Annexure - I

Indian Institute of Technology Jodhpur

Course Booklet

for

Executive M. Tech. (AI)

Program

offered by the

IIT Jodhpur with its Technology Partner: NVIDIA

January 2020

Executive M. Tech. in Artificial Intelligence (AI)

Introduction:

Artificial Intelligence (AI) is a branch of computer science that aims to create machines to act with higher levels of intelligence and emulate the human capabilities of sense, comprehend and act. The core problems of artificial intelligence include programming computers for certain traits such as Knowledge, Reasoning, Problem-solving, Perception, Learning and Planning. AI technology development and applications are evolving rapidly with major implications for economies and societies. As the demand for such applications increases, there is also an increasing need for building the future workforce for AI. For developing the AI ecosystem, this program will be executed in synergy with other M.Tech programs running in IIT Jodhpur, such as Sensors & IoT, Cyber-Physical Systems, and Advanced Manufacturing and Design.

Objectives:

This Executive M. Tech in AI program will offer students with deep knowledge of both fundamental AI technologies, as well as application-oriented AI. A student completing this program will be capable to undertake careers in industry as well as academia. He/She will have the option to explore a variety of domains including Manufacturing, Fintech, Healthcare, Agriculture/Food Processing, Education, Retail/Customer Engagement, Human and Robot interaction/intelligent automation, Smart City, Aid for Differently Abled/Accessibility Technology.

Expected Graduate Attributes:

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

1. Comprehend fundamental concepts and hands-on knowledge of the state-of-the-art AI methodologies.
2. Design and Build real-world AI systems for complex planning, decision making and learning, solving application-specific problems, and to reason about them.
3. Conceive, Design and Develop Intelligent multi-modal multi-sensory Man-Machine interfaces.
4. Design, Develop and Deploy machine learning based applications using structured and unstructured data (e.g., speech, text, images/videos).
5. Understand and Assess reliability, dependability and trust-worthiness of AI-based systems.
6. Design and develop AI applications for resource constrained environments.
7. Adhere to evolving ethics and privacy laws across various domains and territories.
8. Plan and manage technical projects.

Learning Outcome:

1. Understand the fundamentals of Artificial Intelligence, Machine Learning, Inference Engines, Speech, Vision, Natural Language Understanding, Robotics, and Human Computer Interaction.
2. Unify the knowledge of human cognition, AI, Machine Learning and data engineering for designing systems.
3. Demonstrate hands-on knowledge of state-of-the-art AI tools for real-world problem-solving.
4. Ability to develop real-time and robust AI-based systems with specific software, hardware and data requirements.
5. Build solutions to explore fully immersive computer-generated worlds (in VR), and overlay computer graphics onto our view of our immediate environment (AR) along with smart, cognitive functionality.
6. Demonstrate advanced skills to comprehend and communicate effectively.
7. Carry out projects using intelligent cognitive solutions provided by AI algorithms to get more insights in stakeholder management, risk modeling, intelligent resource scheduling and managing project constraints with intelligent use of data models.

Course Structure for
Executive M. Tech. (AI)

List of compulsory courses

1. Statistics, Matrix Computation and Optimization (3 credit)
2. Artificial Intelligence-1 (3 credit)
3. Data Structure and Practices (1 credit)
4. Machine Learning-1 (3 credit)
5. Artificial Intelligence-2 (3 credit)
6. Machine Learning – 2 (3 credit)
7. Real Time Autonomous System (3 credit)
8. Technical Communication (Non-graded) (1 credit)
9. Ethics and Professional Life (Non-graded) (1 credit)
10. System Engineering and Project Management (Non-graded) (1 credit)
11. Intellectual Property (Non-graded) (1 credit)
12. Major project (16 credit)

(Blue color courses are being offered in Feb-May 2020 semester

List of Elective Courses: Please see below to get a list of elective courses which may be offered by IIT Jodhpur. Total 6 program electives (18 credits) and 2 open electives needs to be completed.

