Indian Institute of Technology Jodhpur

Course Booklet

for

M.Tech. (CSE)

and

Dual degree M.Tech. (CSE) + PhD

Programs

offered by the

Department of Computer Science and Engineering

July 2019

M.Tech and M.Tech-Ph.D dual degree programs in Computer Science and Engineering

Introduction:

Traditionally Computer Science and Engineering (CSE) teaching were focusing on two major areas, i.e., theories and systems (database, computer hardware, and operating systems). With the advent of the era of Cloud Computing, Edge Computing, AI and Big Data, the discipline is being transformed by incorporation of new emerging technologies. It is becoming an instrumental tool in solving major problems faced by modern society such as energy, natural disasters, pollution, and water. Through this newly revamped M.Tech and M.Tech-Ph.D dual degree programs in CSE, IIT Jodhpur is making a conscious effort to divulge from the traditional path and planning to reposition itself to become a leading institute in this new genre of Computer Science education.

Objectives:

This M.Tech and M.Tech-Ph.D dual degree programs in CSE will offer students with deep knowledge of core and applied computer science. Through this programme, a student will learn niche subject areas which are of paramount importance in the modern big data era, such as Computer Systems and Security. This programme is aiming at imparting the necessary breadth and depth to the students for pursuing careers in academics as well as in industry. This programme is aiming at extending undergraduate computing skills with up-to-date and in-depth expertise in specialized areas of Computer Systems and Security.

Expected Graduate Attributes:

After completing this programme, a student will be able to develop an ability to:

1. Understand fundamental concepts and hands-on knowledge of emerging fields in Computer Science.
2. Conceive, Design and Develop state-of-the-art scalable parallel and distributed systems
3. Solve Big data problems through the knowledge of advanced data structures, distributed algorithmic design, analysis, and applications.
4. Design and develop network protocols for Wireless, Sensor, Mobile, and Vehicular networks.
5. Ideate, Implement and Integrate cryptographic, fault tolerant algorithms for large scale distributed systems
6. Understand state-of-the-art hardware platforms for running compute intensive distributed algorithms
7. Ability to understand and apply evolving ethics and privacy laws across various domains and territories.
8. Plan and manage technical projects

Learning Outcome:

1. Understand the fundamentals of algorithmic complexity, advanced computer architecture, advanced network, and security protocols.
2. Apply appropriate design principles, framework and protocols to develop dependable systems.
3. Demonstrate hands-on knowledge of cutting edge simulation, synthesizing, programming tools.
4. Ability to design and develop system architecture for mobile, cloud, fog, and edge computing.
5. Demonstrate hands-on knowledge of virtualization, data center design and management, and software defined networking.
6. Skills to comprehend and communicate effectively.
7. Apply appropriate project and business management principles and tools for real-world problems.

Course Structure for the

M.Tech. (CSE) Program and
Dual Degree M.Tech. (CSE)+Ph.D. Program

Cat	Code	Course Title	L-T-P	Cr
I Semester				
C	MAL7xx0	Statistics I Matrix Computation Optimization	1-0-0 1-0-0 1-0-0	3
C	CSL7xx0	Algorithms for Big Data	2-0-0	2
C	CSL7xx0	Machine Learning I	3-0-0	3
C	CSP7xx0	Data Structures and Practices	0-0-2	1
PE	xxxxx	Program Elective 1	3-0-0	3
PE	xxxxx	Program Elective 2	3-0-0	3
NG		Technical Communication	1-0-0	1
			Total Credits: 16	

Cat	Code	Course Title	L-T-P	Cr
II Semester				
C	CSL7xx0	Computer Architecture	3-0-0	3
C	CSL7xx0	Software and Data Engineering	3-0-0	3
C	CSL7xx0	Security and its applications	3-0-0	3
PE	xxxxx	Program Elective 3	3-0-0	3
OE	xxxxx	Open Elective 1	3-0-0	3
NG	xxxxx	Ethics and Professional Life	1-0-0	1
			Total Credits: 16	

*Maths Fractals: Linear Algebra, Probability and Random Processes, Optimization

Cat	Code	Course Title	L-T-P	Cr
III Semester				
P	CSD7xx0	Major Project – Part 1	0-0-10	5
PE	xxxxx	Program Elective 4	3-0-0	3
PE	xxxxx	Program Elective 5	3-0-0	3
OE	xxxxx	Open Elective - 2	3-0-0	3
NG	xxxxx	System Design	1-0-0	1
			Total Credits: 15	

Cat	Code	Course Title	L-T-P	Cr
IV Semester				
P	CSD8xx0	Major Project – Part 2	0-0-22	11
PE	xxxxx	Program Elective 6	3-0-0	3
NG	xxxxx	Intellectual Property	1-0-0	1
			Total Credits: 15	

Credit Distribution		
1	Program Core	18 credits
2	Program Electives	18 credits
3	Open Electives	6 credits
4	Project	16 credits
5	Non-graded	4 credits
	Total	62 credits

Program Electives for M.Tech. (CSE) and Dual Degree M.Tech. (CSE)+Ph.D. Program

Courses offered by Department of Computer Science and Engineering

- Advanced Computer Graphics
- AI for Finance
- Artificial Intelligence I
- Artificial Intelligence II
- Bio-image computing
- Blockchain
- Computer Graphics
- Computer Vision
- Computational Optimization
- Data Visualization
- Dependable AI
- Digital Image Analysis
- Edge and Fog Computing
- Embedded Systems
- GPU Programming
- Graph Theory and Applications
- Human Machine Interface
- Information Retrieval and Web Mining
- Introduction to Augmented Reality and Virtual Reality
- Machine Learning II
- Machine Learning with Big Data
- Natural Language Processing
- Neuromorphic Computing and Design
- Real time Autonomous Systems
- Ad hoc Wireless Networks
- Selected Topics in Artificial Intelligence - I
- Selected Topics in Artificial Intelligence - II
- Selected Topics in Artificial Intelligence - III
- Selected Topics in Computer Science - I
- Selected Topics in Computer Science - II
- Selected Topics in Computer Science - III
- Social Network Analysis
- Speech processing
- Stream Analytics
- Vehicular Ad-hoc Networks (VANETs)

Courses offered by Department of Electrical Engineering

- Adaptive Signal Processing
- Advanced Control System
- Advanced Digital Communication
- Advanced Signal Processing
- Analog and Interfacing Circuits
- Antenna Engineering
- Applied Optimization for Wireless Communication

- Backhaul Networks for Wireless Systems
- Coding Theory
- Compressive Sensing
- Computational Imaging
- Cyber Physical System Modelling Laboratory
- Data Compression
- Digital image and Video Processing Lab
- Digital Image Processing and Applications
- Digital Signal Processing
- Digital Video Processing
- Digital VLSI Design
- Embedded System Design
- Embedded System Design Lab
- Flexible and Printed Electronics
- Free Space Optical Communications
- GNSS Signal Processing
- Image Sensor Design and Applications
- Introduction to Cyber-Physical Systems
- Machine Learning for Communication
- Mathematical Modelling and Simulation
- Microfluidics Technology
- Microsystems Fabrication Technology
- Millimeter Wave Technology
- Multi-rate Digital Signal Processing
- Nanosensors
- Network Information Theory
- Neuromorphic computing and design
- Optical Fiber Communications
- Optimal Filtering
- Physical Layer Security
- Principles of Data and System Security
- Real Time Communications
- Resource Constrained AI
- RF IC Design
- RF IC Design Lab
- Selected Topics in Communication I
- Selected Topics in Communication I
- Selected Topics in Communication II
- Selected Topics in Communication III
- Selected Topics in Sensors & IoT I
- Selected Topics in Sensors & IoT II
- Selected Topics in Sensors & IoT III
- Selected Topics in Signal Processing I
- Selected Topics in Signal Processing II
- Selected Topics in Signal Processing III
- Sensors and IoT Lab
- Sensors and Measurement
- Smart Grid
- Speech and Audio Signal Processing
- Statistical Decision Theory

