Indian Institute of Technology Jodhpur

M.Tech. AI & DS
Curriculum Structure
AY 2020-21

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1. Introduction

This BTech program combines two broad areas, Artificial Intelligence and Data Science, while building a strong foundation in Computer Science. Artificial Intelligence (AI) aims to create machines to act with higher levels of intelligence and emulate the human capabilities of sense, comprehend and act. On the other hand, Data Science (DS) is the art of generating insight, knowledge and predictions by processing data pertaining to a system or a process. AI and Data Science can feed into each other as evolutionary systems that can continuously learn from data and thereby emulate humans better. As the demand for these areas increases, there is also an increasing need for building the future workforce for Artificial Intelligence and Data Science. IIT Jodhpur will offer this unique program to develop the Artificial Intelligence and Data Science ecosystem in the country. The curriculum includes courses in computer science, mathematics, artificial intelligence, machine learning, and their applications in various domains. The curriculum also provides opportunities to the students to explore specialization areas including visual computing, socio-digital realities, robotics, and AIOT. The program also allows the students to venture into Management specialization with AI and Technology focus, leading to MBA (BTech + MBA dual degree program), as well as entrepreneurial activities. The program also enables the students to build strong industry linkages in terms of practical training program, summer internships, and co-supervision on projects.

2. Objectives of the program

1. BTech in AI&DS will offer students with in-depth knowledge of fundamental concepts, as well as application-oriented technologies in the broad areas of Artificial Intelligence and Data Science.
2. A student completing this program will be capable of undertaking careers in industry as well as academia. Interested students may also follow entrepreneurial endeavors in AI&DS areas.
3. He/She will have the option to explore a variety of domains including governance, finance, security, transportation, healthcare, energy management, agriculture/food processing, population studies, legal systems, content creation and management systems, weather prediction, economics, predictive maintenance, smart manufacturing, education, human and robot interaction/intelligent automation, smart city, drug discovery, and aid for differently abled/accessibility technology.

3. Expected Graduate Attributes

After completing this program, a student will develop an ability to:

1. Comprehend fundamental concepts and hands-on knowledge of the state-of-the-art AI&DS methodologies.
2. Skill set to clean, process, analyze, manage and handle security and privacy aspects of structured and unstructured data.
3. Ability to identify, design and apply appropriate pattern recognition and data mining methods for generating relevant insight from data.
4. Design and build real-world AI&DS systems, solving application-specific problems, and to reason about them.
5. Conceive, design and develop Intelligent multi-modal multi-sensory Man-Machine interfaces.
6. Design, develop, and deploy machine learning based applications using structured and unstructured data (e.g., speech, text, images/videos).
7. Capability to follow a unique interdisciplinary approach for solving problems, using knowledge of mathematics, statistics, computing and one or more selected domains among physics, chemistry, biology, engineering sciences, and management.
8. Understand and assess reliability, dependability and trust-worthiness of AI&DS based systems and their impact on societal and environmental context.
9. Design and develop AI applications for resource constrained environments.
10. Adhere to evolving ethics and privacy laws across various domains and territories.
11. Plan and manage technical projects.

4. Learning Outcomes

The student will have an ability to

1. Apply the knowledge of mathematics, science, engineering fundamentals along with artificial intelligence and machine learning knowledge, and an engineering specialization to develop solutions to real-world problems.
2. Apply appropriate theories, design principles, frameworks, and protocols to develop AI & DS based system prototypes.

3. Demonstrate hands-on knowledge of modern simulation, and AI & DS programming tools with an understanding of the limitations.
4. Apply to reason informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
5. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
6. Communicate effectively on complex engineering activities by comprehending and writing effective reports and design documentation, making effective presentations and exchanging clear instructions.
7. Apply appropriate project and business management principles and tools for real-world problems.
8. Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

5. New skill sets targeted

1. AI&DS algorithms for transforming large data into actionable decision
2. Building end to end systems for enhancing human capabilities using vision, language, and text processing
3. Foundations in ML Optimization
4. Ethical, Safe, and Dependable AI/ML Systems
5. Familiarity with emerging and futuristic AI&DS techniques
6. Entrepreneurial capability
7. Written and oral communication

6. Topic clouds and Mapping of Topic clouds with proposed courses

Map topics with courses in the table given below:

Table 1. Topics and Mapping of Topic with Courses

Area	Topics	Category (Core/ Techniques Technology/ Systems)	Course (IE/IS/PC/PE)
AI and ML	Abstract Data Types, Linear Data Structures, Non Linear Data Structures, Stack, Queue, Link List, Heap, Sorting, Hashing, Algorithm Analysis, Graph, Tree	Core	Data Structures and Algorithms (PC)
	Discrete Structures, Logics, Set, Graph and Trees, Deterministic Finite Automata, Non-deterministic Finite Automata, PushDown Automata, Context Free Grammar, Turing Machine, Lexical and Syntax Analysis, Parsing	Core	Maths for Computing (PC)
	Hardware-Software interaction, Digital circuit design and analysis, Computer system design, Instruction set architecture, Language translation, Semantic analysis	Core	Principles of Computer Systems - 1 (PC)
	Network-OS interaction, Process management, Storage management,	Core	Principles of Computer Systems - 2 (PC)
	Complexity Analysis, Divide-and-conquer, Greedy Algorithms, Dynamic Programming, Linear Programming, Universal Hashing, Max-flow Min-cut, Amortized Analysis, Traveling Salesman Problem, Approximation Algorithms	Core	Design and Analysis of Algorithms (PC)
	Bayes Decision Theory, Regression, Bias variance, Maximum Likelihood Estimation, Bayesian Parameter Estimation, Decision Tree, Random Forest, Artificial Neural Network, Clustering, k-means, SVM, Feature Selection, Dimensionality Reduction	Core and Technique	Pattern Recognition and Machine Learning (IE)
	Uninformed Search Strategies, Informed Search Strategies, Local Search Algorithms, Hill Climbing, Constraint Satisfaction Problems, Backtracking, Adversarial Search, Min-Max algorithms, Propositional Logic, Reasoning Patterns, First-order logic, Syntax, Semantics, Q-value, Policy,	Technique	Artificial Intelligence (PC)
	Neural Networks, Gradient Descent, Optimization, Regularization, Autoencoder, Convolutional Neural Network, Recurrent Neural Network, LSTM, Deep Generative Models, Generative Adversarial Network (GAN), Deep Belief Network, Deep Convolutional GAN, Variational Autoencoder, Representation Learning, Unsupervised Pre-training, Transfer Learning, Distributed Representation, Domain Adaptation, Neural Language Model, Adversarial Learning	Technique	Deep Learning (PC)
	Accuracy-explainabilitytradeoff, Interpretability problem, Predictability, Transparency, Traceability, Causality, Reasoning, Attention and Saliency, Interpretable AI, Prediction Consistency, Adversarial Robustness, Trustworthy AI, Integrity, Reproducibility, Accountability, Bias-free AI, Verified AI, Federated Learning, Differential Privacy,	Technique	Dependable AI (PC)

	Convexity, Linear programming, Duality, Integer programming, Nonlinear programming, Lagrange multipliers, First and second order conditions, Local and global convergence, Gradient descent methods	Core and Technique	Optimization for Machine Learning (PC)
	Decision-making, Utility Theory, Utility Functions, Decision Networks, Sequential Decision Problems, Partially Observable MDP, Game Theory, Reinforcement Learning, Generalization, Policy Search, Hidden Markov Model, Kalman Filter, Knowledge Representation, Ontological Engineering, Situation Calculus, Semantic Networks, Description Logic, Planning graphs, Partial-order Planning, Conditional Planning, Continuous Planning, Multi-agent Planning, Hierarchical Task Network Planning, Non-deterministic Domains	Core	Advanced AI (PE)
	Kernel Machines, Variants of Support Vector Machines, PAC Theory, Boosting, Graphical Models, Structural Predictions, Deep Reinforcement Learning, Sparse Coding	Core and Techniques	Advanced Machine Learning (PE)
	Computational complexity of AI models, Prediction accuracy, Numeric accuracy, Precision, Memory footprints, Edge AI, Memory Optimization of Models, Hardware accelerators for Edge AI, Vision Processing Unit, Streaming Hybrid Architecture Vector Engine, Open Neural Network Exchange	Systems and Technique	Resource-constrained Artificial Intelligence (PE)
	Search Engine Architecture, Retrieval Models, Performance Evaluation, Text Categorization, Text Clustering, Web Information Retrieval, Structured Document Retrieval	Technique	Information Retrieval (PE)
	Graph algorithms, Directed and Undirected graph, Planner graph, Graph coloring, Hamiltonion and Eulorian graph, Bipartite graphs, Trees.	Core	Graph Theoretic Algorithms (PE)
	Streaming Algorithms, Stream mining using Clustering, Massive Data Clustering, Data Stream Classification, Distributed Mining of Streaming Data, Change Diagnosis, Forecasting on Stream, Dimensionality Reduction for Streaming data.	Core and Technique	Stream Analytics (PE)
HCI and Social Sensing	User experience, Prototyping techniques and evaluation, Interface design and interaction, Speculative design, Value sensitive design	Technique and Systems	Human-Machine Interaction (PC)
	Visual World, Geometry, Lights and Optics, Tracking, Motion, Depth, devices and tools	Technique	Introduction to AR and VR (PE)
	Graphs, Network Models, Network Data Generation, Structural Properties, Link Prediction, Community Detection, Information Cascade, Small World Phenomenon, Homophily, Structural Balance, Components, NetworkX, Gephi, Network Evolution, Multi-layer network	Technique	Social Networks (PE)
Data and Distributed Sciences	Representing data, Data science ecosystem, data sources, data storage, data model, Structured data, unstructured data, semi-structured data, Accessing data, SQL, NoSQL databases, parallel data reads/writes for high throughput, distributed database, Analysing data, distributed data processing	Techniques and Systems	Data Engineering (PC)
	Data Visualization, Data representation, feature representations, encoded representations, Spatial data representation, Time-series data representations,	Techniques and Systems	Data Visualization (PC)

