# UNIVERSITY OF NORTH BENGAL


# Syllabus for M.Tech.
# (Computer Science and Technology)
## (3 Year, 6 Semesters, Part Time, Self-Financed)

**Department of Computer Science and Technology, University of North Bengal**
Raja Rammohunpur, PO-N.B.U., Dist-Darjeeling, West Bengal, Pin-734013, India

(To be implemented from Session 2023-24)

# General Information regarding MOOCs/ NPTEL/ SWYAM/Open Courses

Ministry of Education, Government of India, New Delhi has developed one of the world's largest SWAYAM MOOCS Platform where several hundreds of courses have been hosted for the benefits of the aspiring Students which are available under SWAYAM/NPTEL online courses together. As advised by Ministry of Education, students to a large extent should be motivated for using online education through SWAYAM MOOCs Platform and SWAYAM PRABHA courses and allow Credits up to 20% of the total courses being offered in a particular program in a Semester. The institutions may kindly look at your curriculum and find the equivalent courses in SWAYAM for all the courses i.e. from first year to final year. The institutes may also find if there are any other equivalent courses which can be taken on SWAYAM and accordingly, decision may be taken at the university level as per the Credit Framework Regulations issued by UGC as well as AICTE. Universities/Colleges may accordingly recognize the credits of technical Courses which are taken up by the Students according to the UGC guidelines.

Keeping the above in view, students are given choices in core and other papers to select and complete from SWAYAM/NPTEL in consultation with the Departmental Committee or other appropriate bodies to decide the equivalence for the paper that may fit suitable according to the proposed syllabus.

Thus, any equivalent or related open course can be taken by any student from NPTEL or SWAYAM that is not taken by the student in the classroom after prior approval from the appropriate body in due time. Credit will be appropriated proportionately if there is any mismatch as per syllabus. Students are advised to consult the HoD prior to registration for such course to get the same considered for his/her results.

As per the corresponding theory paper chosen, laboratory assignments will be given by the concern teacher. In case of no separate lab marks from open/MOOCs course that includes laboratory as integrated part of the course, student may take the laboratory course if available in the department. Else, proportionate masks as decided by the Departmental Committee (DC) will assigned while preparing the result in case of such laboratory course.

Any class room paper can also be completed from NPTEL or SWAYAM by the student. However, the student may be allowed to appear in the University examination for the same paper if he/she has attended adequate class in the department as per rules. In addition to University fees all expenses related to SWAYAM/NPTL /MOOCs courses will be borne by the student himself/herself.

In case of delay of results from the concerned authority i.e. SWAYAM / NPTEL / MOOCS, department shall not bear any responsibility in this regard.

| | Structure of Proposed Syllabus of Six Semester (Part Time) M.Tech (Computer Science and Technology) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Semester** | **Paper Type** | **Paper Code** | **Paper Title** | **Credit** | **Periods/ Week** | **Exam. Marks** | **Continuing Evaluation** |
| 1 | I | CORE | CSMTCCT0101N | Advanced Data Structures and Algorithms | 4 | 4 | 70 | 30 |
| | | CORE | CSMTCCT0102N | Advanced Computer Architecture | 4 | 4 | 70 | 30 |
| | | CORE | CSMTCCT0103N | Advanced Data Communication and Computer Networks | 4 | 4 | 70 | 30 |
| | | CORE | CSMTCCP0104N | Data Structures and Algorithms Lab using C/C++/Java/Python | 2 | 4 | 70 | 30 |
| | | | | | **14** | **16** | **280** | **120** |
| | II | CORE | CSMTCCT0201N | Real Time Operating Systems | 4 | 4 | 70 | 30 |
| | | CORE | CSMTCCT0202N | Advanced RDBMS | 4 | 4 | 70 | 30 |
| | | CORE | CSMTCCT0203N | Elective:<br>• EO-01 : SWAYAM / MOOCs / Open Course | 4 | 4 | 70 | 30 |
| | | CORE | CSMTCCP0204N | RDBMS Lab | 2 | 4 | 70 | 30 |
| | | | | | **14** | **16** | **280** | **120** |
| 2 | III | CORE | CSMTCCT0301N | Selected Topics on Software Engineering | 4 | 4 | 70 | 30 |
| | | DSE | CSMTDET0302N | Electives:<br>• E31: Data Mining and Data Warehousing<br>• E32: Embedded and Real Time Systems<br>• E33: Distributed Systems<br>• E34: Computational Geometry<br>• EO-02: SWAYAM/MOOCs/Open Course | 4 | 4 | 70 | 30 |
| | | DSE | CSMTDET0303N | Electives:<br>• E36: ANN and Pattern Recognition<br>• E37: Machine Learning<br>• E38: Cryptography & Network Security<br>• E39: Big Data<br>• EO-03: SWAYAM/MOOCs/Open Course | 4 | 4 | 70 | 30 |
| | | AEC | CSMTAUT0304N | Elective:<br>• EO-04: SWAYAM / MOOCs /Open Course | 2 | 2 | 70 | 30 |
| | | | | | **14** | **14** | **280** | **120** |

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|---|---|---|---|---|---|---|---|---|
| | IV | DSE | CSMTDET0401N | Electives:<br>• E41: Deep Learning<br>• E42: Soft Computing<br>• E43: Natural Language Processing<br>• E44: Design and Operation of Data Centres<br>• EO-05: SWAYAM / MOOCs / Open Course | 4 | 4 | 70 | 30 |
| | | GE | CSMTGET0402N | Electives:<br>• E45: Cloud Computing<br>• E46: Parallel Computing<br>• E47: Data Storage Technologies<br>• E48: Wireless and Mobile Communication<br>• EO-06: SWAYAM / MOOCs / Open Course | 4 | 4 | 70 | 30 |
| | | SEC | CSMTSFT0403N | Electives:<br>• E50: Cyber Security<br>• E51: Internet of Things (IoT)<br>• E52: E-Commerce<br>• E53: Quantum Computing<br>• E54: Social Network Analysis<br>• E55: Digital Image Processing<br>• EO-07: SWAYAM/ MOOCS /Open Course | 4 | 4 | 70 | 30 |
| | | AEC | CSMTAUT0404N | Elective:<br>• EO-08 : SWAYAM / MOOCs / Open Course | 2 | 2 | 70 | 30 |
| | | | | | **14** | **14** | **280** | **120** |
| 3 | V | DSE | CSMTDET0501N | Elective:<br>• EO-09 : SWAYAM / MOOCs/Open Course | 4 | 4 | 70 | 30 |
| | | GE | CSMTGET0502N | Elective:<br>• EO-10: SWAYAM / MOOCs/Open Course | 4 | 4 | 70 | 30 |
| | | CORE | CSMTCCP0503N | Project Synopsis | 6 | 6 | 140 | 60 |
| | | | | | **14** | **14** | **280** | **120** |
| | VI | CORE | CSMTCCP0601N | Dissertation and Defence | 8 | - | 300 | - |
| | | CORE | CSMTCCP0602N | Grand Viva | 6 | - | - | 100 |
| | | | | | **14** | **-** | **300** | **100** |
| | | | | | **84** | | **2400** | |

## Detailed Syllabus

## Year 1: Semester 1

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### CSTC-101: Advanced Data Structures and Algorithms

**Course Code:** CSTE- 101

**Course Title:** Advanced Data Structures and Algorithms

**Brief Course Description:**

- The course introduces a number of highly efficient algorithms and data structures for fundamental computational problems across a variety of areas. Students are also introduced to techniques such as amortised complexity analysis.

**Prerequisite(s) and/or Note(s):**

- Fundamentals of Data Structures

**Course Objectives:**

- Understand and apply linear data structures-List, Stack and Queue.
- Understand the graph algorithms.
- Learn different algorithms analysis techniques.
- The fundamental design, analysis, and implementation of basic data structures.
- Principles for good program design, especially the uses of data abstraction.
- Various aspects of algorithm development

**Knowledge Acquired:**

- Able to analyze the efficiency of algorithm.
- Basic concepts in the specification and analysis of programs.
- Significance of algorithms in the computer field

**Skills Gained:**

- Apply data structures and algorithms in real time applications

**Competency Developed:**

- Solving algorithmic intensive applications

**Course Syllabus:**

**Unit 1: Linear Data Structures**
Introduction - Abstract Data Types (ADT), Stack, Queue, Circular Queue, Double Ended Queue, Applications of stack, Evaluating Arithmetic Expressions, Other Applications, Applications of Queue, Linked Lists, Singly Linked List, Circularly Linked List, Doubly Linked lists, Applications of linked list, Polynomial Manipulation.

**Unit 2: Non-Linear Tree Structures**
Binary Tree, expression trees, Binary tree traversals, applications of trees, Huffman Algorithm, Binary search tree, Balanced Trees, AVL Tree, B-Tree, Splay Trees, Heap operations, Binomial Heaps, Fibonacci Heaps, Hash set.

**Unit 3: Graphs**
Representation of graph, Graph Traversals, Depth-first and breadth-first traversal, Applications of graphs, Topological sort, shortest-path algorithms, Dijkstra‟s algorithm, Bellman-Ford algorithm, Floyd's Algorithm, minimum spanning tree, Prim's and Kruskal's algorithms.

**Unit 4: Algorithm Design and Analysis**
Algorithm Analysis, Asymptotic Notations, Divide and Conquer: Merge Sort, Quick Sort, Binary Search, Greedy Algorithms: Activity Selection Problem, Knapsack Problem, Dynamic Programming: Rod cutting problem, Matrix Chain Multiplication, Warshall‟s Algorithm for Finding Transitive Closure.

**Unit 5: Advanced Algorithm Design and Analysis**
Backtracking, N-Queen's Problem, Branch and Bound, Assignment Problem, P & NP problems, NP-complete problems, Approximation algorithms for NP-hard problems, Travelling salesman problem-Amortized Analysis.

**Suggestive Readings:**


1. Y. Langsam, M. Augenstin and A. Tannenbaum, Data Structures using C and C++, Pearson Education Asia, 2nd Edition, 2002.
2. Anany Levitin "Introduction to the Design and Analysis of Algorithms" Pearson Education, 2015
3. E. Horowitz, S.Sahni and Dinesh Mehta, "Fundamentals of Data structures in C++", University Press, 2007
4. E. Horowitz, S. Sahni and S. Rajasekaran, "Computer Algorithms/C++", Second Edition, University Press, 2007
5. Gilles Brassard, "Fundamentals of Algorithms", Pearson Education 2015
6. Harsh Bhasin, "Algorithms Design and Analysis", Oxford University Press 2015
7. John R.Hubbard, "Data Structures with Java", Pearson Education, 2015 7. M. A. Weiss, "Data Structures and Algorithm Analysis in Java", Pearson Education Asia, 2013


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## CSTC-102: Advanced Computer Architecture

**Course Code:** CSTC-102

**Course Title:** Advanced Computer Architecture

**Brief Course Description:**
- The course designed to provide students with a fundamental knowledge of computer hardware and computer systems, with an emphasis on system design and performance, elaborate idea about the different memory systems and buses. Further, to introduce the advanced processor architectures, importance of multiprocessor and multi-computers to the students.

**Prerequisite(s) and/or Note(s):**
- Principles of digital electronics
- Basic knowledge of Computer organization.

**Course Objectives:**
- Implement the Hardware for Arithmetic Operations.
- Develop the Pipelining Concept for a given set of Instructions.
- Distinguish the performance of pipelining and non-pipelining environment in a processor.

**Knowledge Acquired:**
- Computational models and Computer Architectures.
- Concepts of parallel computer models.
- Scalable Architectures, Pipelining, Superscalar processors, multiprocessors

**Skills Gained:**

- The course aims to provide students with a fundamental knowledge of computer hardware and computer systems, with an emphasis on system design and performance. The course concentrates on the principles underlying systems organisation, issues in computer system design, and contrasting implementations of modern systems.

**Competency Developed:**

- Analyze the performance of different scalar Computers.
- Development of software to solve computationally intensive problems.

**Course Syllabus:**

**Unit 1: Advanced Processors**

Instruction set architectures-CISC and RISC scalar processors-Super scalar processors-VLIW architecture- Multi-vector and SIMD computers-Vector processing principles-Cray Y-MP 816 system-Inter processor communication

**Unit 2: Multi-Processor and Multi-Computers**

Multiprocessor system interconnects- Cross bar switch, Multiport memory-Hot spot problem, Message passing mechanisms-Pipelined processors-Linear pipeline, on linear pipeline Instruction pipeline design-Arithmetic pipeline design.

**Unit 3: Memory Systems and Buses**

Memory hierarchy-cache and shared memory concepts-Cache memory organization-cache addressing models, Aliasing problem in cache, cache memory mapping techniques-Shared memory organization-Interleaved memory organization, Lower order interleaving, Higher order interleaving; Back plane bus systems-Bus addressing, arbitration and transaction

**Unit 4: Data Flow Computers and VLSI Computations**

Data flow computer architectures-Static, Dynamic-VLSI Computing Structures-Systolic array architecture, mapping algorithms into systolic arrays, Reconfigurable processor array-VLSI matrix arithmetic processors-VLSI arithmetic models, partitioned matrix algorithms, matrix arithmetic pipelines.

**Unit 5: Towards Parallel Computer Models**

Evolution of Computer architecture, system attributes to performance, Multi processors and multi computers, Multi-vector and SIMD computers, PRAM and VLSI models-Parallelism in Programming, conditions for Parallelism-Program Partitioning and Scheduling-program flow Mechanisms-Speed up performance laws-Amdahl‘s law, Gustafson‘s law-Memory bounded speedup Model.

**Suggestive Readings:**


1. Mano, M, Computer System and Architecture, (3rd Ed.), PHI, 1994
2. John L. Hennessy and David A. Patterson, Computer Architecture: A quantitative approach, 5th edition, Morgan Kaufmann Elseveir, 2013
3. Pal Chauduri, P., Computer Organisation and Design, PHI, 1994
4. Pranab Chakraborthy, Computer Organization and Architecture, Universities Press.
5. Rajaraman,V., and Radhakrishnan, T., Introduction to Digital Computer Design" (4th Ed.), PHI, 1997
6. Stallings. W, Computer Organization and Architecture, 2nd Ed., PHI,

7. C. Hamacher, Z. Vranesik, S. Zaky , Computer Organization, McGraw Hill
8. John P. Hayes, Computer Architecture and Organization, McGraw Hill
9. Tannenbaum, Structured Computer Organization, PHI
10. Vravice, Zaky & Hamacher, Computer Organization, TMH

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## CSTC-103: Advanced Data Communication and Computer Networks

**Course Code:** CSTE- 103

**Course Title:** Advanced Data Communication and Computer Networks

**Brief Course Description:**

- This course teaches the design and implementation techniques essential for engineering robust networks. Topics include networking principles, Transmission Control Protocol/Internet Protocol, naming and addressing (Domain Name System), data encoding/decoding techniques, link layer protocols, routing protocols, transport layer services, congestion control, quality of service, network services, Software Defined Networks (SDNs), programmable routers and overlay networks, wireless and mobile networking, security in computer networks, multimedia networking, and network management.

**Prerequisite(s) and/or Note(s):**

- Knowledge of C and C++
- Knowledge of fundamental data structures and associated algorithms.

**Course Objectives:**

- to give an understanding of how networks, especially the Internet, work,
- to give experience with large scale systems,
- to teach you network programming

**Knowledge Acquired:**

- Understand the Internet protocols
- Generalize this knowledge to other networking protocols.
- Think like a networking practitioner
- Create simplicity and reliability out of complexity and unreliability

**Skills Gained:**

- Build implementations of the Internet protocols

**Competency Developed:**

- Be a competent network and systems programmer.

**Course Syllabus:**

**Unit 1: Network layer**

Network Layer Services, Packet Switching, Performance, provided transport layers, implementation connectionless services, implementation connection oriented services, comparison ofvirtual –circuit and datagram subnets.IPV4 Address, Forwarding of IP Packets, Internet Protocol, ICMP v4, Mobile IP

**Unit 2*:* Routing Algorithms**

Distance Vector routing,Link State Routing, Path Vector Routing, Unicast Routing Protocol-Internet Structure, Routing Information Protocol, Open Source Path First, Border Gateway Protocol V4, Broadcast routing, Multicastingrouting, Multicasting Basics, Intradomain Muticast Protocols, IGMP.

**Unit 3: Addressing**

IPv6 Addressing, IPv6 Protocol, Transition from IPv4 to IPv6.Transport Layer Services, connectionless versus connection oriented protocols.Transport Layer Protocols: Simple Protocol, Stop and Wait, Go-Back-N, Selective repeat, Piggy Backing. UDP:User datagram,Services, Applications.TCP: TCP services, TCP features, segement, A TCP connection, Flow control,error control, congestion control.

**Unit 4*:* SCTP**

SCTP services SCTP features, packet format, An SCTP association,flow control, error control.QUALITY OF SERVICE:flow characteristics, flowcontrol toimprove QOS:scheduling, traffic shaping, resource reservation, admission control.

**Unit 5: Internet**

WWW and HTTP, FTP, Telnet, Domain name system, SNMP, Multimediadata, Multimedia in the Internet, recent developments

**Suggestive Readings:**


1. A. S. Tanenbaum, Computer Networks; Pearson Education Asia, 4th Ed., 2003
2. Behrouz A. Forouzan, Data Communication and Networking, 3rd Ed., TMH, 2004
3. Peterson & Davie, Computer Networks: A Systems Approach, Harcourt.
4. Bertsekas and Gallagher Data Networks, PHI
5. William Stallings, Data and Computer Communications, 9th Ed., PHI, 2004
6. Larry L. Peterson and Bruce S. Davie, Computer Networks: A Systems Approach, 5th Ed., Morgan Kaufmann Publishers, 2012
7. James F. Kurose, Keith W. Ross, Computer Networking: A Top-Down Approach, 6th Ed., Addison-Wesley, 2008
8. W. Tomasi, Introduction to Data Communications and Networking, Pearson Education, 2007
9. S. Haykin, Digital Communications, John Wiley & Sons, Inc., 2005
10. P.C. Gupta, Data Communications and Computer Networks, PHI,2006
11. Unix Network Programming: Networking APIs: Sockets and XTI, (Volume 1) by W. Richard Stevens, 2nd Ed., PHI, 1999
12. Computer networks, Mayank Dave, CENGAGE.2)Computer Networks: A Systems Approach , LL Peterson, BS Davie, Morgan-Kauffman , 5th Edition, 2011.3)Computer Networking: A Top-Down Approach JF Kurose, KW Ross, Addison-Wesley , 5th Edition, 2009.