- Systems-on-Chips Design
- VLSI Design Lab
- Wavelets
- Wireless Communication
- Wireless Networks

Courses offered by Department of Mechanical Engineering
- Robotics

Courses offered by Department of Bioscience and Bioengineering
- Bioinformatics
- Computational Biology

Courses offered by Department of Mathematics
- Financial Engineering
- Computational finance
- Computational Game Theory
- Advanced topics in computational PDE
- Dynamical Systems
- Stochastic Processes
- Representation of Finite Groups

Courses offered by Department of Physics
- Quantum Computing
- Quantum Information Processing
- Quantum Cryptography and Coding

Courses offered by IDRP Digital Humanities
- Digital Humanities

Title	**Data structures and practices**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	0–0–2 [1]
Offered for	M.Tech. (CSE) 1st Year	Type	Compulsory
Prerequisite	Computer Programming		

Objectives

The Instructor will:

1. Explain various data structures and provide details to implement and use them in different algorithms

Learning Outcomes

The students are expected to have the ability to:

1. Write, debug and rectify the programs using different data structures
2. Expertise in transforming coding skills into algorithm design and implementation

Contents

Laboratory Experiments

Exercises based on

Abstract Data Types: Arrays, link-list/list, hash tables, dictionaries, structures, *stack, queues* (4 labs)

Data Structures: Heap, Sets, Sparse matrix, Binary Search Tree, B-Tree/ B+ Tree, Graph (4 labs)

Algorithm implementation: Quick or Merge sort, Breadth or Depth first search or Dijkstra's Shortest Path First algorithm, Dynamic programing (6 labs)

Textbook

1. Weiss, M. A. (2007), Data Structures and Algorithm Analysis in C++, Addison-Wesley.
2. Lipschutz, S. (2017), Data Structures with C, McGraw Hill Education.
3. Cormen, T. H., Leiserson, C. E., Rivest, R. L. and Stein, C., (2009), Introduction to Algorithms, MIT Press

Title	**Software and Data Engineering**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Compulsory
Prerequisite			

Objectives

The Instructor will:

1. Discuss techniques to manage a large amount of data
2. Provide mechanisms to design and develop data-intensive computing systems

Learning Outcomes

The students are expected to have the ability to:

1. Design complex end-to-end data pipeline for data processing
2. Critically identify and use the tools for data handling and management
3. Use modern software technologies to design and develop data analytical systems

Contents

(fractal 1) *Basics of complex software design:* Concept of modular software, microservices, communication, 4+1 architectural views and patterns (5 lectures)
Cloud Computing: Architecture of cluster computing, design of data centers, open data center platforms, fault-tolerant system design (5 lectures)
Virtualization: Type-1 and Type-2 virtualization, virtual machine, containers, dockers (4 lectures)
(fractal 2) *Data Management:* Structured data, relational database management, unstructured data, semi-structured data, Nosql database management (mongodb), column database, graph database, XML, JSON, HDFS, Handling drift in data, sensor data reliability at software and algorithmic level, sensor data analysis techniques (14 lectures)
(fractal 3) *Data Intensive Processing Systems:* Architecture of large scale data processing systems, Hadoop, Apache Spark, Storm, parallel data processing concepts such as map-reduce, directed acyclic graph, resilient distributed datasets, dynamic resource allocation, partial & shared computation, storage architecture (14 lectures)

Textbook

1. Bass L., Clements P., Kazman R., (2012), *Software Architecture in Practice*, 3rd edition, Addison-Wesley Professional
2. Martin K., (2017), *Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems*, 1st Edition, O'Reilly Media

Self Learning Material

1. Tylor,R.N., Medvidovic,N. and Dashofy,E.M., (2014), *Software Architecture Foundation: Theory and Practice*, Wiley

Preparatory Course Material

1. IEEE Transactions on Knowledge and Data Engineering
2. International Conference on Data Engineering

Title	**Computer Architecture**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 2nd Year	Type	Compulsory
Prerequisite	Computer Organization		

Objectives

The Instructor will:

1. Provide background to understand various components of a modern computer system, its interconnections, and performance issue

Learning Outcomes

The students are expected to have the ability to:

1. Explain the working principles of various components of modern computer systems
2. Compare between systems using benchmark data
3. Write, execute and debug parallel programs on GPU

Contents

(fractal 1) *Introduction:* Defining Computer Architecture, Flynn's Classification of Computers, Metrics for Performance Measurement. (4 lectures)

Memory Hierarchy: Introduction, Advanced Optimizations of Cache Performance, Memory Technology and Optimizations, Virtual Memory and Virtual Machines, The Design of Memory Hierarchies, Introduction to Pin Instrumentation and Cache grind, Case Study: Intel Core i7 (10 lectures)

(fractal 2) *Instruction-Level Parallelism:* Instruction-level Parallelism: Concepts and Challenges, Basic Compiler Techniques for Exposing ILP, Reducing Branch Costs with Advanced Branch Prediction, Dynamic Scheduling, Superscalar, Limitations of ILP, Case Study: Dynamic Scheduling in Intel Core i7. (9 lectures)

Multicore Processor: Introduction, CPU Interconnections, Network on Chip (NoC), Routing Protocols, Quality of Service on NoC. (5 lectures)

(fractal 3) *Data Level Parallelism:* Introduction, Vector Architecture, SIMD Instruction Set Extensions for Multimedia, Graphics Processing Units, GPU Memory Hierarchy, Detecting and Enhancing Loop- Level Parallelism, CUDA Programming, Case Study: Nvidia Maxwell. (14 lectures)

Textbook

1. Hennessy,J.L. and Patterson,D.A., (2012), *Computer Architecture: A Quantitative Approach*, 5th Edition, Morgan Kauffmann Publishers
2. Shen,J.P. and Lipasti,M.H., (2005), *Modern Processor Design: Fundamentals of Superscalar Processors*, McGraw-Hill Publishers

Self-Learning Material

1. *CUDA: https://developer.nvidia.com/cuda-zone*
2. *OpenMP: https://www.openmp.org/*

Preparatory Course Material

1. Department of Computer Science and Engineering, Indian Institute of Technology Madras, https://nptel.ac.in/courses/106106134/

Title	**Machine Learning-1**	Number	CSXXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 1st Year, Ph.D. 1st Year	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Provide motivation and understanding of the need and importance of Machine Learning in today's world
2. Provide details about various algorithms in Machine Learning

Learning Outcomes

The students are expected to have the ability to:

1. Develop a sense of Machine Learning in the modern context, and independently work on problems relating to Machine Learning
2. Design and program efficient algorithms related to Machine Learning, train models, conduct experiments, and deliver ML-based applications