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 Executive M.Tech. (AI)

Courses offered by Department of Computer Science and Engineering

- Advanced Computer Graphics
- Algorithms for Big Data
- AI for Finance
- Bio-image computing
- Blockchain
- Computer Graphics
- Computer Vision
- Computational Optimization
- Computer Architecture
- 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 with Big Data
- Natural Language Processing
- Neuromorphic Computing and Design
- 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
- Software and Data Engineering
- Security and its Applications
- 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	CSP7XX0
Department	Computer Science and Engineering	L-T-P [C]	0–0–2 [1]
Offered for	M.Tech.	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	**Artificial Intelligence I**	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. Cover various paradigms that come under the broad umbrella of AI.

Learning Outcomes

The students are expected to have the ability to:

1. Develop an understanding of where and how AI can be used.

Contents

Introduction (1 lecture)
Propositional logic (8 lectures)
Search: Uninformed strategies (BFS, DFS, Dijkstra), Informed strategies (A* search, heuristic functions, hill-climbing), Adversarial search (Minimax algorithm, Alpha-beta pruning) (10 lectures)
Predicate logic: Knowledge representation, Resolution (6 lectures)
Rule-based systems: Natural language parsing, Context free grammar (3 lectures)
Constraint satisfaction problems (4 lectures)
Planning: State space search, Planning Graphs, Partial order planning (4 lectures)
Uncertain Reasoning: Probabilistic reasoning, Bayesian Networks, Dempster-Shafer theory, Fuzzy logic (6 lectures)

Textbook

1. Russel,S., and Norvig,P., (2015), *Artificial Intelligence: A Modern Approach*, 3rd Edition, Prentice Hall

Reference Books

1. Research literature

Self Learning Material

1. Department of Computer Science, University of California, Berkeley, http://www.youtube.com/playlist?list=PLD52D2B739E4D1C5F
2. NPTEL: Artificial Intelligence, https://nptel.ac.in/courses/106105077/

Title	**Artificial Intelligence II**	Number	CSL8XX0
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	Artificial Intelligence-1		

Objectives

The Instructor will:

1. Cover modern paradigms of AI that go beyond traditional learning.

Learning Outcomes

The students are expected to have the ability to:

1. Develop an understanding of modern concepts in AI and where they can be used.
2. Design, implement and apply novel AI techniques based on emerging real-world requirements.

Contents

CSL8XX1: Artificial Intelligence: Probabilistic Reasoning and Knowledge Representation 1-0-0[1]

Probabilistic Reasoning over time: Hidden Markov Models, Kalman Filters, Dynamic Bayesian Networks (7 lectures)

Knowledge Representation: Ontological engineering, Semantic Networks, Description Logics (7 lectures)

CSL8XX1: Artificial Intelligence: Making Decisions 1-0-0[1]

Making decisions: Utility theory, utility functions, decision networks, sequential decision problems, Partially Observable MDPs, Game Theory (14 lectures)

CSL8XX1: Artificial Intelligence: Reinforcement Learning 1-0-0[1]

Reinforcement Learning: Passive RL, Active RL, Generalization in RL, Policy Search, Deep Reinforcement Learning (14 lectures)

Textbook

1.Russel,S., and Norvig,P., (2015), *Artificial Intelligence: A Modern Approach*, 3rd Edition, Prentice Hall

Reference Books

1. Yang, Q. (1997), *Intelligent Planning: A decomposition and abstraction based approach,* Springer Verlag, Berlin Heidelberg.

Title	**Machine Learning I**	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: Machine Learning I: 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: Machine Learning I: 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: Machine Learning I: Computational Learning Theory and Deep Neural Networks 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	**Machine Learning II**	Number	CSL8XX0
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	Machine Learning-1		

Objectives

The Instructor will:

1. Provide technical details about various recent algorithms and software platforms related to Machine Learning with specific focus on Deep Learning.