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**CSTL-104: Data Structures and Algorithms Lab using C/C++/Java/Python**

The concern teacher will provide lab assignments based on the theoretical aspects,

## CSTC -201: Real Time Operating Systems

**Course Code:** CSTE- 201

**Course Title:** Real Time Operating Systems

**Brief Course Description:**

- Introduction to the basic concepts and principles of real-time operating systems. The topics to be covered include operating system concepts and structures, multiple processes, inter-process communication, real-time process scheduling, memory management, virtual memory, file system design, security, protection, and programming environments for real-time systems.

**Prerequisite(s) and/or Note(s):**

- Basic concepts of Operating System

**Course Objectives:**

- The objective of the course is to introduce the principles shared by many real-time operating systems, and their use in the development of embedded multitasking application software.
- To understand the basics of operating systems tasks and basic OS architectures and develop these to RTOS
- To understand problems and issues related with multitasking
- To learn strategies to interface memory and I/O with RTOS kernels

**Knowledge Acquired:**

- After completing the course students will understand the fundamental concepts of real-time operating systems.
- To understand concepts of task scheduling

**Skills Gained:**

- They will have an in depth knowledge about the real time operating systems and its applications.
- To impart skills necessary to develop software for embedded computer systems using a real-time operating system.

**Competency Developed:**

- To develop the competency in the

**Course Syllabus:**

**Unit 1: Introduction to Real-Time Systems**

Historical background, Elements of a Computer Control System, RTS- Definition, Classification of Real-time Systems, Time Constraints, Classification of Programs; Concepts of Computer Control: Introduction, Sequence Control, Loop Control, Supervisory Control, Centralized Computer Control, Hierarchical Systems.

**Unit 2: Computer Hardware Requirements for Real-Time Applications**

Introduction, General Purpose Computer, Single Chip Microcomputers and Microcontrollers, Specialized Processors, Process-Related Interfaces, Data Transfer Techniques, Communications, Standard Interface.

**Unit 3: Languages for Real-Time Applications**

Introduction, Syntax Layout and Readability, Declaration and Initialization of Variables and Constants, Cutlass, Modularity and Variables, Compilation of Modular Programs, Data types, Control Structures, Exception Handling, Low-level facilities, Co-routines, Interrupts and Device Handling, Concurrency, Real-Time Support, Overview of Real-Time Languages.

**Unit 4: Operating Systems**

Introduction, Real-Time Multi-Tasking OS, Scheduling Strategies, Priority Structures, Task Management, Scheduler and Real-Time Clock Interrupt Handler, Memory Management, Code Sharing, Resource Control, Task Co-Operation and Communication, Mutual Exclusion.

**Unit 5: Design of RTS**

Introduction, Specification Documents, Preliminary Design, Single-Program Approach, Foreground/ Background System; RTS Development Methodologies: Introduction, Yow-don Methodology, Ward and Mellor Method, Hately and Pirbhai Method.

**Suggestive Readings:**


1. Real-Time Computer Control, Stuart Bennet, 2nd Edn. Pearson Education. 2008.
2. "Real-Time Systems", C.M. Krishna, Kang G Shin, McGraw-Hill International Editions, 1997.
3. Real-Time Systems Design and Analysis, Phillip. A. Laplante, second edition, PHI, 2005.
4. Embedded Systems, Raj Kamal, Tata McGraw Hill, India, third edition, 2005.


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## CSTC- 202: Advanced RDBMS

**Course Code: CSTE- 202**

**Course Title: Advanced RDBMS**

**Brief Course Description:**

- This course intends to introduce more advanced topics in databases such as data mining and data warehousing, distributed databases and client server architecture after introducing the DBMS implementation.

**Prerequisite(s) and/or Note(s):**

- Should have knowledge of relational database systems and experience in computer programming.

**Course Objectives:**

- To the design and implement Distributed Databases.
- To understand advanced DBMS techniques to construct tables and write effective queries, forms, and reports
- Understand Functional Dependency and Functional Decomposition.
- In depth information about system implementation techniques, data storage, representing data elements, database system architecture, the system catalog, query processing and optimization, transaction processing concepts, concurrency control techniques, database recovery techniques, database security and authorization, enhanced data models for advanced applications, temporal databases, deductive databases, database technology for decision support systems, distributed databases and client server architecture, advanced database concepts, and emerging technologies and applications.

**Knowledge Acquired:**

- Execute various advance SQL queries related to Transaction Processing & Locking using concept of Concurrency control.
- Understand how transactions are processed in a database.
- Discuss/explain the concepts of Distributed Databases and Data Warehousing.
- Discuss/explain some database security issues.

**Skills Gained:**

- Discuss/explain the different techniques in Concurrency Control.
- Perform PL/SQL programming using concept of Cursor Management, Error Handling, Package and Triggers.
- Tune and Optimize some Database Applications.

**Competency Developed:**

- Apply various Normalization techniques.

**Course Syllabus:**

**Unit 1: Database Design**

Basics of DBMS, Functional Dependencies, Armstrong's axioms for FD's, Closure of a set of FD's, Minimal covers, Lossy and Non-loss Decomposition, Different normal forms; Dependency Preservation and BCNF, Multi-valued Dependencies and 4NF, Join dependencies and definition of 5NF; ERD, Extended ERD, conversion of ER diagrams to relations, integrity constraints, Mapping and Participation Constraints, Aggregation, Converting the database specification in E/R notation to the relational schema

**Unit 2: Relational Model**

Languages and Systems: Relation Algebra, Expressions, model; ER to relational mapping; Basic Operators; Various types of joins, Division,; Relational Calculus; SQL; Embedded and Dynamic SQL; Creation and Basic Query Structure; DDL, DML, DCL; Update behaviours, Views and Triggers, Basic and nested queries, Aggregation functions group by and having clauses, Nested Subqueries and Sets, Introduction to Oracle Architecture, PL/SQL, IBM DB2 case study- Architecture of DB2, EER to Relational mapping, Translating SQL into relational algebra

**Unit 3: Transactions Management**

Concepts, needs, states, features, properties, recover; Heuristics in query optimization, Selectivity and cost estimates in query optimization, Semantic query optimization, Conflicts and Aborts, Serial and concurrent schedules, serializability and testing, Recoverable and non-recoverable schedules, Cascading rollbacks, cascade-less schedules; Two Phase Commit, Log based Recovery, Checkpoint/Save Points, Concurrency, Serialized and non-serialized schedules, Testing for serializability, Concurrency: need, issues and control; Locking and serializability, Protocols; Deadlocks and starvation, deadlock handling, Recovery Isolation Levels, Recoverable Schedule etc, SQL Facilities for Concurrency

**Unit 4: Information Retrieval Systems**

Multidimensional Indexes: Data Cubes, Grid Files, R-trees.

**Unit 5: Database Recovery**

Classification of failures, Security and Authentication: Recovery concepts, Deferred updates technique, Immediate update technique, Shadow paging, ARIES recovery algorithm, Discretionary access control, Mandatory access control and multi-level security, Statistical database security; System Recovery, Media

Recovery, Log based recovery, shadow paging, buffer management, SQL Facilities for recovery, OLTP environments,

**Unit 6: Distributed Databases**
Distributed databases and issues, Data Distribution, Data fragmentation, replication and allocation in distributed databases, Types of distributed database systems Query processing in distributed databases, Distributed Transactions; Concurrency control and recovery in distributed databases; NoSQL, CAP Theorem and BASE Properties, Types of NoSQL Systems; Dimensionality reduction techniques; Active database concepts;

**Unit-1Overview of Storage and Indexing, Disks and Files**
Data on external storage; File organizations and indexing; Index data structures; Comparison of file organizations; Indexes and performance tuning Memory hierarchy; RAID; Disk space management; Buffer manager; Files of records; Page formats and record formats

Unit 8: Indexing
Tree Structured Indexing: Intuition for tree indexes; Indexed sequential access method; B+ trees, Search, Insert, Delete, Duplicates, B+ trees in practice; **Hash-Based Indexing:** Static hashing; Extendible hashing, Linear hashing,comparisons

**Unit 5: Query Evaluation, External, Sorting, Evaluating Relational Operators**
The system catalog;Introduction to operator evaluation; Algorithms for relational operations; Introduction to query optimization; Alternative plans: A motivating example; what a typical optimizer does. When does a DBMS sort data? A simple two-way merge sort; External merge sort; The Selection operation; General selection conditions; The Projection operation; The Join operation; The Set operations; Aggregate operations; The impact of buffering

**Unit: A Typical Relational Query Optimizer**
Translating SQL queries in to Relational Algebra; Estimating the cost of a plan; Relational algebra equivalences; Enumeration of alternative plans; Nested sub-queries; other approaches to query optimization.

**Unit 8: Physical Database Design and Tuning**
Introduction; Guidelines for index selection, examples; Clustering and indexing; Indexes that enable index-only plans; Tools to assist in index selection; Overview of database tuning; Choices in tuning the conceptual schema; Choices in tuning queries and views; Impact of concurrency; DBMS benchmarking.

**Unit 7: Advanced Topics: Parallel Databases**
Performance measure, Parallel operations for relational operations, Information Integration; Federated Database; Data Warehouses; Mediators; Schema matching methods; Temporal databases, Spatial databases, multi-media databases, Graph Databases, Big Data;

**Unit 8: Recent Applications**
Mobile databases; Multimedia databases;Geographical Information Systems; Genome data management;

**Suggestive Readings:**


1. Abraham Silberschatz, Henry F. Korth, S. Sudharshan, Database System Concepts, Sixth Edition, TMH, 2011
2. Bipin Desai, An Introduction to database systems, Galgotia Publications, 1991
3. C. J. Date, A. Kannan, S. Swamynathan, An Introduction to Database Systems, 8th Ed., Pearson Education, 2006
4. G. K. Gupta, Database Management Systems, TMH, 2011
5. Hector Garcia-Molina, Jeff Ullman and Jennifer Widom, Database Systems: The Complete Book, 2nd edition, Prentice Hall, 2008.

6. Hector Garcia-Molina, Jeff Ullman, and Jennifer Widom, "Database Systems: The Complete Book", Pearson, 2011.
7. Jim Melton, Alan Simon, Understanding the new SQL: A complete Guide, Morgan Kaufmann Publishers, 1993
8. Elmasri and Navathe, *Fundamentals of Database Systems*, 7th Edition, Addison Wesley
9. Niall O'Higgins, "Mongo D B and Python", O'reilly, 2011.
10. P. Rob and C. Coronel, Database Systems: Design, Implementation, and Management, 7th Ed., Thomson Learning, 2006
11. Peter Bailis, Joseph Hellerstein, and Michael Stonebraker, Readings in Database Systems, 5th edition, The MIT Press, 2005
12. Peter Rob and Carlos Coronel, Database Systems: Design, Implementation, and Management, 7th Ed., Thomson Learning, 2006
13. Philip Lewis, Arthur Berstein and Michael Kifer, Databases and Transaction Processing-An application oriented approach, Addison Wesley, 2002
14. Raghu Ramakrishnan, Database Management Systems, 4th Ed., TMH, 2010
15. Ramez Elmasri, Shamkant B. Navathe, Fundamentals of Database Systems, Fifth 8th Ed., Pearson, 2008
16. S. K. Singh, Database Systems Concepts, Design and Applications, Pearson Education 2006
17. Silberschatz, Korth and Sudarshan, "Database Concepts", Sixth Edition, Tata McGraw Hill, 2010.

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## CSTE- 203: Elective 1 (SWAYAM)

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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## CSTL-204: RDBMS Lab

**Course Code:** CSTL- 204

**Course Title:** RDBMS Lab

**Brief Course Description:**

- This course intends to introduce more advanced topics in databases such as data mining and data warehousing, distributed databases and client server architecture after introducing the DBMS implementation.

**Prerequisite(s) and/or Note(s):**

- Should have knowledge of relational database systems and experience in computer programming.

**Course Objectives:**

- To the design and implement Distributed Databases.
- To explore the features of a Database Management Systems
- To interface a database with front end tools
- To understand the internals of a database system

**Knowledge Acquired:**

- Execute various advance SQL queries related to Transaction Processing & Locking using concept of Concurrency control.
- Discuss/explain the concepts of Distributed Databases and Data Warehousing.
- Discuss/explain some database security issues.

**Skills Gained:**

- Perform PL/SQL programming using concept of Cursor Management, Error Handling, Package and Triggers.
- Tune and Optimize some Database Applications.

**Competency Developed:**

- Design effective database.

**Course Syllabus:**

Study features of a commercial RDBMS package such as Oracle, Foxpro, MS Access and Structures Query Language (SQL) use with the RDBMS. Laboratory exercises should include defining scheme for applications, creation of a database, writing SQL queries to retrieve information from the database. Use of host language interface with embedded SQL. Students should learn to use the forms and report writer packages available with the chosen RDBMS product. Students are also to be exposed to front-end development tools, ODBC; Internet based access to databases and database administration.

Experiments in the Following Topics:

1. Data Definition - Manipulation of Tables and Views.
2. Database Querying Simple queries - Nested queries - Sub queries and Joins.
3. Triggers.
4. Transaction Control.
5. Embedded SQL.
6. Database Connectivity with Front End Tools.
7. Front End Tools / Programming Languages.
8. High level language extensions - PL/SQL Basics.
9. Procedures and Functions.

Database Design and Implementation i.e. Accounting for a shop, Database manager for a magazine agency or newspaper agency, Ticket booking for performances, Preparing greeting and birth day cards, Personal accounts - insurance, loans, mortgage payments etc., Doctor's diary, billing, Personal bank account, Class marks management, Hostel accounting, Video tape library, History of cricket scores, Cable transmission program manager, Personal library.

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## CSTC- 301: Selected Topics on Software Engineering

**Course Code:** CSTC- 301

**Course Title:** Selected Topics on Software Engineering

**Brief Course Description:**

- This course focuses on software engineering for smart, critical, and complex software-intensive systems
- This course is intended to provide an extensive hands-on experience in dealing with various issues of software development. It involves a semester-long group software development project spanning analysis of requirements, construction of software architecture and design, implementation, and quality assessment
- The requirements specification module focuses on methods to transit from user requirements to high-quality technical requirements
- Testing management model focuses on testing strategies
- Code quality module focuses on code analysis, code review, and code refactoring
- Complex system module focuses on verification and validation of complex software systems

**Prerequisite(s) and/or Note(s):**

- Basic knowledge about the principles of software engineering and the software lifecycle.
- Sufficient programming skills for the team development project.

**Course Objectives:**

After having taken this course, students should be able to:

- Identify and correct typical requirements quality issues
- Apply different testing, code review, code analysis, and code refactoring approaches
- Explain industrial state of the practice methods of advanced software engineering
- To introduced the current developments in the field of software engineering

**Knowledge Acquired:**

- State-of-the-art knowledge on concepts, methods, and technology platforms in the field of Software Engineering
- Can explain the development of scientific knowledge and engineering methods in the field of Software Engineering

**Skills Gained:**

- Can plan and carry out independent applied research work or practical projects in the topics covered by the curriculum.
- Can review research work, and relate it to established knowledge in the topics covered by the curriculum
- Can follow scientific methods to review, evaluate or compare software tools and frameworks which are relevant for the topics covered by the curriculum
- Students will apply the requirement specification, testing techniques, and code review and refactoring to homework assignments and group projects throughout the course

**Competency Developed:**

- Can participate in research discussions, practical projects and research collaboration in the topics covered by the special curriculum

**Course Syllabus:**

**Unit 1: Overview**
Introduction: FAQs about Software Engineering; Professional and Ethical Responsibility; Software Process: Models; Process Iteration, Specification, Software Design and Implementation; Verification & Validation; Software Evolution; Automated Process Support.

**Unit 2: Agile Process Models**
Definition, advantages and disadvantages, Continuous Software Engineering/DevOps, compare and contrast different agile approaches, Extreme programming and Scrum; Software Process Improvement

**Unit 3: System Models, Software Prototyping and Specifications System models**
Context, Behavioural, Data, and Object models, CASE Workbenches; Software Prototyping: Prototyping in the Software Process, Rapid Prototyping Techniques, User Interface Prototyping; Specifications: Formal Specification in the Software Process, Interface Specification, Behavioural Specification.