Contents

(fractal 1) *Introduction:* Motivation, Different types of learning, Linear regression, Logistic regression (2 lectures)
Gradient Descent: Introduction, Stochastic Gradient Descent, Subgradients, Stochastic Gradient Descent for risk minimization (2 lectures)
Support Vector Machines: Hard SVM, Soft SVM, Optimality conditions, Duality, Kernel trick, Implementing Soft SVM with Kernels (4 lectures)
Decision Trees: Decision Tree algorithms, Random forests (2 lectures)
Nearest Neighbour: k-nearest neighbour, Curse of dimensionality (1 lecture)
Neural Networks: Feedforward neural networks, Expressive power of neural networks, SGD and Backpropagation (3 lectures)
(fractal 2) *Clustering:* Linkage-based clustering algorithms, k-means algorithm, Spectral clustering (2 lectures)
Dimensionality reduction: Principal Component Analysis, Random projections, Compressed sensing (2 lectures)
Generative Models: Maximum likelihood estimator, Naive Bayes, Linear Discriminant Analysis, Latent variables and Expectation-maximization algorithm, Bayesian learning (4 lectures)
Feature Selection and Generation: Feature selection, Feature transformations, Feature learning (3 lectures)
Model selection and validation: Validation for model selection, k-fold cross-validation, Training-Validation-Testing split, Regularized loss minimization (3 lectures)
(fractal 3) *Statistical Learning Framework:* PAC learning, Agnostic PAC learning, Bias-complexity tradeoff, No free lunch theorem, VC dimension, Structural risk minimization, Adaboost (7 lectures)
Foundations of Deep Learning: DNN, CNN, RNN, Autoencoders (7 lectures)

Textbook

1. Shalev-Shwartz,S., Ben-David,S., (2014), *Understanding Machine Learning: From Theory to Algorithms*, Cambridge University Press

Reference Books

1. Mitchell Tom (1997). *Machine Learning,* Tata McGraw-Hill

Self Learning Material

1. Department of Computer Science, Stanford University, https://see.stanford.edu/Course/CS229

Title	**Ad-Hoc Wireless Networks**	Number	CS 6XX
Department	Computer Science and Engineering	L-T-P[C]	3–0–0 [3]
Offered for	M.Tech. 1st Year, PhD 1st Year	Type	Compulsory
Prerequisite	Networks		

Objectives

The Instructor will:

1. Introduce the mathematical models and network protocol designs in wireless Ad-hoc networks
2. Provide a systematic exposition of network protocols and their cross-layer interactions
3. To provide more advanced in-depth networking knowledge. Upon completion of this course, students will be able to apply the knowledge in their networking research. A broad perspective on the active research areas in wireless Ad-hoc networks

Learning Outcomes

The students are expected to have the ability to:

1. Demonstrate advanced knowledge of networking and wireless networking in particular
2. Compare different solutions for communications at each network layer
3. Demonstrate knowledge of protocols used in wireless communications

Contents

Basics of wireless networks and mobile computing: Ad hoc Networks: Introduction, Issues in Ad hoc wireless networks, Ad hoc wireless internet (3 lectures)
Media access control in ad hoc and sensor networks: MAC Protocols for Ad hoc Wireless Networks: Introduction, Issues in designing a MAC protocol for Ad hoc Wireless Networks, Design goals of a MAC protocol for Ad hoc Wireless Networks, Classification of MAC protocols, Contention based protocols with reservation mechanisms. Contention-based MAC protocols with scheduling mechanism, MAC protocols that use directional antennas, Other MAC protocols, Network and transport layer issues for ad hoc and sensor networks (8 lectures)
Routing protocols for Ad hoc Wireless Networks: Introduction, Issues in designing a routing protocol for Ad hoc Wireless Networks, Classification of routing protocols, Table drive routing protocol, On-demand routing protocol, Hybrid routing protocol, Routing protocols with effective flooding mechanisms, Hierarchical routing protocols, Power aware routing protocols (8 lectures)
Transport layer protocols: Transport layer protocols for Ad hoc Wireless Networks: Introduction, Issues in designing a transport layer protocol for Ad hoc Wireless Networks, Design goals of a transport layer protocol for Ad hoc Wireless Networks, Classification of transport layer solutions, TCP over Ad hoc Wireless Networks, Other transport layer protocols for Ad hoc Wireless Networks (8 lectures)
Security issues for ad hoc networks: Security: Security in wireless Ad hoc Wireless Networks, Network security requirements, Issues & challenges in security provisioning, Network security attacks, Key management, Secure routing in Ad hoc Wireless Networks (6 lectures)
QoS for ad hoc Networks: Quality of service in Ad hoc Wireless Networks: Introduction, Issues and challenges in providing QoS in Ad hoc Wireless Networks, Classification of QoS solutions, MAC layer solutions, network layer solutions (3 lectures)
Advanced Topics: Software-defined network (SDN), Mesh networking, Energy issues and Sensor networks (6 lectures)

Laboratory Experiments

Programming exercises using NS2/NS3, QualNet, Java and OmNet++

Textbook

1. Siva Ram Murthy, C., & Manoj, B. S. (2015). Ad hoc wireless networks: Architectures and protocols. *PHI Pearson Education*
2. Akyildiz, Ian F., and Xudong Wang(2015). *Wireless mesh networks*. Vol. 3. John Wiley & Sons

Reference Books

1. Basagni, S., Conti, M., Giordano, S., & Stojmenovic, I. (Eds.). (2015). *Mobile ad hoc networking*. John Wiley & Sons
2. Perkins, C. E. (2001). *Ad hoc networking* (Vol. 1). Reading: Addison-wesley
3. Toh, C. K. (2001). *Ad hoc mobile wireless networks: protocols and systems*. Pearson Education

4. Cheng, X., Huang, X., & Du, D. Z. (Eds.). (2013). *Ad hoc wireless networking* (Vol. 14). Springer Science & Business Media

Self Learning Material

1. Computer Networks - MIT OpenCourseWare
https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-829-computer-networks-fall-2002/lecture-notes/
2. Mobile and Wireless Networks and Applications, Stanford University,
https://web.stanford.edu/class/cs444n/
3. IEEE Transactions and other journals

Title	**Autonomous Systems**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	0–0–2 [1]
Offered for	M.Tech. (CSE) 1st Year	Type	Compulsory
Prerequisite	Networks and Machine Learning-1		

Objectives

The Instructor will:

1. Provide the problem of Modelling and Estimation of Autonomous Systems
2. Introduce the Implementation of Autonomous Systems for solving Engineering Problems
3. Provide the theory of advanced techniques such as Fuzzy Logic, PSO and Neural Networks
4. Provide the implement simulations and real systems for the control and estimation of processes such as a mobile robotic platform

Learning Outcomes

The students are expected to have the ability to:

1. Understand the theory and application of the Systems and their Design for solving diverse types of problems in the area of Engineering
2. Be able to develop software for applying the theory and actually solving complex problems.
3. Have experience in using state of the art sensors, used in Field Robotics and Autonomous Systems

Contents

Systems and their Design: introduction to systems and design
The Global Architecture of an Autonomous System: Introduction to autonomous systems including the architecture of autonomous systems
Designing a Multi-Agent Autonomous System: design of agents
Generation of Current Representation and Tendencies
The Notions of Point of View, Intent and Organizational Memory
Towards the Minimal Self of an Autonomous System
Global Autonomy of Distributed Autonomous Systems
Real-time reactive systems

Laboratory Experiments

Textbook

1. Mhamed Itmi, Alain Cardon(2016), New Autonomous Systems, Wiley-ISTE
2. De Gyurky, S. M., & Tarbell, M. A. (2013). *The Autonomous System: A Foundational Synthesis of the Sciences of the Mind*. John Wiley & Sons