Learning Outcomes

The students are expected to have the ability to:

1. Design and program efficient algorithms related to recent machine learning techniques, train models, conduct experiments, and develop real-world ML-based applications and products

Contents

CSL7XX1: Machine Learning II: Introduction to Deep Learning 1-0-0[1]

Model Search: Optimization, Regularization, AutoML (4 lectures)
Deep Networks: Attention layers, Gated CNNs, Graph Neural Networks (8 lectures)
Applications: Neural language models (2 lectures)

CSL7XX2: Machine Learning II: Representation Learning & Structured Models 1-0-0[1]

Representation Learning: Unsupervised pre-training, transfer learning and domain adaptation, distributed representation, discovering underlying causes (7 lectures)
Structured models: learning about dependencies, inference and approximate inference, sampling and Monte Carlo Methods, Importance Sampling, Gibbs Sampling, Partition Function, MAP inference and Sparse Coding, Variational Inference (7 lectures)

CSL7XX3: Machine Learning II: Deep Generative Models 1-0-0[1]

Deep Generative Models: Deep Belief Networks, Variational Autoencoder, Generative Adversarial Network (GAN), Deep Convolutional GAN, Autoencoder GANs, iGAN, pix2pix, CycleGAN, Conditional GANs, StackGAN (14 lectures)

Laboratory Experiments

Overview of Deep Learning platforms such Tensorflow and PyTorch.

Textbook

1.Goodfellow,I., Bengio.,Y., and Courville,A., (2016), *Deep Learning*, The MIT Press

Reference Books

1. Charniak, E. (2019), *Introduction to deep learning,* The MIT Press.

Self Learning Material

1. https://www.deeplearningbook.org/

Title	Real Time Autonomous Systems	Number	CSL8XX0
Department	Computer Science and Engineering	L-T-P [C]	2–0–0 [2]
Offered for		Type	Compulsory
Prerequisite	**Machine Learning I, Artificial Intelligence I**		

Objectives

The Instructor will:

1. Provide an understanding about autonomous/ semi autonomous systems like autonomous cars and drones.

Learning Outcomes

The students are expected to have the ability to:

1. Understand and use the methodologies to design, model and implementation of autonomous systems for real time applications.

Contents

Introduction to Agents, Agent Architectures: Subsumption Architecture, Situated Automata, Hybrid Architecture (4)

Real time System Implementation (3)

Mobile agents – locomotion (wheeled, legged, aerial), sensors and mechanisms. (3)

Robot localisation & SLAM (4)

Planning and Navigation (6)

Case Study: Autonomous car – learning to drive; human centered autonomous vehicle. (8)

Laboratory Experiments

Textbook

1. Seigwart, R. and Nourbakhsh, I.R. *Introduction to Autonomous Mobile Robots*, 2nd edition, MIT Press 2011
2. Giorgio C. Buttazzo, *Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications*," Springer US, Year: 2011
3. Stuart J. Russell and Peter Norwig, *Artificial Intelligence: A Modern Approach*, 3rd edition, Pearson Press
4. Markus Maurer et al. eds. *Autonomous Driving*, Springer Link (open access)
5. Gerhard Weiss ed., *Multiagent System*, Second Edition, MIT Press, 2013

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

Course Contents for the new Elective courses offered by the Department of Computer Science and Engineering

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

Title	**Stream Analytics**	Number	CSL8XX0
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

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)

Distributed mining of data streams: Outlier and anomaly detection, Clustering, Frequent item-set 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)

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	CSL8XX0
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

Introduction: What is big data, Unreasonable effectiveness of data (1 lecture)
Streaming algorithms: Streaming Naive Bayes, Stream and sort (2 lectures)

Platforms for learning from big data
MapReduce, New Software Stack, Large Scale File System Organization (5)

Nearest Neighbour Search, Jaccardi Similarity of Sets, Similarity of Documents, Locality Sensitive Hashing, The Stream Data Model (4)

Randomized methods: Clustering, Hashing, Sketching, Scalable stochastic gradient descent (3 lectures)

Frequent Itemsets: The Market Basket Model, A-Priori Algorithm, Handling larger datasets in Main Memory, Limited-Pass Algorithms, Counting Frequent Items in a Stream (6)

Parameter Servers: Introduction, Abstraction, Parameter Cache Synchronization, Asynchronous execution, Model Parallel Examples (3 lectures)

Graph-based methods: Link Analysis
Page Rank, Topic Sensitive Page Rank, Approaches to Page Rank iteration, Link Spam, Semi-supervised learning, Scalable link analysis, Models for Recommendation Systems, Social Networks as Graphs (9 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	**Computer Vision**	Number	CSL7XX0
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	**Digital Image Analysis**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for		Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Introduce the origin and formation of digital imaging.
2. Develop the understanding of different types of image processing and analysis for different purposes.
3. Show how to develop modular systems for image analysis through hands-on application development.