**Unit 4: Software Architectural Design**
Introduction: System Structuring; Control Models; Modular Decomposition; Domain- Specific Architectures; Object Oriented Design: Objects and Object Classes and Design Process, Design Evolution; Real Time Software Design: Systems Design, Real-Time Executives, Monitoring and Control Systems, Data Acquisition Systems; Design with Reuse: Component-Based Development, Application Families, Design Patterns; User Interface Design; Distributed Systems Architectures: Multiprocessor Architectures; Client-Server Architectures, Distributed Object Architectures; CORBA (Common Object Request Broker Architecture)

**Unit 5: Verification, Validation and Testing**
Verification and Validation: Static Vs. Dynamic, Goals, Debugging, Software Inspections / Reviews, Clean-Room Software Development; Software Testing: Defect Testing, Integration Testing, Interface Testing, Object-Oriented Testing, Testing Workbenches; Security and automated testing tools (static/dynamic/fuzzing)

**Unit 6: Project Management**
Management Activities, Project Pl Software Project Management and Requirements Project Management: Management Activities, Project Planning, Project Scheduling, Risk Management; Software Requirements: Functional and Non-Functional Requirements, User Requirements, System Requirements, Requirements Document; Requirements Engineering Process: Feasibility Studies, Requirements Elicitation and Analysis, Requirements Validation, Requirements Management

**Unit 7: Manging People**
Introduction; Limits to Thinking; Memory Organization; Knowledge Modeling; Motivation; Group Working; Choosing and Keeping People; the People Capability Maturity Model

**Unit 8: Product Metrics**
Measures, indicators, principles, process, Function point and LOC based metrics, Logical vs Physical, McCabe's Cyclomatic Complexity, Metrics for testing, Metrics for maintenance; Estimate the size of the product, effort (person-months), schedule; Estimation for agile projects, PERT and CPM; Reliability Engineering- Faults, errors, failures, Fault management, Reliability and availability; System Security; Software deployment and maintenance

**Unit 9: Software Cost Estimation and Quality Management**
Software Cost Estimation: Productivity, Estimation Techniques, Algorithmic Cost Modelling, Project Duration and Staffing; Quality Management: Quality Assurance and Standards, Quality Planning, Quality Control, Software Measurement and Metrics; Process Improvement: Process and Product Quality, Process Analysis and Modelling, Process Measurement, the SEI Process Maturity Model, and Process Classification

**Unit 10: Evolution**
Legacy Systems: Structures, Design, and Assessment; Software Change: Program Evolution Dynamics, Software Maintenance, Architectural Evolution; Software Re- Engineering: Source Code Translation, Reverse Engineering, Program Structure Improvement, Program Modularization, Data Re-Engineering; Configuration Management; Global Software development, Reuse-oriented programming and open-source software (e.g. code search, trust), Software archaeology and code comprehension, Software 2.0

**Suggestive Readings:**


1. Ali Behforooz, and Frederick J. Hudson, Software Engineering Fundamentals, Oxford University Press
2. Bernd Bruegge and Allen H. Dutoit , Object-Oriented Software Engineering: Using UML, Patterns and Java, 2nd Edition, , Prentice Hall, 2003.
3. C. Larman, Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and the Unified Process, 2nd ed.
4. Dean Leffingwell, Don Widrig , Managing Software Requirements: A Use Case Approach, 2nd edition, , Addison Wesley
5. F. Brooks, The Mythical Man-Month, 2nd edition, Addison-Wesley, 1995,
6. G. Booch, Benjamin-Cummings, Object-Oriented Analysis and Design, with Applications, , 1994
7. G. Schneider and J. P. Winters , Applying Use Cases: A Practical Guide, , Addison-Wesley, 1998.
8. Ghezzi, Jayazeri, and Mandrioli, Fundamentals of Software Engineering, Prentice-Hall
9. I. Sommerville, Software Engineering, 9th edition, Addison Wesley Professional, 2010
10. J. F. Peters and W. Pedrycz, Software Engineering: An Engineering Approach, John Wiley and Sons
11. J. Martin and J. Odell, Object-Oriented Methods: A Foundation, Prentice-Hall, 1995
12. J. Rumbaugh, I. Jacobson and G. Booch, The Unified Modeling Language User Manual, G. Booch, J. Rumbaugh and I. Jacobson, Addison-Wesley, 1998.
13. Roger Pressman, Software Engineering: A Practitioner's Approach, McGraw-Hill
14. The Unified Modeling Language Reference Manual, , Addison-Wesley, 1998


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**CSTE- 302(Electives):**

## E31: Data Mining and Data Warehousing

**Course Code:** CSTE- 302:E31

**Course Title:** Data Mining and Data Warehousing

**Brief Course Description:**

- Data Mining and Data Warehousing are class of analytical techniques that examine a large amount of data to discover new and valuable information. This course is designed to introduce the core concepts of data mining and data warehousing, its techniques, implementation, benefits, and outcome expectations from this new technology. Data warehousing involves data pre-processing, data integration, and providing online analytical processing (OLAP) tools for the interactive analysis of multidimensional data, which facilitates effective data mining. This course also introduces data warehousing and data mining techniques and their software tools.

**Prerequisite(s) and/or Note(s):**

- No specific prerequisite

**Course Objectives:**

- Introduce data mining principles and techniques.

- Introduce the concepts of Data Warehousing, difference between database and data warehousing.
- To understand the principles of Data warehousing and Data Mining.
- To be familiar with the Data warehouse architecture and its implementation.
- To know the Architecture of a Data Mining system.
- To understand the various Data pre-processing Methods.
- To perform classification and prediction of data.
- Introduce data mining as a cutting edge business intelligence tool.
- Describe and demonstrate basic data mining algorithms, methods, tools,
- Describe ETL Model and the Star Schema to design a Data Warehouse.

**Knowledge Acquired:**
**At the end of the course student will be able to:**

- Design a data warehouse or data mart to present information needed by the client and can be utilized for managing clients.
- Use data mining tools for projects and to build reliable products as per demand.
- Identify data mining problems and implement the data warehouse
- Write association rules for a given data pattern.
- Choose between classification and clustering solution.

**Skills Gained:**

- Design and implement a quality data warehouse or data mart effectively and administer the data resources in such a way that it will truly meet management's requirements.

**Competency Developed:**

- Evaluate standards and new technologies to determine their potential impact on your information resource for a large complex data warehouse/data mart.

**Course Syllabus:**

**Unit 1: Introduction to Data Mining**

Definition of data mining ,Data Mining functionalities, Classification of data mining systems , Data Mining Applications, Architectures of data mining systems, Data mining class comparison.

**Unit 2: Data Mining Algorithms**

Concept Description: Definition, Data Generalization and Summarization – Based Characterization, Mining Descriptive Statistical Measures in Large Databases; Mining Association Rules: Association Rule Mining, Market Basket Analysis, Association Rule Classification, The Apriori Algorithm, Mining Multilevel Association Rules, Constraint-Based Association Mining, Sequential mining

**Unit 3: Classification and Prediction**

What is Classification and Prediction? Data Classification Process, Issues Regarding Classification and Prediction, Classification by Decision Tree Induction, Bayesian Classification, Classification Based on Association Rule Mining, Other Classification Methods Cluster Analysis: What is Cluster Analysis? Types of Data in Cluster Analysis, Categorization of Clustering Methods, Partitioning methods

**Unit 4: Introduction to Data Warehousing**

Introduction to Decision Support System: DSS Definition, History of DSS, Ingredients of DSS, Data and Model Management, DSS Knowledge base, User Interfaces, The DSS Users, Categories and Classes of DSSs Need for data warehousing, Operational & informational data, Data Warehouse Definition and characteristics, Operational

**Unit 5: Data Stores Data warehouse Components**

Architectural components, Data Preprocessing: Why Preprocess Data? Data Cleaning Techniques, Data Integration and Transformation, Data Reduction Techniques, Discretization and Concept Hierarchy, Generation for numeric and categorical data, Significant role of metadata, Building a Data warehouse, Benefits of Data Warehousing.

**Unit 6: OLAP in the Data Warehouse**

A Multidimensional Data Model, Schemas for Multidimensional Databases: Stars, Snowakes, Star join and Fact Constellations Measures, Concept Hierarchies, OLAP Operations in the Multidimensional Data Model, Need for OLAP, OLAP tools , Mining Multimedia Databases, Mining Text Databases, Mining the World Wide Web.

**Suggestive Readings:**


1. Alex Berson and Stephen J. Smith, Data Warehousing, Data Mining & OLAP, Tata McGraw – Hill Edition, 2007.
2. Arun K Pujari, Data Mining Techniques, Universities Press
3. G. K. Gupta, Introduction to Data Mining with Case Studies, Prentice Hall of India, 2006.
4. H. Dunham, Data Mining: Introductory and Advanced Topics, Pearson Education.
5. Jiawei Han, Micheline Kamber and Jian Pei, Data Mining Concepts and Techniques, 3rd Edition, Elsevier, 2011.
6. K.P. Soman, Shyam Diwakar and V. Ajay, Insight into Data mining Theory and Practice, Easter Economy Edition, Prentice Hall of India, 2006.
7. Mallach, Data Warehousing System, McGraw Hill.
8. Margaret Dunham, Data Mining: Concepts and Techniques, Morgan Kaufmann
9. Michael. J. Berry, Gordon. S. Linoff, Mastering Data Mining, Wiley Edition, 2nd edition, 2012.
10. Pang-Ning Tan, Michael Steinbach, Vipin Kumar, Introduction to Data Mining, Pearson, First impression, 2014.
11. Paul Punnian, Data Warehousing Fundamentals, John Wiley
12. Ralph Kimball, The Data Warehouse Lifecycle toolkit, John Wiley
13. Sam Anahory, Dennis Murray, Data Warehousing in the Real World: A Practical Guide for Building Decision Support Systems, Pearson Education.
14. Sam Anahory, Dennis Murray: Data Warehousing in the Real World, Pearson, 2012.


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## E32: Embedded and Real Time Systems

**Course Code:** CSTE- 302:E32

**Course Title:** Embedded and Real Time Systems

**Brief Course Description:**

- Introduces microcontrollers and embedded processors. Gives knowledge of embedded system programming. Students can independently design and develop a hardware platform encompassing a microcontroller and peripherals. Firmware is developed in C language and assembly language programming.

**Prerequisite(s) and/or Note(s):**

- Basic understanding of Operating Systems, computer organization
- Basic programming skill

**Course Objectives:**

- Understand the concepts of embedded system design and analysis
- Learn the architecture and programming of ARM processor
- Be exposed to the basic concepts of embedded programming
- Learn the real time operating systems
- Understand the concepts of embedded system design and analysis
- Learn the architecture and programming of ARM processor
- Be exposed to the basic concepts of embedded programming
- Learn the real time operating systems

**Knowledge Acquired:**

- Design and implement embedded circuits involving microcontrollers, sensors, and actuators,
- Use code and circuit design tools,
- Design, program and debug embedded sensing and control software,

**Skills Gained:**

- Apply the concepts of embedded system.
- Explain and work on Real time operating systems.

**Competency Developed:**

- Design and program for Embedded Systems.

**Course Syllabus:**

**Unit 1: Introduction**

Embedded Systems, Challenges of Embedded Systems, fundamental components, examples of embedded systems, hardware fundamentals, gates, timing diagrams, memory, DMA, buses, interrupts, schematiIT, build process of embedded systems, examples.

**Unit 2: Embedded System Design and Implementation**

Requirements of an embedded system, Meeting real time constraints, Multi-state systems and function sequences, architecture styles and patterns, design methodologies and practices, implementation aspects and choices, 8051/89c51 and Advanced Processor Architectures, Memory Organization and Real world Interfacing, Memory access procedure, types of memory, memory management methods, Pointer related issues, polling versus interrupts, types of interrupts, interrupt latency, re-entrancy, interrupt priority, programmable interrupt controllers, interrupt service routines.

**Unit 3: Real-Time Operating Systems**

Desktop Operating Systems versus RTOS, Basic design using an RTOS, need for Board Support Packages, Interrupt handling in RTOS, task management, race conditions, priority inversion, scheduling, inter task communication, timers, semaphores, queues, OS Security Issues; *RTOS Programming*-Micro/Os-II and VxWorks: Basic Functions and Types of RTOSES, RTOS mCOS-II, RTOS VxWorks Real-time Operating System, Windows CE, OSEK and Real-time Linux functions. Windows CE, OSEK, Linux 2.6.x and RTLinux

**Unit 4: Programming Concepts and Embedded Programming in C, C++ and Java**

Software Programming In Assembly Language (ALP) and in High-level Language C, Object-Oriented Programming, Embedded Programming in C++, Embedded Programming in Java.

**Unit 5: Embedded Software Development Tools**

Host and target machines, cross compilers, linker and locators for embedded software, Emulators and debuggers, address resolution, locating program components, initialized data and constant strings, PROM programmers, ROM emulators, Flash memory.

**Suggestive Readings:**


1. Ajay Deshmukh, Microcontrollers: Theory and Applications, TMH
2. Andrew N Sloss, Dominic Symes, Chris Wright, ARM System Developer's Guide: Designing and Optimizing System Software, Morgan Kaufmann Publisher, 2008.
3. C R Sarma, Embedded Systems Engineering, Universities Press
4. C.M. Krishna, Kang G. Shin, Real-Time Systems, International Editions, Mc Graw Hill 1997
5. David. E. Simon, An Embedded Software Primer, 1st Edition, Addison Wesley Professional, 2007.
6. Frank Vahid and Tony Givargis, Embedded System Design, John Wiley & Sons publishers, 2002
7. Jane W. S. Liu, Real Time Systems, Pearson Education, 3rd Indian Reprint, 2003.
8. Jonathan W. Valvano, Embedded Microcomputer Systems Real Time Interfacing, 3rd Edition Cengage Learning, 2012.
9. K. V. K. K. Prasad, Embedded Real-Time Systems: Concepts, Design & Programming, Dream Tech Press, 2005.
10. Lyla B. Das, Embedded Systems: An Integrated Approach, Pearson Education, 2013.
11. M. A. Mazidi & J.G. Mazidi & R.D. McKinley Raj Kamal, The 8051Microcontroller and Embedded Systems, 2nd Ed.
12. Marilyn Wolf, Computers as Components - Principles of Embedded Computing System Design, 3rd Edition, Morgan Kaufmann Publisher, 2012.
13. Raj Kamal , Embedded Systems Architecture, Programming and Design, Tata McGraw-Hill, 2003
14. Raj Kamal, Microcontroller, 2nd Indian Print
15. Raymond J. A. Buhr, Donald L. Bailey, An Introduction to Real-Time Systems: From Design to Networking with C/C++, Prentice Hall, 1999.
16. Sriram V. Iyer, Pankaj Gupta, Embedded Real-time Systems Programming, TMH, 2004
17. Tammy Noergaard, Embedded Systems Architecture, Elsevier, 2006.
18. Wayne Wolf, Computers as Components – Principles of Embedded Computing System Design, Morgan Kaufmann Publisher (An imprint of Elsevier), 3rd Edition, 2008.


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## E33: Distributed Systems

**Course Code:** CSTE- 302:E33

**Course Title:** Distributed Systems

**Brief Course Description:**

- This course covers a broad range of topics related to parallel and distributed computing, including parallel and distributed architectures and systems, parallel and distributed programming paradigms, parallel algorithms and scientific and other applications of parallel and distributed computing.

**Prerequisite(s) and/or Note(s):**

- Fundamentals of Operating Systems
- Basic Programming skills

**Course Objectives:**

- Familiarize the students with the basics of distributed computing systems.
- This course provides an insight into Distributed systems.
- Topics include- Peer to Peer Systems,

- Transactions and Concurrency control,
- To introduce the concepts of distributed file systems, shared memory and message passing systems, synchronization and resource management.
- Security and Distributed shared memory

**Knowledge Acquired:**
At the end of the course student will be able to:
- Compare various resource allocation strategies.
- Understand Transactions and Concurrency control.
- Understand Security issues.
- Understanding Distributed shared memory.

**Skills Gained:**
- Design distributed systems for basic level applications.

**Competency Developed:**
- Design and develop various algorithms for problems in distributed computing

**Course Syllabus:**

**Unit 1: Fundamentals of Distributed System**
Definition, Evolution, Goals, types of distributed systems; system models, issues in the design of distributed systems, distributed computing environment, Operating System Support, Networking support

**Unit 2: Basics of Architectures, Processes, and Communication:**

Architectures - Types of System Architectures, Self-Management in Distributed Systems; Processes - Basics of Threads, Virtualization, Roles of Client and Server, Code Migration;

**Unit 3: Processes and Communication**

Types of Communications, Remote Procedure Calls, Message-Oriented Communication, Stream-Oriented Communication, Multicasting; Message Passing – Features and Issues, Synchronization, Buffering, Process Addressing, Failure Handling; Remote procedure call (RPC)- Model, Implementation, Stub generation, RPC messages, Marshaling, server Management, Call semantics, communication protocols for RPC-Client server binding – RMI.

**Unit 4: Naming**

Names, Identifiers, Addresses, Flat Naming, Structured Naming, Attribute Based Naming

**Unit 5: Distributed Shared Memory**
Distributed shared memory- Design and implementation issues- Sequential consistency – Release consistency, Process migration Features & Mechanism

**Unit 6: Synchronization**
Synchronizing physical clocks, Logical clocks, Distributed coordination, Event Ordering, Mutual Exclusion, Deadlock, Global Positioning of Nodes, Election algorithms.

**Unit 7: Distributed File Systems**
Introduction, File Models, File accessing, sharing and caching, File Replication, Atomic transactions; Case Study HADOOP: Resource and process management, Task assignment approach, Load balancing approach, Load sharing approach

**Unit 8: Security**

Introduction to Security- Security Threats, Policies, and Mechanisms, Design Issues, Basics of Cryptography, Secure Channels- Authentication, Message Integrity and Confidentiality, Secure Group Communication; Access Control- General Issues in Access Control, Firewalls, Secure Mobile Code, Denial of Service; Security Management-Key Management, Secure Group Management, Authorization Management

**Unit 9: Consistency, Replication and Fault Tolerance**

Introduction to Replication, Data Centric Consistency Models, Client-Centric Consistency Models, Replica Management, Consistency Protocols, Basics of Fault Tolerance, Process Resilience, Reliable Client Server Communication, Reliable Group Communication, Distributed Commit, Recovery

**Suggestive Readings:**


1. A. S. Tanenbaum and M.V. Steen, "Distributed Systems – Principles and Paradigms", Pearson Education.
2. Ajay D. Kshemakalyani and Mukesh Singhal, "Distributed Computing, Principles, Algorithms and Systems", Cambridge, rp 2010.
3. Andrzej Goscinski, "Distributed Operating Systems, the logical Design", Addison Wesley Publishing Company, USA, 1991.
4. Coulouris, G.F., Dollimore, J. and Kindberg, T., "Distributed Systems: Concepts and Design", Pearson Education, 2005.
5. Gerard Tel, "Introduction to Distributed algorithms", Cambridge University Press, USA, 2000.
6. Liu, M.L., "Distributed Computing: Principles and Applications", Pearson Education Inc., 2003
7. Lynch, N.A., "Distributed algorithms", Elsevier, 1996
8. Pradeep K Sinha, "Distributed Operating Systems: Concepts and Design", Prentice Hall of India, New Delhi, 2003.


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## E34: Computational Geometry

**Course Code:** CSTE- 302:E34

**Course Title:** Computational Geometry

**Brief Course Description:**

- In this course, we will study the basic geometric constructs of Computational Geometry, including 2D and 3D convex hulls, planar triangulations, Voronoi diagrams, and Arrangements in 2D and 3D. We will learn about deterministic and randomized algorithms and their data structures for computing them efficiently and for computing fundamental geometric problems including polygon triangulation, point location, range queries, and applications in motion planning. The course will be taught so as to balance between theoretical and applied issues.

**Prerequisite(s) and/or Note(s):**

- A course in Algorithms and Data Structures
- Mathematical maturity

**Course Objectives:**

- Introduce rigorous algorithmic analysis for problems in Computational Geometry.

