, Retrieval Evaluation, Open Source IR Systems, History of Web Search, Web Characteristics, Impact of the web on IR, IR Versus Web Search, Components of a Search engine

UNIT II MODELING 10

Taxonomy and Characterization of IR technique, IR Models: Boolean Model - Vector Model - Term Weighting - Scoring and Ranking – Language Models - Set Theoretic Models - Probabilistic Models- Algebraic Models - Structured Text Retrieval Models - Models for Browsing

UNIT III INDEXING 9

Static and Dynamic Inverted Indices, Index Construction and Index Compression, Searching: Sequential Searching and Pattern Matching, Query Operations: Query Languages - Query Processing - Relevance Feedback and Query Expansion, Automatic Local and Global Analysis, Measuring Effectiveness and Efficiency

UNIT IV CLASSIFICATIONANDCLUSTERING 9

Text Classification and Naïve Bayes, Vector Space Classification, Support vector machines, Machine learning on documents, Clustering: Hierarchical Clustering, Matrix decompositions and latent semantic indexing, Fusion and Meta learning

UNIT V SEARCHING AND RANKING 10

Static and Dynamic Ranking, Web Crawling and Indexing, Link Analysis, XML Retrieval, Indexing and Searching: Parallel IR - Distributed IR, Case Study: Google search engine – Components – retrieval process – algorithms – retrieval evaluation

TOTAL PERIODS: 45

OUTCOMES

Upon completion of this course, the student should be able to

- Build an Information Retrieval system using the available tools
- Design the various components of an Information Retrieval system
- Apply machine learning techniques to text classification and clustering which is used for efficient Information Retrieval
- Design an efficient search engine and analyze the Web content structure

REFERENCES

1. Ricardo Baeza – Yates, Berthier Ribeiro – Neto, Modern Information Retrieval: The concepts and Technology behind Search (ACM Press Books), Second Edition 2011

2. Christopher D. Manning, Prabhakar Raghavan, Hinrich Schutze, Introduction to Information Retrieval, Cambridge University Press, First South Asian Edition 2012
3. Stefan Buttcher, Charles L. A. Clarke, Gordon V. Cormack, Information Retrieval Implementing and Evaluating Search Engines, The MIT Press, Cambridge, Massachusetts London, England, 2010
4. Amy N. Langville and Carl. D. Meyer, Google's Page rank and beyond: Science of search engine rankings, Princeton University Press, 2006 http://www.jstor.org/stable/j.ctt7t8z9.

PIF1225	MOBILE APPLICATION DESIGN AND DEVELOPMENT	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to help students to

- Understand the mathematical essentials for the mobile application development
- Understand the system requirements for mobile applications
- Identify suitable design using specific mobile development frameworks
- Learn mobile application design patterns
- Implement the design using specific mobile development frameworks
- Deploy the mobile applications in marketplace for distribution.

UNIT I MATHEMATICS ESSENTIALS 9

Basic linear algebra: Vectors and matrices, Geometry and Transformations for 2D/3D graphics, Modeling games using graph theory, Modeling data for mobile application using databases

UNIT II BASIC DESIGN 9

Introduction to mobile computing, Introduction to mobile application development technologies: Development environment - Issues of Mobile Application Development - Setting up multiple development environments for different platforms, Design constraints for mobile applications: Hardware and software related, Architecting mobile applications: Life cycle of a mobile application - User interfaces for mobile applications

UNIT III ADVANCED DESIGN 9

Designing applications with 2D/3D graphics and multimedia with web access capabilities, Telephony, Notifications and Alarm, Connecting sensors, Integration with GPS and social media networking applications, Accessing applications hosted in a cloud computing environment, Design patterns for mobile applications, Security and Hacking

UNIT IV ANDROID 9

Introduction: Establishing the development environment, Android architecture: Activities and views, Interacting with UI, Persisting data using SQLite, Creating content providers: Packaging and deployment, Interaction with server side applications, Apps for wearable devices, Using Google Maps, GPS and WiFi, Integration with social media applications

UNIT V IOS 9

Introduction to Objective C, iOS features: UI implementation – Touch frameworks, Data persistence using Core Data and SQLite, Navigation Based Applications: Working with Sprite Kit – Location aware applications using Core Location and Map Kit, Integrating calendar and address book with social media application, Using WiFi, iPhone mark

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should be able to:

- Infer the requirements for mobile applications
- Explain the challenges in mobile application design and development
- Develop design for mobile applications for specific requirements
- Demonstrate the design using Android SDK
- Demonstrate the design using Objective C and iOS
- Design the mathematical model for graphics and gaming applications.
- Deploy mobile applications in Android and iPone marketplace for distribution

TEXT BOOKS

1. Jeff McWherter and Scott Gowell, Professional Mobile Application Development, Wrox, 2012.
2. Charlie Collins, Michael Galpin and Matthias Kappler, Android in Practice, DreamTech, 2012.
3. David Mark, Jack Nutting, Jeff LaMarche and Frederic Olsson, Beginning iOS 6 Development: Exploring the iOS SDK, Apress, 2013.

