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	**Algorithms for Big Data**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	2–0–0 [2]
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 (4 lectures)

Numerical linear algebra: Algorithms for big matrices, Regression, Low-rank approximation, Matrix completion (8 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 (8 lectures)

Reference Books

Markovsky I, (2014), *Low Rank Approximation: Algorithms, Implementation, Applications,* Springer

Eldar Y C., Kutyniok G. (2012), *Compressed Sensing: Theory and Applications,* Cambridge University Press.

Self Learning Material

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

Title	**Data structures and practices**	Number	CSP7XX0
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

Online Course Material

1. Department of Computer Science and Engineering, IIT Delhi, http://www.nptelvideos.in/2012/11/data-structures-and-algorithms.html

Title	**Software and Data Engineering**	Number	CSL7XX0
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

CSL7XX0 Cloud Computing and Virtualization 1-0-0 [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)

CSL7XX0 Data Management 1-0-0 [1]

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)

CSL7XX0 Data Intensive Processing Systems 1-0-0 [1]

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	CSL7XX0
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

CSL7XX0 Multi System Architecture 1-0-0 [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)

CSL7XX0 Multicore Processing 1-0-0 [1]

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)

CSL7XX0 Fundamentals of Parallel Programming 1-0-0 [1]

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	CSL7XX0
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

CSL7XX1: Introduction to Machine Learning: Supervised Learning 1-0-0[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)

Neural Networks: Feedforward neural networks, Expressive power of neural networks, SGD and Backpropagation (3 lectures)

Model selection and validation: Validation for model selection, k-fold cross-validation, Training-Validation-Testing split, Regularized loss minimization (1 lectures)

CSL7XX2: Introduction to Machine Learning: Unsupervised Learning and Generative Models 1-0-0[1]

Nearest Neighbour: k-nearest neighbour, Curse of dimensionality (1 lecture)

Clustering: Linkage-based clustering algorithms, k-means algorithm, Spectral clustering (3 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 (5 lectures)

Feature Selection and Generation: Feature selection, Feature transformations, Feature learning (3 lectures)

CSL7XX3: Introduction to Machine Learning: Computational Learning Theory and Deep Learning 1-0-0[1]

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	**Security and Its Application**	Number	CSL7XX0
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

CSL7xx1 Introduction to Cryptography 1-0-0 [1]

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 (3 lectures)

CSL7xx2 Network Security 1-0-0 [1]

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) (6 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 (4 lectures)

CSL7xx3 Cyber-physical security and Blockchain 1-0-0 [1]

(fractal 3) *Cyber-physical security*: IoT security, sensor actuator network security (4 lectures) *Block Chain:* Introduction to Blockchain, Blockchain Architecture and Design, Consensus (Byzantine Fault, Proof of Work, Poof of Stake,), Permissioned Blockchains, Components of blockchain (10 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