- Discuss applications of Computational Geometry to graphical rendering.
- Introduce the notions of Voronoi diagrams and Delaunay Triangulations.
- Develop expected case analyses for linear programming problems in small dimensions

**Knowledge Acquired:**
- Geometry basics, 2D convex hulls
- Line Segment Intersection
- Polygon triangulation
- Orthogonal Range Searching
- Voronoi diagrams
- Delaunay triangulations
- Line arrangement
- Visibility

**Skills Gained:**
- At the end of the course, the students will be able to design, analyze, and develop algorithms and methods for solving geometric problems efficiently.
- The students will be able to assess theoretical and practical problems that involve geometry and will devise and adapt efficient methods to solve them, or prove that they cannot be solved efficiently.

**Competency Developed:**
- Algorithmic study of geometrical entities.
- Facility in solving real life problems in the field of Computer Graphics, Computer Vision, Computer-Aided Design, and Robotics.

**Course Syllabus:**

**Unit 1: Geometry basics, 2D convex hulls**
Types of polygons: convex, star, monotone, simple, holes; Convex hull properties and convex hull construction algorithms (gift wrapping, Graham's algorithm etc.); Euler's formula for planar subdivisions; Data structure for planar subdivision

**Unit 2: Line Segment Intersection**
Sweep line algorithm; Boolean polygon operations: intersection, union, difference; Convex polygon intersection; polygon tangents

**Unit 3: Polygon Triangulation**
Triangulation theory – dual graph, diagonals; Monotone polygon triangulation; Simple polygon partition into monotone polygons; Trapezoidal partition

**Unit 4: Range Searching**
Geometric data structures; 1-D range searching; Grids, quad trees; Range trees, Kd trees

**Unit 5: Voronoi Diagrams**
Definitions, basic properties; Algorithms: Incremental, Sweep line algorithm, Divide and conquer; Closest pair problems

**Unit 6: Delaunay Triangulations**
Basic properties of triangulations; Delaunay triangulation – duality Voronoi diagram; Incremental algorithm and complexity

**Unit 7: Arrangement**
Line arrangements- definition, properties; Incremental algorithm

**Unit 8: Visibility**
Art gallery problems; Motion planning and visibility graphs

**Suggestive Readings**


1. F. P. Preparata and M. I. Shamos, "Computational Geometry: An Introduction", Springer-Verlag.
2. J. O'Rourke, "Computational Geometry in C", Cambridge University Press.
3. M. Laszlo, "Computational Geometry and Computer Graphics in C++", Prentice-Hall.
4. M. De Berg, M. van Kreveld, M. Overmars, O. Schwarzkopf, "Computational Geometry: Algorithms and Applications", Springer –Verlag.


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## EO-02: Open/Swayam Course

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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**CSTE- 303 (Electives):**

## E36: ANN and Pattern Recognition

**Course Code:** CSTE- 302:E36

**Course Title:** ANN and Pattern Recognition

**Brief Course Description:**

- This course will cover several topics on pattern recognition (PR) and artificial neural networks (ANN). Pattern recognition is a classical research area that deals with recognizing patterns (objects) based on their features (traits or appearance). It has seen wide applications in speech recognition, image analysis, target detection, optical character recognition, fingerprint identification, insurance fraud detection, DNA sequence alignment, protein structure matching, data mining, and network intrusion detection, among many others. Artificial neural networks provide a general computing framework which is purported to be highly parallel, distributed, and fault tolerant.

**Prerequisite(s) and/or Note(s):**

- It is assumed the students have a working knowledge of calculus, linear algebra, and probability theory. It is also assumed the students have some experience programming in a scientific computing environment.

**Course Objectives:**

- To provide an introduction to the field of artificial neural networks and machine learning
- To teach students how to solve practical problems via implementation of these techniques via simulation
- Learn about pattern recognition and its broad applications in various aspects of our day to day life.
- Understand the algorithms used in various phases of pattern recognition systems, including data acquisition, pre-processing, segmentation, feature extraction and classification.
- Knowledge of various applications of pattern recognition in real life, this includes reading research papers and preparing presentations by the students.

**Knowledge Acquired:**

- Machine vision and pattern classification
- Supervised, unsupervised and reinforcement learning
- Dimensionality reduction
- Feature selection criteria and algorithms
- Artificial Neural Network for pattern classification

**Skills Gained:**

- After taking the course, the student should have a clear understanding of the design and construction a pattern recognition system. The students will be able to understand the theoretical issues involved in pattern recognition system design. Finally, the student will have a clear working knowledge of implementing pattern recognition techniques and the scientific Python/Matlab computing environment.

**Competency Developed:**

- Pattern recognition algorithms
- Wide applications in speech recognition, image analysis, target detection, optical character recognition, fingerprint identification, insurance fraud detection, DNA sequence alignment, protein structure matching, data mining, and network intrusion detection

**Course Syllabus:**

**Unit 1: Introduction**

Basic concepts on pattern recognition and machine learning; Overview of problems of machine vision and pattern classification; Pattern and Pattern classes.Decision boundaries, discriminate functions (linear and non-linear), Bayesian classification, training and test sets, parametric and non-parametric learning, minimum distance classifiers, k-NN rule.

**Unit 2: Supervised Learning and Unsupervised learning**

Linear Regression, Logistic Regression, Support Vector Machine, Multi-class Classification, Decision tree, Bayesian Logic, Clustering, KNN, and A priori algorithm

**Unit 3: Clustering Algorithms**

Clustering Algorithms: An overview of Clustering Algorithms in Pattern Recognition; Hierarchical and non-hierarchical algorithms

**Unit 4: Dimensionality Reduction**

Algorithms used for dimensionality reduction; Studies on applications, advantages and disadvantages of the algorithms.

**Unit 5: Similarity Measures**

Similarity or distance measures in Pattern Recognition; Metric measures: Minkowski Distance, Mahalanobis Distance, Euclidean Distance, Weighted Euclidean Distance; Feature selection: Need for Feature Selection, Feature Selection Methods/Techniques, Feature selection criteria and algorithms.

**Unit 6: Feature Extraction and Pattern Classification**

Image feature extraction; Principal components analysis (PCA) (as a tool) and its some applications

**Unit 7: Artificial Neural Network**

Artificial Neural Network for pattern classification.

**Suggestive Readings:**


1. M. K. Pkhira, Digital Image Processing and Pattern Recognition PHI.
2. R. O. Duda, P. E. Hart and D. G. Stork: Pattern Classification and Scene Analysis, 2nd ed., Wiley, New York.
3. J. T. Tou and R. C. Gonzalez: Pattern Recognition Principles, Addison-Wesley, London, 1974.

4. Frank Y. Shih, Image Processing and Pattern Recognition: Fundamentals and Techniques, Wiley-IEEE Pres
5. Bishop, Neural Networks for pattern recognition, Oxford

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## E37: Machine Learning

**Course Code:** CSTE-303: E37

**Course Name:** Machine Learning

**Brief Course Description:**

- Machine learning is the study of computer algorithms that can improve automatically through experience and by the use of data (samples). It is seen as a part of artificial intelligence.

**Prerequisite(s) and/or Note(s):**

- Probability and Statistics
- Basic knowledge of Artificial Intelligence

**Course Objectives:**

- To learn how to apply Machine learning Techniques to solve a wide range of real-world problems in Image Processing, Natural Language Processing, Data Science and in various other domains.

**Knowledge acquired:**

- Concept of Machine learning
- Supervised, Unsupervised and Semi-supervised learning
- Different Machine learning classifiers
- Application of Machine learning to a wide range of real-world applications.

**Skills gained:**

- Learn different ML classifiers
- Identify solution based on ML classifier to solve problem
- Identify suitable ML classifier for specific problem
- Learn to implement different ML classifier to a range of real-world applications.

**Competency Developed:**

- Have a good understanding of the fundamental issues and challenges of machine learning: data, model selection, model complexity, etc.
- Have an understanding of the strengths and weaknesses of many popular machine learning approaches.
- Be able to design and implement various machine learning algorithms in a range of real-world applications.

**Course Syllabus:**

**Unit 1: Introduction**
Machine learning applications, concepts learning

**Unit 2: Bayesian Learning Theory**
Conditional Probability, Bayes Rule, Regression, Feature Selection, Naive Bayes classifier

**Unit 3: Supervised Learning**
Supervised Learning, Training, Testing, Decision Trees, *Hidden Markov Model*, Maximum Entropy, K-nearest Neighbours, Support Vector Machine, Conditional Random Field

**Unit 4: Artificial Neural Network**
Single layer neural network, linear reparability, general gradient descent, perceptron learning algorithm, multi-Layer perceptron: back propagation learning; Unsupervised learning: Introduction, Clustering, Various clustering methods: Hierarchical clustering, Partitioning Clustering, Density-based Clustering, etc.

**Unit 5: Advanced and Ensemble Methods**
Introduction, Semi-supervised learning, CNN, RNN, LSTM, BiLSTM, Ensemble Learning

**Suggestive Readings:**

1. T. M. Mitchell, Machine Learning, McGraw-Hill, 1997.
2. E. Alpaydin, Introduction to Machine Learning, Prentice Hall of India, 2006.
3. C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.
4. R. O. Duda, P. E. Hart, and D.G. Stork, Pattern Classification, John Wiley and Sons, 2001.
5. Vladimir N. Vapnik, Statistical Learning Theory, John Wiley and Sons, 1998.
6. Shawe-Taylor J. and Cristianini N., Cambridge, Introduction to Support Vector


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## E38: Cryptography and Network Security

**Course Code:** CSTE-303: E38

**Course Name:** Cryptography and Network Security

**Brief Course Description:**
- The aim of this course is to introduce the student to the areas of cryptography and cryptanalysis. This course develops a basic understanding of the algorithms used to protect users online and to understand some of the design choices behind these algorithms. Objective is to develop a workable knowledge of the mathematics used in cryptology in this course. The course emphasizes to give a basic understanding of previous attacks on cryptosystems with the aim of preventing future attacks.

**Prerequisite(s) and/or Note(s):**
- It is assumed the students have knowledge of modular arithmetic. It is also assumed the students have some experience in programming on a scientific computing environment. Ability to manage large files using a programming language

**Course Objectives:**
- To understand basics of Cryptography and Network Security
- Introduction of network security using various cryptographic algorithms
- Underlying network security applications
- It focuses on the practical applications that have been implemented and are in use to provide email and web security
- To be able to secure a message over insecure channel by various means
- To learn about how to maintain the Confidentiality, Integrity and Availability of a data
- To understand various protocols for network security to protect against the threats in the networks

**Knowledge Acquired:**
- To understand Cryptography Theories and Algorithms.
- To understand necessary Approaches and Techniques to build protection mechanisms in order to secure messages over computer networks.

**Skills Gained:**
- After taking the course, the student should have a clear understanding of
- Basics of Cryptography and Network Security

- To be able to secure a message over insecure channel by various means
- To learn about how to maintain the Confidentiality, Integrity and Availability of a data.
- To understand various protocols for network security to protect against the threats in the networks.

**Competency Developed:**

- Understand cryptography and network security concepts and application
- Apply security principles to system design
- Identify and investigate network security threat
- Analyze and design network security protocols
- Conduct research in message security

**Core Syllabus:**

**Unit 1: Introduction to Classical Cryptosystems**
Introduction, Need and importance of Cryptography, Classical Cryptosystems, Introduction to symmetric and asymmetric cryptography, Cryptanalysis of Classical Cryptosystems, Shannons Theory

**Unit 2: Mathematical Foundations**
Number Theory, Number Theoretic Results, Factorization- Factoring Algorithms, Quadratic Sieve Factoring Algorithm, Pollard-Rho Method; Modular Arithmetic- Groups, Solving Modular Linear Equations, Chinese Remainder Theorem, Modular Exponentiation, Discrete Logarithm Problem; GCD Computation- Euclids Algorithm, Extended Euclids Algorithm, Probability and Information Theory, The Discrete Logarithm Problem (DLP), Computation of Generators of Primes; Stream Ciphers, Pseudorandom functions.

**Unit 3: Symmetric Key Ciphers and Cryptanalysis**
Introduction, Symmetric Key Ciphers, Modern Block Ciphers- DES, AES; Linear Cryptanalysis, Differential Cryptanalysis, Other Cryptanalytic Techniques, Overview on S-Box Design Principles, Modes of operation of Block Ciphers, NIST recommendations; Hash Functions and MACs: Hash functions, The MerkleDamgard Construction, Message Authentication Codes (MACs)

**Unit 4: Asymmetric Key Ciphers and Cryptanalysis**
Construction and Cryptanalysis, RSA Cryptosystem, Different Attacks & Remedies on RSA, Semantic Security of RSA, The Discrete Logarithm Problem (DLP), Diffie Hellman Key Exchange algorithm, The ElGamal Encryption Algorithm, Massey-Omura; Construction and Cryptanalysis, Cryptanalysis of DLP

**Unit 5: Modern Trends in Asymmetric Key Cryptography**
Overview of Modern Cryptography, Elliptic curve theory and Elliptic Curves based cryptography, Security of Elliptic Curves Cryptography, Elliptic Curve Factorization

**Unit 6: Digital Signatures**
Introduction, Signature schemes, Authentication Protocols, Digital Signature Standards (DSS), Proxy Signatures

**Unit 7: Network Security**
Secret Sharing Schemes, Network Protocols, Kerberos, Pretty Good Privacy (PGP), Secure Socket Layer (SSL), Intruders and Viruses, Firewalls

**Unit 8: Primality Testing**
Primality Testing, Quadratic Residues, Randomized Primality Test & Deterministic Polynomial Time Algorithm

**Suggestive Readings:**

1. Neal Koblitz, A Course in Number Theory and Cryptography, Springer Verlag, New York Inc, 2001
2. William Stallings, Cryptography and Network security: Principles and Practice, Pearson Education, 2002
3. W. Trappe and L. C. Washington, Introduction to Cryptography with Coding Theory, Pearson Education 2007
4. V VYaschenko, Cryptography: An Introduction, Universities Press
5. R. Motwani and P. Raghavan, Randomized Algorithms, Cambridge University Press, 1995
6. Douglas Stinson, Cryptography Theory and Practice, 2nd Ed., Chapman & Hall/CRC
7. B. A. Forouzan, Cryptography & Network Security, TMH
8. Wenbo Mao, Modern Cryptography, Theory & Practice, Pearson Education.
9. Hofistein, Pipher, Silvermman, An Introduction to Mathematical Cryptography, Springer
10. J. Daemen, V. Rijmen, The Design of Rijndael, Springer.
11. Joux,Algorithmic Cryptanalysis, CRC Press
12. S. G. Telang, Number Theory, TMH
13. Boyd, A. Mathuria, Protocols for Authentication and Key Establishment, Springer
14. Matt Bishop, Computer Security, Pearson Education

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## E39: Big Data Analytics

**Course Code:** CSTE-303: E39

**Course Name:** Big Data Analytics

**Brief Course Description:**

- This course gives an overview of Big Data, i.e. storage, retrieval and processing of big data. In addition, it also focuses on the "technologies", i.e., the tools/algorithms that are available for storage, processing of Big Data. It also helps a student to perform a variety of "analytics" on different data sets and to arrive at positive conclusions.

**Prerequisite(s) and/or Note(s):**

- Should have knowledge of one Programming Language (Java preferably)
- Practice of SQL (queries and sub queries)

**Course Objectives:**

- Understand the Big Data Platform and its Use cases
- Provide an overview of Apache Hadoop
- Provide hands on Hodoop Eco System
- Apply analytics on Structured, Unstructured Data

**Knowledge Acquired:**

The students will be able to:

- Identify Big Data and its Business Implications
- List the components of Hadoop and Hadoop Eco-System
- Access and Process Data on Distributed File System
- Develop Big Data Solutions using Hadoop Eco System
- Analyze Infosphere, BigInsights Big Data Recommendations.

**Skills Gained:**

- Design classification models for various standard datasets and user datasets.
- Develop clustering techniques and association rules for large standard datasets and user datasets.
- Analyse large scale data using MAPREDUCE programming which includes JAVA and HADOOP frameworks

**Competency Developed:**

- Understand Big Data and its analytics in the real world
- Analyze the Big Data framework like Hadoop and NOSQL to efficiently store and process Big Data to generate analytics
- Design and Implementation of Big Data Analytics to solve data intensive problems and to generate analytics

**Course Syllabus:**

**Unit 1: Introduction to big data and Hadoop**
Types of Digital Data, Introduction to Big Data, Big Data Analytics, History of Hadoop, Apache Hadoop, Analysing Data with Unix tools, Analysing Data with Hadoop, Hadoop Streaming, Hadoop Echo System, IBM Big Data Strategy, Introduction to InfosphereBigInsights and Big Sheets.

**Unit 2: Hadoop Distributed File System (HDFS)**
The Design of HDFS, HDFS Concepts, Command Line Interface, Hadoop file system interfaces, Data flow, Data Ingest with Flume and Scoop and Hadoop archives, Hadoop I/O: Compression, Serialization, Avro and File-Based Data structures.

**Unit 3: Map Reduce**
Anatomy of a Map Reduce Job Run, Failures, Job Scheduling, Shuffle and Sort, Task Execution, Map Reduce Types and Formats, Map Reduce Features.

**Unit 4: Hadoop Eco System**
Pig- Introduction to PIG, Execution Modes of Pig, Comparison of Pig with Databases, Grunt, Pig Latin, User Defined Functions, Data Processing operators; Hive- Hive Shell, Hive Services, Hive Metastore, Comparison with Traditional Databases, HiveQL, Tables, Querying Data and User Defined Functions; Hbase- HBasics, Concepts, Clients, Example, Hbase Versus RDBMS; Big SQL- Introduction

**Unit 5: Data Analytics with R**
Machine Learning- Introduction, Supervised Learning, Unsupervised Learning, Collaborative Filtering; Big Data Analytics with BigR

**Suggestive Readings:**


1. AnandRajaraman and Jefrey David Ulman, “Mining of Massive Datasets”, Cambridge University Press, 2012.
2. Arvind Sathi, “Big Data Analytics: Disruptive Technologies for Changing the Game”, MC Press
3. Bill Franks, “Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with Advanced Analytics”, John Wiley & sons.
4. Glen J. Myat, “Making Sense of Data”, John Wiley & Sons
5. Jay Liebowitz, “Big Data and Business Analytics” Auerbach Publications, CRC press
6. Michael Berthold, David J. Hand, "Intelligent Data Analysis”, Springer
7. Michael Mineli, Michele Chambers, Ambiga Dhiraj, "Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses", Wiley Publications.
8. Paul Zikopoulos ,Dirk DeRoos , Krishnan Parasuraman , Thomas Deutsch , James Giles , David Corigan, "Harness the Power of Big Data The IBM Big Data Platform ", Tata McGraw Hill Publications.
9. Pete Warden, “Big Data Glossary”, O’Reily.
10. Seema Acharya, SubhasiniChellappan, "Big Data Analytics" Wiley.
11. Tom Plunkett, Mark Hornick, “Using R to Unlock the Value of Big Data: Big Data Analytics with Oracle R Enterprise and Oracle R Connector for Hadoop”, McGraw-Hill/Osborne Media , Oracle press.
12. Tom White, “Hadoop: The Definitive Guide”, 3rd Edition, O’reily Media.