	visualization of multivariate data, geometry, Information illustration, Maps and Graphics, Advanced Visualization, Interactive graphics, infographics, visualization of high dimensional data		
	Multivariate analysis, Sampling theory, Matrix decomposition, Algorithms for big matrices, Data intensive processing	Techniques and Systems	Maths for Big Data (PC)
Decision Sciences and Cognition	Computational Neuroscience Models: Descriptive, Mechanistic and Interpretive models, Synapse, Neural encoding, Neural decoding, Neuron models, Spikes, Modeling connections between neurons, Synaptic plasticity and learning, Unsupervised and supervised learning from the perspective of neurons		Computational Neuroscience (PE)
	Biological signals, Biomedical imaging modalities, Sectioning, Multimodal images, Reconstruction, Image segmentation, Object delineation, Classification, Image registration, Deep Learning for Bio-imaging, Tracking, Interactive image analysis		Bio-imaging (PE)
Applications	Image digitization, Pixel relationships and distances, Camera model and stereo imaging, Image transforms, Image Enhancement: Spatial and Frequency domain, Image Restoration, Image segmentation, Color image processing, image morphology, Image compression and coding, Image features	Technique	Digital Image Processing (PE)
	Spoken language technology, dialog and conversational systems, automatic speech recognition, speech synthesis, affect detection, dialogue management.	Techniques	Speech Understanding (PE)
	Image formation and transformations, Camera calibration, Image restoration, Spatial and Wavelet-based processing, Epipolar Geometry, SfM, Optical flow, Key-point detection, Feature description and matching, Deep learning for vision, Applications	Techniques	Computer Vision (PE)
	Geometric primitives, clipping, viewing, rendering, animation, Shading, Coloring, OpenGL	Technique	Computer Graphics (PE)
	Word representation, NLP tasks, Seq2Seq model, Question Answering, Sentiment Analysis, Dialogue system, Machine Translation, natural language generation, Interpretability, Knowledge Graphs	Applications	Natural Language Understanding (PE)
	Biometric system design, Genesis of biometrics, System architecture, Performance evaluation, Biometric modalities, Biometric security, Biometric devices, Biomedical applications	Applications	Advanced Biometrics (PE)
	Multi-dimensional signals, systems, transforms and sampling; Camera models; Motion and shape estimation; Video segmentation and tracking; Video filtering, compression and restoring; Ego-centric, 360-degree and Streaming video	Applications	Video Processing (PE)

7. Course Categories, credit distribution and Credit Structure of B.Tech. Programmes

Table 2. ProposedCourse Categories and credit distribution in the proposed B.Tech. Programmes

S.N.	Course Type	Course Category	Regular B.Tech.		Double B.Tech.	
			Credit	Total	Credit	Total
1	Institute Core (I)	Engineering (IE)	**34**	**69**	**34**	**59**
		Science (IS)	16		**16**	
		Humanities (IH)	12		9	
2	Programme Linked (L)	Science (LS)	7		0	
3	Programme Core (P)	Programme Compulsory (PC)	**51**	**71**	**47+3**	**71**
		Programme Electives (PE)	**17**		21-3	
		B.Tech. Project (PP)	3		3	
4	Open (O)	Open Electives (OE)	10	**10**	0	**0**
5	Engineering Science (E)	Engineering Science Core (EC)	0	**0**	**22**	**22**
		Engineering Science Elective (EE)	0	**0**	**8,11**	**8**
Total Graded				**150**		**160**
6	Non-Graded (N)	Humanities (NH)	6	**15**	6	**15**
		Engineering (NE)	3		3	
		Design/Practical Experience (ND)	6		6	
Total Graded + Non-Graded				**165**		**175**

8. Credit Structure of B.Tech. Programmes

Table 4. Credit Structure for B.Tech. Programmes (Up 6000 Level)

Type	L-T-P	Distribution of contact and beyond contact hours			Total Credits (TC=TH/3)
		Contact Hours (CH)	Beyond Contact Hours (BCH)	Total Hours (TH)	
1 hour of Lecture	1-0-0	1 hr	2 hr	3 hr	1
1 hour of Tutorial	0-1-0	1 hr	2 hr	3hr	1
1 hour of Lab/Project	0-0-1	1 hr	0.5 hr	1.5 hr	0.5

#Contact hour for projects refers to the involvement of students in the laboratory, discussion, etc.

9. List of Programme Compulsory Courses

Table 5. Programme Compulsory Courses

Sr. No	Course Name	LTP	Contact Hours	Credit
1	Data Structure and Algorithms	3-0-2	5	4
2	Maths for Computing	3-1-0	4	4
3	Principles of Computer Systems - 1 (Compilers and CA)	2-0-2	4	3
4	Data Engineering	3-0-3	6	4.5
5	Human-Machine Interaction	0-0-4	4	2
6	Design and Analysis of Algorithms	3-1-0	4	4
7	Artificial Intelligence	3-0-0	3	3
8	Optimization for ML	3-0-3	6	4.5
9	Principles of Computer Systems - 2	3-0-2	4	4
10	Data Visualization	3-0-3	6	4.5
11	Deep Learning	3-0-3	6	4.5
12	Dependable AI	3-0-0	3	3
13	DSAI Core Elective 1 (DS + X)	3-0-0	3	3
14	DSAI Core Elective 2 (AI + X)	3-0-0	3	3
15	Maths for Big Data*	2-1-0	3	3
			Total	**51**

*For Core ES + AI&DS program, under DS+X for regular program, Ethics, Policy, Law and Regulations in AI (0-0-2) is a core course under Professional Ethics - II (Sem VI).

10. Area-wise Programme Elective Courses

Table 6. Stream-wise Programme Electives Courses

S. No.	Stream	Courses	L-T-P	Credit
1	AI and ML	Advanced Artificial Intelligence	3-0-0	3
2		Advanced Machine Learning	3-0-0	3
3		Resource Constrained Artificial Intelligence	3-0-0	3
4		Scalable Machine Learning	3-0-0	3
5		Computational Learning Theory	3-0-0	3
6		Information Retrieval	3-0-0	3
7		Graph Theoretic Algorithms	3-0-0	3
8		Stream Analytics	3-0-0	3
9	Robotics and Automation	Introduction to Robotics	3-0-0	3
10		Planning and Decision Making of Robots	3-0-0	3
11		Multi-Agent Systems	3-0-0	3
12		Autonomous Systems	3-0-0	3
13	Socio-Digital Reality	Multimodal Interfaces	0-0-2	2
14		Introduction to Haptics	3-0-0	3
15		Introduction to AR and VR	3-0-0	3
16		Advanced Human-Machine Interaction	3-0-0	3
17		Social Networks	3-0-0	3
18	Science of Intelligence	Computational Neuroscience	3-0-0	3
19		Connectomics	3-0-0	3
20		Bioimaging	3-0-0	3
21	Applications	Digital Image Processing	3-0-0	3
22		Computer Vision	3-0-0	3
23		Natural Language Understanding	3-0-0	3
24		Speech Understanding	3-0-0	3
25		Computational Linguistics	3-0-0	3
26		Advanced Biometrics	3-0-0	3
27		Computer Graphics	3-0-0	3
28		Video Processing	3-0-0	3
29		Animation	3-0-0	3
30		GPU Programming	3-0-0	3
31	Cyber Physical Systems, Sensors and Internet of Things	Introduction to Cyber Physical Systems	3-0-0	3
32		Embedded Systems Design	3-0-0	3
33		Security in CPS	3-0-0	3
34		Edge and Fog Computing	3-0-0	3
35		Real Time Systems	3-0-0	3
36	Data and Discovery Science	Introduction to Space Science	3-0-0	3
37		Reliability Engineering and Life Testing	3-0-0	3
38		Introduction to Game Theory	3-0-0	3
39		Nonlinear Dynamics and Chaos	3-0-0	3
40		Differential Geometry	3-0-0	3
41		Introduction to Financial Engineering	3-0-0	3
42		Computational Chemistry	3-0-0	3
43	Special Topics	Special Topics in ML	3-0-0	3
44		Special Topics: Advancements in Computer Vision	3-0-0	3
45		Special Topics in Data Science	3-0-0	3

11. Specialization to be offered by the department

Table 7a. Specialization and courses

S. No.	Name of Specialization	Specialization Core (8 credits)	Specialization Elective (12 Credits)
1.	Visual Computing (CS, AI&DS, EE)	Computer Graphics (3-0-0), Computer Vision (3-0-0), Visual Computing Lab (0-0-4)	Digital Image Processing, Video Processing and Analysis, Advanced Machine Learning, Introduction to AR and VR, Scalable Machine Learning, Computational Photography, Computational Imaging,Principles of Biological Vision, Bioimaging, Medical Image Analysis, Visual Perception, Advancements in Computer Vision, Animation, Real-time Vision Architecture, Image Synthesis, 3D Shape Analysis, Image and Video Forensics, Selected Topics in Computer Vision, Project (0-0-12)
2.	Socio-Digital Reality (CS, AI&DS, EE)	Social Network (3-0-0), Introduction to AR and VR (3-0-0), Multimodal interface Lab (0-0-4)	Introduction to Haptics, Design Process, Speech Understanding, Computer Graphics, HCI, NLU, Computer Vision, Visual Perception, Image and Video Forensics, Project (0-0-12)
3.	Intelligent Communications and Networking	Jointly with EE	Jointly with EE
4.	Robotics	Jointly with RM-IDRP	Jointly with RM-IDRP
5.	AIOT	Jointly with EE	Jointly with EE
6.	AI (for non-AI, non-CS Students)	AI (3-0-0), Deep Learning (3-0-0), AI Lab (0-0-4)	Algorithm for big data, computer vision, machine learning with big data, edge and fog computing, NLP, GPU Programming, Data Visualization, Introduction to AR and VR, Dependable AI, Resource constrained AI, Social Network Analysis, Optimization, Computer Graphics, Advanced AI, Advanced ML, Project (0-0-12)

***Science of Intelligence, Smart Healthcare, and Language Technologies Specializations will be added in the future**

Table 7b. AI+X courses.