Learning Outcomes

The students are expected to have the ability to:

1. Enhance image in spatial and frequency domain.
2. Implement various aspects of image segmentation, compression, and content analysis.

Contents

Digital Image Fundamentals: Image modeling, Sampling and Quantization, Imaging Geometry,Digital Geometry, Image Acquisition Systems, Different types of digital images. (4)
Bilevel Image Processing: Basic concepts of digital distances, distance transform, medial axis transform, component labeling, Histogram of grey level images, Optimal thresholding. (5)
Images Enhancement: Point processing, enhancement in spatial domain, enhancement in frequency domain. (5)
Detection of edges and lines in 2D images: First order and second order edge operators,multi-scale edge detection, Canny's edge detection algorithm, Hough transform for detecting lines and curves. (5)
Color Image Processing: Color Representation, Laws of color matching, chromaticity diagram, color enhancement, color image segmentation, color edge detection. (5)
Image compression: Lossy and lossless compression schemes, prediction based compression schemes, vector quantization, sub-band encoding schemes, JPEG compression standard. (6)
Segmentation: Segmentation of grey level images, Watershed algorithm for segmenting grey level image. (5)
Morphology: Dilation, erosion, opening, closing, hit and miss transform, thinning, extension to grey scale morphology. (4)
Feature Detection: Fourier descriptors, shape features, object matching/features(3)

Textbook

1. Gonzalez and Woods, Digital Image Processing, Prentice-Hall.
2. Fundamentals of Digital Image Processing by Anil K. Jain.

Self-Learning Material

NPTEL: Digital Image Processing
https://nptel.ac.in/courses/117105079/

Title	**Edge & Fog Computing**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech., Ph.D	Type	Elective
Prerequisite			

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

CSL7XX1 Introduction to IoT 1-0-0 [1]

(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)

CSL7XX2 Communication in IoT 1-0-0 [1]

(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)

CSL7XX3 Cloud and IoT 1-0-0 [1]

(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	CSL7XX0
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 English Language

Contents

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)

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)

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	CSL7XX0
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

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)

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 lectur*es)*

Functions: Device functions, host functions, kernels, functors, Using libraries (such as Thrust), developing libraries, (3 lectures)

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	CSL7XX0
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

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)
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)
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 Augmented Reality and Virtual Reality**	Number	CSL7XX0
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 AR and VR
2. Explain the Hardware and software related issues related to AR and VR

Learning Outcomes

The students are expected to have the ability to:

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

Contents

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)
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)
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
3. Schmalstieg D, and Hollerer T. (2016). *Augmented Reality: Principles & Practice*, Pearson Education India

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	CSL7XX0
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

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)
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)
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	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech., PhD	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	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for		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

CSL7XX1 Bio-signal Acquisition and Representation 1-0-0 [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)

CSL7XX1 Machine Learning for Bio-signal analysis 1-0-0 [1]

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)

CSL7XX2 Deep Learning for Bio-imaging 1-0-0[1]

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)

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	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for		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

CSL7xx1 Introduction to Neuromorphic Engineering 1-0-0 [1]

(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)

CSL7xx2 Neuromorphic Computing 1-0-0 [1]

(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)

CSL7xx3 Neuromorphic Hardware Implementation 1-0-0 [1]

(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	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech 4th Year and M.Tech., PhD	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. Assess 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 defenses - 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.

Reference Book

1. 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	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech 4th Year and M.Tech., PhD	Type	Elective
Prerequisite	Machine Learning		

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	**Ad-Hoc Wireless Networks**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P[C]	3–0–0 [3]
Offered for	M.Tech. 1st Year, PhD 1st Year	Type	
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. 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/

Title	**Vehicular Ad-Hoc Networks(VANETs)**	Number	CSL 7XX 0
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. Center for Autonomous Intelligent Networks and Systems (CAINS), University of California, Los Angeles (UCLA),http://www.cains.cs.ucla.edu/

Title	**Selected Topics in Computer Science - I**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	1–0–0 [1]
Offered for	M.Tech., PhD	Type	Elective
Prerequisite	Decided by the instructor		

Objectives

The Instructor will:

1. Expose the students to the latest upcoming fields in the area of computer science

Learning Outcomes

The students are expected to have the ability to:

1. Apply the knowledge of recent topics to specific research areas in the field of computer science

Contents

The topic clouds for the course include contemporary topics in computer science and may be updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Self-Learning Material

Relevant Textbook and/or research papers to be announced by the instructor.