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**EO-03: Open/Swayam Course**

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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## CSTE- 304: Elective: EO-04 (SWAYAM)

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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## CSTE- 401 (Electives):

## E41: Deep Learning

**Course Code:** CSTE-401: E41

**Course Name:** Deep Learning

**Brief Course Description:**

- Machine learning is everywhere today - from self-driving cars to automatic cancerous tumours detection. Deep learning is a sub-field in the world of Machine learning mainly based around neural networks. Using this model we are capable of achieving wonderful results in solving complex problems that were once out of our reach.

**Prerequisite(s) and/or Note(s):**

- Basic understanding of AI and Neural Networks

**Course Objectives:**

- In this course we will start our journey in the world of deep learning - we will start by getting familiar with basic concepts and theory, all the way down to actual hands-on practice.
- To Introduce deep learning (DL) algorithms including convolutional neural networks (CNN), recurrent neural networks (RNN) and its variants viz. LSTM and GRU
- To train on how to fine tune hyper parameters of DL algorithms
- To impart concepts that help identify suitable applications for CNN, RNN, LSTM and GRU and study them

**Knowledge Acquired:**

The students will be able to:

- Convolutional neural networks (Convolution, Correlation, and Filtering), Generative Adversarial Networks, Deep reinforcement learning, common tools and much more.

**Skills Gained:**

- Design and choose appropriate DL algorithm to solve the problem with appropriate hyper parameter setting

**Competency Developed:**

- Decide if DL is suitable for a given problem

**Course Syllabus:**

**Unit 1: Deep learning basics**

Introduction, History, capabilities, the perceptron; Bayesian Learning, Decision Surfaces; Neural network learning: Back-Propagation; Practical network training; Autoencoders, Batch-normalization; Why does it work? Overfitting and generalization; Linear Classifiers, Linear Machines with Hinge Loss; Optimization Techniques, Gradient Descent, Batch Optimization

**Unit 2: Convolutional neural networks**

Introduction to Neural Network, Multilayer Perceptron, Back Propagation Learning; Unsupervised Learning with Deep Network, Autoencoders; Intro to CNNs, Convolution, Correlation, Filtering; Building blocks of CNN, CNN architectures; Detection and Segmentation; Transfer Learning; Visualizing and Understanding; Advanced CNNs for computer vision; Revisiting Gradient Descent, Momentum Optimizer, RMSProp, Adam

**Unit 3: Advanced Deep architectures**
Recurrent Neural networks (RNNs); Advanced RNN: LSTM, GRU; Generative Adversarial Networks (GANs); Advanced GANs; Effective training in Deep Net- early stopping, Dropout, Batch Normalization, Instance Normalization, Group Normalization

**Unit 4: Advanced topics**
Deep reinforcement learning; Visual Question Answering, Visual Dialog; Novel deep methods; Recent Trends in Deep Learning Architectures, Residual Network, Skip Connection Network, Fully Connected CNN etc.; LSTM Networks; Classical Supervised Tasks with Deep Learning, Image Denoising, Semanticd Segmentation, Object Detection etc.; Generative Modeling with DL, Variational Autoencoder, Generative Adversarial Network Revisiting Gradient Descent, Momentum Optimizer, RMSProp, Adam

**Unit 5: Tools**
Tensorflow, Pytorch

**Suggestive Readings:**

1. Ian Goodfelllow, Yoshua Benjio, Aaron Courville, "Deep Learning", The MIT Press
2. Richard O. Duda, Peter E. Hart, David G. Stork, "Pattern Classification", John Wiley & Sons Inc.


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## E42: Soft Computing

**Course Code:** CSTE-401: E42

**Course Name:** Soft Computing

**Brief Course Description:**
- Soft Computing is a subject which includes algorithms like artificial neural networks (ANN), fuzzy logic, and genetic algorithms (GA).These algorithms are tolerant of imprecision, uncertainty, partial truth and approximation. It is contrasted with hard computing: algorithms which find provably correct and optimal solutions to problems.

**Prerequisite(s) and/or Note(s):**
- Discrete Mathematics (Sets, Relations, Functions, Logic, Probability)

**Course Objectives:**
- Understand Soft Computing concepts, technologies, and applications
- Understand the underlying principle of soft computing with its usage in various applications.
- Understand different soft computing tools to solve real life problems.

**Knowledge Acquired:**
- Understand the basic areas of Soft Computing including Artificial Neural Networks, Fuzzy Logic and Genetic Algorithms.
- Provide the mathematical background for carrying out the optimization associated with neural network learning.
- To discuss the ideas of fuzzy sets, fuzzy logic and use of heuristics based on human experience.
- To relate with neural networks that can learn from available examples and generalize to form appropriate rules for inference systems.
- To describe with genetic algorithms and other random search procedures useful while seeking global optimum in self-learning situations

**Skills Gained:**
- Familiar with current research problems and research methods in Soft Computing by working on a research or design project.

- Comprehend the fuzzy logic and the concept of fuzziness involved in various systems and fuzzy set theory.

**Competency Developed:**

- To understand the concepts of how an intelligent system work and its brief development process.
- This course exposes learners to Neural Network, Fuzzy Logic and Genetic Algorithms, which are the major building blocks of Intelligent Systems.

**Course Syllabus:**

**Unit 1: Introduction to Soft Computing**
Concept of computing systems, "Soft" computing versus "Hard" computing, Characteristics of Soft computing, Some applications of Soft Computing techniques.

**Unit 2: Fuzzy Logic**
Introduction to Fuzzy logic, Fuzzy sets and membership functions, Operations on Fuzzy sets, Fuzzy relations, rules, propositions, implications and inferences, Defuzzification techniques, Fuzzy logic controller design, Some applications of Fuzzy logic.

**Unit 3: State Space Search**
Uninformed Search (BFS, DFS, DLS, IDS, Bi-directional Search, Uniform Cost Search), Informed/Heuristic Search (Greedy Best First Search, A*, IDA*), Local Search and Optimization (Concept of optimization, Hill Climbing, Tabu Search, Simulated Annealing, Beam Search)
Genetic Algorithms: Concept of "Genetics" and "Evolution" and its application to probabilistic search techniques, Basic GA framework, GA operators: Encoding, Crossover, Selection, Mutation, etc., Solving single-objective optimization problems using GAs.

**Unit 4: Artificial Neural Networks (ANN)**
Biological neurons and its working, Simulation of biological neurons to problem solving, Different ANNs architectures. Training techniques for ANNs, Applications of ANNs to solve some real life problems

**Suggestive Readings:**

1. Neuro Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence - Jang, Sun and Mizutani, Printice Hall.
2. Soft Computing: Integrating Evolutionary, Neural, and Fuzzy Systems, by Tettamanzi, Andrea, Tomassini, and Marco. (2001), Springer.

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## E43: Natural Language Processing

**Course Code:** CSTE-401: E43

**Course Name:** Natural Language Processing

**Brief Course Description:**

- Natural language processing is a subfield of linguistics, computer science, and artificial intelligence concerned with the interactions between computers and human language, in particular how to program computers to process and analyze large amounts of natural language data.

**Prerequisite(s) and/or Note(s):**

- Basic understanding of Formal Language & Automata Theory
- Basic understanding of Probability and Statics
- Basic understanding of SET Theory
- Knowledge of Grammar

**Course Objectives:**

- To gain the knowledge of computational linguistics and NLP applications which have huge demands in market (Data science, E-commerce and social media analysis)

**Knowledge Acquired:**

- Understanding techniques to process Natural Language
- Understanding Grammar
- Understanding Computational Linguistics

**Skills Gained:**

- Computational Linguistics
- Application of NLP techniques for Text Classification
- Application of NLP techniques for Sentiment Analysis
- Application of NLP techniques for Opinion Mining and Trend Estimation
- Application of NLP techniques for Question-Answering

**Competency Developed:**

- Computational Linguistics
- Application of NLP techniques which have huge demands in market (Data science, E-commerce and social media analysis).

**Course Syllabus:**

**Unit 1: Regular Expressions and Automata**
Introduction to NLP, Regular Expression, Finite State Automata, Computational Linguistic

**Unit 2: Tokenization**
Word Tokenization, Normalization, Sentence Segmentation, N-gram, POS and POS tagging, Rule based and Machine Learning based approaches, Evaluation, Multi Word Extraction,

**Unit 3: Morphology**
Morpheme, Morphology – Inflectional and Derivational Morphology, Root Word,Infections, The Lexicon and Morphotactics, Morphological Parsing with Finite State Transducers, Orthographic Rules and Finite State Transducers, Stemming, Porter Stemmer, Lemma, Lemmatization; Minimum Edit Distance and Noisy Channel: Edit Distance and String similarity, Minimum Edit Distance, Definition, Levenshtein Distance, Computing alignments, Sequence Alignment, Backtracking, Weighted Edit Distance, Spelling Error: Detection and Correction, Types of spelling errors, Noisy Channel.

**Unit 4: Language Modeling**
Introduction to N-grams, Chain Rule, Smoothing – Add-One Smoothing, Backoff, Deleted Interpolation, N-grams for Spelling and Word Prediction, Evaluation of language models

**Unit 5: Text Classification**
Text Classification, Rule based and Machine Learning based approaches, Naïve Bayes' Text Classification, Evaluation, Sentiment Analysis – Opinion Mining and Emotion Analysis, Resources and other Techniques.

**Unit 6: Parsing**
Probabilistic Parsing, Lexicalized Parsing, Dependency Parsing, Dependency Relation, Parsing tools and techniques

**Unit 7: Computational Lexical Semantics**

Introduction to Lexical Semantics – Homonymy, Polysemy, Synonymy, Thesaurus –WordNet, Computational Lexical Semantics – Thesaurus based and Distributional Word Similarity, Word Sense Disambiguation

**Unit 8: Information Retrieval and Application**
Boolean Retrieval, Term-document incidence, The Inverted Index, Query Optimization, Phrase Queries, Ranked Retrieval, Term Frequency, Inverse Document Frequency, based ranking, Zone Indexing, Query term proximity, Cosine ranking, Combining different features for ranking, Search Engine Evaluation, Relevance Feedback, Named Entity Recognition, Relation Extraction, Summarization: Single-document summarization, Multiple-document summarization, Machine Translation, Recommender system

**Unit 9: Question-Answering**
Type of Question: Subjective Question and Objective Question, Generation of subjective and objective Questions from natural language corpus, Automatic answer grading and assessment.

**Suggestive Readings:**


1. Alexander Clark, Chris Fox, and Shalom Lappin (Editors): The Handbook of Computational Linguistics and Natural Language Processing (Blackwell Handbooks in Linguistics).
2. AksharBharathi, Vineet Chaitanya, and Rajeev Sangal: Natural Language Processing: A Paninian Perspective. Prentice Hall of India.
3. Allen, James, Natural Language Understanding, Second Edition, Benjamin/Cumming, 1995.
4. Charniack, Eugene, Statistical Language Learning, MIT Press, 1993.
5. Jurafsky, Dan and Martin, James, Speech and Language Processing, Second Edition, Prentice Hall, 2008.
6. Manning, Christopher and Heinrich, Schutze, Foundations of Statistical Natural Language Processing, MIT Press, 1999.
7. Radford, Andrew et. al, Linguistics, An Introduction, Cambridge University Press, 1999.


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## E44: Design and Operation of Data Centres

**Course Code:** CSTE-401: E44

**Course Name:** Design and Operation of Data Centres

**Brief Course Description:**

- Our digital footprint grows phenomenally every year and that data passes through, is stored and processed by the contents of these largest of energy intensive buildings on the planet. From Microsoft to Google, 5G to blockchain, selfies to self-driving, the internet is expected to become an even bigger part of our lives - and it's all supported by a growing legion of mammoth facilities known as data centers. In this course, students shall learn the basics to enter into the world of data centers, the fastest growing sector in the design and construction industry.

**Prerequisite(s) and/or Note(s):**

- A curiosity and desire to learn about data center infrastructure.
- A basic understanding of networking and structured cabling.
- No previous infrastructure design experience required.

**Course Objectives:**
After learning the course the students should be able to:

- Introduction to data centers, their types and sizes

- Differing priorities of data centers, from financial to search engines to blockchain
- Supporting equipment, systems, and controls
- Manage Server Systems and Data Centres Infrastructure Management
- Utilize the Storage, Bandwidth, Efficiency of systems and other resources for Data centre.
- Monitoring the Networks and Resources.
- Understand data center design from an infrastructure point of view.
- Introduction to data center cooling and mechanical systems
- Redundancy concepts for mechanical and cooling systems
- Understanding of mechanical & plumbing systems and controls
- Data Center Facility equipment, design, Operation and maintenance
- Supporting equipment, and systems

**Knowledge Acquired:**

- Planning for Flexible resource allocation.
- Defining data center infrastructure as the spaces, pathways, racks, cabinets, cabling, power, grounding, and cooling

**Skills Gained:**

- Fundamentals of Data center infrastructure.
- Understanding data center electrical and power systems
- Understanding redundancy concepts for electrical distribution and equipment
- Understanding of electrical equipment, systems, and controls

**Competency Developed:**

- How differing priorties and data center types change the electrical design
- How differing priorities, locations, and more change the cooling design.
- Designing a modern data centre.

**Course Syllabus:**

**UNIT 1: Introduction to Data Center**

Introduction to data centers (DC) and their importance; types & sizes; differing priorities of DC; supporting equipment and systems, and controls; summarized history of technology; DC center reliability; DC equipment; DC Critical and support Spaces; DC security and safety, DC networks and IT.

**UNIT 2: Data Center Requirements**

Data center prerequisites, Required Physical Area for Equipment and Unoccupied Space, Required power to run all the devices, required cooling and HVAC required weight, Required Network bandwidth, Budget Constraints

**UNIT 3: Data Center Location, Design and Disaster Management**

Selecting a Geographic Location, Safety from Natural hazards and Manmade disaster, Availability of local Technical talent, Abundant and Inexpensive Utilities, Selecting an Existing building; **Data Center design:** Characteristics of an Outstanding Design, Guidelines for Planning a Data Center, Data Center structures, Raised Floor Design and Deployment, Suspended Ceiling, Design and Plan against Vandalism

**UNIT 4: Data Center Infrastructure Design**

Physical and logical layout of the resources and equipment within a data center facility, primary elements of a data center, core elements, types and layers of data centre, Data center servers, Sever Capacity

Planning; Data center infrastructure standards and ratings for infrastructure availability; Data center spaces, pathways, and aisle layouts for airflow, network cabling; Guidelines for data center equipment racks and cabinets; Infrastructure Labelling, Labelling guidelines for data center Computer Rooms

**UNIT 5: Data Center Networking and Load Balancing**

**DC Networking**: Data center grounding guidelines and Common Bonding Networks; Data Center Networking, Required Network bandwidth, Data center network devices and networking protocols; Computer Room Topologies; Network Cabling – Copper and Optical Fiber, Cable Management, Modular Cabling Design, Centralized vs. In-Row vs. Top-of-Rack design topologies; Points of Distribution, ISP Network Infrastructure, ISP WAN Links; **Load Balancing**: Device Naming, Naming Practices, NIS, DNS, LDAP, Load balancing, Terminology, Advantages, Types of load balancing, Implementing a Network with Load-Balancing Switches; Network Operations Center, Network Monitoring

**UNIT 6: Data Center Power & Electrical**

**Introduction to DC electrical and power systems:** Required power to run all the devices, path of power, and diagrams - typical electrical terms, power path from grid to chip; Redundancy concepts for electrical distribution and equipment, redundancy levels; **Data Center Voltages & Components:** Voltages and primary equipment - AC/DC power, the major electrical equipment that supports all of the data center power needs; **Data Center UPS Systems:** UPS systems and components - primary & secondary purposes, types, operations, and efficiencies; **Data Center Power Distribution Units:** Power distribution - PDUs, RPPs, power monitoring, controls, receptacles & plugs; **Data Center Conductors, Conduits, and Breakers:** Conductors, conduits and breakers - protection devices, standards, sizing, switches and other devices; Power delivery, Power Distribution, Typical data center power loads, types, and distribution;

**UNIT 7: Data Center Mechanical & Cooling**

**Introduction:** Computer Room Grounding and Cooling, Required cooling and their types, operating conditions - the typical mechanical terms, cooling operations, and redundancy levels, and HVAC Required weight; **DC Air Cooling:** Air cooling solutions - air cooling and operating parameters for typical and atypical data centers; **DC Water Cooling:** water cooling components, circulation, and typical arrangements for modularity and redundancy; **DC Water Systems Operation:** operating the data center cooling systems efficiently and effectively, including water cooled servers and immersion cooling, DC environmental requirements and thermal management;

**UNIT 8: Security**

Data center physical security, Data center Logical security, Security Guidelines, Internet security, Source Security Issues

**UNIT 9: Data Center Consolidation**

Data center Consolidation, Reasons for data center Consolidation, Consolidation opportunity, Server consolidation, Storage Consolidation, Network Consolidation, Service Consolidation, Process Consolidation, Staff Consolidation, Data Consolidation phases

**UNIT 10: Best Practices for System Administration, Management and Maintenance**

Best Practices for System Administration, System Administration Work Automation; System Management Best Practices, Server Cluster Best Practices, Data Storage Best Practices, Network Management Best Practices, Documentation Best Practices; Data Center Maintenance;Data center design case Study

**Reference Books:**


- Administering Data Centers: Servers, Storage and Voice over IP, Kailash Jayaswal
- Data Center Fundamentals, Mauricio Arregoces and Maurizio Portol, Cisco Press
- Handbook on Data Centers, Edited by Samee U. Khan and Albert Y. Zomaya, Springer
- Building a Modern Data Center: Principles and Strategies of Design, Scott D. Lowe, James Green and David Davis; ActualTech Media

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## EO-05: Open/Swayam Course

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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## CSTE- 402 (Electives):

## E45: Cloud Computing

**Course Code:** CSTE-402: E45

**Course Name:** Cloud Computing

**Brief Course Description:**

- This course gives comprehensive introduction to cloud computing with an emphasis on advanced topics. It focuses on cloud computing concepts, technological foundations, infrastructure, and architecture. Further, security and technology challenges are covered. Then, the course concentrates on applications, implementation issues, and management and governance.