S. No.	Course	Status
1.	AI + Industry 4.0	Jointly with ME
2	Autonomous Systems	IDRP
3.	AI + Transportation	CSE

Table 7c. DS+X (Applied Statistics) courses.

S. No.	Course	Status
1.	Maths for Big Data	CS+Math course
2.	Statistical Inference and Simulation Techniques	Maths course
3.	Introduction to Financial Engineering	Maths course
4.	Time Series Analysis	Math course

12. Curriculum of B.Tech. AI&DS (Regular)

Table 8b. Curriculum of B.Tech. in **AI&DS**

Cat	*Course*	*LTP*	*CH*	*NC*	*GC*	*Cat*	*Course*	*LTP*	*CH*	*NC*	*GC*
	I Semester						**II Semester**				
IE	Introduction to Electrical Engineering	3-0-2	5	-	4	IE	Engineering Mechanics	2-1-0	3	-	3
IE	Introduction to Computer Science	3-0-2	5	-	4	IS	Chemistry	3-0-0	3	-	3
IE	Introduction to Bioengineering	3-0-2	5	-	4	IS	Physics	3-0-0	3	-	3
						IS	Chemistry Lab	0-0-2	2	-	1
						IS	Physics Lab	0-0-2	2	-	1
IS	Mathematics I	3-1-0	4	-	4	IS	Mathematics II	3-1-0	4	-	4
IE	Engineering Visualization	0-0-2	2	-	1	IE	Engineering Realization	0-0-2	1	-	1
NE	Engineering Design I	0-0-2	2	1	-	NE	Engineering Design II	0-0-2	2	1	-
NH	Communication Skill I	0-0-2	2	1	-	NH	Communication Skill II	0-0-2	2	1	-
NH	Social Connect and responsibilities I	0-0-1	1	0.5	-	NH	Social Connect and responsibilities II	0-0-1	1	0.5	-
NH	Performing Arts I/ Sports I	0-0-1	1	0.5	-	NH	Performing Arts II/ Sports II	0-0-1	1	0.5	-
	Total	**12-1-14**	**27**	**3**	**17**		**Total**	**11-2-12**	**25**	**3**	**16**
	III Semester						**IV Semester**				
LS	PSSP	3-1-0	4	-	4	IE	Materials Science & Engineering (Electronic materials)	1 × 1-0-0	1	-	1
IE	i-Energy materials ii- Computational Materials Design	2X 1-0-0	2	-	2						
PC	Data Structures and Algorithms	3-0-2	5	-	4	IE	Pattern Recognition and Machine Learning	3-0-2	5	-	4
PC	Maths for Computing	3-1-0	4	0	4	IE	Thermodynamics	3-1-0	4	-	4
IE	Signals and Systems	3-1-0	4	-	4	**PC**	HMI PCS-1 PCS-2	0-0-4 2-0-2 3-0-2	4 2 4	- - -	2 3 4
LS	Quantum Info Processing	3-0-0	3	-	3						
NE	Intro. To Profession	0-0-2	2	1		IH	Humanities I	3-0-0	3	-	3
	Total	**17-3-4**	**24**	**1**	**21**		**Total**	**15-1-10**	**24**	**-**	**21**
	V Semester						**VI Semester**				
PC	DA of Algorithms Artificial Intelligence Optimization in ML Data Engineering	3-1-0 3-0-0 3-0-3 3-0-3	4 3 6 6	- - -	4 3 4.5 4.5	**PC**	Data Visualization Deep Learning AI+X / DS+ X Dependable AI	3-0-3 3-0-3 3-0-0 3-0-0	6 6 3 3	- - -	4.5 4.5 3 3

IH	Humanities II	3-0-0	3	-	3	PE	Programme/ Open Elective	6-0-0	6		6
NH	Professional Ethics I	0-1-0		1	-	NH	Ethics, Policy, Law and Regulations in AI	0-0-2		1	-
	Total	**15-2-6**	**22**	**1**	**19**		**Total**	**18-0-4**	**24**	**1**	**21**
	VII Semester						**VIII Semester**				
PP	B. Tech. Project	0-0-6	6	-	3	IH	Humanities IV	3-0-0	3	-	3
PCPE / OE	AI+X / DS+ X Programme/ Open Electives	3-0-0 6-0-0	3 6	-	3 6	PE/ OE	Programme/ Open Electives	15-0-0	15	-	15
IH	Humanities III	3-0-0	3	-	3						
IS	Environmental Sci	2-0-0	2	-	2						
	Total	**14-0-6**	**21**	**-**	**17**		**Total**	**18-0-0**	**18**	**-**	**18**
										Total of graded and Non-Graded Credit	**9**	**150**
										Non-Graded Design Credits	**6**	**-**
										Grand Total	**165**	

13. Curriculum of Double B.Tech. : B.Tech. AI&DS Engineering and Engineering Science

Table 9. Programme structure of Double B.Tech.

Cat	*Course*	*LTP*	*CH*	*NC*	*GC*	*Cat*	*Course*	*LTP*	*CH*	*NC*	*GC*
	I Semester						II Semester				
First two semesters same as Table 8a or 8 b 33 Graded and 6 non graded credits											
	III Semester						IV Semester				
ES	Probability, Statistics, Stochastic Processes	3-1-0	4	-	4	IE	Materials Science & Engineering	3 × 1-0-0	3	-	3
ES	Modern Physics	3-0-0	3	-	3	ES	Embedded Systems and IoT	3-0-2	5	-	4
IE	Thermodynamics	3-1-0	4	-	4	IE	Pattern Recognition and Machine Learning	3-0-2	5	-	4
ES	Data Structures and Algorithms	3-0-2	5	-	4	ES	Design of Experiments	3-0-0	3	-	3
IE	Signals and Systems	3-1-0	4	-	4	ES	Modelling and Simulation	3-0-2	5	-	4
NE	Intro. To Profession	0-0-2	2	1		IH	Humanities I	3-0-0	3	-	3
	Total	15-3-4	22	1	19		Total	18-0-6	24	-	21
	V Semester						VI Semester				
PC	Maths for Comp. DA of Algorithm Artificial Intelligence Optimization in ML HMI	3-1-0 3-1-0 3-0-0 3-0-3 0-0-4	4 4 3 6 4	- - - - 	4 4 3 4.5 2	PC	PCS-1 PCS-2 Data Engg Data Visualization Deep Learning AI+X / DS+ X Dependable AI	2-0-2 3-0-2 3-0-3 3-0-3 3-0-3 3-0-0 3-0-0	2 4 6 6 6 3 3	- - - 	3 4 4.5 4.5 4.5 3 3
PE	Programme/ Engineering Science Elective/ Multimodal Bouquet (3)	3-0-0	3		3						
IH	Humanities II	3-0-0	3	-	3						
NH	Professional Ethics I	0-1-0		1	-	NH	Ethics, Policy, Law and Regulations in AI	0-0-2		1	-
	Total	18-3-7	27	1	23.5		Total	20-0-15	30	1	26.5
	VII Semester						VIII Semester				
PP	B. Tech. Project	0-0-6	6	-	3	PE/ ES	Programme/ Engineering	14-0-0	14	-	14

							Science Electives				
PC	AI+X / DS+ X Maths for Big Data	3-0-0 2-1-0	3 3	- -	3 3	IH	Humanities III	3-0-0	3	-	3
PE/ OE	Programme/ Engineering Science Electives/ Multimodal Bouquet (3)	9-0-0	9	-	9						
IS	Environmental Science	2-0-0	2	-	2						
	Total	16-1-6	25	-	20		Total	17-0-0	17	-	17
										9	160
										6	-
										175	

Note: ES are proposed Engineering Science compulsory courses

14. Detailed Course Content of Programme Compulsory Courses

Course Title	**Data Structures and Algorithms**	Course No.	**CSxxx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-2 [4]
Offered for	B.Tech of all branches	Type	Compulsory
Prerequisite	Introduction to Computer Programming		

Objectives

1. To introduce and practice the implementation of various data structures used for indexing, searching, and sorting operations.
2. To introduce basic mathematical techniques for algorithm analysis and design.

Learning Outcomes

1. Ability to design and implement appropriate data structures for indexing, searching, and sorting operations for real-world problems.
2. Designing of new algorithms using standard data structures.
3. Analyzing the time and space complexities of standard data structures and basic algorithms.

Contents

Algorithm analysis and complexity: Big/little -Oh, Omega, Theta notation, Recurrence equations. (2 Lectures)
Abstract data types: Linear data structures, Tree, Binary trees, Tree traversal, Applications. (7 Lectures)
Search trees: Binary search trees, Balanced search trees, AVL trees, B-Trees. (5 Lectures)
Heaps: Binary Heap, Heap order property and min/max heaps. (3 Lectures)
Sets: Disjoint set ADT, Basic operations on Sets, Union/Find algorithm. (2 Lectures)
Sorting algorithms: Bubble sort, Selection sort, Bucket sort, Insertion sort, Overview of Divide-and-conquer, Quick sort, Merge sort. (6 Lectures)
Hashing: Hash tables and operations, Hash function, Open and closed hashing, External and internal hashing, Collision resolving methods, Rehashing. (5 Lectures)
Graph algorithms: Definitions, Branch and bound, Backtracking, Representation, Traversal, Shortest-path algorithms, Minimum Spanning Tree algorithm, Topological sorting. (8 Lectures)
Greedy techniques and Dynamic programming (4 Lectures)

Laboratory

1. Implementation of data structures using C programming language.
2. Practically verifying and comparing run-time performance and asymptotic behavior of various data structures and related algorithms.
3. Applications of data structures from real-life scenarios.

Text Book

M. A. WEISS (2002), Data Structures and Algorithm Analysis in C, Addison-Wesley, 2nd Edition.

Reference Book

T. H. CORMEN, C. E. LEISERSON, R.L. RIVEST, C. STEIN (2009),Introduction to Algorithms, MIT Press, 3rd Edition.

Title	**Principles of Computer Systems - I**	Course No.	AIDSLXXX
Department	CSE, AI & DS	Structure (L-T-P [C])	2–0–2 [3]
Offered for	B.Tech (AI)	Type	Compulsory
Prerequisite	Maths for Computing	Antirequisite	Computer Architecture

Objectives

The Instructor will:

1. Explain necessary layered abstraction of a system
2. Provide an understanding of basic concepts of several hardware components and design of computing components
3. Introduce language translation schemes

Learning Outcomes

The students will have the ability to:

1. Design combinational and sequential circuits for a set of problems
2. Explain the working principles of several components of a computer
3. Design algorithms for language translations.