Preparatory Course Material

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Selected Topics in Computer Science - II**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	2–0–0 [2]
Offered for	M.Tech., PhD	Type	Elective
Prerequisite	Decided by the instructor		

Objectives

The Instructor will:

1. Expose the students to the latest upcoming fields in the area of computer science

Learning Outcomes

The students are expected to have the ability to:

1. Apply the knowledge of recent topics to specific research areas in the field of computer science

Contents

The topic clouds for the course include contemporary topics in computer science and may be updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Self-Learning Material

Relevant Textbook and/or research papers to be announced by the instructor.

Preparatory Course Material

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Selected Topics in Computer Science - III**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech., PhD	Type	Elective
Prerequisite	Decided by the instructor		

Objectives

The Instructor will:

1. Expose the students to the latest upcoming fields in the area of computer science

Learning Outcomes

The students are expected to have the ability to:

1. Apply the knowledge of recent topics to specific research areas in the field of computer science

Contents

The topic clouds for the course include contemporary topics in computer science and may be updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Self-Learning Material

Relevant Textbook and/or research papers to be announced by the instructor.

Preparatory Course Material

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Selected Topics in Artificial Intelligence - I**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	1–0–0 [1]
Offered for	M.Tech., PhD	Type	Elective
Prerequisite	Decided by the instructor		

Objectives

The Instructor will:

1. Expose the students to the latest upcoming fields in the area of artificial intelligence

Learning Outcomes

The students are expected to have the ability to:

1. Apply the knowledge of recent topics to specific research areas in the field of artificial intelligence

Contents

The topic clouds for the course include contemporary topics in artificial intelligence and may be updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Self-Learning Material

Relevant Textbook and/or research papers to be announced by the instructor.

Preparatory Course Material

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Selected Topics in Artificial Intelligence - II**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	2–0–0 [2]
Offered for	M.Tech., PhD	Type	Elective
Prerequisite	Decided by the instructor		

Objectives

The Instructor will:

1. Expose the students to the latest upcoming fields in the area of artificial intelligence

Learning Outcomes

The students are expected to have the ability to:

1. Apply the knowledge of recent topics to specific research areas in the field of artificial intelligence

Contents

The topic clouds for the course include contemporary topics in artificial intelligence and may be updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Self-Learning Material

Relevant Textbook and/or research papers to be announced by the instructor.

Preparatory Course Material

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Selected Topics in Artificial Intelligence - III**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech., PhD	Type	Elective
Prerequisite	Decided by the instructor		

Objectives

The Instructor will:

1. Expose the students to the latest upcoming fields in the area of artificial intelligence

Learning Outcomes

The students are expected to have the ability to:

1. Apply the knowledge of recent topics to specific research areas in the field of artificial intelligence

Contents

The topic clouds for the course include contemporary topics in artificial intelligence and may be updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Self-Learning Material

Relevant Textbook and/or research papers to be announced by the instructor.

Preparatory Course Material

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Graph Theory and Applications**	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	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Introduce various terminologies, concepts and algorithms related to graphs, and discuss their applications in real-world scenarios.