REFERENCES

1. Gilbert Strang, Linear Algebra and Its Applications, Cengage Learning, 4th edition, 2006.
2. John Vince, Geometry for Computer Graphics: Formulae, Examples and Proofs, 2004. Springer; 2005.
3. Reto Meier, Professional Android 4 Application Development Paperback, Wiley-India Edition, 2012.
4. James Dovey and Ash Furrow, Beginning Objective C, Apress, 2012.
5. B.M. Harwani, Android Programming Unleashed, 1st Edition, Sams Publishing, 2012.
6. Greg Nudelman, Android Design Patterns: Interaction Design Solutions for Developers (MISL-WILEY) Paperback, Wiley, 2013.
7. Wei-Meng Lee, Beginning Android 4 Application Development Paperback – Import, Wrox, 2012.
8. Sheran Gunasekera, Android Apps Security Paperback, 1st Edition, APress, 2012.

PROFESSIONAL ELECTIVES (PE)

SEMESTER II

ELECTIVE IV

PIF1226	HIGH PERFORMANCE COMPUTING	L	T	P	C
		3	0	0	3

Pre-requisites : Computer Organization & Architecture

OBJECTIVES

- To introduce the concepts of Modern Processors.
- To introduce Optimization techniques for serial code.
- To introduce Parallel Computing Paradigms.
- To introduce Parallel Programming using OpenMP and MPI.

UNIT I MODERN PROCESSORS 9

Modern Processors : Stored Program Computer Architecture - General purpose cache- based microprocessor - Performance based metrics and benchmarks - Moore's Law - Pipelining - Superscalarity SIMD- Memory Hierarchies Cache- mapping- prefetch- Multicore Stored Program Computer Architecture processors- Mutithreaded processors- Vector Processors- Basic optimization techniques for serial code

UNIT II PARALLEL COMPUTERS 9

Parallel Computers : Taxonomy of parallel computing paradigms-Shared memory computers- Cache coherance- UMA - ccNUMA- Distributed-memory computers- Hierarchical systems- Networks- Basic performance characteristics- Buses- Switched and fat- tree networks- Mesh networks- Hybrids, Basics of parallelization : Why parallelize - Data Parallelism - Function Parallelism, Parallel Scalability: Factors that limit parallel execution- Scalability metrics- Simple scalability laws- parallel efficiency - serial performance Vs Strong scalability

UNIT III PARALLEL PROGRAMMING 9

Distributed memory parallel programming with MPI : message passing - introduction to MPI – example - messages and point-to- point communication- collective communication – non blocking point-to-point communication- virtual topologies - MPI parallelization of Jacobi solver- MPI implementation - performance properties

UNIT IV OPENMP PROGRAMMING 9

Shared memory parallel programming with OpenMp : Introduction to OpenMp - parallel execution - data scoping- OpenMp work sharing for loops - synchronization - reductions - loop scheduling tasking, OpenMp parallel jacobi algorithm - advanced OpenMp wavefront parallelization, Efficient OpenMP programming : Profiling OpenMP programs - Performance pitfalls, Case study: Parallel Sparse matrix-vector multiply

UNIT V MPI PROGRAMMING 9

Efficient MPI programming : MPI performance tools communication parameters - Synchronization - serialization - contention - Reducing communication overhead - optimal domain overhead - optimal decomposition - Aggregating messages – Nonblocking Vs Asynchronous communication - Collective communication - Understanding intra-node point-to-point communication

TOTAL PERIODS : 45

OUTCOMES

The students will be able to

- Outline the concepts used in Modern Processors for increasing the performance.
- Explain Optimization techniques for serial code.
- Explain Parallel Computing Paradigms.
- Analyse the performance issues in Parallel Programming using OpenMP and MPI.

TEXT BOOKS

1. Georg Hager, Gerhard Wellein, Introduction to High Performance Computing for Scientists and Engineers, Chapman & Hall / CRC Computational Science series, 2011.
2. Charles Severance, Kevin Dowd, High Performance Computing, O'Reilly Media, 2nd Edition, 1998.
3. Kai Hwang, Faye Alaye Briggs, Computer Architecture and Parallel Processing, McGraw Hill, 1984.
4. Y. Deng, Applied Parallel Computing, World Scientific, 2011.
5. L. R. Scott et al., Scientific Parallel Computing, Princeton, 2005.

PIF1227	NATURE-INSPIRED COMPUTING	L	T	P	C
		3	0	0	3

OBJECTIVES

- To Learn bio-inspired theorem and algorithms
- To Understand random walk and simulated annealing
- To Learn genetic algorithm and differential evolution
- To Learn swarm optimization and ant colony for feature selection To understand bio-inspired application in image processing

UNIT I INTRODUCTION **9**

Introduction to algorithm - Newton's method - optimization algorithm - No-Free-Lunch Theorems - Nature-Inspired Mata heuristics - Analysis of Algorithms - Nature Inspired Algorithms - Parameter tuning and parameter control.

UNIT II RANDOM WALK AND ANEALING **9**

Random variables - Isotropic random walks - Levy distribution and flights - Markov chains - step sizes and search efficiency - Modality and intermittent search strategy - importance of randomization- Eagle strategy-Annealing and Boltzmann Distribution - parameters -SA algorithm - Stochastic Tunneling.

UNIT III GENETIC ALOGORITHMS AND DIFFERENTIAL EVOLUTION **9**

Introduction to genetic algorithms and - role of genetic operators - choice of parameters - GA variants - schema theorem - convergence analysis - introduction to differential evolution - variants - choice of parameters - convergence analysis - implementation.