Contents

Introduction: Layered architecture of a system, Hardware, Software, Hardware-software Interaction (2 Lectures)

Digital Circuit Design: Combinational Circuits, Combinational Analysis and Design, Sequential Circuits, Sequential Analysis and Design (10 Lectures)

Computer System Design: Instruction set Architecture, CPU, Performance analysis, Pipelining, Memory Hierarchy, I/O, ILP (10 Lectures)

Language Translation**:** Levels of language translation, Compiler, Semantic Analysis, Code generation (6 Lectures)

Laboratory

Digital Logic Circuits, Digital Hardware, VHDL state machines, Machine Language Design, Memory, CPU, Assembler, Parallel Programming.

Text Books

1. S. WARFORD (2017), Computer Systems, Jones and Bartlett Learning, 5th Edition.
2. R. BRYANT, D. O'HALLARON (2016), Computer Systems A Programmer's Perspective, Pearson, 3rd Edition.

Reference Books

1. Saltzer, J. and Kaashoek, F. (2009), *Control Systems - Principles & Design*, 3rd Edition, Morgan Kaufmann
2. John L. Hennesy, David A. Patterson (2017), Computer Architecture: A Quantitative Approach, 6th Edition, Morgan Kaufmann.

Online Material

NPTEL Course, Foundations of Computer Systems Design, https://nptel.ac.in/courses/106106197/

Title	**Principles of Computer Systems - II**	Course No.	AIDSLXXX
Department	CSE, AI & DS	Structure (L-T-P [C])	3–0–2 [4]
Offered for	B.Tech (AI & DS)	Type	Compulsory
Prerequisite	Principles of Computer Systems - I (Same Semester)	Antirequisite	OS, CN

Objectives

The Instructor will:

1. Explain necessary layered abstraction of a system
2. Provide an understanding of the fundamentals of operating systems and networking
3. Introduce the concepts of Virtualization

Learning Outcomes

The students will have the ability to:

1. Explain the working principles of operating systems
2. Design interconnected environments using basic networking protocols.
3. Apply concepts of Virtualization in a practical environment

Contents

Introduction: Layered architecture of a system, Kernel, Network-Operating System Interaction (4 Lectures)
Process Management:Process, process states, concurrent processes, inter-process communication, Synchronization, Deadlock (12 Lectures)
Storage management: Memory Allocation, Virtual Memory, File Management (9 Lectures)
Network Design:Working principles, Layered Architecture, IP Addressing, Protocols for Transport, and Application Layers. (12 Lectures)
Virtualization: Basics of Virtual Machines, Containers, Virtualization techniques, Cloud and Data Centers (5 Lectures)

Laboratory

Introduction to the Linux environment, Process Management, and Synchronization, Scheduling, Memory Management, Client-Server message passing, Internet protocols, IP addressing, peer to peer protocol, virtualization.

Text Books

1. S. WARFORD (2017), *Computer Systems*, Jones and Bartlett Learning, 5th Edition.
2. N.F. SCHNEIDEWIND, (2012), Computer, Network, Software, and Hardware Engineering with Applications, Wiley-IEEE Press.

Reference Books

1. A. SILBERSCHATZ, P.B. GALVIN, G. GAGNE (2013), Operating System Concepts, Wiley 8th Edition.
2. S. DAS (2017), UNIX Concepts and Applications, Tata McGraw-Hill.
3. J. KUROSE, K.ROSS (2016), Computer Networking: A Top-Down Approach, Pearson, 7th Edition.

Online Material

1. NPTEL Course: Operating System Fundamentals, https://nptel.ac.in/courses/106/105/106105214/
2. NPTEL Course: Computer Network and Internet Protocol, https://nptel.ac.in/courses/106/106/106106091/

Course Title	**Pattern Recognition and Machine Learning**	Course No.	**CSL2xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3-0-2
Offered for	B.Tech (CSE, AI&DS, EE)	Type	Compulsory
Prerequisite	Introduction to Computer Sc., Probability, Statistics and Stochastic Processes	Antirequisite	Introduction to Machine Learning

Objectives

1. To understand various key paradigms for pattern classification and machine learning approaches
2. To familiarize with the mathematical and statistical techniques used in pattern recognition and machine learning.
3. To understand and differentiate among various pattern recognition and machine learning techniques.

Learning Outcomes

The students are expected to have the ability to:

1. To formulate a machine learning problem
2. Select an appropriate pattern analysis tool for analyzing data in a given feature space.
3. Apply pattern recognition and machine learning techniques such as classification and feature selection to practical applications and detect patterns in the data.

Contents

Introduction: Definitions, Datasets for Pattern Recognition, Different Paradigms of Pattern Recognition and Machine Learning, Data Normalization, Hypothesis Evaluation, VC-Dimensions and Distribution, Bias-Variance Tradeoff, Regression (Linear) (8 Lectures)

Discriminative Methods: Distance-based methods, Linear Discriminant Functions, Decision Tree, Random Decision Forest and Boosting (5 Lectures)

Bayes Decision Theory: Bayes decision rule, Minimum error rate classification, Normal density and discriminant functions, Bayesian networks (7 Lectures)

Parameter Estimation: Maximum Likelihood and Bayesian Parameter Estimation (3 Lectures)

Feature Selection and Dimensionality Reduction:PCA, LDA, ICA, SFFS, SBFS (4 Lectures)

Artificial Neural Networks*:* MLP, Backprop, and RBF-Net (4 Lectures)

Kernel Machines: Kernel Tricks, Support Vector Machines (primal and dual forms), K-SVR, K-PCA (6 Lectures)

Clustering: k-means clustering, Gaussian Mixture Modeling, EM-algorithm (5 Lectures)

Laboratory

Programming labs on Normalization, Visualization, Evaluation, Regressions, Decision Tree, Bayes, Parameter Estimation, PCA, LDA, ANN, SVM, K-means, GMM, Feature Selection

Text Book

1. R. O. DUDA, P. E. HART, D. G. STORK (2000), Pattern Classification, Wiley-Blackwell, 2nd Edition.

Reference Books

1. C. M. BISHOP (2006), Pattern Recognition and Machine Learning, Springer-Verlag New York, 1st Edition.
2. T. M. MITCHELL (2017), Machine Learning, McGraw Hill Education, 1st Edition.

Self-learning Material

1. Introduction to Machine Learning, NPTEL Course Material, Department Computer Science and Engineering, IIT Madras: http//nptel.ac.in/courses/106106139/
2. Machine Learning, Stanford University: https://see.stanford.edu/Course/CS229

Course Title	**Maths for Computing**	Course No.	**CSLXXX**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-1-0 [4]
Offered for	B.Tech CSE, AI&DS	Type	Compulsory
Prerequisite	None		

Objectives

1. To learn about languages, grammars, and computation models
2. To learn about computability
3. To learn basics of parsing techniques

Learning Outcomes

The students are expected to have the ability to:

1. Model computer science problems using discrete mathematical structures
2. Distinguish between computable and uncomputable problems
3. Develop understanding of properties of languages and design parsers

Contents

Discrete Structures:Can computers solve every problem? The Limits of Computing, Set Theory, Proof Techniques, Relations and Functions, Propositional Logic, First-Order Logic, Counting techniques. (14 Lectures)

Graph Theory: Properties of graphs, Graph matching and coloring. (7 Lectures)

Automata Theory:DFAs, NFAs, Equivalence of DFAs and NFAs, Closure Properties of Regular Languages, Regular Expressions, Equivalence of Regular Expressions and NFAs, Nonregular Languages, Context-Free Grammars, Context-Free Languages. (10 Lectures)

Turing Machine:Introduction, Designing Turing Machines, The Universal Turing Machine. (7 Lectures)

Parsing Techniques: LR, LALR, Shift-Reduce Parsers. (4 Lectures)

Text Books

1. M. SIPSER (2014), Introduction to the Theory of Computation, Cengage Learning, 3rd Edition.
2. K.H. ROSEN (2018), Discrete Mathematics and its Applications, McGraw-Hill, 2018, 8th Edition.

References

1. J.E. HOPCROFT, R. MOTWANI, J.D. ULLMAN (2008), Pearson, Introduction to Automata Theory, Languages, and Computation, 3rd Edition.
2. R. JOHNSONBAUGH (2017), Discrete Mathematics, Prentice Hall, 8th Edition.

Self-learning material

Stanford CS103:http://web.stanford.edu/class/cs103/

Course Title	**Design and Analysis of Algorithms**	Course No.	**CSLXxx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-1-0 [4]
Offered for	B.Tech CSE, AI&DS	Type	Compulsory
Prerequisite	Data Structures and Algorithms		

Objectives

1. To introduce and implement various techniques for designing algorithms and advanced data structures.
2. To learn space and time complexity analysis of algorithms.

Learning Outcomes

1. Ability to choose and implement appropriate algorithm design techniques for solving problems.
2. Understand how the choice of data structures and algorithm design methods impact the performance of programs.
3. Ability to analyze the worst-case and average-case behaviour of algorithms in terms of time and memory requirements.