Learning Outcomes

The students are expected to have the ability to:

1. Formulate and solve real-world problems using the mathematical foundations of graph theory.

Contents

Preliminaries: Graphs, Isomorphism, Subgraphs, Matrix representations, Degree, Operations on graphs, Degree sequences (3 lectures)
Connected graphs and shortest paths: Walks, Trails, Paths, Connected graphs, Distance, Cut-vertices, Cut-edges, Blocks, Connectivity, Weighted graphs, Shortest path algorithms (4 lectures)
Trees: Characterizations, Number of trees, Minimum spanning trees (3 lectures)
Special classes of graphs: Bipartite graphs, Line graphs, Chordal graphs (2 lectures)
Eulerian graphs: Characterization, Fleury's algorithm, Chinese-postman-problem (2 lectures)
Hamilton graphs: Necessary conditions and sufficient conditions (3 lectures)
Independent sets, coverings, matchings: Basic equations, Matchings in bipartite graphs, Perfect matchings, Greedy and approximation algorithms (6 lectures)
Vertex colorings: Chromatic number and cliques, Greedy coloring algorithm, Coloring of chordal graphs, Brook's theorem (2 lectures)
Edge colorings: Gupta-Vizing theorem, Class-1 graphs and Class-2 graphs, Equitable edge-coloring (5 lectures)
Planar graphs: Basic concepts, Euler's formula, Polyhedrons and planar graphs, Characterizations, Planarity testing, 5-color-theorem (3 lectures)
Directed graphs: Out-degree, In-degree, Connectivity, Orientation, Eulerian directed graphs, Hamilton directed graphs (5 lectures)
Applications: Biology, Social Sciences, Engineering, Computer Science (4 lectures)

Textbook

1.West,D.B., (2002), *Introduction to Graph Theory*, 2nd Edition, Prentice Hall of India
2.Deo,N., (2003), *Graph Theory: With Application to Engineering and Computer Science*, Prentice Hall of India

Reference Books

1. Research literature

Self Learning Material

1. NPTEL: Graph Theory (for CSE), https://nptel.ac.in/courses/106108054/39
2. NPTEL: Graph Theory (for Mathematics), https://nptel.ac.in/courses/111106050/

Title	**Social Network Analysis**	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	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Introduce the social networks and the research areas therein.
2. Provide with the mathematical foundation required for social network analysis
3. Cover various concepts, terminologies and algorithms related to social network analysis
4. Conduct tutorial sessions to use NetworkX library in Python for network analysis

Learning Outcomes

The students are expected to have the ability to:

1. Understand the applications related to social networks
2. Write program with social network datasets in Python
3. Formulate real-world problems with any relational data set resembling social networks

Contents

Introduction and Different Types of Networks (1 Lecture)
Graph Introduction: Adjacency Matrix, Paths, Connectivity, Incidence Matrix, Distance, Breadth-First-Search, Directed Graph (1 Lecture)
Introduction to Python and NetworkX (1)
Network Measures, Centrality, Core, Cliques and Clan, Strong and Weak Ties, Homophily, Structural Balance, Components (4 Lectures)
Network Data Sets and Structural Analysis in Python+NetworkX+Pandas (2)
Network Models: Random Networks, Scale Free Networks, The Barabási-Albert Model, Fuzzy-Granular Social Network (4 Lectures)
Generate Synthetic Networks, Using Network Models in Python+NetworkX (2)
Game Theory Introduction, Modeling Network Traffic using Games (3 Lectures)
Information Cascades, Small-World Phenomenon, Epidemics (4 Lectures)
Implementing Information Diffusion Algorithms in Python+NetworkX (2)
Community Detection (3 Lectures)
Implementing Community Detection Algorithms in Python+NetworkX (2)
Link Prediction (2 Lectures)
Implementing Link Prediction Algorithms in Python+NetworkX (2)
Evolving Network and Temporal Networks (2 Lectures)
Working with Temporal Network Data (2)
Connected Caveman Problem, Link Analysis and Web Search (2 Lectures)
Implementing PageRank algorithm in Python+NetworkX (1)
Network Data Science State-of-the-art (2 Lectures)

Textbook

1. Networks, Crowds, and Markets: Reasoning About a Highly Connected World, by David Easley and Jon Kleinberg, (Cambridge University Press - Sep 2010) -- Pre-publication draft available online.
2. Network Science, by Albert-Laszlo Barabasi, (Cambridge University Press - August 2016) -- freely available under the Creative Commons licence.
3. Networks, by Mark Newman, (Oxford University Press, 2nd-edition - Sep 2018)