UNIT IV SWARM OPTIMIZATION AND FIREFLY ALGORITHM **9**

Swarm intelligence - PSO algorithm - accelerated PSO - implementation - convergence analysis - binary PSO - The Firefly algorithm - algorithm analysis - implementation - variants - Ant colony optimization toward feature selection.

UNIT V APPLICATION IN IMAGE PROCESSING **9**

Bio-Inspired Computation and its Applications in Image Processing: Overview - Fine Tuning Enhanced Probabilistic Neural Networks Using Meta-heuristic-driven Optimization - Fine Tuning Deep Belief Networks using Cuckoo Search - Improved Weighted Thresholded Histogram Equalization Algorithm for Digital Image Contrast Enhancement Using Bat Algorithm - Ground Glass Opacity Nodules Detection and Segmentation using Snake Model - Mobile Object Tracking Using Cuckoo Search

TOTAL PERIODS: 45

OUTCOMES

Upon completion of the course, the students will be able to

- Apply bio-inspired algorithms
- Explain random walk and simulated annealing
- Apply genetic algorithms
- Explain swarm intelligence and ant colony for feature selection
- Apply bio-inspired techniques in image processing.

REFERENCES

1. Eiben, A.E., Smith,James E, Introduction to Evolutionary Computing, Springer 2015.
2. Helio J.C. Barbosa, Ant Colony Optimization - Techniques and Applications, Intech 2013
3. Xin-She Yang , Jaao Paulo papa, Bio-Inspired Computing and Applications in Image Processing, Elsevier 2016
4. Xin-She Yang, Nature Inspired Optimization Algorithm,Elsevier First Edition 2014
5. Yang ,Cui,XIao,Gandomi,Karamanoglu ,Swarm Intelligence and Bio-Inspired Computing, Elsevier First Edition 2013

PIF1228	REVERSIBLE COMPUTING	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to

- Understand reversible logic
- Understand reversible circuits
- Understand thermodynamic concepts related to reversibility
- Understand quantum computing

UNIT I BOOLEAN ALGEBRA AND GROUP THEORY 9

Boolean Functions of One, two Variables, *n* Variables, Minterm and Maxterm Expansion, Reed–Muller Expansion, Minimal ESOP Expansion, Linear Functions, Affine Linear Functions, Monotonic Functions, Boolean Derivative, Boolean Decompositions

UNIT II GROUP THEORY 9

Permutation Groups, Matrix Groups, Group Generators, Subgroups, Young Subgroups, Sylow *p*-Subgroups, Cyclic Subgroups

UNIT III REVERSIBLE CIRCUITS 9

Conservative Circuits, Monotonic Circuits, Linear Circuits, Affine Linear Circuits, Exchange Gates, SWAP Gates, Affine Exchange Gates, Control Gates, Sylow Circuits, Gate Cost and Logic Depth, Methods of Synthesis, Cosets, Double Cosets, The Synthesis Algorithm, Variable Ordering, Linear Synthesis Algorithm, Preset Bits and Garbage Bits, Duplicating Circuit, Controlled NOT, Full Adder

UNIT IV LOW POWER COMPUTING 9

Entropy, Permutation Matrices, Landauer's Theorem, Thermodynamics, Quasi-adiabatic Addressing

UNIT V QUANTUM COMPUTING 9

Doubly Stochastic Matrices, Unitary Matrices, Entropy in the Quantum World, Entanglement, Control Circuits and Control Gates, Synthesis, Decomposition, One-(Qu)bit Calculations, Two-(Qu) bit Calculations, Three- and Multi-(Qu) bit Calculations, Quantum Fourier Transform, Nonlinear Computations

TOTAL PERIODS: 45

OUTCOMES

Upon completion of the course, the student should be able to

- Make use of reversible computing systems
- Make use of quantum computing areas

TEXT BOOKS

1. Alexis De Vos, Reversible Computing: Fundamentals, Quantum computing with applications, Wiley-VCH Verlag GmBH & Co. KGaA, 2010.
2. M.A. Nielsen and I.L.Chuang, Quantum Computation and Quantum Information, Cambridge University Press 2000.
3. Lecture Notes, http://www.the
4. ory.caltech.edu/~preskill/ph219/index.html#lecture

PIF1229	SOFT COMPUTING	L	T	P	C
		3	0	0	3

OBJECTIVES

- To understand basics of fuzzy system, genetic algorithms and other optimization techniques
- To learn artificial neural network models 7 their functions
- To understand probabilistic methods and learning theory
- Apply soft computation tools to solve a variety of problems

UNIT I FUZZY LOGIC 8

Introduction to Computational Intelligence, Uncertainty, Fuzzy sets and operations of fuzzy sets, Fuzzy rules and fuzzy inference, Fuzzy Expert Sytems, Case Study

UNIT II NEURAL NETWORKS 10

Artificial neurons: activation functions - neural network architectures, Supervised learning neural networks: multi-layer feedforward neural networks - simple, recurrent neural networks, Introduction to Deep neural networks: CNN - Autoencoder - RNN - LSTM, Case Study.

UNIT III EVOLUTIONARY COMPUTATION 8

Genetic Algorithms: Chromosomes - fitness functions and selection mechanisms - crossover and mutation, Swarm Intelligence: Ant Colony Optimization – Particle Swarm Optimization, Case Study.