Contents

Reasoning About Algorithms: P, NP, NP-completeness, Reductions, Complexity analysis. (5 lectures)
Graph Algorithms: Strongly-connected components, Kosaraju's Algorithm 1 and 2, Applications. (4 lectures)
Greedy Techniques: Local versus Global optimality, Interval Scheduling, Exchange arguments. (5 lectures)
Divide-and-Conquer: Optimality, Recursive algorithms, Divide-and-Conquer Recurrences, The Master Theorem and applications, Non-uniform Recurrences. (6 lectures)
Dynamic Programming: Reusing sub-computations (Sequence alignment, Bellman-Ford algorithm), Precomputing (Floyd-Warshall algorithm, Johnson's algorithm), Combinatorial problems. (Knapsack) (6 lectures)
Linear Programming: Canonical and standard forms, Feasibility and optimization, Simplex Algorithm. (5 lectures)
Approximation Algorithms: Relative Approximations, PAS and FPAS Scheduling. (4 lectures)
Randomized Algorithms: Random guess (Quick select), Random guess with high confidence (Karger's min-cut algorithm), Storing associative data (Hashing), Error bounds. (7 lectures)

Text Book

T. H. CORMEN, C. E. LEISERSON, R.L. RIVEST, C. STEIN (2009), Introduction to Algorithms, MIT Press, 3rd Edition.

Reference Book

J. KLEINBERG, E. TARDOS (2005), Algorithm Design, Pearson Education, 1st Edition.

Course Title	**Human-Machine Interaction**	Course No.	**CSL2xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	0-0-4 [2]
Offered for	B.Tech (CSE, AI&DS)	Type	Compulsory
Prerequisite	None		

Objectives

To provide a practical understanding of human-machine interaction (HMI) design, including concepts of user-centered and design thinking, usability, interfaces, rapid prototyping, and evaluation.

Learning Outcomes

The students will have:

1. A broad understanding of human-machine interaction and the latest technologies.
2. Understanding of perceptual and cognitive basis of human-machine interaction.
3. Knowledge of user-centered design and techniques for rapid prototyping.
4. Knowledge of assessing usefulness and usability of a design
5. Introduction to approaches for gathering and analyzing interaction data, and conveying design concepts.

Laboratory and Assignments (primary approach)

1. Find a poorly designed item (anything). Submit either a picture or sketch and describe why it is poorly designed, Heuristic Evaluation and Interview, User Scenarios, Personas, and Storyboards, User Journeys, Wireframes: Paper and Digital Prototyping, Prototype Evaluation Study Design, Value Sensitive Design Evaluation (Week 1-4)
2. Design visual Interfaces (laptop, mobile) - e.g. gesture-based, Design voice interfaces - e.g. speech chatbot, Design multimodal interactions (Week 5-14)

Text Book

H. SHARP, J. PREECE, Y. ROGERS (2019), Interaction Design: Beyond Human-Computer Interaction, Wiley, 5th Edition.

Online Material

NPTEL Course, Introduction to Human-Computer Interaction,
https://nptel.ac.in/courses/106/106/106106177/

Course Title	**Artificial Intelligence**	Course No.	**CSL3xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech (CSE, AI&DS)	Type	Compulsory
Prerequisite	Data Structures and Algorithms		

Objectives

To provide the foundations for AI problem solving techniques and knowledge representation formalisms.

Learning Outcomes

The students are expected to have the ability to:

1. Identify and formulate appropriate AI methods for solving a problem.
2. Implement AI algorithms
3. Compare different AI algorithms in terms of design issues, computational complexity, and assumptions

Contents

Introduction: Uninformed search strategies**,** Greedy best-first search, And-Or search, Uniform cost search, A* search, Memory-bounded heuristic search (5 Lectures)

Local Search Techniques: Beam Search, Hill Climbing Search, Genetic Search techniques (2 lectures)

Constraint Satisfaction Problems: Backtracking search for CSPs, Local search for CSPs (4 Lectures)

Adversarial Search: Optimal Decision in Games, The minimax algorithm, Alpha-Beta pruning, Expectimax search (5 Lectures)

Knowledge and Reasoning: Propositional Logic, Reasoning Patterns in propositional logic; First order logic: syntax, semantics, Inference in First order logic, unification and lifting, backward chaining, resolution (7 Lectures)

Representation: Information extraction, representation techniques, foundations of Ontology (4 Lectures)

Planning: Situation Calculus, Deductive planning, STRIPES, sub-goal, Partial order planner (4 Lectures)

Bayesian Network and causality: Probabilistic models, directed and undirected models, inferencing, reasoning, causality (6 lectures)

RL: MDP, Policy, Q-value (5 Lectures)

Text Book

S. RUSSEL, P. NORVIG (2020), Artificial Intelligence: A Modern Approach, Pearson, 4th Edition.

Reference Books

1. E. RICH, K. KNIGHT, S. B. NAIR (2017), Artificial Intelligence, McGraw Hill Education, 3rd Edition.
2. J. PEARL (2009), Causality: Models, Reasoning and Inference, Cambridge University Press, 2nd Edition.
3. D. KOLLER, N. FRIEDMAN (2009), *Probabilistic Graphical Models: Principles and Techniques,* MIT Press

Course Title	**Deep Learning**	Course No.	**CSL4xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3-0-3 [4.5]
Offered for	B.Tech. AI&DS	Type	Compulsory
Prerequisite	Introduction to Machine Learning/Pattern Recognition and Machine Learning		

Objectives

The objective of this course is

1. To introduce students through some of the latest techniques in deep learning.
2. Hands on and the students should be able to design intelligent deep learning systems for solving the problems in the area of their interests.

Learning Outcomes

The students are expected to have the ability to:

1. Understand various deep learning models such CNN, Autoencoders, RNN etc.
2. Analyze various applications solved through the use of deep learning models
3. Design and implement their own deep learning models for the problem of their choice

Contents

Neural networks: DL Optimizers (SGD, MBGD, AdaGrad, Adam) and Regularization, Initialization Methods (7 Lectures)

DL Models: Autoencoder, Convolutional Neural Networks, Recurrent Neural Networks, LSTM, Network Architecture Search (NAS) (14 Lectures)

Deep Generative Models: Deep Belief Networks, Variational Autoencoders, Generative Adversarial Networks, Deep Convolutional GAN (12 Lectures)

Representation learning: Unsupervised Pre-training, Transfer learning and Domain adaptation, Distributed representation, Discovering underlying causes (9 Lectures)

Laboratory

Autoencoder, CNN, LSTM, DBM, GANs (variants), Transfer Learning, NLM, Graph NN, Adversarial losses

Text Book

I. GOODFELLOW, Y. BENGIO, A. COURVILLE (2016), Deep Learning, The MIT Press, 1st Edition.

Reference Books

1. A. ZHANG, Z. LIPTON, M. LI, A. SMOLA (2020) Dive into Deep Learning (Release 0.7.1), https://d2l.ai/d2l-en.pdf.
2. D. FOSTER (2019), Generative Deep Learning, O'Reilly Media, 1st Edition.

Self-learning Material

1. Practical Machine Learning with Tensorflow, NPTEL Course Material, Department Computer Science and Engineering, IIT Madras: https://nptel.ac.in/courses/106106213/
2. Stanford CS class (CS231n), Convolutional Neural Networks for Visual Recognition: http://cs231n.github.io/

Course Title	**Dependable Artificial Intelligence**	Course No.	**CSL4xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech (AI&DS)	Type	Compulsory
Prerequisite	Introduction to Machine Learning/Pattern Recognition and Machine Learning, AI	Preferred Knowledge	Deep Learning (same semester)

Objectives

The Instructor will:

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 (3 Lectures)
Explainable AI: Accuracy-explainabilityTradeoff, Interpretability Problem, Predictability, Transparency, Traceability, Causality, Reasoning, Attention and Saliency (10 Lectures)
Interpretable AI: Prediction Consistency, Application Level Evaluation, Human Level Evaluation, Function Level Evaluation (5 Lectures)
Adversarial Robustness: Adversarial Attacks and Defences (8 Lectures)
Trustworthy AI: Integrity, Reproducibility, Accountability (2 Lectures)
Bias-free AI: Accessibility, Fair, Data Agnostics Design, Disentanglement (4 Lectures)
Privacy Preserving AI:Federated Learning, Differential Privacy and Encrypted Computation (6 Lectures)
Verified AI:Environment and Specification Modeling, Design with Formal Inductive Synthesis, Evaluation Platforms for AI Safety (4 Lectures)

Textbooks

1. J. PEARL (2018), The Book of Why: The New Science of Cause and Effect, Basic Books.
2. N. BOSTROM (2014), The Ethics of Artificial Intelligence. The Cambridge Handbook of Artificial Intelligence, Cambridge University Press.

Self-learning Material

Udacity course on Secure and Private AI: https://www.udacity.com/course/secure-and-private-ai--ud185

Title	**Data Engineering**	Course No.	CSLXXX
Department	Computer Science and Engineering, Maths	Structure (L-T-P [C])	3-0-3 [3]
Offered for	B.Tech (AI&DS)	Type	Compulsory
Prerequisite	Principles of Computer System - II/ Operating System	Antirequisite	Database Systems

Objectives

The Instructor will:

1. Introduce fundamental concepts in representing data, accessing it and analysing it
2. Explore applications in data science and big data projects

Learning Outcomes

The students will have the ability to:

1. Develop suitable data science ecosystem for the given application
2. Understand various data storage and retrieval techniques
3. Understand SQL and NoSQL databases and their usage
4. Analyse data using Python and Python-based tools

Contents

Introduction: Data source, Big Data, Structured and unstructured data (2 Lectures)
Data Models and Storage: Relational databases, NoSQL database, normalized and denormalized data models, Data cleaning, Distributed Data Storage and Management, Hashing, Indexing (14 Lectures)
Query processing: Querying big data using SQL and NoSQL, Elastic Search, Query optimization, speeding up, maintaining ACID property, Design Patterns, Data reliability, quality and provenance, Distributed query processing, Query optimization and Processing (16 Lectures)
Data Warehousing: OLAP, OLTP (4 Lectures)
Streaming Data analytics: In-memory Analytics, data pipelines and dashboards, Predictive Analytics (6 Lectures)

Laboratory

Lab exercises should be in accordance with the theory Lectures. The lab sessions may cover the following topics:

1. Data Collection Techniques
2. Indexing implementation for the structured data and unstructured data
3. SQL queries (schema, DDL, DML, DQL)
4. Data format interchange using XML, JSON
5. NoSQL system (HBase, Hive, MongoDB)
6. Data wrangling, data operations (e.g. NumPy)
7. Hadoop, Spark and MapReduce

Textbooks

1. M. KLEPPMANN (2017), Designing Data-Intensive Applications The Big Ideas Behind Reliable, Scalable, and Maintainable Systems, O'Reilly.
2. L. WEISE (2015), Advanced Data Management: For SQL, NoSQL, Cloud and Distributed Databases, Walter de Gruyter GmbH.
3. A. SILBERSCHATZ, H.F. KORTH, S. SUDARSHAN (2011), Database System Concepts, McGraw Hill Publications, 6th Edition.