**Prerequisite(s) and/or Note(s):**

- This course requires knowledge of computer networking and distributed computing, and familiarity with web services, service-oriented architecture, Web 2.0, and virtualization as well as research methodology. An interest in research and good technical writing and presentation skills would also be assets for anyone taking this course. Students who are concerned about not meeting the prerequisite for this course are encouraged to contact the course coordinator before registering.

**Course Objectives:**

- Understand the fundamental principles of cloud computing
- Understand the concept of Cloud Security
- Understand the importance of virtualization and how this has enabled the development of Cloud Computing

**Knowledge acquired:**

- Analyze the performance of Cloud Computing.
- Identify the technical foundations of cloud systems architectures.
- Learn the Concept of Cloud Infrastructure Model.

**Skills gained:**

- Identify and define technical challenges for cloud applications and assess their importance.

**Competency Developed:**

- Apply principles of best practice in cloud application design and management.
- Analyze the problems and solutions to cloud application problems.

**Course Syllabus:**

**Unit 1: Introduction to Grid Computing**
What is a grid? Infrastructure of hardware and software, Main Projects and Applications, The Open Grid Forum, International Grid Trust Federation; Grid Architecture, Overview of Resource Managers, Overview of Grid Systems; Application Management: Grid Application Description Languages, Application Partitioning, Meta-scheduling, Mapping, Monitoring; Web Services, Grid Portals,

**Unit 2: Overview of Cloud Computing**
What is a cloud, Definition of cloud, Characteristics of cloud, Why use clouds, How clouds are changing, Driving factors towards cloud, Comparing grid with cloud, Public clouds (commercial), Cloud Computing and SOA, Enterprise Cloud drivers and adoption trends, Typical Cloud Enterprise workloads, Cloud service models/types, Cloud deployment models, Cloud ROI models, Cloud reference architectures, Cloud standards, Technology providers vs. Cloud providers vs. Cloud vendors, Planning Cloud transformations

**Unit 3: Cloud service delivery**
Cloud service, Cloud service model architectures, Infrastructure as a service (IaaS) architecture, Platform as a service (PaaS) architecture, Platform as a service (PaaS), Software as a service (SaaS) architecture, Examples of SaaS applications, Business Process as a Service (BPaaS) Architecture, Trade-off in cost to install versus, Common cloud management platform reference architecture: Architecture overview diagram, Common cloud management platform.

**Unit 4: Cloud deployment scenarios**
Cloud deployment models, Public clouds, Hybrid clouds, Community, Virtual private clouds, Vertical and special purpose, Migration paths for cloud, Selection criteria for cloud deployment, Case study example: IBM Smart Cloud

**Unit 5: Security in cloud computing**
Cloud security, Cloud security reference model, How security gets integrated, Cloud security challenges, Understanding security risks, Cloud security approaches: encryption, Digital signature, tokenization/ obfuscation, cloud security alliance standards, cloud security models and related patterns; Virtualization and multitenancy, Internal security breaches, Data corruption or loss, User account and service hijacking, Steps to reduce cloud security breaches, Steps to reduce cloud security breaches; Identity detection, forensics and management, What is SSL? Cloud security in mainstream vendor solutions; Mainstream Cloud security offerings: security assessment, secure Cloud architecture design; Design a secure Cloud architecture to support the deployment of a secure version of the course project application.

**Suggestive Readings:**


1. Barrie Sosinsky, Cloud Computing Bible, Wiley-India, 2010
2. RajkumarBuyya, James Broberg, Andrzej M. Goscinski, Cloud Computing: Principles and Paradigms, Wiley, 2011
3. Nikos Antonopoulos, Lee Gillam, Cloud Computing: Principles, Systems and Applications, Springer, 2012
4. Ronald L. Krutz, Russell Dean Vines, Cloud Security: A Comprehensive Guide to Secure Cloud Computing, Wiley-India, 2010
5. ArshdeepBahga and Vijay Madisetti, Cloud Computing: A Hands-on Approach, Universities Press
6. AnirbanBasu, Rajiv Ranjan, RajkumarBuyya, Advances in Cloud Computing, Universities Press
7. M. N. Rao, Cloud Computing, PHI


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## E46: Parallel Computing

**Course Code:** CSTE-402: E46

**Course Name:** Parallel Computing

**Brief Course Description:**

- Concepts of parallel computer architecture and aspects related to programming such computers are discussed.

**Prerequisite(s) and/or Note(s):**

- Basic understanding of programming languages
- Basic understanding of Data Structure and Algorithms
- Basic understanding of Computer Organization and Architecture

**Course Objectives:**

- This parallel computer course aims to acquaint students with the basic concepts, techniques and tools of a parallel computer. Attending this course will allow you to use a parallel computer in your application area and prepare you for advanced courses in more specific areas of the parallel computer.

**Knowledge acquired:**

- Critical methods and techniques related to parallel computing. Particularly
- Focuses on hardware, algorithm, and programming of parallel systems, providing students a complete picture to understand pervasive parallel computing.
- Deep understanding of how parallel systems are designed and what are the fundamental methods to program and analyze them.
- An ability to apply knowledge of computing and mathematics appropriate to the discipline
- Extensive use of the PMU technology infrastructure

**Skills gained:**

- Explain how large-scale parallel systems are architecture and how massive parallelism are implemented in accelerator architectures
- Design efficient parallel algorithms and applications
- An ability to analyze a problem and identify the computing requirements appropriate for its solution; an ability to design, implement and evaluate a computer-based system, process, component or program to meet desired needs
- An ability to apply mathematical foundations, algorithmic principles and computer science theory to the modelling and design of computer based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices
- An ability to apply design and development principles in the construction of software systems of varying complexity.
- Parallel Computing develop skills necessary for understanding the design of parallel computing applications so as to appreciate the strengths and limitations of parallel computing approaches to problem solving.

**Competency Developed:**

- Be conversant with performance analyze and modeling of parallel programs
- Complete significant projects outside of class time.

**Course Syllabus:**

**Unit1: Review of Sequential Computing**

Uniprocessor Architecture- The CPU, Memory, I/O and Networking, Design Tradeoffs; Enhancing Uniprocessor Performance- Increasing Processor Clock Frequency, Parallelizing ALU Structure, Using Memory Hierarchy, Pipelining, Very Long Instruction Word (VLIW) Processors, Instruction-Level Parallelism (ILP) and Superscalar Processors, Multithreaded Processor, Performance bottlenecks of sequential computing,

**Unit 2: Introduction to Parallel Computing**

Motivation, What is Parallel Computing and Why to Use? Concurrent, Parallel, Distributed computing, interacting with hardware- Composite Capabilities, How Do Languages and Environments Assist with These Tasks? Applications of Parallel Computing, RAM and PRAM model, PRAM pseudo code, Data vs. Task parallelism,

**Unit 3: Parallel Computers Architectures**
Modifications to the Von-Neumann Model, Memory Barriers, Memory Hierarchy and organization, Different types of memory access-UMA and NUMA, Shared memory, distributed memory and distributed shared memory architectures, Cache Coherence and Memory Consistency, classification of parallel computers, Flynn's Classical Taxonomy, ILP, Multi-threaded architectures and TLP, Pipeline Parallelism, I/O Operations; Overheads- Hardware System Architecture, Costs of Operations; Parallel Architecture Design Tradeoffs and Future Directions, SIMD Processors, Systolic Processors, Cluster Computing, Grid and Cloud Computing, Multicore Systems, GPU computing, Synchronization and Mutual Exclusion; Scalability and Load Balance,

**Unit 4: Interconnection Networks**
Introduction, Communication between Parallel Processors, Classification of Interconnection Networks by Logical Topologies, Interconnection Network Switch Architecture, Routing Mechanisms for Interconnection Networks,

**Unit 5: Performance Analysis and Tuning**
Measuring Benefits of Parallel Computing, Performance, Performance Metric, Scalability and Scalability Metric, Speed up, Amdahl's law, Gustafson–Barsis's Law, efficiency, Scalability, Granularity, Latency, Bandwidth, Throughput, Cache, false sharing, Performance Analysis Tools- Tau.

**Unit 6: Principles of Parallel Algorithm Design**
Decomposition Techniques, Characteristics of Tasks and Interactions, Mapping Techniques for Load Balancing, Methods for Containing Interaction Overheads, Parallel Algorithm Models, templates, Basic parallel programming techniques-loop splitting, spin locks, contention barriers and row conditions, Variations in splitting, self and indirect scheduling. Data dependency-forward and backward, block scheduling.

**Suggestive Readings:**

1. AnanthGrama, Anshul Gupta, George Karypis, and Vipin Kumar, Introduction to Parallel Computing, 2nd Ed., Pearson ducatio, 2003
2. B. Wilkinson and M. Allen, Parallel Programming: Techniques and Applications Using Networked Workstations and Parallel Computers, 2nd Ed., PHI, 2005
3. Michael J. Quinn. Parallel Programming in C with MPI and OpenMP. TMH, 2004
4. M. Sasi Kumar, Dinesh Shikhare P. Raviprakash, Introduction to Parallel Processing, PHI
5. V. Rajaraman And C. Siva Ram Murthy, Parallel Computers – Architecture and Programming
6. Peter S. Pancheo, An Introduction to Parallel Programming, 2011
7. Brawer, S., Introduction to parallel programming, Academic Press, New York, 1989
8. Bruce P. Lester. The Art of Parallel Programming, 2nd Ed., 1st World Publishing, 2006
9. Kenneth A. Berman and Jerome L. Paul. Algorithms: Sequential, Parallel, and Distributed, Thomson Course Technology, 2005


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## E47: Data Storage Technologies

**Course Code: CSTE- 302:E34**

**Course Title:** Data Storage Technologies

**Brief Course Description:**
- Storage systems are among the most fascinating and the most important parts of computer systems. They often dominate the performance of a system, and failures of other components are

frequently addressed by restarting from the data stored on them. There continues to be great demand for bright people and better solutions in this critical field of computer systems. This course covers the design, implementation, and use of storage systems, from the characteristics and operation of individual storage devices to the OS, database, and networking approaches involved in tying them together and making them useful in servers and large-scale distributed systems.

**Prerequisite(s) and/or Note(s):**
Basic understanding of:

- OS and Networking
- Computer Organization and architecture

**Course Objectives:**
After learning the course the students should be able:

- To explain the design of a data center and storage requirements
- To discuss the various types of storage and their properties
- To explain physical and virtualization of storage
- To explain the backup, archiving with regard to recovery and business continuity

**Knowledge Acquired:**

- Basic understanding of Enterprise Data Storage and Management Technologies
- Discuss the Networked Attached Storage and Networking issues.
- Classify the applications as per their requirements and select relevant SAN solutions.

**Skills Gained:**

- Study storage technologies: SAN, NAS, IP storage etc., which will bridge the gap between the emerging trends in industry and academics.
- Explain the Optical, Semiconductor media and techniques for read/write operations

**Competency Developed:**

- Overview of Virtualization Technologies, Storage Area Network

**Course Syllabus:**

**Unit 1: Introduction to Information Storage**
Fundamentals of Storage; Magnetic, Optical and Semiconductor Media, Techniques for read/write Operations, Issues and Limitations; Storage hierarchy; Storage Arrays: Architectural principles; File Systems and I/O; RAID: Keeping your Data Safe, RAID Concepts, RAID Levels; Evolution of storage architecture, key data center elements, virtualization, and cloud computing

**Unit 2: Data Center Environment**
Key data center elements – Introduction, site selection, environmental consideration, host (or compute), connectivity, storage, and application in both classic and virtual environments, addressing scheme, hierarchical or Layered Architecture, Architect Roles, Goals and Skills, Architecture Precursors; and performance of mechanical and solid-state drives.

**Unit 3: Mirroring and RAID**
Storage Architecture - Storage Partitioning, Storage System Design, Caching, Legacy Systems; RAID implementations, techniques, and levels; impact of RAID on application performance.

**Unit 4: Intelligent Storage System**
This chapter details components of intelligent storage systems. It also covers virtual storage provisioning and intelligent storage system implementations.

**Unit 5: Network Attached Storage (NAS)**

Hardware and Software Components, Storage Clusters/Grids; Network File System (NFS) – An Introduction; NFS Configuration; NAS Arrays; Samba (SMB/CIFS); Storage Area Networks (SAN)-NAS vs. SAN; Storage QoS– Performance, Reliability and Security issues.

**Unit 6: Fibre Channel Storage Area Network (FC SAN) and IP SAN**
Fibre Channel(FC) SAN components, connectivity options, and topologies; access protection mechanism 'zoning'; FC protocol stack, addressing, and other fabric services; iSCSI SAN; FC IP protocols for storage access over IP network.; Converged protocol Fibre Channel over Ethernet (FCoE) and its components SAN-based virtualization and VSAN technology;

**Unit 7: Storage Applications**
Replication Technologies: Synchronous, Asynchronous, Application layer, Hypervisor based, Array based; Capacity Optimization Technologies: Thin Provisioning, Compression, Deduplication, Auto-tiering

**Unit 8: Securing Storage and Storage Virtualization**
Information Security, Critical security attributes for information systems, Storage security domains, Analyze the common threats in, each domain; Storage Virtualization: Forms, types- Block-level and File-Level; Host based, Network based, Storage based, Controller based, Software defined storage, Configurations and Challenges

**Unit 9: Cloud Storage**
Cloud Computing Basics, Storage and the Cloud: Public, Private and Hybrid storage

**Unit 10: Future Trends**
Storage and the Cloud: Public, Private and Hybrid storage; Backup and Recovery: Backup Architecture, Backup methods, Backup types, Backup retention policies; maintenance

**Suggestive Reading:**


1. Robert Spalding, Storage Networks: The complete Reference. TMH.
2. Nigel Poulton , Data Storage Networking-Real World Skills for the CompTIA Storage+ Certification and Beyond, Publishers: SYBEX a Wiley brand
3. Mauricio Arregoces, Data Center Fundamentals, Cisco Press; 1st edition, 2003.
4. Robert Spalding, Storage Networks: The Complete Reference, Tata McGraw Hill, Osborne, 2003.
5. Marc Farley, Building Storage Networks, Tata McGraw Hill, Osborne. 2001.
6. Meeta Gupta, Storage Area Network Fundamentals, Pearson Education Limited, 2002
7. G. Somasundaram, Alok Shrivastava, Information Storage and Management, EMC Education Series, Wiley, Publishing Inc., 2011.
8. Gustavo Santana, Data Center Virtualization Fundamentals: Understanding Techniques and Designs for Highly Efficient Data Centers with Cisco Nexus, UCS, MDS, and Beyond, Cisco Press; 1 edition, 2013
9. The Complete Guide to Data Storage Technologies for Network-centric Computing Paperback– Import, Mar 1998 by Computer Technology Research Corporation
10. Nigel Poulton ; Data Storage Networking: Real World Skills for the CompTIA Storage
11. http://www.snia.org
12. http://searchstorage.techtarget.com


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## E48: Wireless and Mobile Communication

**Course Code:** CSTE-402: E48

**Course Name:** Wireless and Mobile Communication

**Brief Course Description:**

- The Mobile and Pervasive Computing module aims to provide an understanding of the issues, technologies and concepts underlying the prospects of an extended computing infrastructure, especially wireless networks, context awareness, sensors and programming for limited and mobile devices. The module also provides experience in scientific and engineering techniques in design, experimentation, writing and critical literature. This can be achieved through a combination of lectures on basic concepts and theory, seminars on literature and design, laboratory exercises on the implementation of systems of these technologies and a separate study of the construction of this work in the classroom. Appropriate experimental methods, including simulation and experimentation, and forms for analyzing the results are discussed through the study of various topics.

**Prerequisite(s) and/or Note(s):**

- Basic understanding of computer networks and data communications

**Course Objectives:**

- Get acquainted with the characteristics, basic concepts and problems of mobile and advanced computer systems
- Illustrate the architecture and protocols of advanced computing and the latest advances in technology in this area to identify trends
- To provide practical experience in the field through the design and implementation of a medium research project
- Successfully design mobile and advanced computer applications and services
- Evaluate critical design differences related to different mobile technologies, architectures, interfaces and business models and how they affect commercial usability, mobile security and complex computing services and applications.