UNIT IV PROBABILISTIC METHODS 9

Bayesian network: representation, inference methods and learning, Temporal models: Hidden Markov models - HMM Inference (forward-backward & Viterbi's algorithms) - HMM learning (Baum-Welch) - Application to speech recognition

UNIT V LEARNING THEORY 10

VC dimension, Feature selection, Inductive inference, Boosting, Probably approximately correct learning , Error tolerance , Equivalence , Distribution Learning Theory, Machine Learning basics: Supervised learning - SVM - Unsupervised learning - K-Means - PCA - Reinforcement Learning.

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students will be able to:

- Explain Fuzzy logic and its applications.
- Explain Artificial neural networks and its applications.
- Solve single-objective optimization problems using GAs.
- Explain applications of Soft computing to solve problems in varieties of application domains.

TEXT BOOKS

1. H.K. Lam, S.S.H. Ling, and H.T. Nguyen, Computational Intelligence and Its Applications: Evolutionary Computation, Fuzzy Logic, Neural Network and Support Vector Machine, Imperial College Press, 2011.
2. A.P. Engelbrecht, Computational Intelligence: An Introduction, 2nd Edition, John Wiley & Sons, 2012

3. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine by Jyh-Shing Roger Jang, Chuen-Tsai Sun, Eiji Mizutani, Prentice Hall, 1997.
4. Mohamad H. Hassoun, Foundamentals of Artificial Neural Networks, The MIT Press, 1995
5. R.J. Jr., Bauer, Genetic Algorithms and Investment Strategies, John Wiley & Sons, 1994.

REFERENCES

1. Simon Haykin, Neural Networks: A Comprehensive Foundation, Macmillan College Publishing Company, 1994.
2. E. Cox, The Fuzzy Systems Handbook, Boston: AP Professional, 1998
3. F.F. Soulie and P. Gallinari (Editors), Industrial Applications of Neural Networks, Singapore; River Edge, NJ: World Scientific, 1998
4. Selected papers on computational intelligence techniques for various applications including IoT, data analysis and bio-informatics

PIF1231	ADVANCES IN OPERATING SYSTEMS	L	T	P	C
		3	0	0	3

OBJECTIVES

- To learn the fundamentals of Operating Systems
- To understand Virtualization Concepts
- To gain knowledge on Distributed operating system concepts that includes architecture, Mutual exclusion algorithms, Deadlock detection algorithms and agreement protocols
- To gain insight on to the distributed resource management components viz. the algorithms for implementation of distributed shared memory, recovery and commit protocols
- To know the components and management aspects of Real time and Database operating systems

UNIT I INTRODUCTION TO OPERATING SYSTEMS AND VIRTUALIZATION 9

Functions of an Operating System, Design Approaches – Types of Advanced Operating System - OS Structure Overview - The SPIN Approach - The Exokernel Approach -The L3 Micro-Kernel Approach –Memory and CPU Virtualization – Memory, CPU and device virtualization

UNIT II DISTRIBUTED OPERATING SYSTEMS 9

Introduction, Communication Primitives, Inherent Limitations, Lamport's Logical Clock**:** Vector Clock – Causal Ordering – Global State – Cuts – Termination Detection, Distributed Mutual Exclusion – Non-Token Based Algorithms – Lamport's Algorithm – Token-Based Algorithms – Suzuki-Kasami's Broadcast Algorithm, Distributed Deadlock Detection**:** Issues – Centralized Deadlock Detection Algorithms - Distributed Deadlock Detection Algorithms, Agreement Protocols: Classification – Solutions – Applications

UNIT III DISTRIBUTED RESOURCE MANAGEMENT 9

Distributed File systems**:** Architecture – Mechanisms – Design Issues, Distributed Shared Memory**:** Architecture – Algorithm – Protocols – Design Issues, Distributed Scheduling **:** Issues – Components – Algorithms, Failures and Fault Tolerance , Case Study**:** Google File

UNIT IV FAILURE RECOVERY AND FAULT TOLERANCE 9

Basic**:** Classification of failures – Basic approaches to recovery: Recovery in concurrent system - Synchronous and Asynchronous Check Pointing and Recovery – Check Pointing in Distributed Database Systems, Fault Tolerance: Issues – Two-phase and Non-blocking Commit Protocols – Voting Protocols – Dynamic Voting Protocols.

UNIT V ADVANCED OPERATING SYSTEMS 9

Multi Processor Operating Systems**:** Structures – Design Issues – Threads, Process Synchronization, Processor Scheduling, Database Operating Systems**:** Concurrency Control – Distributed Database Systems – Concurrency Control Algorithms, Real Time Operating Systems: Issues in real time computing - structure of a real time system - task classes - performance measures for real time systems

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should demonstrate competency to

- Analyze and understand the need for virtualization
- Discuss the various synchronization, scheduling and memory management issues

- Discuss and Apply the various resource management techniques for distributed systems
- Understand the need and different features of real time and database operating systems apply appropriate concepts in real time

TEXT BOOKS

1. Mukesh Singhal and N. G. Shivaratri, Advanced Concepts in Operating Systems, McGraw-Hill, 2000.
2. Andrew S. Tanenbaum, Distributed Operating Systems, 1st ed., Pearson Education, 1995.

REFERENCES

1. Abraham Silberschatz, Peter B. Galvin, G. Gagne, Operating System Concepts, Sixth Edition, Addison Wesley Publishing Co. , 2003.
2. Andrew S. Tanenbaum, Modern Operating Systems, Second Edition, Addison Wesley, 2001.
3. C.M. Krishna, Kang G. Shin, Real-Time Systems, McGraw-Hill International Editions, 1997.