Reference Books

1. Tzafestas, S. G. (Ed.). (2012). *Advances in intelligent autonomous systems* (Vol. 18). Springer Science & Business Media
2. Ge, S. S. (2006). *Autonomous mobile robots: sensing, control, decision making and applications*. CRC press

Self Learning Material

IEEE Transactions and other journals

Title	**Stream Analytics**	Number	CSXXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech. 3rd and 4th Year, M.Tech. 1st and 2nd Year	Type	Elective
Prerequisite	Machine Learning-1		

Objectives

The Instructor will:

1. Provide background on some of the important models, algorithms, and applications related to stream data

Learning Outcomes

The students are expected to have the ability to:

1. Understand and apply the practical and algorithmic aspects related to various topics of data streams

Contents

(fractal 1) *Introduction:* Stream and mining algorithms (2 lectures)
Clustering massive data streams: Micro-clustering based stream mining, Clustering evolving data streams, Online Micro-cluster maintenance, High-dimensional projected stream clustering, Classification of data streams using micro-clustering, On-demand stream classification, Applications of micro-clustering (7 lectures)
Classification methods in data streams: Ensemble based classification, Very fast decision trees, On demand classification, Online Information Network, LWClass algorithm, ANNCAD algorithm, ALLOP algorithm (5 lectures)
(fractal 2) *Distributed mining of data streams:* Outlier and anomaly detection, Clustering, Frequent itemset mining, Classification, Summarization, Mining distributed data streams in resource constrained environments (5 lectures)
Change diagnosis algorithms in evolving data streams: Velocity density method, Use of clustering for characterizing stream evolution (5 lectures)
Multi-dimensional analysis of data streams using stream cubes: Architecture for on-line analysis of data streams, Stream data cube computation, Performance study (4 lectures)
(fractal 3) *Indexing and querying data streams* (3 lectures)
Dimensionality reduction and forecasting on streams: Principal Component Analysis, Auto-regressive models and recursive least squares, MUSCLE, Tracking correlations and hidden variables (6 lectures)
Distributed data stream mining: Local algorithm, Bayesian network learning (5 lectures)

Textbook

1. Aggarwal,C.C., (2007), *Data Streams: Models and Algorithms*, 1st Edition, Kluwar Academic Publishers

Reference Books

1. Research literature

Self Learning Material

1. http://charuaggarwal.net/streambook.pdf

Title	**Machine Learning with Big Data**	Number	CSXXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech. 4th Year, M.Tech. 2nd Year, Ph.D. 2nd Year	Type	Elective
Prerequisite	Artificial Intelligence-1 and Machine Learning-1		

Objectives

The Instructor will:

1. Provide an understanding of the role of big data in the real-world scenarios
2. Provide technical details about various algorithms and software/hardware tools/platforms related to big data

Learning Outcomes

The students are expected to have the ability to:

1. Develop an understanding of big data in the modern context, and independently work on problems relating to big-data
2. Design and program efficient algorithms for big data from the perspective of a project

Contents

(fractal 1) *Introduction*: What is big data, Unreasonable effectiveness of data (1 lecture)
Streaming algorithms: Streaming Naive Bayes, Stream and sort (2 lectures)
Parallel algorithms: Perceptrons, SVM (3 lectures)
Ranking and Structured Prediction: Using nearest neighbour, perceptron support vector, neural network and tree based methods (6 lectures)
Fast nearest neighbour techniques (2 lectures)
(fractal 2) *Randomized methods:* Clustering, Hashing, Sketching, Scalable stochastic gradient descent (8 lectures)
Parameter Servers: Introduction, Abstraction, Parameter Cache Synchronization, Asynchronous execution, Model Parallel Examples (3 lectures)
Operations on large-scale matrices like inverse and factorization (3 lectures)
(fractal 3) *Graph-based methods:* Semi-supervised learning, Scalable link analysis (8 lectures)
Platforms for learning from big data (3 lectures)
Large-scale Machine Learning with CPUs and GPUs (3 lectures)

Textbook

1. Leskovec,J., Rajaraman,A., Ullman,J., (2014), *Mining of Massive Datasets*, 2nd Edition, Cambridge University Press
2. Bekkerman,R., Bilenko,M., Langford,J., (2011), *Scaling Up Machine Learning*, Cambridge University Press

Reference Books

1. Research literature

Self Learning Material

1. Department of Machine Learning, Carnegie Mellon University, Machine Learning with Large Datasets Course
2. Department of Computer Science, University of California, Berkeley, Scalable Machine Learning
3. ETH Zurich, Data Mining: Machine Learning from Large Datasets

Title	**Algorithms for Big Data**	Number	CSXXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 1st Year, Ph.D. 1st Year	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Introduce some algorithmic techniques developed for handling large amounts of data.
2. Emphasize on both theoretical as well as practical aspects of such algorithms.

Learning Outcomes

The students are expected to have the ability to:

1. Analyze existing algorithms as well as design novel algorithms pertaining to big data.

Contents

Sketching and Streaming: Extremely small-space data structures (8 lectures)
Dimensionality reduction: General techniques, Impossibility results, Geometric structure preservation (8 lectures)
Numerical linear algebra: Algorithms for big matrices, Regression, Low-rank approximation, Matrix completion (9 lectures)
Compressed Sensing: Sparse signals, Linear measurements, Signal recovery (8 lectures)
External memory and cache-obliviousness: Minimizing I/O for large datasets, Algorithms and data structures such as B-trees, Buffer trees, Multiway mergesort (9 lectures)

Reference Books

1. Research literature

Self Learning Material

1. Department of Computer Science, Harvard University, Algorithms for Big Data

Title	**Computer Vision**	Number	CSXXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech. 4th Year, M.Tech. 1st and 2nd Year, Ph.D. 2nd Year	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide insights into fundamental concepts and algorithms behind some of the remarkable success of Computer Vision
2. Impart working expertise by means of programming assignments and a project

Learning Outcomes

The students are expected to have the ability to:

1. Learn and appreciate the usage and implications of various Computer Vision techniques in real-world scenarios
2. Design and implement basic applications of Computer Vision

Contents

Introduction: The Three R's - Recognition, Reconstruction, Reorganization (1 lecture)
Perspective: Static Perspective, Transformations, Dynamic perspective (5 lectures)
Fundamentals of Image formation and processing: Radiometry of image formation, Basic image processing, Biological visual processing (5 lectures)
Recognition: Object recognition case study - identifying digits with multiple approaches, Visual grouping, Convolutional Neural Network (ConvNet) based approaches to visual recognition of objects and scenes, Deformable Parts Model (DPM), Attributes, pose and actions (8 lectures)
Analysis: Binocular Stereopsis, Markov Random Fields in Computer Vision, Solving for stereo correspondence, Optical flow, Review of differential geometry (12 lectures)
Detection and Segmentation: Contour detection, Bottom-up segmentation, Gestalt grouping heuristics, Semantic segmentation - instance segmentation and pixel classification, Pose and keypoint estimation (5 lectures)
Image understanding: Scene understanding from RGBD images, 3D perception from a single image, Face recognition (6 lectures)

Textbook

1. Hartley,R. Zisserman,A., (2004), *Multiple View Geometry in Computer Vision*, 2nd Edition, Cambridge University Press
2. Szeliski,R., (2010), *Computer Vision: Algorithms and Applications*, Springer-Verlag London