**Knowledge acquired:**

- To discover the characteristics , privacy and of pervasive computing applications including the major system components and architectures of the systems
- To analyze the strengths and limitations of the tools and devices for development of pervasive computing systems
- To explore the characteristics of different types of mobile networks on the performance of a pervasive computing system

**Skills gained:**

- To develop an attitude to propose solutions with comparisons for problems related to pervasive computing system through investigation

**Competency Developed:**

- To analyze and compare the performance of different data dissemination techniques and algorithms for mobile real time applications

**Course Syllabus:**

**Unit 1: Mobile Computing**

Introduction, Differences between Mobile Communication and Mobile Computing, Contexts and Names; Functions, Applications and Services, Design Considerations, Integration of Wireless and Wired Networks Standards Bodies;

**Unit 2: Wireless Transmission and Networks**

Wireless Transmission, Signal Propagation, Spread Spectrum, Satellite Networks, Frequency/Capacity Allocation, FAMA, DAMA, MAC; *Wireless networks*- Wireless LAN, IEEE 802.11 Standard, Architecture, Services, AdHoc Network, HiperLan, Blue tooth, WiFi, WiMAX, 3G, WATM; Cellular Wireless Networks, GSM, Architecture, Protocols, Connection Establishment; *Routing*-Mobile IP,

DHCP, Proactive and Reactive Routing Protocols, Multicast Routing; Handover, GPRS; Transport And Application Layers- TCP over Adhoc Networks, Mobile IP protocols -WAP push architecture; WWW Programming Model, WDP, WTLS, WTP, WSP, WAE, WTA Architecture, WML, WML Scripts and applications

**Unit 3: Sensor and Mesh Networks**
Sensor Networks, Role in Pervasive Computing in Network Processing and Data Dissemination, Sensor Databases, Data Management in Wireless Mobile Environments, Wireless Mesh Networks Architecture, Mesh Routers, Mesh Clients Routing, Cross Layer Approach, Security Aspects of Various Layers in WMN, Applications of Sensor and Mesh networks

**Unit 4: 3g and 4g Cellular Networks**
Migration to 3G Networks, IMT 2000 and UMTS, UMTS Architecture, User Equipment Radio Network Subsystem, UTRAN Node, B RNC functions, USIM Protocol Stack, IT and PS Domains, IMS Architecture, Handover 3.5G and 3.9G, a brief discussion 4G LAN and Cellular Networks, LTE Control Plane, NAS and RRC User Plane, PDCP, RLC and MAC WiMax IEEE 802.16d/e WiMax Internetworking with 3GPP

**Unit 5: Context Aware Computing**
Adaptability Mechanisms for Adaptation, Functionality and Data Transcoding, Location Aware Computing, Location Representation, Localization Techniques, Triangulation and Scene Analysis, De-launay Triangulation and Voronoi graphs, Types of Context, Role of Mobile Middleware, Adaptation and Agents, Service Discovery Middleware;

**Unit 6: Mobile computing environment**
Functions-architecture-design considerations, content architecture, CC/PP exchange protocol, context manager; Data management in WAECoda file system, caching schemes, Mobility QOS, Security in mobile computing

**Unit 7: Handoff in wireless mobile networks**
Reference model-handoff schemes, Location management in cellular networks, Mobility models, location and tracking management schemes, time, movement, profile and distance based update strategies, ALI technologies

**Unit 8: Open protocols**
Service discovery technologies- SDP, Jini, SLP, UpnP protocols, data synchronization, SyncML framework, Context aware mobile services, Context aware sensor networks, addressing and communications, Context aware security

**Unit 9: Pervasive Computing:**
BasiIT, Vision and Principles; CharacteristiIT- interaction transparency, context aware, automated experience capture; Architecture for pervasive computing, Pervasive devices, Categories of Pervasive Devices, embedded controls, smart sensors and actuators, Context communication and access services

**Unit 10: Application Development**
Three tier architecture, MVC Architecture, Memory Management, Information Access Devices, PDAs and Smart Phones, Smart Cards and Embedded Controls, J2ME Programming for CLDC, GUI in MIDP Application Development ON Android and iPhone.

**Suggestive Readings:**

1. Asoke K Talukder, Hasan Ahmed, Roopa R Yavagal, Mobile Computing: Technology, Applications and Service Creation, 2nd Ed., TMH, 2010
2. Asoke K Taukder, Roopa R Yavagal, Mobile Computing, TMH, 2005
3. Frank Adelstein, Fundamentals of Mobile and Pervasive Computing, TMH, 2005

4. JochenBurthardt et al, Pervasive Computing: Technology and Architecture of Mobile Internet Applications, Pearson Education, 2003
5. Stefan Poslad, Ubiquitous Computing: Smart Devices, Environments and Interactions, Wiley, 2009
6. Ivan Stojmenovic , Handbook of Wireless Networks and Mobile Computing, John Wiley & sons Inc, Canada, 2002
7. Jochen Schiller, Mobile Communications, PHI/Pearson Education, 2nd Ed., 2003
8. Uwe Hansmann, LotharMerk, Martin S. Nicklons and Thomas Stober, Principles of Mobile Computing, Springer, New York, 2003.
9. C.K.Toh, AdHoc Mobile Wireless Networks, PHI, 2002
10. Charles E.Perkins, AdHoc Networking, Addison-Wesley, 2001
11. Seng Loke, Context-Aware Computing Pervasive Systems, Auerbach Pub., New York, 2007

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## EO-06: Open/Swayam Course

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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## CSTE- 403 (Electives):

## E50: Cyber Security

**Course Code:** CSTC-403: E50

**Course Name:** Cyber Security

**Brief Course Description:**

- The course will be focusing on information systems, information security, security threats and risks, computer crimes, data security and backup, importance of digital forensic, issues in computer and mobile forensic and cyber laws in detail.

**Prerequisite(s) and/or Note(s):**

- Basic understanding of Data communication
- Basic understanding of Computer Networks

**Course Objectives:**

- Identify the process in taking digital evidence
- Assess the different forensics tools
- To study the fundamentals of Computer Forensics

**Knowledge acquired:**

- Differentiate among different types of security attacks
- Define computer forensics

**Skills gained:**

- To study the tools and tactics associated with Cyber Forensics
- Describe how to conduct an investigation using methods of memory, operating system, network and email forensics

**Competency Developed:**

- To learn, analyze and validate Forensics Data

**Course Syllabus:**

**Unit 1: Information Security Concepts**
Introduction, History, Critical Characteristics of Information, Information System and its components, Security Vs. Protection, Need for Security, Information Security Overview, Goals for Security, Securing the Components, Information Security Services, The Security SDLC, Business Needs, Security Threats and Vulnerabilities , Attacks and Types of Attacks, Legal, Ethical and Professional Issues, Balancing Security and Access, NSTISSC Security Model, E-commerce Security, Computer Forensics, Steganography,

**Unit 2: Security Engineering**
Security Threats, vulnerabilities and Scanning: Overview of Security threats, Hacking Techniques, Password Cracking, Insecure Network connections, Malicious Code, Programming Bugs, Cybercrime and Cyber terrorism, Information Warfare and Surveillance, Overview of vulnerability scanning, Open Port / Service Identification, Banner / Version Check, Traffic Probe, Vulnerability Probe, Vulnerability Examples, OpenVAS, Metasploit. Networks Vulnerability Scanning - Netcat, Socat, understanding Port and Services tools - Datapipe, Fpipe, WinRelay, Network Reconnaissance – Nmap, THC-Amap and System tools. Network Sniffers and Injection tools – Tcpdump and Windump, Wireshark, Ettercap, Hping Kismet

**Unit 3: Network Defense tools**
Firewalls and Packet Filters- Firewall Basics, Packet Filter Vs Firewall, How a Firewall Protects a Network, Packet Characteristic to Filter, Stateless Vs Stateful Firewalls, Network Address Translation (NAT) and Port Forwarding, the basic of Virtual Private Networks, Linux Firewall, Windows Firewall, Snort: Introduction Detection System

**Unit 4: Web Application Tools**
Scanning for web vulnerabilities tools: Nikto, W3af, HTTP utilities, Curl, OpenSSL and Stunnel, Application Inspection tools, Zed Attack Proxy, Sqlmap. DVWA, Webgoat, Password Cracking and Brute-Force Tools, John the Ripper, L0htcrack, Pwdump, HTC-Hydra

**Unit 5: Network and Computer Security**
Cryptography, Access Control and Intrusion Detection, Access Control Devices, Physical Security, Security and Personnel, Security issues in wireless

**Unit 6: Cyber Security**
Introduction, Weak / Strong Passwords and Password Cracking, Web Browsers Security, Email Security: PGP and SMIME, Web Security: web authentication, SSL and SET, Firewall and Utm,

**Unit 7: Cyber Forensics**
Firewalls and Packet Filters, password Cracking, Keyloggers and Spyware, Virus and Warms, Trojan and backdoors, Steganography, DOS and DDOS attack, SQL injection, Buffer Overflow, Attack on wireless Networks

**Unit 8: Cyber Crimes and Law**
Cyber Crimes, Types of Cybercrime, Hacking, Attack vectors, Cyberspace and Criminal Behavior, Clarification of Terms, Traditional Problems Associated with Computer Crime, Introduction to Incident Response, Digital Forensics, Realms of the Cyber world, Recognizing and Defining Computer Crime, Contemporary Crimes, Computers as Targets, Contaminants and Destruction of Data, Cyber Law, Indian IT Act, 2000, Information Security Policy, Standards and Practices, NIST Models, VISA International Security Model, Design of Security Architecture, Planning for Continuity, SSE-CMM / COBIT, ISO 17799/BS 7799, ISO 27001, Basics of Indian Evidence ACT IPC and CrPC , Electronic Communication Privacy ACT, Legal Policies.

**Suggestive Readings:**


1. Michael E Whitman and Herbert J Mattord, Principles of Information Security, Vikas Publishing House, 2003
2. Matt Bishop, Computer Security Art and Science, Pearson Education, 2002
3. Ron Weber, Information Systems Control and Audit, Pearson Education, 2004
4. Stuart Mc Clure, Joel Scrambray, George Kurtz, Hacking Exposed, TMH, 2003
5. Mike Shema, Anti-Hacker Tool Kit (Indian Edition), TMH
6. Nina Godbole and SunitBelpure, Cyber Security: Understanding Cyber Crimes, Computer Forensics and Legal Perspectives, Publication Wiley
7. Garms, Jess and Daniel Somerfield, Professional Java Security, Wrox. 2001
8. Nelson Phillips and EnfingerSteuart, Computer Forensics and Investigations, Cengage Learning, New Delhi, 2009
9. Kevin Mandia, Chris Prosise, Matt Pepe, Incident Response and Computer Forensics, TMH, 2006
10. Bernadette H Schell, Clemens Martin, Cybercrime, ABC – CLIO Inc, California, 2004
11. Understanding Forensics in IT, NIIT Ltd, 2005


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## E51: Internet of Things (IoT)

**Course Code:** CSTC-403: E51

**Course Name:** Internet of Things (IoT)

**Brief Course Description:**

- This course will describe the market around the Internet of Things (IoT), the technology used to build these kinds of devices, how they communicate, how they store data, and the kinds of distributed systems needed to support them.

**Prerequisite(s) and/or Note(s):**

- Computer Networks and Data Communication
- Microprocessors
- Basic understanding of programming languages

**Course Objectives:**

- The objective of this course is to enable you to build an IoT system from the ground up. Students will be explored to the interconnection and integration of the physical world and the cyberspace
- To understand about the fundamentals of Internet of Things and its building blocks along with their characteristics
- To understand the recent application domains of IoT in everyday life
- To understand the protocols and standards designed for IoT and the current research on it
- To understand the other associated technologies like cloud and fog computing in the domain of IoT

**Knowledge acquired:**

- Describe what IoT is and how it works today
- Able to understand building blocks of Internet of Things and characteristics
- Design and program IoT devices
- Use real IoT protocols for communication
- Secure the elements of an IoT device
- Transfer IoT data to the cloud and in between cloud providers
- Define the infrastructure for supporting IoT deployments

**Skills gained:**

- Recognise the factors that contributed to the emergence of IoT
- Able to realize the revolution of Internet in Mobile Devices, Cloud & Sensor Networks

- Able to design & develop IOT Devices

**Competency Developed:**

- Design an IoT device to work with a Cloud Computing infrastructure.

**Course Syllabus:**

**Unit 1: Basics of IoT**

Introduction to IoT, Sensing & actuation, various sensors and sensing techniques, impact of IoT on society; review of various IoT application domain including agriculture, healthcare, manufacturing, device management, and vehicle to vehicle communication and wearable computing devices; Technological trends in IoT, basics of Networking, Communication Protocol, Sensor Networks, Machine-to-Machine Communications

**Unit 2: Microcontroller and Interfacing Techniques for IoT Devices**

Architecture layers, IoT smart devices, typical embedded computing systems, introduction to ARM architecture and programming method, introduction to interfacing techniques, embedded system development: a case study

**Unit 3: IoT Protocols & Security**

Networking and basic networking hardware; Networking protocols, Interaction between software and hardware in an IoT device; IoT components and technologies to secure systems and devices; various security issues related to the IoT and security architectures; hardware security threats and security vulnerabilities; protecting physical hardware

**Unit 4: Location Tracking**

Introduction to device localization and tracking; different types of localization techniques: time-of-arrival (TOA) based, time-difference-of-arrival (TDOA) based, angle-of-arrival (AOA) based, received signal strength (RSS) based, Radio-Frequency Identification (RFID) based and fingerprinting based; Monte-Carlo tracking; Kalman filter based tracking; Cramer-Rao lower bound (CRLB) for device location estimator; Device diversity/heterogeneity issue in IoT networks.

**Unit 5: Industry 4.0**

Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Smart and Connected Business Perspective, Industrial Processes, Industrial Sensing & Actuation, Industrial Internet Systems, Smart Factories, Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis,

**Unit 6: IIoT**

Introduction to IIoT, Business Model and Reference Architecture: IIoT-Business Models, IIoT Reference Architecture, IIoT Sensing, IIoT Processing, IIoT Communication, IIoT Networking

IoT in Big Data Analytics and Software Defined Networks: IoT Analytics - Introduction, Machine Learning and Data Science, Data Handling and Analytics, R and Julia Programming, Data Management with Hadoop, Data Center Networks, Introduction to SDN, SDN for IoT

**Unit 7: Fog Computing**

Fog Computing in IIoT, Security in IIoT, Cloud Computing in IIoT, Cloud Computing, Sensor-Cloud

**Unit 8: Deep learning for IoT**

This topic will focus how to build good model from the past data so as to predict correctly when the system is provided with a data-point. In this course mostly, supervised learning will be considered. Basics of neural network, activation functions, back-propagation, etc. will be covered. At the end some of the challenges in the context of IoT will be mentioned.

**Unit 9: Arduino Programming**
Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Introduction to Python programming, Introduction to Raspberry Pi, Implementation of IoT with Raspberry Pi

**Unit 10: Smart grid**
Introduction to smart grid, Integration of IoT into smart grid, Standardization activities for IoT aided smart grid, Applications of IoT aided smart grid, Architectures for IoT sided smart grid, Prototypes, Applications of big data and cloud computing, Open Issues and challenges;

**Unit 11: IoT-based Smart Home and Nano-grid Monitoring System**
Sensor-Controller Coordination of a DC Microgrid in IoT Platform, Cyber physical system, dc microgrid, dc–dc power converter, distributed energy generator, sensor control and controller design. Low Cost DC Nano-grid with Smart Remote Monitoring Unit, DC-DC converter modeling, closed loop control, placement of IoT devices, sensors, micro grid, solar energy, low cost communication system design, Introduction, objective, components of home monitoring system, control and management, Zigbee, Wireless Sensor Network (WSN), Internet of Things (IoT)

**Unit 12: Internet of Robotic Things (IoRT)**
Introduction to stationary and mobile robots; Brief introduction to localization, mapping, planning, and control of robotic systems; Introduction to cloud-enabled robotics; Applications of IoT in robotics; Architectures for IoRT; Examples and case studies; Open issues and challenges.

**Unit 13: IoT Application Domains**
Agriculture, Healthcare, Factories and Assembly Line, Food Industry, Activity Monitoring, Milk Processing and Packaging Industries, Manufacturing Industries, Power Plants, Inventory Management & Quality Control, Plant Safety and Security, Facility Management; Oil, chemical and pharmaceutical industry; Applications of UAVs in Industries, Virtual Reality, Steel Technology, Connected Vehicles, Smart Grid, Smart Cities and Smart Homes, Student Projects

**Suggestive Readings:**

1. RajkumarBuyaa and Amir V Dastjerdi, Internet of things: Principles and Paradigms, Morgan Kaufmann
2. A Bahga& V Madisetti, Internet of Things: A Hands On Approach, Universities Press
3. Adrian McEwen and Hakim Cassimally, Designing the Internet of Things, Wiley
4. Olivier Hersent, David Boswarthick and Omar Elloumi, The Internet of Things: Key applications and Protocols, Wiley
5. ArshdeepBahga and Vijay Madisetti, Internet of Things: A Hands-on Approach, Universities Press
6. Daniel Kellmereit, “The Silent Intelligence: The Internet of Things”.2013,ISBN 0989973700
7. Pethuru Raj and Anupama C. Raman , The Internet of Things: Enabling Technologies, Platforms, and Use Cases, CRC Press


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## E52: E-Commerce

**Course Code:** CSTC-403: E52

**Course Title:** E-Commerce

**Brief Course Description:**
- This course introduces the concepts, vocabulary, and procedures associated with E-Commerce and the Internet. The student gains an overview of all aspects of E-Commerce. Topics include development of the Internet and E-Commerce, options available for do-ing business on the Internet, features of Web sites and the tools used to build an E-Commerce web site, marketing issues, payment options, security issues, and customer service.

**Prerequisite(s) and/or Note(s):**

- Nil

**Course Objectives:**

**The objective of this course is to:**

- Discuss fundamentals of e-commerce, types and applications.
- Evaluate the role of the major types of information systems in a business environment and their relationship to each other
- Assess the impact of the Internet and Internet technology on business electronic commerce and electronic business
- Identify the major management challenges for building and using information systems and learn how to find appropriate solutions to those challenges.
- Learn strategies for e-commerce, Mobile Commerce, Wireless Application Protocol, WAP technology and Mobile Information devices.

**Knowledge Acquired:**
**At the end of the course student will be able to:**

- Understand the basic concepts and technologies used in the field of management information systems
- Understand the processes of developing and implementing information systems
- Understand the role of information systems in organizations, the strategic management processes, and the implications for the management and learn about the importance of managing organizational change associated with information systems implementation

**Skills Gained:**

- Develop an understanding of how various information systems work together to accomplish the information objectives of an organization

**Competency Developed:**

- Be aware of the ethical, social, and security issues of information systems and

**Course Syllabus:**

**Unit 1: E-commerce and its Technological Aspects**

Overview of developments in Information Technology and Defining E-Commerce: The scope of E commerce, Electronic Market, Electronic Data Interchange, Internet Commerce, Benefits and limitations of E-Commerce, Produce a generic framework for E-Commerce, Architectural framework of Electronic Commerce, Web based E Commerce Architecture.