Reference books

1. H.G. MOLINA, J. ULLMAN, J. WIDOM (2014), Database Systems: The Complete Book, Pearson, 2nd Edition.
2. P. RAJ, A. RAMAN, D. NAGARAJ, S. DUGGIRALA (2015), High-Performance Big-Data Analytics: Computing Systems and Approaches, Springer, 1st Edition.

Self-Learning Material

1. NPTEL course on 'Indexing and Searching Techniques in Databases' by Dr Arnab Bhattacharya, IIT Kanpur: https://nptel.ac.in/courses/106/104/106104021/
2. NPTEL course on 'NOC: Fundamentals of Database Systems' by Dr Arnab Bhattacharya, IIT Kanpur: https://nptel.ac.in/courses/106/104/106104135/

Course Title	**Data Visualization**	Course No.	**CSL4xx**
Department	Maths, CSE	Structure (L-T-P [C])	3-0-3 [4.5]
Offered for	B.Tech (AI&DS)	Type	Compulsory
Prerequisite	Data Engineering / DBMS		

Objectives

The instructor will

1. Explain techniques and algorithms for creating effective visualizations based on principles from graphic design.
2. Introduce several industry-standard software tools to create a compelling and interactive visualization of various types of data.

Learning Outcomes

1. An understanding of the key techniques and theory used in visualization, including data models, graphical perception, and techniques for visual encoding and interaction.
2. Exposure to a number of common data domains and corresponding analysis tasks, including multivariate data, networks, text, and cartography.
3. Practical experience building and evaluating visualization systems.

Contents

Introduction: Data for Graphics, Design principles, Value for visualization, Categorical, time series, and statistical data graphics, Introduction to Visualization Tools (3 Lectures)

Graphics Pipeline: Introduction, Primitives: vertices, edges, triangles, Model transforms: translations, rotations, scaling, View transform, Perspective transform, window transform (3 Lectures).

Aesthetics and Perception: Graphical Perception Theory, Experimentation, and the Application, Graphical Integrity, Layering and Separation, Color and Information, Using Space Effectively (5 Lectures)

Visualization Design: Visual Display of Quantitative Information, Data-Ink Maximization, Graphical Design, Exploratory Data Analysis, Heat Map (8 Lectures)

Multidimensional Data: Query, Analysis and Visualization of Multi-dimensional Relational Databases, Interactive Exploration, tSNE (5 Lectures)

Interaction: Interactive Dynamics for Visual Analysis, Visual Queries, Finding Patterns in Time Series Data, Trend visualization, Animation, Dashboard, Visual Storytelling (8 Lectures)

Collaboration: Graph Visualization and Navigation, Online Social Networks, Social Data Analysis, Collaborative Visual Analytics, Text, Map, Geospatial data (10 Lectures)

Laboratory

Visualization Design, Exploratory data analysis, Interactive Visualization Tools like Tableau, Gephi, D3, etc. Mini Project.

Text Books

1. E. TUFTE (2001), The Visual Display of Quantitative Information, Graphics Press, 2nd Edition.
2. J. KOPONEN, J. HILDÉN (2019), Data Visualization Handbook, CRC Press.

Reference Books

1. M. LIMA (2014), The Book of Trees: Visualizing Branches of Knowledge, Princeton Architectural Press.
2. R. TAMASSIA (2013), Handbook of Graph Drawing and Visualization, CRC Press.
3. S. MURRAY (2017), Interactive Data Visualization for the Web, O'Reilly Press, 2nd Edition.

Course Title	**Maths for Big Data**	Course No.	MAL3XXX
Department	Mathematics	Structure (L-T-P [C])	2-1-0 [3]
Offered for	B.Tech (AI & DS)	Type	Compulsory
Prerequisite	Mathematics - II, Probability, Statistics and Stochastic Processes	Antirequisite	CSL7093

Objectives

To introduce basic concepts and core techniques which enable the students to handle large o equip students with sufficient knowledge of core techniques which can be used by the students in their respective fields of interest.

Learning Outcomes

1. Understanding of novel techniques to handle a large amount of data.
2. Develop concepts and tools to ingest, process and analyse massive data in real time.

Contents

Statistical Methods: Multivariate Analysis, Sampling theory: simple random sampling, stratified sampling, cluster sampling, ratio and regression estimators, two stage sampling, Compressive sensing. (14 Lectures)
Numerical linear algebra: Spectral decomposition, Schur Decomposition, QR Factorization, Singular value decomposition (SVD), PCA for large matrices, Algorithms for big matrices, Least square approximations, Low-Rank Approximation, Manifolds. (14 Lectures)

Text Books

1. D. MINER, A. SHOOK (2016), Mapreduce Design Patterns: Building Effective Algorithms and Analytics for Hadoop and Other Systems, O'Reilly Media.
2. V. MAYER-SCHÖNBERGER, K. CUKIER (2013), Big Data: A Revolution that Will Transform How We Live, Work, and Think, Houghton Mifflin Harcourt.
3. N. MARZ, J. WARREN (2015), Big Data: Principles and Best Practices of Scalable Real-time Data Systems, Manning.

Reference Books

1. M. MITTAL, V.E. BALAS, D.J. HEMANTH, R. KUMAR (2018), Data Intensive Computing Applications for Big Data, IOS Press.
2. B. FURHT, A. ESCALANTE, (Eds.), Handbook of Data Intensive Computing, Springer, 2011, 1st Edition.
3. G. STRANG (2005), Linear Algebra and its Applications, Cengage Learning, 4th Edition.

Course Title	**Optimization in ML**	Course No.	**CSL4xx**
Department	Mathematics	Structure (L-T-P [C])	3-0-3 [4.5]
Offered for	B.Tech (AI&DS)	Type	Compulsory
Prerequisite	PRML or Introduction to ML	Antirequisite	Optimization

Objectives

1. To understand the theory of optimization methods and algorithms developed for solving various types of optimization problems
2. To apply the mathematical results and numerical techniques of optimization theory to Machine Learning problems

Learning Outcomes

The students are expected to have the ability to:

1. Compose existing theoretical analysis with new aspects and algorithm variants.
2. Formulate the most important optimization algorithms for machine learning applications

Contents

Introduction to optimization: Machine Learning and Optimization, linear and non-linear optimization, discrete optimization, Network flows, convex sets, functions. (14 Lectures)

Regularizations and SGD: L1 and L2 regularization, First-order methods: gradient descent, acceleration and subgradient method, Stochastic gradient methods, SGD heuristics and tricks, escaping saddle points. (14 Lectures)

Other topics relevant to optimization for ML: Interior point and cutting-plane methods for ML, Min-Max Problems (convex-concave and nonconvex),Non-Euclidean and Submodular optimization. (14 Lectures)

Reference Books

1. S. BOYD, L. VANDENBERGHE (2003), Convex Optimization, Cambridge University Press.
2. S. SRA, S. NOWOZIN, S. WRIGHT, (Eds.), Optimization for Machine Learning, MIT Press, 2011.
3. E. HAZAN (2019), Lecture Notes: Optimization for Machine Learning [https://arxiv.org/abs/1909.03550].
4. D. BERTSEKAS (2016), Nonlinear Programming, Athena Scientific, 3rd Edition.

Self Learning Material

1. http://suvrit.de/teach/6881/

Course Title	**Ethics, Policy, Law and Regulations in AI**	Course No.	**CSL7xx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	Pattern Recognition and Machine Learning, AI		

Objectives

1. To understand implications and consequences of ethics, law, Regulations (data - privacy, ownership, data marketplace, etc) Policy in AI

Learning Outcomes

The students are expected to have the ability to develop an understanding of:

1. Ramifications of AI technologies on society
2. Ethical aspects of AI, ML and DS systems
3. Data privacy, ownership and IPR issues
4. Law, Regulations, Liabilities and Policies of AI, ML and DS systems

Contents

Ethics in AI
Law and Regulations
IPR
Policies
Case Studies

Text Book

1. Online resources
2. Will be added in future

Reference Books

15. Detailed Course Content of Programme Elective Courses

Course Title	**Advanced Machine Learning**	Course No.	**CSL7xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	PRML/Introduction to ML, AI		

Objectives

This is an advanced course on Machine Learning. It is intended for senior undergraduate and graduate students who already have a background in PR or ML. The course is designed as a set of special topics that will be covered through research papers and books. The course will focus on algorithms and models along with providing a good perspective of different real world applications.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the algorithms and functioning of advanced techniques and concepts such as deep learning, distance metric learning, and domain adaptation
2. Understand the advantages and limitations of the algorithms and their potential applications
3. Run several public domain machine learning toolboxes on real world databases such as MNIST and CIFAR10
4. Design experiments for evaluation and analyze the results to test the effectiveness of individual components of an algorithm

Contents

Kernel Machines: Kernel properties, Kernels for structure data and text, Multiple kernel learning, Generative models (3 Lectures)
Variants of Support Vector Machine: Hard and soft margin SVM, Online SVM, Distributed SVM (3 Lectures)
PAC Theory (6 Lectures)
Boosting: Adaboost, Gradient boosting (2 Lectures)
Structured Prediction and Graphical Models: Learning directed and undirected models, Sampling, MAP inference and prediction, variational inference, causality (14 Lectures)
Dictionary Learning: Fundamentals, Regularization, Supervised and unsupervised dictionary, learning, Transform learning (6 Lectures)
Deep Reinforcement Learning (8 Lectures)

Text Books

1. N. CRISTIANINI, J. S-TAYLOR (2000), An Introduction to Support Vector Machines and Other Kernel-based Learning Methods, Cambridge University Press, 1st Edition.
2. B. SCHOLKOPF, A. J. SMOLA (2001), Learning with Kernels: Support Vector Machines, Regularization, Optimization, and Beyond, The MIT Press, 2001, 1st Edition.
3. R. S. SUTTON, A. G. BARTO (2018), Reinforcement Learning: An Introduction, The MIT Press, 2nd Edition.
4. D. KOLLER, N. FRIEDMAN (2009), Probabilistic Graphical Models: Principles and Techniques, MIT Press.