Reference Books

1. Research literature

Title	**Edge & Fog Computing**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech., Ph.D	Type	Elective
Prerequisite	Distributed Systems and Algorithms		

Objectives

The Instructor will:

1. Introduce research, frameworks, and applications in Edge Computing to the audience

Learning Outcomes

The students are expected to have the ability to:

1. Understand various edge devices and their ecosystems
2. Develop edge-based distributed computing platforms and applications

Contents

(fractal 1) *Introduction to IoT:* Internet of things as an interdisciplinary domain, IoT as a data centric technology, Data, information, knowledge and wisdom (DIKW) relationship (3 lectures)
Analytics in IoT: Analytics as a knowledge extraction technique, Role of Statistical analysis, Machine learning, Deep learning and Artificial Intelligence in the emergence of Internet of things, IoT Semantics and Streaming data analysis (4 lectures)
IoT Endpoint - architecture, design, and performance: IoT Endpoint architecture, Design and development of IoT endpoints (4 lectures)
IoT Gateways: Roles of Gateway in IoT networks– Field Gateway, state-of-the-art solutions (3 lectures)
(fractal 2) *Communication in IoT:* Fundamentals of data communication, Network architecture and reference models (OSI – TCP/IP), Communication technologies standards – Wired & Wireless data link layer standards (Bluetooth/WiFi/Zigbee/802.15.4/LoRa/Sigfox), Application layer protocols – HTTP, MQTT, CoAP, AMQP (11 lectures)
Sensor Networks: Algorithmic Models for Sensor Networks, Aggregation service for ad-hoc sensor networks, Gossip-Based Computation of Aggregate Information, Optimal aggregation algorithms for middleware, Efficient top-K query calculation in distributed networks (3 lectures)
(fractal 3) *Cloud and IoT (Fog & Edge):* Cloud and IoT services stack, End to End solutions development and design of cloud-based IoT services, device integration, stream analytics, Analytics use cases: Smart building, smart cities, wearable, smart retail and smart workspaces, Leveraging cloud hosted application to build monitoring and control solutions integrated with field devices, Integration of user devices with cloud hosted applications/services to enable users to interact with gateways and end points (14 lectures)

Textbook

1. Buyya R, Srirama S. N., (2019), Fog and Edge Computing: Principles and Paradigms, 1st edition, Wiley

Self Learning Material

1. Cao J.,, Zhang Q, Shi W., (2018), Edge Computing: A Primer, Springer

Preparatory Course Material

1. Edge Computing (EDGE) Conference Series, Springer

Title	**Natural Language Processing**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 2nd Year	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide background to understand various modern techniques for natural language processing, understanding, and synthesis

Learning Outcomes

The students are expected to have the ability to:

1. Explain various NLP algorithms
2. Implement NLP Systems for Engligh Language

Contents

(fractal 1) *Introduction:* NLP tasks in syntax, semantics, and pragmatics, Applications such as information extraction, question answering, and machine translation, The problem of ambiguity, The role of machine learning. Brief history of the field (4 lectures)
Language Models: The role of language models, Simple N-gram models, Estimating parameters and smoothing, Evaluating language models, Part of Speech Tagging (10 lectures)
(fractal 2) *Sentences:* Basic ideas in compositional semantics, Classical Parsing (Bottom up, top down, Dynamic Programming: CYK parser) (7 lectures)
Syntactic parsing: Grammar formalisms and treebanks, Efficient parsing for context-free grammars (CFGs), Statistical parsing and probabilistic CFGs (PCFGs), Lexicalized PCFGs, Neural shift-reduce dependency parsing (7 lectures)
(fractal 3) *Semantic Analysis:* Lexical semantics and word-sense disambiguation, Compositional semantics, Semantic Role Labeling and Semantic Parsing (3 lectures)
Information Extraction: Named entity recognition and relation extraction, IE using sequence labeling (3 lectures)
Machine Translation: Basic issues in MT. Statistical translation, word alignment, phrase-based translation, and synchronous grammars (8 lectures)

Textbook

1. Jurafsky,D. and Martin,J.H., (2003), *Speech And Language Processing*, 2nd Edition, Pearson Education India

Self-Learning Material

1. Goldberg,Y. and Hirst,G., (2017), *Neural Network Methods for Natural Language Processing*, Morgan & Claypool Publishers
2. Clark,A., Fox,C. and Lappin,S., (2010), *The Handbook of Computational Linguistics and Natural Language Processing*, Wiley-Blackwell

Preparatory Course Material

1. Natural Language Processing with Python, Steven Bird, Ewan Klein and Edward Loper, O'Reilly, http://www.nltk.org/book/
2. Natural Language Pocessing, NPTEL Lectures, https://www.youtube.com/watch?v=aeOLjFe256E&list=PLD392E2ACAEF0C689

Title	**GPU Programming**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 2nd Year	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide background to understand various aspects of Graphics Processing Unit (GPU)
2. Introduce parallel programming using GPUs.

Learning Outcomes

The students are expected to have the ability to:

1. Explain various concepts involving GPU Programming
2. Implement programs of GPU
3. Debug and profile parallel programs.

Contents

(fractal 1) *Introduction:* History, graphics processors, graphics processing units, GPGPUs. Clock speeds, CPU / GPU comparisons, heterogeneity. Accelerators, parallel programming, CUDA / OpenCL / OpenACC (2 lectures)
Hello World Computation: Kernels, launch parameters, thread hierarchy, warps/wavefronts, thread blocks/workgroups, streaming multiprocessors, 1D / 2D / 3D thread mapping, device properties, simple programs (8 lectures)
Support: Debugging GPU programs. Profiling, profile tools, performance aspects (2 lectures)
(fractal 2) *Memory:* Memory hierarchy, DRAM / global, local / shared, private/local, textures, constant memory, Pointers, parameter passing, arrays and dynamic memory, multi-dimensional arrays, Memory allocation, memory copying across devices, Programs with matrices, performance evaluation with different memories (5 lectures)
Synchronization: Memory consistency. Barriers (local versus global), atomics, memory fence, Prefix sum, reduction. Programs for concurrent data structures such as worklists, linked-lists, Synchronization across CPU and GPU (6 lectures)
Functions: Device functions, host functions, kernels, functors, Using libraries (such as Thrust), developing libraries, (3 lectures)
(fractal 3) *Streams:* Asynchronous processing, tasks, task-dependence, Overlapped data transfers, default stream, synchronization with streams, Events, event-based-synchronization - overlapping data transfer and kernel execution, pitfalls (6 lectures)
Advanced topics: Case studies, Dynamic Parallelism, Unified virtual memory, Multi-GPU processing, Peer access, Heterogeneous processing (8 lectures)

Textbook

1. Kirk,D. and Hwu,W., (2010), *Programming Massively Parallel Processors: A Hands-on Approach*, Hwu; Morgan Kaufman

Self-Learning Material

1. Cook,S., (2012), *CUDA Programming: A Developer's Guide to Parallel Computing with GPUs*, Morgan Kaufman

Preparatory Course Material

1. Introduction to Parallel Programming, https://www.youtube.com/watch?v=F620ommtjqk&list=PLAwxTw4SYaPnFKojVQrmyOGFCqHTxfdv2&index=1

Title	**Data Visualization**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 2nd Year	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide background to understand various aspects of Data Visualization
2. Discuss various principles of visualizing heterogeneous types of data