**Unit 2: Consumer Oriented E-Commerce**

E-Retailing: Traditional retailing and e retailing, Benefits of e retailing, Key success factors, Models of e retailing, Features of e retailing. E services: Categories of e-services, Web-enabled services, match making services, Information-selling on the web, e entertainment, Auctions and other specialized services. Business to Business Electronic Commerce

**Unit 3: Electronic Data Interchange**

Benefits of EDI, EDI technology, EDI standards, EDI communications, EDI Implementation, EDI Agreements, EDI Security. Electronic Payment Systems, Need of Electronic Payment System: Study and examine the use of Electronic Payment system and the protocols used, Study Electronic Fund Transfer

and secure electronic transaction protocol for credit card payment. Digital economy: Identify the methods of payments on the net – Electronic Cash, cheques and credit cards on the Internet.

**Unit 4: Security in E-Commerce**

Threats in Computer Systems: Virus, Cyber Crime Network Security: Encryption, Protecting Web server with a Firewall, Firewall and the Security Policy, Network Firewalls and Application Firewalls, Proxy Server.

**Unit 5: Issues in E-Commerce**

Understanding Ethical, Social and Political issues in E-Commerce: A model for Organizing the issues, Basic Ethical Concepts, Analyzing Ethical Dilemmas, Candidate Ethical principles Privacy and Information Rights: Information collected at E-Commerce Websites, The Concept of Privacy, Legal protections Intellectual Property Rights: Types of Intellectual Property protection, Governance.

**Suggested Reading:**


1. Elias. M. Awad, “Electronic Commerce", Prentice-Hall of India Pvt Ltd.
2. RaviKalakota, Andrew B. Whinston, "Electronic Commerce-A Manager's guide", Addison-Wesley.
3. Efraim Turban, Jae Lee, David King, H. Michael Chung, “Electronic Commerce–A Managerial Perspective", Addison-Wesley.
4. Elias M Award, “Electronic Commerce from Vision to Fulfilment”, 3rd Edition, PHI,
5. Judy Strauss, Adel El-Ansary, Raymond Frost, “E-Marketing”, 3rd Edition, Pearson Education.
6. Ravi Kalakota, Andrew Winston, “Frontiers of Electronic Commerce”, Addison Wesley.
7. Pete Lohsin , John Vacca “Electronic Commerce”, New Age International
8. Goel, Ritendra “E-commerce”, New Age International
9. Laudon, “E-Commerce: Business, Technology, Society”, Pearson Education
10. Bajaj and Nag, “E-Commerce the cutting edge of Business”, TMH
11. Turban, “Electronic Commerce 2004: A Managerial Perspective”, Pearson Education


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## E53: Quantum Computing

**Course Code:** CSTC-403: E53

**Course Name:** Quantum Computing

**Brief Course Description:**

- A basic introduction to quantum mechanics, linear algebra, and familiarity with the Dirac notation is provided first to get one’s quantum concepts right. This is then followed by an introductory treatment of quantum computation and quantum information covering aspects of quantum entanglement, quantum algorithms, quantum channels.

**Prerequisite(s) and/or Note(s):**

- Basic understanding of mathematics
- Basic organizing and problem-solving ability

**Course Objectives:**

- To introduce the basic concepts of quantum computing
- To make students familiar with 1-qubit and 2-qubit gate operations

- To become familiar with the concepts of superposition and entanglement and be able to analyze quantum state
- To make students familiar with quantum algorithms

**Knowledge acquired:**
- Introductory idea about basic concepts of quantum computing.
- Clear idea about qubits and their applications.
- An ability to develop quantum algorithms.

**Skills gained:**
- Ideas about Qubits and quantum circuits.
- Develop quantum algorithms for implementations.

**Competency Developed:**
- Become familiar with the concepts of superposition and entanglement and be able to analyse quantum state transformations.
- Understand quantum algorithms and compare effectiveness versus classical algorithms.

**Course Syllabus:**

**Unit 1: Fundamentals of quantum computing**
Introduction to quantum computing, elementary quantum mechanics, linear algebra for quantum mechanics, Quantum Computing Vs Quantum Mechanics

**Unit 2: Superposition**
Concepts of superposition, entanglement, analyse simple states of superposition, and the effect of doing the measurement in different basis states.

**Unit 3: Qubits**
Qubits 1-bit, 2-bit. Qubit notations, build simple quantum circuits with single and two-qubit gates CNOT, Toffoli, Fredkin, SWAP gate and Simple circuits.

**Unit 4: Basics of linear algebra**
Introduction, Dirac notation, vectors, complex conjugate and norms

**Unit 5: Introduction to quantum algorithms**
Concepts of simple quantum algorithms

**Suggestive Readings:**

1. Quantum Computation and Quantum Information, M A Nielsen and I L Chuang.
2. An Introduction to Quantum Computing, P Kaye, R Laflamme and M Mosca.
3. Quantum Computing for Everyone (The MIT Press), Chris Bernhardt
4. Linear Algebra and its Applications, G. Strang.


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## E54: Social Network Analysis

**Course Code:** CSTC-403: E54

**Course Title:** Social Network Analysis

**Brief Course Description:**
- Social Network Analysis (SNA) has become a widely applied method in research and business for inquiring the web of relationships on the individual, organizational and societal level. With ready access to computing power, the popularity of social networking websites such as Facebook, and

automated data collection techniques the demand for solid expertise in SNA has recently exploded.

**Prerequisite(s) and/or Note(s):**

- Basic knowledge of Graph Theory

**Course Objectives:**

- To understand the concept of semantic web and related applications
- To learn knowledge representation using ontology.
- To understand human behaviour in social web and related communities.
- To learn visualization of social networks.
- Collect network data in different ways and from different sources while adhering to legal standards and ethics standards, legal standards and ethics standard.

**Knowledge Acquired:**

- Basic concepts and analysis techniques in Social Network Analysis (SNA).
- Identifying the key individuals and groups in social systems, to detect and generate fundamental network structures, and to model growth and diffusion processes in networks.

**Skills Gained:**

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

- Develop semantic web related applications.
- Represent knowledge using ontology.
- Predict human behaviour in social web and related communities.

**Competency Developed:**

- In this course, students learn how to conduct Social Network Analysis (SNA) projects and how to approach SNA with theoretic, methodological, and computational rigor.
- Able to design and execute network analysis projects including collecting data and considering ethical and legal implications, to perform systematic and informed analyses of network data for personal, commercial and scholarly use, and to critically review SNA projects conducted by others.

**Course Syllabus:**

**Unit 1: Introduction to Social Network Analysis**

Introduction to Semantic Web: Limitations of current Web, Development of Semantic Web, Emergence of the Social Web; Social Network analysis: Definition, scope, development of Social Network Analysis, key concepts and measures in network analysis; steps in social network analysis: network definition, manipulation, calculation, visualization; electronic sources for network analysis: Electronic discussion networks; Blogs and online communities, Web-based networks, Applications of Social Network Analysis, Technological networks; Sampling and data characteristics, Review of Graph Properties / Visualization

**Unit 2: Large-scale Structure of Networks / Algorithms**

Shortest-paths and the small-world effect; Degree distributions; Power laws and scale-free networks; clustering coefficients; Basic graph algorithms: computing properties of nodes and dyads; Maximum flow; Network Growth Models; Link Analysis; Prediction; Cascade Behavior and Network Effects; Anomaly Detection

**Unit 3: Ego Analysis / Bi-partite networks**

Analysis of local networks; Structural holes theory; Measures of constraint; Bi-partite and affiliation networks; One-mode projections and analyses

**Unit 4: Exponential Random Graph Modeling**
Frameworks for evaluating results in network analysis: autocorrelation, matching techniques, QAP regression, exponential random graphs, and p* models. Computational considerations

**Unit 5: Network Evolution**
Actor models; Network dynamics vs behavior dynamics; RSiena; Model creation and estimation; Animation with RSonia;

**Unit 6: Modelling, Aggregating and Knowledge Representation**
Ontology and their role in the Semantic Web: Ontology-based knowledge Representation - Ontology languages for the Semantic Web: Resource Description Framework - Web Ontology Language - Modelling and aggregating social network data: State-of-the-art in network data representation - Ontological representation of social individuals - Ontological representation of social relationships - Aggregating and reasoning with social network data - Advanced representations.

**Unit 7: Extraction and Mining Communities in Web Social Networks**
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 social network infrastructures and communities; Decentralized online social networks; Multi-Relational characterization of dynamic social network communities

**Unit 8: Predicting Human Behaviour and Privacy Issues**
Understanding and predicting human behaviour for social communities; User data management; Inference and Distribution; Enabling new human experiences; Reality mining; Context; Awareness; Privacy in online social networks; Trust in online environment; Trust models based on subjective logic; Trust network analysis; Trust transitivity analysis; Combining trust and reputation; Trust derivation based on trust comparisons; Attack spectrum and countermeasures.

**Unit 9: Applications of Social Networks**
Applications; Cover networks; Community welfare; Collaboration networks; Co-Citation networks

**Suggested Reading:**


1. Tanmoy Chakraborty, Social Network Analysis, Wiley, 2021
2. Stanley Wasserman, Katherine Faus; Social Network Analysis: Methods and Applications; Cambridge University Press
3. Peter Mika, Social Networks and the Semantic Web, 1st Edition, Springer 2007.
4. Borko Furht, Handbook of Social Network Technologies and Applications, 1st Edition, Springer, 2010.
5. Guandong Xu ,Yanchun Zhang and Lin Li, Web Mining and Social Networking – Techniques and applications, First Edition, Springer, 2011.
6. Dion Goh and Schubert Foo, Social information Retrieval Systems: Emerging Technologies and Applications for Searching the Web Effectively, IGI Global Snippet, 2008.
7. Max Chevalier, Christine Julien and Chantal Soulé-Dupuy, Collaborative and Social Information Retrieval and Access: Techniques for Improved user Modelling, IGI Global Snippet, 2009.
8. John G. Breslin, Alexander Passant and Stefan Decker, The Social Semantic Web, Springer, 2009.
9. Newman, M.E.J. , Networks: An Introduction, Oxford University Press, 2010
10. Stanley Wasserman, Katherine Faus; Social Network Analysis: Methods and Applications, Cambridge University Press


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## E55: Digital Image Processing

**Course Code:** CSTC-403: E55

**Course Name:** Digital Image Processing

**Brief Course Description:**

- Concepts of Digital Image Processing cycle, steps along with introduction to steganography are discussed.

**Prerequisite(s) and/or Note(s):**

- Basic understanding of programming languages
- Basic understanding of Data Structure and Algorithms
- Basic understanding of Computer Graphics

**Course Objectives:**

- To introduce the concepts of image processing and basic analytical methods to be used in image processing. To familiarize students with image enhancement and restoration techniques, To explain different image compression techniques. To introduce segmentation and morphological processing techniques
- To study the image fundamentals and mathematical transforms necessary for image processing
- To study the image enhancement techniques
- To study image restoration procedures
- To study the image compression procedures

**Knowledge acquired:**

- Analyze general terminology of digital image processing.
- Describe and explain basic principles of digital image processing.
- To study the image fundamentals and mathematical transforms necessary for image processing.
- Examine various types of images, intensity transformations and spatial filtering.
- Understand the need for image compression and to learn the spatial and frequency domain techniques of image compression.
- Evaluate the methodologies for image segmentation, restoration etc.
- Learn the signal processing algorithms and techniques in image enhancement and image restoration, and image compression procedures.
- Implement image process and analysis algorithms.
- Understand the rapid advances in Machine vision.
- Learn different causes for image degradation and overview of image restoration techniques.
- Learn different feature extraction techniques for image analysis and recognition
- Understand and analyze image processing problems
- Understand the role of alternative color spaces, and the design requirements leading to choices of color space.

**Skills gained:**

- Get broad exposure to and understanding of various applications of image processing in industry, medicine, and defence.
- Design algorithms to solve image processing problems and meet design specifications.
- Be able to conduct independent study and analysis of image processing problems and techniques.
- Apply image processing algorithms in practical applications.
- Review the fundamental concepts of a digital image processing system.

**Competency Developed:**

- Acquire an appreciation for the image processing issues and techniques and be able to apply these techniques to real world problems.
- Design and implement algorithms that perform basic image processing and image analysis

- Assess the performance of image processing algorithms and systems.
- Interpret Image compression standards, image segmentation and representation techniques.
- Develop any image processing application.

**Course Syllabus:**

**Unit 1: Fundamentals of Image Processing**
Image Acquisition, Image Model, Sampling, Quantization, Relationship between pixels and distance measurement, connectivity, Image Geometry, Photographic film, Light, Brightness adaption and discrimination, Perspective Projection, Spatial Domain Filtering, Grayscale and Color fundamentals, color models (RGB, CMY, HIS), formulation, color complements, color slicing, tone and color corrections, image file formats

**Unit 2: Image Filtering in Spatial Domain Filtering**
Intensity transformations, contrast stretching, histogram equalization, Correlation and convolution, Smoothing filters, sharpening filters, gradient and Laplacian;
Image Filtering Frequency domain Filtering- Hotelling Transform, Fourier Transforms and properties, FFT, Convolution, Correlation, 2-D sampling, Discrete Cosine Transform, Frequency domain filtering, Inverse filtering, Least squares filtering. Recursive filtering

**Unit 3: Image Segmentation**
Definition, Detection of Discontinuities, Point, line detection, Edge detection, Edge linking, local processing, regional processing, Hough transform, Iterative and Multivariable thresholding, Otsu's method, Moving averages, Boundary detection based techniques; Characteristics of segmentation, Pixel based, Region based and histogram based segmentation methods, segmentation by sub region aggregation, split and merge technique, Watershed segmentation, Use of motion in segmentation (spatial domain technique only),

**Unit 4: Image Enhancement in Spatial Domain Methods**
Arithmetic and Analytical operations, pixel or point operations, size operations) Smoothing filters Mean, Median, Mode filters. Low pass filters, high pass filters, sharpening filters;

**Unit 5: Image Enhancement in Frequency Domain Method**
Design of Low Pass, High Pass, Edge enhancement, Sharpening filters in frequency domain, Bufier Worth Filter, Homomorphic filters in frequency domain and spatial domain.

**Unit 6: Image Restoration**
Basic Framework and models, Interactive Restoration, Image deformation and geometric transformations, image morphing, Restoration techniques, Noise characterization, Noise restoration filters, Adaptive filters, Linear, Position invariant degradations, Estimation of Degradation functions, Restoration from projections.

**Unit 7: Morphological Image Processing**
Basics, SE, Erosion, Dilation, Opening, Closing, Hit-or-Miss Transform, Boundary Detection, Hole filling, Connected components, convex hull, thinning, thickening, skeletons, pruning, Geodesic Dilation, Erosion, Reconstruction by dilation and erosion;

**Unit 8: Image Compression**
Image Compression: Encoder-Decoder model, Types of redundancies, Lossy and Lossless compression, Entropy of an information source, Shannon's Theorem, Hufiman Coding, Arithmetic Coding, Golomb Coding, LZW coding, Transform Coding, Sub-image size selection, blocking artifacts, DCT implementation using FFT, Run length coding, FAX compression, Symbol-based coding, JBIG-2, Bit-plane encoding, Bit-allocation, Zonal Coding, Threshold Coding, JPEG, Lossless predictive coding, Lossy predictive coding, Motion Compensation; Wavelet based Image Compression- Expansion of functions, Multi-resolution analysis, Scaling functions, MRA refinement equation, Wavelet series

expansion, Discrete Wavelet Transform, Continuous Wavelet Transform, Fast Wavelet Transform, 2-D wavelet Transform, JPEG-2000 encoding, Digital Image Watermarking; Fidelity criterion- MSE, PSNR, Compression ratio

**Unit 9: Application domains of Digital Image Processing**
Application domains of Digital Image Processing i.e. Medical Image processing, GIS and Agricultural Image Processing, Face recognition, character recognition, Steganography etc.

**Suggestive Readings:**


1. Gonslaez, et.a1, "Digital Image Processing", Addison Wesley, Reading, M.A., 1990
2. Anil K Jain; Fundamentals of Digital Image Processing
3. Rafael C Gonzalez, Richard E Woods; Digital Image Processing, Pearson Education
4. Rafael C Gonzalez, Richard E Woods, Eddins; Digital Image Processing using MATLAB, Pearson Education
5. B Chanda & D Dutta Majumder; Digital Image Processing and Analysis, PHI
6. Jaydeep Chakravorty, Introduction to MATLAB Programming, Toolbox and Simulink, Universities Press


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## EO-07: Open/Swayam Course

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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## CSTE- 404: Elective: EO-08 (SWAYAM)

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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## Year 3: Semester 5

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### CSTE- 501: Elective: EO-09 (SWAYAM)

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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### CSTE- 502: Elective: EO-10 (SWAYAM)

For SWAYAM courses in a particular semester, students can opt for only those courses which are not covered in any other semester and are not offered by the Department in that semester. The selection of the SWAYAM courses should be done in consultation with the SWAYAM course Coordinator of the Department. For general information regarding MOOCs/ NPTEL/ SWYAM/ Open Courses, refer to the section at the beginning of the syllabus.

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### CSTC- 503: Project Synopsis

The students are to take one minor research project in parallel to the academic curriculum of the semester. Synopsis is the gist of the planned project submitted for approval from the concerned Supervisor. It gives a panoramic view of the research/project for quick analysis by the Supervisor.
A synopsis can be structured in the following manner:

- Title
- Statement of the problem and hypothesis
- Aims and objectives
- Review of literature / Existing Work
- Research methodology

Focus should be given on current research areas in the concerned academic domain. The complete detail project report to be prepared and to be presented before the examiners after being certified by the supervisor.

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## Year 3: Semester 6

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### CSTC- 601: Dissertation and Defence

**Course Description:**
This is in continuation to the project proposal submitted during Semester-V. The students are required to implement the proposed project using any suitable programming language and technologies. Detailed dissertation report to be submitted and defended before the Examiners.

**Course Outcome:**

- Students will have the experience of working in any one laboratories of repute in our country like CSIR Lab, DST Lab, C-DAC, NPL, MTRDC, SAC, ISRO, Academic Institutions including University of North Bengal, and in various industry etc.
- Students will gain an experience on working on research topics/ application domain.

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### CSTC- 602: Grand Viva

**Course Description:**

A student has to appear before a board of examiners at the end of Semester VI, for a grand viva-voce examination covering the entire course curriculum.

**Course Outcome:**

Students would gain an idea about how far he/ she has learned during the three year study of M.Tech. in Computer Science and Technology.

**Core Syllabus:**

Entire course curriculum.

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