Course Title	**Advanced Artificial Intelligence**	Course No.	**CSL7xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	Pattern Recognition and Machine Learning		

Objectives
To 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
Making decisions: Utility theory, utility functions, decision networks, sequential decision problems, Partially Observable MDPs, Game Theory (14 Lectures)
Reinforcement Learning: Passive RL, Active RL, Generalization in RL, Policy Search, (7 Lectures)
Probabilistic Reasoning over time: Hidden Markov Models, Kalman Filters (7 Lectures)
Knowledge Representation: Ontological engineering, Situation Calculus, semantic networks, description logic (6 Lectures)
Planning: Planning with state space search, Partial-Order Planning, Planning Graphs, Planning with Propositional Logic, hierarchical task network planning, non-deterministic domains, conditional planning, continuous planning, multi-agent planning (8 Lectures)

Text Book
1. S. RUSSEL, P. NORVIG (2009), Artificial Intelligence: A Modern Approach, Pearson, 3rd Edition.

Reference Book
1. E. RICH, K. KNIGHT, S. B. NAIR (2017), Artificial Intelligence, McGraw Hill Education, 3rd Edition.
2. R.S. SUTTON, A.G. BARTO (2015), Reinforcement Learning: An Introduction, The MIT Press, 2nd Edition.

Course Title	**Natural Language Understanding**	Course No.	**CSL7xx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	Pattern Recognition and Machine Learning/Machine Learning 1		

Objectives

1. To provide insights into fundamental concepts and algorithms related to Natural Language Understanding.
2. Impart working expertise by introducing practical problems.

Learning Outcomes

The students are expected to have the ability to:

1. Formulate natural language understanding tasks
2. Design and implement basic applications of NLU

Contents

Traditional NLU: Introduction to NLU, Motivation, Morphology, Parts-of-Speech, Language Models, Word Sense Disambiguation, Anaphora Resolution, Basics of Supervised and Semi-supervised Learning for NLU, Hidden Markov Models for language modeling, EM Algorithm, Structured Prediction, Dependency Parsing, Topic Models, Semantic Parsing, Sentiment analysis. (14 Lectures)

Deep Learning for NLU: Intro to Neural NLU, Word Vector representations, Neural Networks and backpropagation -- for named entity recognition, Practical tips: gradient checks, overfitting, regularization, activation functions, Recurrent neural networks -- for language modeling and other tasks, GRUs and LSTMs -- for machine translation, Recursive neural networks -- for parsing, Convolutional neural networks -- for sentence classification, Question answering and dialogue system, Graph Neural Network for NLU, Natural Language Generation, Analysis and Interpretability of Neural NLU. (22 Lectures)

Knowledge Graphs: Knowledge graph embedding techniques, Inference on knowledge graphs. (6 Lectures)

Text Book

1. C. MANNING, H. SCHÜTZE (1999), Foundations of Statistical Natural Language Processing, MIT Press.
2. D. JURAFSKY, J.H. MARTIN, Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition (3rd Edition Draft), 2019.

Reference Books

1. E. BENDER (2013), Linguistic Fundamentals for NLP, Morgan Claypool Publishers..
2. J. ALLEN (1995), Natural Language Understanding, Pearson Education, 1995.
3. Research Literature.

Self Learning Material

1. http://web.stanford.edu/class/cs224n/index.html#schedule (Deep learning for NLP)

Course Title	**Neuromorphic Design and Computing**	Course No.	**CSL7xx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	Artificial Intelligence, PRML/Introduction to ML		

Objectives

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

Learning Outcomes

The students are expected to have the ability to:

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

Contents

(*Fractal 1*)

Foundational Concepts: Introduction to neuromorphic engineering, neuroanatomy of human brain, signaling and operation of biological neurons, neuron models - LIF, IF, HH, synapses and plasticity rules, spike-time-dependent plasticity (STDP), biological neural circuits, non-von Neumann computing approach, learning rules, retina, cochlea. (14 Lectures)

(*Fractal 2*)

Neuromorphic Computing: Spiking Neural Networks (SNN), Advanced Nanodevices for Neuron Implementation, Synaptic emulation - non-volatile memory (NVM), Flash, RRAM, memristors, CNT, Case study on Intel's Loihi neuromorphic chip. (14 Lectures)

(*Fractal 3*)

Hardware Implementation: Electronic synapses, Digital/Analog neuromorphic VLSI, Hardware Implementation of Neuron circuits, Hardware Implementation of Synaptic and Learning circuits, Synaptic programming methodology optimization. (14 Lectures)

Text Books

1. S. C. LIU (2002), Analog VLSI: Circuits and Principles, MIT Press.
2. R. KOZMA (2012), Advances in Neuromorphic Memristor Science, Springer.
3. E. KANDEL (2012), Principles of Neural Science, McGraw Hill.

Course Title	**Information Retrieval**	Course No.	**CSLXXX**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech	Type	Elective
Prerequisite	PRML/Introduction to ML		

Objectives

Information retrieval covers the tasks of indexing, searching, and recalling data, particularly text or other unstructured forms. It has an important role to play in a large number of applications viz., digital libraries, office automation, internet and e-commerce. The aim of the course is to study theoretical aspects as well as implementation issues of classical and modern retrieval problems.

Learning Outcomes

The students are expected to learn and gather expertise in:

1. The underlying technologies of modern information retrieval system
2. Developing new search engines with high search accuracy

Contents

Introduction to Information Retrieval: The nature of unstructured and semi-structured text, Inverted index and Boolean queries. (2 Lectures)

Search Engine Architecture: Basic building blocks of a modern search engine system: web crawler, basic text analysis techniques, Inverted index, Query processing, Search result interface, Semantic search using Ontology (7 Lectures)

Retrieval Models: Boolean vector space, TFIDF, Okapi, Probabilistic language modeling, Latent semantic indexing, Vector space scoring, The cosine measure, Efficiency considerations, Document length normalization, Relevance feedback and query expansion, Rocchio, Ontological models (8 Lectures)

Performance Evaluation: Evaluating search engines, User happiness, Precision, Recall, F-measure, Creating Test collections: kappa measure, Interjudge agreement. (5 Lectures)

Text Categorization and Filtering: Introduction to text classification, Naive Bayes model, Spam filtering, Vector space classification using hyperplanes, Centroids, K-Nearest Neighbors, Support vector machine classifiers, Kernel functions, Boosting. (6 Lectures)

Text Clustering: Clustering versus classification, Partitioning methods, K-means clustering, Gaussian mixture model, Hierarchical agglomerative clustering, Clustering terms using documents. (6 Lectures)

Advanced Topics: Summarization, Topic detection and tracking, Personalization, Question answering, Cross language information retrieval (3 Lectures)

Web Information Retrieval: Hypertext, web crawling, Search engines, Ranking, Link analysis, PageRank, HITS. (3 Lectures)

Retrieving Structured Documents: XML retrieval, Semantic web (2 Lectures)

Textbooks

1. C.D. MANNING, P. RAGHAVAN, H. SCHUETZE (2008), Introduction to Information Retrieval, Cambridge University Press.
2. B. CROFT, D. METZLER, T. STROHMAN (2010), Search Engines: Information Retrieval in Practice, Pearson Education.
3. B. RICARDO, B. RIBEIRO-NETO (2011), Modern Information Retrieval, Addison-Wesley, 2nd Edition.

Course Title	**Resource Constrained AI**	Course No.	**CSL7xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	Artificial Intelligence, Introduction to Machine Learning/PRML		

Objectives

1. To provide motivation and understanding of the need and importance of deploying Machine Learning in resource constrained devices
2. To provide details about various optimized and resource efficient algorithms in Machine Learning

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

Implementation of Bonsai, CNN training using SeeDot language.

Text Book

1. C. ALIPPI (2014), Intelligence for Embedded Systems: A Methodological Approach, Springer, 1st Edition.

Preparatory Course Material

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

Title	**Social Networks**	Course No.	CSL4XX0
Department	Computer Science and Engineering	Structure (L-T-P [C])	3–0–0 [3]
Offered for	B. Tech	Type	Elective
Prerequisite	None		

Objectives
Provide introduction to social network analysis, its mathematical foundation and application.

Learning Outcomes
The students are expected
1. To gain the ability to understand the applications related to social networks
2. Write program with social network datasets and Formulate real-world problems with any relational data set resembling social networks

Contents
Introduction: Graphs, Social Networks, Network Types, Network Data Sets, Gephi for Network Analysis (5 Lectures)
Network Properties: Network Measures, Strong and Weak Ties, Homophily, Structural Balance, Components (4 Lectures)
Network Models: Random Networks, Scale Free Networks, The Barabási-Albert Model, Erdos-Renyi Model (5 Lectures)
Structural Analysis of Networks using Python: Python for Network Analysis, Empirical Studies, Structural Properties, Generate Synthetic Networks, Working with signed networks (5 Lectures)
Social Network Applications: Information Cascades, Small-World Phenomenon, Epidemics, Community Detection, Link Prediction, Page Rank (14 Lectures)
Evolving Network and Temporal Networks: Network evolution, working with Temporal Network Data (5 Lectures)
Multiplex and Multi-layer network (1 Lecture)
Network Analysis in Other Fields:Network Analysis in Biology, Sports, Transports (3 Lectures)

Textbooks
1. D. EASLEY, J. KLEINBERG (2010), Networks, Crowds, and Markets: Reasoning About a Highly Connected World, Cambridge University Press. (http://www.cs.cornell.edu/home/kleinber/networks-book/)
2. A. BARABASI (2016), Network Science, Cambridge University Press. (http://barabasi.com/networksciencebook/)
3. M. NEWMAN (2018), Networks, Oxford University Press, 2nd Edition. (https://global.oup.com/academic/product/networks-9780198805090?cc=us&lang=en&#/)

Reference Books
1. C. GROS (2015), Complex and Adaptive Dynamical Systems, Springer, Springer, 4th Edition.
2. E. ESTRADA (2011), The Structure of Complex Networks Theory and Applications, Oxford University Press.
3. W. de NOOY, A. MRVAR, V. BATAGELJ (2018), Exploratory Social Network Analysis with Pajek, Cambridge University Press, 3rd Edition.