Reference Books

1. Complex and Adaptive Dynamical Systems, by Claudius Gros, (Springer, 4th Edition - 2015).

2. The Structure of Complex Networks Theory and Applications, by Ernesto Estrada, (Oxford University Press - Dec 2011).

3. Exploratory Social Network Analysis with Pajek, by Wouter de Nooy, Andrej Mrvar, and Vladimir Batagelj, (Cambridge University Press, 3rd Edition - July 2018)

Self Learning Material

1. https://www.barabasilab.com/course
2. https://nptel.ac.in/courses/106106169/#

Title	**Blockchain**	Number	CSL8XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Elective
Prerequisite	Security		

Objectives
The Instructor will:
1. Explain how blockchain technology works
2. Integrate blockchain technology into the current business processes to make them Secure

Learning Outcomes
The students are expected to have the ability to:

1. Understand what and why of Blockchain
2. Explore the major components of Blockchain and Identify a use case for a Blockchain application
3. Create your own Blockchain network application

Contents

Introduction to Blockchain: Digital Trust, Asset, Transactions, Distributed Ledger Technology, Types of network, Components of blockchain (cryptography, ledgers, consensus, smart contracts) (5 lectures)
PKI and Cryptography: Private keys, Public keys, Hashing, Digital Signature (3 lectures)
Consensus: Byzantine Fault, Proof of Work, Poof of Stake (4 lectures)
Cryptocurrency: Bitcoin creation and economy, Limited Supply and Deflation, Hacks, Ethereum concept and Ethereum classic, Hacks Why it is so revolutionary – both (8 lectures)
Hyperledger Fabric: Hyperledger Architecture, Membership, Blockchain, Transaction, Chaincode, Hyperledger Fabric, Features of Hyperledger, Fabric Demo (4 lectures)
Blockchain Applications: Building on the Blockchain, Ethereum Interaction - Smart Contract and Token (Fungible, non-fungible), Languages, How you would go about creating your own blockchain, Blockchain-as-a-service (4 lectures)
Blockchain Use Cases: Finance, Industry and Blockchain in Government (4 lectures)
Security and Research Aspects: Blockchain Security (DDos), Research Aspects in Blockchain, AI, Blockckahin and Big Data (4 lectures)

Laboratory Experiments

Textbook
1. Bahga, A., & Madisetti, V. (2017). *Blockchain Applications: A Hands-On Approach*. VPT.

Self Learning Material
1. Swan, M. (2015). *Blockchain: Blueprint for a new economy*. " O'Reilly Media, Inc.".
2. Wattenhofer, Roger. *The science of the blockchain*. CreateSpace Independent Publishing Platform, 2016.
3. Bashir, I. (2017). *Mastering blockchain*. Packt Publishing Ltd.
4. Levy, K. E. (2017). *Book-smart, not street-smart: blockchain-based smart contracts and the social workings of law*. Engaging Science, Technology, and Society, *3*, 1-15.

Preparatory Course Material
1. MIT Online Blockchain Course, Learn Blockchain Technology, https://getsmarter.mit.edu/

Title	**Computational Optimization**	Number	CSL7XX0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for		Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Introduce various terminologies, concepts and algorithms related to classical, heuristic and nature inspired optimization algorithms
2. Discuss their applications in real-world scenarios

Learning Outcomes

The students are expected to have the ability to:

1. Utilize state of the art heuristic optimization algorithms in their research activities
2. Design and propose new and hybrid optimization algorithms
3. Customize heuristic optimization algorithms for special applications

Contents

Introduction, Definitions and Concepts: Optimization, Operational Research (OR), Engineering Optimization, Definition of an Optimization Problem, Feasibility Problem, Classification of Optimization Problems, Classification of Optimization Techniques, Heuristic Algorithms vs. Metaheuristics, Swarm Intelligence, Population-Based Optimization, Multi-objective Optimization, Parallelization, Evaluation of the Optimization Algorithms (6 lectures)

Overview of Classical Optimization Techniques: Linear programming, Nonlinear Programming (3 lectures)

Overview of Heuristic Optimization Algorithms: Neighborhood Search, Hill Climbing Methods, Greedy Algorithms, Simulated Annealing (3 lectures)