PIF1232	DEEP LEARNING AND NEURAL NETWORK	L	T	P	C
		3	0	0	3

OBJECTIVES

To provide the mathematical and computational demands of building neural networks
To study the concepts of deep learning
To introduce dimensionality reduction techniques
To apply deep learning techniques for real time applications

UNIT I MACHINE LEARNING BASICS 9

Learning algorithms: regression - classification - clustering, Underfitting and Overfitting, Hyperparameters and validation sets, Estimators, bias and variance, Maximum likelihood estimation, Stochastic gradient descent.

UNIT II FOUNDATIONS OF DEEP NETWORKS 11

Neural networks: Biological neuron - Perceptron - Multilayered Feedforward Networks - Backpropagation learning, Activation functions: Linear - sigmoid - rectified linear and softmax, Loss functions, regularization, Deep networks: Unsupervised Pretrained Networks - Deep Belief Networks - Generative Adversarial Networks

UNIT III CONVOLUTIONAL NEURAL NETWORKS (CNNs) 8

Convolutional Operation, Motivation, Pooling layers, Fully connected layers, A complete CNN architecture: AlexNet - VGG - Inception - ResNet, Training a Convnet: weights initialization - batch normalization - hyperparameter optimization

UNIT IV SEQUENCE MODELING USING RECURRENT NETS 9

Recurrent Neural Networks (RNN), Bidirectional RNNs, Encoder-Decoder squence-to-sequence architectures, Deep RNNs, Recursive NN, Challenge of long term dependencies, Long Short-Term Memory (LSTM) and other Gated RNNs

UNIT V APPLICATIONS OF DEEP LEARNING 8

Case studies (one in each) in Computer Vision, Speech Processing, Natural Language Processing

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should be able to

- Analyze the deep learning algorithms which are more appropriate for various types of learning tasks in various domains.
- Solve real-world problems by implementing deep learning algorithms .

REFERENCES

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 2016
2. Josh Patterson, Adam Gibson, Deep Learning: A Practitioner's Approach, O'Reilly Media, 2017.
3. Tom Mitchell, Machine Learning, McGraw Hill, 3rd Edition,1997. 4. Charu C. Aggarwal, Data Classification Algorithms and Applications , CRC Press, 2014.

PROFESSIONAL ELECTIVES (PE)

SEMESTER III

ELECTIVE V

PIF1321	SOCIAL NETWORK ANALYSIS	L	T	P	C
		3	0	0	3

OBJECTIVES

The primary objective of this course is to

- Understand the concept of semantic web and related applications.
- Model and visualize social network
- Understand human behaviour in social web and related communities
- Learn visualization of social networks.

UNIT I INTRODUCTION 9

Introduction to Semantic Web: Limitations of current Web - Development of Semantic Web - Emergence of the Social Web, Social Network analysis: Development of Social Network Analysis - Key concepts and measures in network analysis, Electronic sources for network analysis: Electronic discussion networks, Blogs and online communities - Web-based networks

UNIT II MODELLING AND VISUALIZATION 9

Visualizing Online Social Networks: Taxonomy of Visualizations - Graph Representation – Centrality, Clustering, Matrix-Based Representations: Node-Edge Diagrams - Node-Link Diagrams - Hybrid Representations, Modelling and aggregating social network data, Random Walks and their Applications, Use of Hadoop and Map Reduce, Ontological representation of social individuals and relationships

UNIT III EXTRACTION & MINING COMMUNITIES IN WEB SOCIAL NETWORKS 9

Extracting evolution of Web Community from a Series of Web Archive, Detecting communities in social networks: Definition of community - Evaluating communities - Methods for community detection and mining, Applications of community mining algorithms, Tools for detecting communities, Decentralized online social networks, Multi-Relational characterization of dynamic social network communities

UNIT IV PREDICTING HUMAN BEHAVIOUR AND PRIVACY ISSUES 9

Understanding and predicting human behaviour for social communities, Reality mining, Models and Algorithms for Social Influence Analysis: Influence Related Statistics - Social Similarity and Influence - Influence Maximization in Viral Marketing, Algorithms and Systems for Expert Location in Social Networks: Expert Location without Graph Constraints - with Score Propagation – Expert Team Formation, Link Prediction in Social Networks: Feature based Link Prediction

UNIT V APPLICATIONS OF SOCIAL NETWORKS 9

Applications: Learning Based Approach for Real Time Emotion Classification of Tweets- New Linguistic Approach to Assess the Opinion of Users in Social Network Environments

TOTAL PERIODS: 45

OUTCOMES

Upon completion of the course, the student should be able to

- Develop semantic web related applications.
- Show knowledge using ontology and graph.
- Predict human behaviour in social web and related communities.
- Illustrate social networks using visualization techniques.

TEXT BOOKS

1. Peter Mika, Social Networks and the Semantic Web, First Edition, Springer 2007.
2. Borko Furht, Handbook of Social Network Technologies and Applications, 1st Edition, Springer, 2010.