Learning Outcomes

The students are expected to have the ability to:

1. Present data with visual representations for the target audience, task, and data
2. Analyze, critique, and revise data visualizations
3. Apply appropriate design principles in the creation of presentations and visualizations

Contents

(fractal 1) *Visual Queries:* Process of Seeing, The Act of Perception, Design Implications, Distributed Cognition, Visual Search Strategies (3 lectures)
Data and Visualization: Data Type, Coordinate Systems, Scale (2 lectures)
Visualization Design: Amount, Distribution, Proportion, Trends, Time Series, Geospatial (10 lectures)
(fractal 2) *Narratives:* Telling Stories with Data, Sequencing, Visualization Rhetoric, text visualization (4 lectures)
Mapping and Cartography: The Cartogram, Value-by-Area Mapping (4 lectures)
Optimal Space Usage: Aspect Ratio Selection, Geometry & Aesthetics, Wilkinson's Algorithm and its extension (6 lectures)
(fractal 3) *Networks:* Scalable, Versatile and Simple Constrained Graph Layout, Visualization of Adjacency, Multiple Network Analysis and Visualization, Visualizing Online Social Networks (7 lectures)
Animation and Color: Trend Visualization, Transitions in Statistical Data Graphics, Graphs with Radial Layout, Cartoons, Color and Information, Infographics (7 lectures)

Textbook

1. Tufte,E., (2001), *The Visual Display of Quantitative Information*, 2nd Edition, Graphics Press
2. Tufte,E., (1990), *Envisioning Information*, Graphics Press

Self-Learning Material

1. Wilke,C.O., (2019), *Fundamentals of Data Visualization: A Primer on Making Informative and Compelling Figures*, O'Reilly Media
2. Ware,C. and Kaufman,M., (2008), *Visual thinking for design*. Burlington: Morgan Kaufmann Publishers
3. Wong,D., (2011), *The Wall Street Journal guide to information graphics: The dos and don'ts of presenting data, facts and figures*, New York: W.W. Norton & Company

Preparatory Course Material

1. Data Visualization Course, https://curran.github.io/dataviz-course-2018/

Title	**Introduction to Virtual Reality**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Discusses such issues, focusing upon the human element of VR
2. Explain the Hardware and software related issues related to VR

Learning Outcomes

The students are expected to have the ability to:

1. Explain perceptual concepts governing virtual reality
2. Identify and solve the issues of various virtual reality frameworks
3. Design immersive experience using VR Software

Contents

(fractal 1) *Introduction:* Definition of X-R (AR, VR, MR), modern experiences, historical perspective, Hardware, sensors, displays, software, virtual world generator, game engines (6 lectures)

Geometry of Visual World: Geometric modeling, transforming rigid bodies, yaw, pitch, roll, axis-angle representation, quaternions, 3D rotation inverses and conversions, homogeneous transforms, transforms to displays, look-at, and eye transform, canonical view and perspective transform, viewport transforms (8 lectures)

(fractal 2) *Light and Optics:* Interpretation of light, reflection, optical systems (4 lectures)

Visual Perception: Photoreceptors, Eye and Vision, Motion, Depth Perception, Frame rates and displays (6 lectures)

Tracking: Orientation, Tilt, Drift, Yaw, Lighthouse approach (4 lectures)

(fractal 3) Head Mounted Display: Optics, Inertial Measurement Units, Orientation Tracking with IMUs, Panoramic Imaging and Cinematic VR, Audio (8 lectures)

Frontiers: Touch, haptics, taste, smell, robotic interfaces, telepresence, brain-machine interfaces (6 lectures)

Textbook

1. Shirley, M., (2016), *Fundamentals of Computer Graphics*, 4th Edition, CRC Press
2. LaValle, (2016), *Virtual Reality*, Cambridge University Press

Reference Books

1. Jerald,J., (2015), *The VR Book: Human-Centered Design for Virtual Reality*, Morgan & Claypool
2. Mather,G., (2009), *Foundations of Sensation and Perception*, 2nd Edition, Psychology Press
3. Shirley,P., Ashikhmin,M., Marschner,S. and Peters,A.K., *Fundamentals of Computer Graphics*, 3rd Edition, CRC Press
4. Bowman,D.A., Kruijff,E., LaViola,J.J. and Poupyrev,I., (2014), *3D User Interfaces: Theory and Practice*, 2*nd* Edition, Addison Wesley Professional

Self Learning Material

1. Steven M. LaValle, Video Lectures, https://www.youtube.com/playlist?list=PLbMVogVj5nJSyt80VRXYC-YrAvQuUb6dh

Title	**Advanced Computer Graphics**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Discusses fundamentals of 2D and 3D object modeling and rendering
2. Explain the Hardware and software related issues of Computer Graphics

Learning Outcomes

The students are expected to have the ability to:

1. Understand fundamentals of graphics used in various real life applications
2. Identify the performance characteristics of graphics algorithms
3. Employ algorithm to model engineering problems, when appropriate

Contents

(fractal 1) *Introduction:* Review of 2-D, and 3D Geometry, Viewing and Clipping (5 lectures)
Curves and Fractals: Parametric Cubic curves: B-spline, Bezier, Hermite, Surfaces, Fractals and its applications (9 lectures)
(fractal 2) *Solid Modeling:* Representation of Solids, Sweep and Boundary Representation, Constructive Solid Geometry (8 lectures)
Illumination and Shading: Surface detail, shadows and Transparency, Inter object Reflections Illumination Models, Extended Light Sources, Ray Tracing, Radiosity (6 lectures)
(fractal 3) *Image Based Rendering:* Image synthesis, Geometry based, Plenoptic Function, Panorama, Lumigraph, Rendering Virtual Reality (8 lectures)
Animation: Introduction, morphing, character animation and facial animation (3 lectures)
Graphics Hardware: Special-purpose computer graphics processors and accelerators (3 lectures)

Textbook

1. Shirley,M., (2016), *Fundamentals of Computer Graphics*, 4th Edition, CRC Press
2. vanDam,F. and Hughes,F., (2013), *Computer Graphics: Principles and Practice*, 3rd Edition, Addision Wesley

Reference Books

1. Mukundan,R., (2012), *Advanced Methods in Computer Graphics: With Examples in OpenGL*, Springer
2. Ruben H., (2017), *Computer Graphics: Principles and Practice*, Larsen and Keller Education

Self Learning Material

1. Computer Graphics, NPTEL Video Lectures, https://nptel.ac.in/courses/106106090/

Title	**Embedded Systems**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Elective
Prerequisite	Computer Organization and Architecture		

Objectives

The Instructor will:

1. Explain the design of embedded systems and introduce concepts of different architectures and programming languages of embedded processors

Learning Outcomes

The students are expected to have the ability to:

1. Program and to design embedded system using embedded processors
2. Design Embedded AI systems
3. Use different IDE and debugging tools

Contents

Introduction: Review of Embedded Computing, embedded system design process (4 lectures)
Architectures of embedded processors: Architecture of ARM Cortex M3, DSP and graphics processors, memory system mechanism, caches, memory management units and address translation, interfacing (10 lectures)
Programming and Software: models for program, data flow graphs, C and assembly language programming of ARM Cortex M3, Hardware- Software Co-design (12 lectures)
Embedded Operating Systems: Linux*,* Processes and real time operating systems; Multi-rate system; scheduling algorithms (8 lectures)
Embedded AI: Basics of embedded learning and adaptive systems, intelligent sensors, rule-based systems, hardware accelerators for AI, heterogeneous memory system design, current trends and future directions (8 lectures)