Overview of Nature Inspired Optimization Algorithms: Evolutionary Algorithms, Tabu Search, Ant Colony Optimization, Particle Swarm Optimization (2 lectures)

Simulated Annealing: Real Annealing and Simulated Annealing, Metropolis Algorithm, Simulated Annealing Algorithm, Continuous Simulated Annealing, One-loop Simulated Annealing, Temperature Scheduling, Convergence of Simulated Annealing, Applications, Normalization of the Parameters, Tuning the Parameters of an algorithm (9 lectures)

Evolutionary Algorithms: Methods of encoding, Operators of Evolution, Models of Evolution, Genetic Algorithms, Steady State Genetic Algorithms, Genetic Programming, Memetic Algorithms, Differential Evolution (7 lectures)

Tabu Search: Basic Tabu Search, Short-term Memory, Long-term Memory, Diversification and Intensification, Continuous Tabu Search (4 lectures)

Ant Colony Optimization: Collective Behavior of Social Insects, Basic ACO Algorithms, Ant Algorithms for TSP, Adaptation to Continuous Problems, Applications (5 lectures)

Particle Swarm Optimization: Canonical PSO Algorithm, Important Parameters, Neighborhood Topologies (3 lectures)

Textbook

1.Michalewicz,Z. and Fogel,D.B., (2004), *How to Solve it: Modern Heuristics*, 2nd Edition, Springer
2.Simon, D., (2013), *Evolutionary Optimization Algorithms*, Wiley
3.Yang,X.S., (2014), *Nature-inspired Metaheuristic Algorithms*, Luniver Press

Reference Books

1. Rao, S.S., (2013), *Engineering Optimization: Theory and Practice*, 3rd Edition, New Age International Publishers

Self Learning Material

1. NPTEL: Traditional and Non-traditional Optimization Tools
   https://nptel.ac.in/courses/112105235/1

Title	**Computer Graphics**	Number	CSL7xx0
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for		Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide a thorough introduction to computer graphics techniques, focusing on 2D and 3D modelling, image synthesis and rendering

Learning Outcomes

The students are expected to have the ability to:

1. Explain and create interactive graphics application
2. Implement graphics primitives
3. Synthesize and render images for animation and visualization

Contents

CSL7xx1 Introduction to Graphical Primitives 1-0-0 [1]

Introduction: Overview of computer graphics, representing pictures, preparing, presenting & interacting with pictures for presentations;
Scan conversion: 2D Geometric Primitives; Area Filling algorithms. Clipping algorithms, Anti Aliasing
Transformations and viewing: 2D and 3D transformations, Matrix representations & homogeneous coordinates, Viewing pipeline, Window to viewport co-ordinate transformation, clipping operations, viewport clipping, 3D viewing.

CSL7xx2 Graphical Object Representation 1-0-0 [1]

Curves and Surfaces: Conics, parametric and non-parametric forms; Bezier (Bernstein Polynomials) Curves, Cubic-Splines, B-Splines; Quadratic surfaces, Bezier surfaces and NURBS, 3-D modelling.

CSL7xx3 Graphics Rendering 1-0-0 [1]

Hidden surfaces: Depth comparison, Z-buffer algorithm, Back face detection, BSP tree method, the Printer's algorithm, scan-line algorithm; Hidden line elimination, wire frame methods, fractal - geometry.
Color & shading models: Phong's shading model, Gouraud shading, Shadows and background, Color models, Photo-realistic rendering
Animation and OpenGL primitives: Functions, pipeline, sample programs for drawing 2-D, 3-D objects; event handling and view manipulation, Introduction to GPU and animation

Textbook

1. J. D. Foley, A. Van Dam, S. K. Feiner and J. F. Hughes, Computer Graphics; Principles and practice, Addison Wesley, 2nd Edition in C, 1997.
2. D. F. Rogers and J. A. Adams, Mathematical elements for Computer Graphics, McGraw-Hill, 2nd Edition, 1990.

Self-Learning Material

1. Blender*: https://www.blender.org/download/*
2. OpenGL: http://www.opengl-tutorial.org/

Preparatory Course Material

1.Department of Computer Science and Engineering, Indian Institute of Technology Madras, https://nptel.ac.in/courses/106106090/