REFERENCES

1. Stanley Wasserman, Katherine Faust Social Network Analysis: Methods and Applications Volume 8 of Structural Analysis in the Social Sciences, ISSN 0954-366X, Cambridge University Press, 1994
2. Guandong Xu ,Yanchun Zhang and Lin Li, Web Mining and Social Networking – Techniques and applications, First Edition Springer, 2011.
3. Dion Goh and Schubert Foo, Social information Retrieval Systems: Emerging Technologies and Applications for Searching the Web Effectively, IGI Global Snippet, 2008.
4. Max Chevalier, Christine Julien and Chantal Soulé-Dupuy, Collaborative and Social Information Retrieval and Access: Techniques for Improved user Modelling, IGI Global Snippet, 2009.
5. John G. Breslin, Alexandre Passant and Stefan Decker, The Social Semantic Web, Springer, 2009.

PIF1322	GPU ARCHITECTURE AND PROGRAMMING	L	T	P	C
		4	0	0	4

OBJECTIVES

The primary objective of this course is

- To know the fundamental of parallel and GPU programming.
- To study the concepts of GPU involved in parallel programming.
- To introduce the various parallel algorithms in OpenCL.
- To enable the students to know about the different parallel computing techniques to improve the performance of real time systems.
- To study the architecture of VideoCore and programming.

UNIT I INTRODUCTION TO OPENCL 9

GPU Computing: Definition-Need for GPU computing, OpenCL: Overview-Programming model-Host program and device kernel-OpenCL objects- Basic programs, Mathematical modeling: tasks/Objects modeling for execution in CPU and GPU

UNIT II ALGORITHMS IN OPENCL 9

Parallel Algorithms: Square matrix transpose-Square matrix multiplication-Work-groups-OpenCL synchronization model-OpenCL memory model-Matrix multiplication with local memory-Parallel reduction algorithms-Sorting algorithms-Mathematical models for parallel algorithms

UNIT III ARCHITECTURE OF A GPU 9

AMD Southern Islands: Architecture-instruction set -SIMD (Single-Instruction Multiple-Data) execution model-Scalar and vector instructions-Thread divergence- Nested control flow, Simulation Environment: Multi2Sim simulation framework-Disassembler-Emulator-Timing simulator-pipeline visualization.

UNIT IV PROGRAMMING GPU IN RASPBERRY PI 9

OpenMax Technology:OpenMax buffers-OpenMax for image processing-OpenMax for video processing-OoenMax for audio processing-Text processing in OpenVG.

UNIT V MISCELLANEOUS RESEARCH TOPICS AND OPPORTUNITIES 9

Future directions:Memory hierarchies and coherence protocols on GPUs-Interconnection networks on GPUs-Rendering graphics using OpenGL-The GPU graphics pipelines-Simulation of new GPU architectures-OpenCL/CUDA to LLVM compiler front-ends-LLVM to NVIDIA/Intel/AMD compiler back-ends and optimizers.

TOTAL PERIODS: 45

OUTCOMES

After completing this course, students should be able to

- Design Power efficient and parallel algorithms for execution on GPU.
- Analyze the different parallel algorithms for performance and complexity.
- Implement various parallel algorithms using OpenCL.
- Develop and restructure the algorithms for parallel execution on the GPU.
- Demonstrate audio, video and image processing on the GPU of Raspberry Pi.

TEXT BOOKS

1. B. Gaster, L. Howes, D. Kaeli, P. Mistry, D. Schaa, Heterogeneous Computing with OpenCL, Morgan Kaufmann, 1st Edition, 2011.

2. Jan NewMarch, Raspberry Pi GPU Audio Video Programming, Apress, 2017

REFERENCES

1. The OpenCL Specification, Aaftab Munshi, The OpenCL Group
2. ARM Mali -T600 Series GPU OpenCL Version 2.0 Developer Guide.
3. AMD accelerated parallel processing in OpenCL , August 2011.
4. Introduction to OpenCL Programming, Training Guide.

PIF1323	CYBER FORENSICS	L	T	P	C
		3	0	0	3

OBJECTIVES

The student should be made to:

1. Learn the security issues network layer and transport layer.
2. Be exposed to security issues of the application layer.
3. Learn computer forensics.
4. Be familiar with forensics tools.
5. Learn to model and interpret forensics data.

UNIT I NETWORK LAYER SECURITY &TRANSPORT LAYER SECURITY 9

IPSec Protocol: IP Authentication Header - IP ESP, Key Management Protocol for IPSec.Transport layer Security: SSL protocol- Cryptographic Computations – TLS Protocol

UNIT II E-MAIL SECURITY & FIREWALLS 9

Internet Firewalls for Trusted System, Roles of Firewalls: Firewall related terminology- Types of Firewalls - Firewall designs, SET for E-Commerce Transactions, PGP, S/MIME

UNIT III INTRODUCTION TO COMPUTER FORENSICS 9

Introduction to Traditional Computer Crime, Introduction to Identity Theft & Identity Fraud, Types of techniques: Incident and incident response methodology - Forensic duplication and investigation, Preparation for IR: Creating response tool kit- IR team, Understanding Computer Investigation: Forensics Technology – Systems- Data Acquisition

UNIT IV EVIDENCE COLLECTION AND FORENSICS TOOLS 9

Processing Crime and Incident Scenes, Working with OS, Computer Forensics Tools: Software Tools - Hardware Tools

UNIT V THEORETICAL INTERPRETATIONS AND MODELING IN FORENSICS 9

Applications of Graph theory and Bayesian models. Applying Machine Trust Models to Forensic Investigations - Exploring Big Haystacks- Forensic Techniques- Countering Hostile Forensic Techniques

TOTAL PERIODS : 45

OUTCOMES

Upon completion of the course, the student should be able to:

- Discuss the security issues network layer and transport layer.
- Apply security principles in the application layer.
- Explain computer forensics.
- Make use of forensics tools.
- Analyze and validate forensics data.