Textbook

1. Wolf, M., (2012), *Computers as Components: Principles of Embedded Computing System Design*, 3rd Edition, Elsevier
2. Yiu, J., (2013), *The definitive Guide to ARM Cortex M3 and M4 Processors*, 3rd Edition, Elsevier
3. Alippi, C., (2014), *Intelligence for Embedded Systems: A Methodological Approach*, Springer

Preparatory Course Material

1. Mazidi, M.A., (2007), *The 8051 Microcontroller and Embedded Systems: Using Assembly and C,* 2nd Edition, Pearson Education India

Title	**Bio-image Computing**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 1st Year	Type	Elective
Prerequisite	Computer Programming, Basics in linear algebra, probability and statistics		

Objectives

The Instructor will:

1. Provide details of bio-signal and medical image acquisition process
2. Explain information extraction and image analysis techniques using machine learning with emphasis on the field of healthcare, agriculture and environment

Learning Outcomes

The students are expected to have the ability to:

1. Understand different imaging modalities and acquisition process
2. Apply machine learning techniques for bio-signal interpretation, image representation and analysis

Contents

(fractal 1) *Introduction:* Overview of biological signals and biomedical imaging modalities, ECG, NMR spectroscopy, electron microscopy, magnetic resonance imaging, X-ray, computed tomography, positron emission tomography, ultrasound, elastography, optical imaging and others, Noise and error propagation in biomedical signals and image data (10 lectures)
Visualization: Sectioning, multimodal images, overlays, rendering surfaces and volumes (4 lectures)
(fractal 2) *Reconstruction:* Mathematical models of image regularity, random fields, practical data sampling and acquisition schemes (4 lectures)
Restoration: Deconvolution, degradation models for corrupted and missing data, Bayesian graphical modeling and inference, regression methods for filtering of CT, MRI ultrasound and other images (4 lectures)
Image segmentation, object delineation, classification: Clustering, graph partitioning, classification, mixture models, expectation maximization, variational methods using geometric and statistical modeling, computer aided diagnosis (4 lectures)
Registration: Deformation models, optimization algorithms, 2D-3D registration, multi-modal registration (2 lectures)
(fractal 3) *Deep Learning for Bio-imaging:* Enhancement, Segmentation of anatomical structures, subcellular objects, cells, learning with little or no training data, spatial transformer network for registration, image-based phenotyping, analysis of radio-genomic data (10 lectures)
Analysis of motion: Tracking of cells, tissues, organisms, and particles (2 lectures)
Interactive image analysis: Human in loop, image interpretation (2 lectures)

(fractal 4) **Laboratory Experiments**
Ultrasound image enhancement, tumor segmentation in BraTS dataset, registration of MRI images etc.

Textbook

1. Wu, G., (2016), *Machine Learning and Medical Imaging*, Elsevier
2. Epstein, C.L., (2003), *Mathematics of Medical Imaging*, Prentice Hall
3. Bankman, I., (2009), *Handbook of Medical Image Processing and Analysis*, 2nd Edition, Academic Press

Preparatory Course Material

1. Bishop, C., (2006), *Pattern Recognition and Machine Learning,* Springer

Title	**Neuromorphic Computing and Design**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide information about neuroscientific progress towards reverse-engineering the brain
2. Provide essentials on key hardware building blocks, system level VLSI design and practical real-world applications of neuromorphic Systems

Learning Outcomes

The students are expected to have the ability to:

1. View neuromorphic computing as a computer architecture research problem
2. Perform software and hardware implementation of basic biological neural circuits

Contents

(fractal 1) *Foundational Concepts:* Introduction to neuromorphic engineering, neuroanatomy of human brain, signaling and operation of biological neurons, neuron models - LIF, IF, HH, synapses and plasticity rules, spike-time-dependent plasticity (STDP), biological neural circuits, non-von Neumann computing approach, learning rules, retina, cochlea (14 lectures)
(fractal 2) *Neuromorphic Computing:* Spiking Neural Networks (SNN), Advanced Nanodevices for Neuron Implementation, Synaptic emulation - non-volatile memory (NVM), Flash, RRAM, memristors, CNT, Case study on Intel's Loihi neuromorphic chip (14 lectures)
(fractal 3) *Hardware Implementation:* Electronic synapses, Digital/Analog neuromorphic VLSI, Hardware Implementation of Neuron circuits, Hardware Implementation of Synaptic and Learning circuits, Synaptic programming methodology optimization (14 lectures)

Textbook

1. Liu, S.C., (2002), *Analog VLSI: Circuits and Principles*, MIT Press.
2. Kozma, R., (2012), *Advances in Neuromorphic Memristor Science*, Springer.
3. Kandel, E., (2012), *Principles of neural science*, McGraw Hill.

Title	**Dependable AI**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 1st Year	Type	Elective
Prerequisite	Machine Learning, Artificial Intelligence		

Objectives

The Instructor will:

1. Provide characteristic details of AI and machine learning systems to make them dependable, such as explainability, interpretability, safety etc.

Learning Outcomes

The students are expected to have the ability to:

1. Asses the dependability of AI systems
2. Develop explainable, robust, and safe AI models

Contents

Introduction: Overview, motivation, challenges – medical and surveillance (4 lectures)
Explainable AI: Accuracy-explainablity tradeoff, interpretability problem, predictability, info-besity, Transparency, Traceability, Environmental effects on AI systems (4 lectures)
Methods: Causality, reasoning, layerwise relevance propagation (LRP), attention maps, saliency maps, DeepLIFT, Local Interpretable Model-Agnostic Explanations (LIME) (10 lectures)
Interpretable AI: Prediction consistency, Application Level Evaluation, Human Level Evaluation, Function level evaluation (4 lectures)
Trustworthy AI: Integrity, Reproducibility, Accountability, Interactive AI - Human in the loop, Human on the loop, Human in command, Adaptability, fallback plan, Machine learning as service (MLaaS), General Data Protection Right (GDPR) (6 lectures)
Safe AI: Robustness, Adversarial attacks and defences - White-box, black-box, gray-box attacks, Defence mechanisms (10 lectures)
Bias-free AI: Accessibility, Fair, data agnostics design, disentanglement (4 lectures)

Textbook

1. Pearl, J., (2018), *The Book of Why: The New Science of Cause and Effect*, Basic Books.
2. Bostrom, N., (2014), *The Ethics of Artificial Intelligence. The Cambridge handbook of artificial intelligence*, Cambridge University Press.

Preparatory Course Material

1. Proceedings of IJCAI: Workshop on Explainable Artificial Intelligence (XAI).

Title	**Resource Constrained AI**	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 1st Year	Type	Elective
Prerequisite	Machine Learning, Artificial Intelligence		

Objectives

The Instructor will:

1. Explain the challenges of implementing AI and machine learning algorithms on devices with memory and power constraints
2. Provide methods to reduce computational complexity of AI techniques

Learning Outcomes

The students are expected to have the ability to:

1. Understand the constraints of implementing AI algorithms on limited memory devices
2. Design and develop techniques to reduce inference time memory footprint of machine learning models

Contents

Introduction: Overview and motivation, challenges of resource constrained AI, why AI on edge (4 lectures)
Edge Computing: Edge devices and their limitations, Edge and fog computing, Distributed computing, communication links, communication overhead in IoT devices (8 lectures)
Monitoring: Prediction accuracy, numeric accuracy, precision, memory footprints, computational complexity of AI models (4 lectures)
Memory Optimization of Models: KiloByte-size models, floating-point v/s fixed-point, SeeDot (8 lectures)
Edge AI: Resource-efficient kNN, SVM and deep learning models, Toeplitz matrix, Bonsai, ProtoNN, EMI-RNN, FastRNN, FastGRNN (10 lectures)
Current Trends and Future: Hardware accelerators for Edge AI, Vision Processing Unit (VPU), Streaming Hybrid Architecture Vector Engine (SHAVE), Intel's Movidius Neural Compute Stick (NCS), Open Neural Network Exchange (ONNX), Future trends (10 lectures)

Laboratory Experiments

Implementation of Bonsai, CNN training using SeeDot language etc.

Textbook

1. Alippi, C., (2014), *Intelligence for Embedded Systems: A Methodological Approach*, Springer.

Preparatory Course Material

1. EdgeML by Microsoft, https://github.com/Microsoft/EdgeML/#edge-machine-learning
2. NCSDK by Intel https://github.com/movidius/ncsdk

Title	**Security and Its Application**	Number	CS 6XX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Elective
Prerequisite	Networks		

Objectives

The Instructor will:

1. Provide the fundamental principles of access control models and techniques, authentication and secure system design
2. Introduce a strong understanding of different cryptographic protocols and techniques and be able to use them
3. Provide methods for authentication, access control, intrusion detection and prevention

Learning Outcomes

The students are expected to have the ability to:

1. Understand cryptography and network security concepts and application
2. Identify and investigate network security threat
3. Analyze and design network security protocols

Contents

Shannon's Approach to Cryptography: Measures of security, Perfect secrecy, Definition of entropy, One-time pad (3 lectures)
Symmetric Key Cryptography: The notion of a symmetric key cryptography, The Data Encryption Standard (DES) and differential cryptanalysis, The Advanced Encryption Standard (AES) (4 lectures)
Cryptographic Hash Functions: Definition of hash functions and properties, Unkeyed hash functions, Keyed hash functions, Message Authentication Codes (MAC), The Random Oracle Model (ROM) (4 lectures)
Authentication: Definition of authentication, A simple authentication protocol and possible attacks, Strong password protocols, BM Encrypted Key Exchange (EKE), Key Distribution Centers (KDC), Certification authorities and certificate revocation, KDC based authentication protocols (6 lectures)
Public Key Cryptosystems: Fundamentals of Public-key Cryptography, Background on number theory, The RSA public key cryptosystem, The ElGamal public key cryptosystem and discrete logs
Digital Signatures: An RSA based signature scheme, The ElGamal based signature scheme,The Schnorr signature scheme, The Digital Signature Algorithm (DSA) (8 lectures)
Key Distribution and Key Agreement Protocols: Key Predistribution: Diffie-Hellman key Exchange, The MTI key Exchange (4 lectures)
Network Security: TCP/IP threats, The IPSEC protocol, The SSL and TLS protocols, Firewalls and Virtual Private Networks (VPNs), Electronic mail security, Worms, DDoS attacks, BGB and security considerations (5 lectures)
Cyber-physical security: IoT security, sensor actuator network security (4 lectures)
Block Chain: Introduction to Blockchain, Blockchain Architecture and Design, Consensus, Permissioned Blockchains (4 lectures)

Laboratory Experiments

Programming exercises using Exata and AVISPA Tools

Textbook

1. Stallings, W. (2017). *Cryptography and network security, 7/E*. Pearson Education India
2. Douglas R. Stinson, Maura B. Paterson (2018). *Cryptography: theory and practice*. 4/E Chapman and Hall/CRC

Reference Books

1. Mao, W. (2004). *Modern cryptography: theory and practice*. Pearson Education India
2. Pfleeger, C. P., & Pfleeger, S. L. (2018). *Security in computing*. 5/E, Prentice Hall Professional Technical Reference
3. Goldreich, O. (2009). *Foundations of cryptography: volume 2, basic applications*. Cambridge university press
4. Forouzan, B. A. (2015). *Cryptography & network security*. 3/E, McGraw-Hill, Inc.

Self Learning Material

1. Network and Computer Security - MIT OpenCourseWare https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-857-network-and-computer-security-spring-2014/
2. Cryptography I, Coursera, Stanford University, https://www.coursera.org/learn/crypto
3. IEEE Transactions and other journals.

Title	**Vehicular Ad-Hoc Networks(VANETs)**	Number	CS 6XX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Elective
Prerequisite	Network		

Objectives

The Instructor will:

1. Introduce the emerging technologies, standards and applications in vehicular communication systems.
2. Provide the design considerations and challenges of vehicle-to-infrastructure and vehicle-to-vehicle communications. Theories such as vehicular mobility modeling, and vehicular technologies and standards from the physical to network layers will be introduced in the course. Examples of emerging applications of vehicular communications in Intelligent Transportation Systems will also be studied and discussed.

Learning Outcomes

The students are expected to have the ability to:

1. Understand and describe the basic theories and principles, technologies, standards, and system architecture of vehicular ad-hoc networks (VANET) or inter-vehicle communication networks.
2. Analyze, design, and evaluate vehicular communication platforms for various kinds of safety and infotainment applications.

Contents

Introduction: Basic principles and challenges, past and ongoing VANET activities (2 Lectures)
Cooperative Vehicular Safety Applications: Enabling technologies, cooperative system architecture, safety applications (2 lectures)
Vehicular Mobility Modeling: Random models, flow and traffic models, behavioral models, trace and survey based models, joint transport and communication simulations (4 lectures)
Physical Layer Considerations for Vehicular Communications: Signal propagation, Doppler spread and its impact on OFDM systems (4 lectures)
MAC Layer of Vehicular Communication Networks: Proposed MAC approaches and standards, IEEE 802.11p (8 lectures)
*VANET Routing protocols***:** Opportunistic packet forwarding, topology-based routing, geographic routing (8 lectures)
Emerging VANET Applications: Limitations, example applications, communication paradigms, message coding and composition, data aggregation (8 lectures)
Standards and Regulations: Regulations and Standards, DSRC Protocol Stack, Cellular V2X (6 lectures)

Laboratory Experiments

Programming exercises using NS3, QualNet and Java

Textbook

1. Olariu, S., & Weigle, M. C. (2017). *Vehicular networks: from theory to practice*. Chapman and Hall/CRC
2. Murthy, C. S. R. (2006). *Ad hoc wireless networks: Architectures and protocols*. Pearson Education India

Reference Books

1. Emmelmann, M., Bochow, B., & Kellum, C. (Eds.). (2010). *Vehicular networking: Automotive applications and beyond* (Vol. 2). John Wiley & Sons
2. Claudia Campolo , Antonella Molinaro, Riccardo Scopigno(2015). Vehicular ad hoc Networks, Springer
3. Hartenstein, H., & Laberteaux, K. (2010). *VANET: vehicular applications and inter-networking technologies* (Vol. 1). Chichester: Wiley
4. Sommer, C., & Dressler, F. (2015). *Vehicular networking*. Cambridge University Press
5. Moustafa, H., & Zhang, Y. (2009). *Vehicular networks: techniques, standards, and applications*. Auerbach publications

Self Learning Material

1. IEEE Transactions and other journals