TEXT BOOKS

1. Man Young Rhee, Internet Security: Cryptographic Principles, Algorithms and Protocols, Wiley Publications, 2003.
2. Nelson, Phillips, Enfinger, Steuart, Computer Forensics and Investigations, Cengage Learning, India Edition, 2008.

REFERENCES

1. John R.Vacca, Computer Forensics, Cengage Learning, 2005

2. Richard E.Smith, Internet Cryptography, 3rd Edition Pearson Education, 2008.
3.Marjie T.Britz, Computer Forensics and Cyber Crime: An Introduction, 3rd Edition, Prentice Hall, 2013.
4. Peterson, Gilbert, and Sujeet Shenoi, Advances in Digital Forensics IX, Vol. 410, Springer, 2013.

PIF1324	BLOCK CHAIN TECHNOLOGIES	L	T	P	C
		3	0	0	3

OBJECTIVES

- To understand trust networks
- To learn how decentralization of trust is achieved
- To study the technologies behind cryptocurrencies
- To impart knowledge in block chain network mining
- To acquire knowledge in emerging concepts using block chain

UNIT I TRUST NETWORKS 9

Technical and Business Imperatives, Trust Networks to enable the machine economy : Decentralization of Trust, Technologies Blockchain and Crypto currency,Study of finitefields to understand role of numbers in blockchain

UNIT II BLOCKCHAIN NETWORKS 9

Centralization Vs Decentralization : Building Consensus – Distributed Consensus – Consensus Algorithm – Consensus without Identity, Incentives and Proof of Work, Forming the Decentralized Network, Blockchain the protocol : Types of Blockchain Networks – Design principles of the Blockchain economy, Networked Integrity, Distributed power, Value as Incentive, Security and Privacy : Rights and Inclusion, Distributed Ledger : Non Repudiation

UNIT III CRYPTOCURRENCIES 9

Cryptographic Hash Functions, Cryptography basics and Concepts, Bitcoin: Digital Signatures as Identities – eWallets – Personal Crypto security

UNIT IV BLOCKCHAIN NETWORK MINING 9

Bitcoin Mining: Mining Hardware – Energy Consumption – Mining Pools – Mining Incentives and Strategies

UNIT V EMERGING CONCEPTS AND FRAMEWORKS 9

Smart Contracts, Ethereum, Hyper ledger, Mulitchain Frameworks, Solidity Programming Language, Blockchain with IOT and Cloud

TOTAL PERIODS: 45

OUTCOMES

Upon completion of this course the students will be able to

- Explain the importance of trust networks
- Infer the challenges and design issues in bitcoin technology
- Analyze the algorithms developed for bitcoin mining
- Make use of appropriate techniques for designing trust-based business networks

REFERENCES

1. Don and Alex Tapscott, Blockchain Revolution. Portfolio Penguin 2016.
2. William Mougayar, Business Blockchain Promise, Practice and Application of the Next Internet Technology, John Wiley & Sons 2016.

PIF1325	AUTOMATA THEORY AND FORMAL LANGUAGES	L	T	P	C
		3	0	0	3

OBJECTIVES

The student should be able to

- Understand the concepts in automata theory and theory of computation
- Identify different formal language classes and their relationships
- Design grammars and recognizers for different formal languages
- Prove or disprove theorems in automata theory using its properties
- Determine the decidability and intractability of computational problems.

UNIT I REGULAR SETS AND FINITE STATE AUTOMATA 9

Finite state automata: Deterministic and non-deterministic model - Languages accepted by Finite State Automata, Regular Expression: Pumping Lemma for regular set

UNIT II CONTEXT FREE LANGUAGES 9

Grammar: Context Free Grammars - Derivation trees - Simplification of context - Free grammar (only Construction and no proof of equivalence of grammars) , Chomsky normal Form, Greibach Normal Form

UNIT III PUSH DOWN AUTOMATA AND CONTEXT FREE LANGUAGES 9

Pushdown automata: Push down automata and Context free languages - Pumping lemma for context free languages

UNIT IV TURING MACHINE AND UNDECIDEABILITY 9

Turing Machine model: Computational languages and functions - Modifications of Turing machines (only description, no proof for theorems on equivalence of the modification) - Problems - Properties of recursive and recursively enumerable languages - Universal Turing Machine and the undecidable problem

UNIT V THE CHOMSKY HIERARCHY 9

Regular grammar: Unrestricted grammar, Context Sensitive languages, Linear bounded automata, Relation between classes of languages.

TOTAL PERIODS: 45

OUTCOMES

At the end of the course, the students would be able to

- Develop understanding of finite state systems and their language generations, grammars and their language generations
- Explain equivalence between these two language generations
- Infer the Chomsky Hierarchy of formal languages
- Develop understanding of the principles of computability and complexity including decision problems, halting problems and basic complexity classes such as P and NP.
- Explain the limits of computation.

TEXT BOOK

1. Hopcroft J.E. and Ullman J.D, Introduction to Automata Theory, Languages and Computation, Narosa Publishing House, 2002.

REFERENCES

1. Hopcroft, J.E., Rajeev Motwani and Ullman, J.D. Introduction to Automata Theory, Languages, and Computation, Pearson Education, Second Edition, 2000.
2. Mishra K.L.P and Chandrasekaran. N, Theory of Computer Science: Automata, Languages and Computation, Prentice Hall of India, Third Edition, 2008.
3. Peter Linz, An Introduction to Formal Languages and Automata, Narosa Publishing House, Fourth Edition, 2012.

PIF1941	SPEECH AND NATURAL LANGUAGE PROCESSING	L	T	P	C
		3	0	0	3

OBJECTIVES:

The primary objective of this course is to make the student

- Learn the language models
- Understand the levels of knowledge in language processing
- Learn the roles of language models building a large vocabulary speech recognition system
- Understand the phonological rules to build a TTS system

UNIT I OVERVIEW AND LANGUAGE MODELING **9**

Origins and challenges of NLP, Knowledge in Language Processing, NLP Applications. Language Modeling: Language and Grammar, Grammar-based Language Models: Lexical Functional Grammar - Government and Binding, Statistical Language Model: N-gram Model - Smoothing Techniques.

UNIT II WORD LEVEL AND SYNTACTIC ANALYSIS **9**

Word Level Analysis: Regular Expressions - Survey of Morphology - Word and Sentence Tokenization - Stemmer - Spelling Error Detection and correction - Word classes - Part-of-Speech Tagging - HMM POS Tagging - Tree bank, Syntactic Analysis: Constituency - Context-free Grammar - Dependency Grammar - Top-down parsing - Bottom-up parsing - Ambiguity - Early algorithm - CYK - Probabilistic CYK Parsing.

UNIT III SEMANTIC ANALYSIS AND DISCOURSE PROCESSING **9**

Semantic Analysis: Meaning Structure of Language - Lexical Semantics - Word senses, relations - WordNet - Word Sense Disambiguation - Word Similarity, Discourse Processing: Reference Resolution - Anaphora Resolution Algorithms - Co-reference Resolution.

UNIT IV SPEECH RECOGNTION **9**

Large Vocabulary Continuous Speech Recognition: Introduction – Subword units – Subword Unit Models – Training of Subword Unit Models – Laguage Models – Statistical Language Modeling – Perplexity – Overall Recognition System – Semantic Postprocessor.

UNIT V TEXT TO SPEECH SYNTHESIS **9**

Computational Phonology: Speech Sounds and Phonetic Transcription - Phoneme and Phonological Rules - Machine learning of Phonological Rules - Mapping Text to Phones, HMM-based Approach: HMM-based Speech Synthesis System – F0 Modeling – Speech-parameter Generation from an HMM.

TOTAL PERIODS: 45

OUTCOMES

On successful completion of this course, the student will be able to

- Explain the language models.
- Explain levels of knowledge in language processing.
- Build a speech recognition with language models
- Explain the intricacies in developing a voice using HMM

TEXT BOOKS

1. Daniel Jurafsky and James H Martin, "Speech and Language Processing: An introduction to Natural Language Processing, Computational Linguistics and Speech Recognition", 2nd Edition, Prentice Hall, 2008.
2. Lawrence Rabiner, Biing-Hwang Juang, B. Yegnanarayana, "Fundamentals of Speech Recogntion" 1st Edition, Pearson, 2009.

REFERENCS

1. Tanveer Siddiqui, Tiwary U S, "Natural Language Processing and Information Retrieval", Oxford University Press, 2008.
2. Shrikanth Narayanan, Abeer Alwan, "Text To Speech Synthesis – New Paradigms and Advances", Prentice Hall, 2005.

PIF1041	INTRODUCTION TO NANO ELECTRONICS	L	T	P	C
		3	0	0	3

OBJECTIVES

To learn

- Basic working principle of MOSFET
- Theory of scaling
- Various nanoelectronic devices

UNIT I INTRODUCTION TO SEMICONDUCTOR 9

Energy band Theory, Theory of electrical conduction, Generation-Recombination, PN junction diode

UNIT II INTRODUCTION TO MOSFET 9

MOS capacitor, Threshold voltage, Current in MOSFET: Gradual channel approximation, Scaling theory of MOSFET

UNIT III PROBLEMS IN NANOSCALE MOSFETS 9

DIBL, SCE, Hot carrier degradation, Poly depletion, Gate leakage, Reverse SCE

UNIT 1V EVOLUTION OF MOSFET DEVICES 9

SOI MOSFET, FinFET, Tri-gate, Quadruple gate, Gate all-around or Nanowire FET, Nano-tube FET, Junctionless devices

UNIT V RECONFIGURABLE DEVICES 9

Metal contact, Schottky barriers, SBMOSFET, Reconfigurable MOSFET: different reconfigurable structures

TOTAL PERIODS : 45

OUTCOMES

At the end of the course, the student is expected to

- Interpret the challenges faced by CMOS devices in nano dimensions
- Explain the various alternate nanoelectronic devices
- Make use of novel devices to build circuits
- Choose a device for the given application

TEXT BOOK

1. Collinge J P, FinFETs and Other Multi-Gate Transistors, Springer, 2008

REFERENCES

3. Shunri Oda, and David Ferry, Silicon Nanoelectronics, Taylor & Francis Group, 2006
3. Ben G Streeman, Solid State Devices, Prentice Hall India Learning Private Limited, 2006.
4. M.Weber, et al "Reconfigurable Nanowire electronics – A review", Solid-State Electronics, ELSEVIER, 2014.