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

Course Title	**Stream Analytics**	Course No.	**CSLxxx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech 3rd and 4th years; PG	Type	Elective
Prerequisite	Introduction to Machine Learning, PRML		

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

Learning Outcomes
Ability to 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. (12 Lectures)
Classification Methods in Data Streams: Ensemble based classification, Very fast decision trees, On-demand classification, Online Information Network. (6 Lectures)
Distributed Mining of Data Streams: Outlier and anomaly detection, Clustering, Frequent itemset mining, Classification, Summarization. (6 Lectures)
Change Diagnosis Algorithms in Evolving Data Streams: Velocity density method, Clustering for characterizing stream evolution. (4 Lectures)
Multidimensional Analysis of Data Streams using Stream Cubes: Architecture for online analysis of data streams, Stream data cube computation, Performance study. (6 Lectures)
Dimensionality Reduction and Forecasting on Streams: Principal Component Analysis, Auto-regressive models and recursive least squares, Tracking correlations and hidden variables. (6 Lectures)

Text Book
C.C. AGGARWAL, (Ed.), Data Stream: Models and Algorithms, Kluwer Academic Publishers, 2007.

Title	**Computer Vision**	Course No.	CSLXXX
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3–0–0 [3]
Offered for	B.Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	Linear Algebra		

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)
Fundamentals: Formation, Filtering, Transformation, Alignment, Color (5 Lectures)
Image Restoration: Spatial Processing and Wavelet-based Processing (5 Lectures)
Geometry:Homography, Warping, Epipolar Geometry, Stereo, Structure from Motion, Optical flow (9 Lectures)
Segmentation:Key point Extraction, Region Segmentation (e.g., boosting, graph-cut and level-set), RANSAC (6 Lectures)
Feature Description and Matching:Key-point Description, handcrafted feature extraction (SIFT, LBP) (3 Lectures)
Deep Learning based Segmentation and Recognition: DL-based Object detection (e.g. Mask-RCNN, YOLO), Semantic Segmentation, Convolutional Neural Network (CNN) based approaches to visual recognition (9 Lectures)
Applications: Multimodal and Multitask Applications (4 Lectures)

Textbooks

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

Reference Books

1. Research literature

Course Title	**Introduction to AR and VR**	Course No.	**CSL7xx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	Graphics		

Objectives

1. To discuss issues focusing upon the human element of VR.
2. To explain the Hardware and software related issues related to VR.

Learning Outcomes

The students are expected to have the ability to:

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

Contents

(*Fractal 1*)

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

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

(*Fractal 2*)

Light and Optics: Interpretation of light, reflection, optical systems (4 Lectures)

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

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

(*Fractal 3*)

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

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

Text Books

1. M. SHIRLEY (2016), Fundamentals of Computer Graphics, CRC Press, 4th Edition.
2. LA VALLE (2016), Virtual Reality, Cambridge University Press.

Reference Books

1. J. JERALD (2015), The VR Book: Human-Centered Design for Virtual Reality, Morgan & Claypool.
2. G. MATHER (2016), Foundations of Sensation and Perception, Psychology Press, 3rd Edition.
3. S. MARSCHNER, P. SHIRLEY (2015), Fundamentals of Computer Graphics, CRC Press, 4th Edition.
4. D. A. BOWMAN, E. KRUIJFF, J. J. LAVIOLA, I. POUPYREV (2017), 3D User Interfaces: Theory and Practice, Addison Wesley Professional, 2nd Edition.

Self Learning Material

1. Virtual Reality, NPTEL, IIT Madras, https://nptel.ac.in/courses/106106138/.

Course Title	**Advanced Biometrics**	Course No.	**CSL7xx**
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	Pattern Recognition and Machine Learning/Deep Learning/Machine Learning 1		

Objectives

1. To familiarize the students with types of biometrics including physical and behavioural modalities, understanding biometric strengths, weaknesses and limitations, and biometric standards.
2. Describe a few techniques for designing biometric systems

Learning Outcomes

The students are expected to have the ability to:

1. Develop new biometric systems for real-world applications, and become familiar with various stages of biometric system development.
2. Develop an understanding of future direction and emerging technologies in biometrics.

Contents

Introduction:Biometric system design, Genesis of biometrics: human body properties, and biometric data acquisition, System architecture, Performance Evaluation: Verification, Identification (4 Lectures)

Traditional and Emerging Biometric Modalities: Image/signal processing, Fingerprint matching, face recognition, iris modelling, signature authentication, biometric pattern recognition, multi-modal biometrics (23 Lectures)

Biometric Security: Encryption, cancelable biometrics and fuzzy vault (6 Lectures)

Biometric Devices: Security-Target design, Reliability design, Industry standards (6 Lectures)

Biomedical applications of Biometrics (3 Lectures)

Text Book

1. A.K. JAIN, A. ROSS, K. NANDAKUMAR (2011), Introduction to Biometrics, Springer.

Reference Books

1. A.K. JAIN, A. ROSS, K. NANDAKUMAR, (Eds.), Handbook of Biometrics, Springer, 2008.
2. S.Z. LI, A.K. JAIN, (Eds.), Handbook of Face Recognition, Springer, 2011, 2nd Edition.
3. D. MALTONI, D. MAIO, A. JAIN, S. PRABHAKAR, (Eds.), Handbook of Fingerprint Recognition, Springer, 2009, 2nd Edition.
4. M.J. BURGE, K.W. BOWYER, (Eds.), Handbook of Iris Recognition, Springer, 2016, 2nd Edition.
5. On-line resources will be provided.

Course Title	**Computer Graphics**	Course No.	**CSL4xx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisite	Data Structures and Algorithms		

Objectives

To 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. Create and explain graphics primitives and interactive graphics applications in C++
2. Synthesize and render 2D and 3D worlds for visualization and animation

Contents

Introduction to Computer Graphics & Graphics Systems: Overview of computer graphics, representing pictures, preparing, presenting & interacting with pictures for presentations, OpenGL Primitives (3 Lectures)

Scan Conversions: Points & lines, Line drawing algorithms, Circle generation algorithm; Ellipse generating algorithm; scan line polygon, fill algorithm, Clipping algorithms: line and polygon, anti-aliasing (6 Lectures)

Transformations and Viewing: Basic transformations: translation, rotation, scaling; Matrix representations and homogeneous coordinates, transformations between coordinate systems; reflection shear; Viewing pipeline, Window to viewport coordinate transformation, clipping operations, viewport clipping, 3D viewing (9 Lectures)

Curves and Surfaces: Conics, parametric and non-parametric forms; Curves and Splines; Surfaces and NURBS, 3-D modelling (8 Lectures)

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 (6 Lectures)

Color and Shading Models:Phong's shading model, Gouraud shading, Shadows and background, Color models, Photo-realistic rendering, Radiosity (5 Lectures)

Animation: Functions, pipeline, sample programs for drawing 2-D, 3-D objects; event handling and view manipulation (5 Lectures)

Text Book

1. D. HEARN, P. BAKER (2002), Computer Graphics, Pearson Education India, 2002, 2nd Edition.

Reference Books

1. J. F. HUGHES, A. VAN DAM, M. McGUIRE, D.F. SKLAR, J. D. FOLEY, S. K. FEINER, K. AKELEY (2014), Computer Graphics: Principles and Practices, Addison Wesley, 3rd Edition.
2. D. F. ROGERS, J. A. ADAMS (1989), Mathematical Elements for Computer Graphics, McGraw Hill, 2nd Edition.
3. Z. XIANG, R. PLASTOCK (2015), Schaum's Outline of Computer Graphics, McGraw Hill Education, 2nd Edition.
4. J. KESSENICH, G. SELLERS, D. SHREINER (2017), OpenGL Programming Guide, Pearson Education, 9th Edition.

Self Learning Material

NPTEL Computer Science and Engineering - Computer Graphics:
https://nptel.ac.in/courses/106106090/.

Course Title	**Cyber Security**	Course No.	**CS 7XX**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3–0–2 [4]
Offered for	B.Tech	Type	Elective
Prerequisite	Computer Networks		

Objectives

The Instructor will provide the skills needed to protect networks, secure electronic assets, prevent attacks, ensure the privacy of your customers, and build secure infrastructure.

Learning Outcomes

The students are expected to have the ability to:

1. To protect data and respond to threats that occur over the Internet
2. Design and implement risk analysis, security policies, and damage assessment
3. To Provide contingency operations that include administrative planning process for incident response, disaster recovery, and business continuity planning within information security

Contents

Introduction to Cyber Security*:* Internet Governance – Challenges and Constraints, Cyber Threats. (2 Lectures)

Cyber Security Vulnerabilities and Cyber Security Safeguards: Cyber Security Vulnerabilities, Cyber Security Safeguards, Access control, Audit, Authentication, Biometrics, Cryptography, Deception, Denial of Service Filters, Ethical Hacking, Firewalls, Response, Scanning, Security policy, Threat Management. (8 Lectures)

Securing Web Application, Services and Servers: Basic security for HTTP Applications and Services, Basic Security for SOAP Services, Identity Management and Web Services, Authorization Patterns, Security Considerations, Challenges. (8 Lectures)

Intrusion Detection and Prevention: Intrusion detection and Prevention Techniques, Anti-Malware software, Network based Intrusion detection Systems, Network based Intrusion Prevention Systems, Host based Intrusion prevention Systems, Security Information Management, Network Session Analysis, System Integrity Validation. (7 Lectures)

Overview of Firewalls: Types of Firewalls, User Management, VPN Security Security Protocols: - PGP and S/MIME, Security at Transport Layer- SSL and TLS, Security at Network Layer-IPSec. (5 Lectures)

Cyberspace and the Law: Cyber Security Regulations, Roles of International Law, the state and Private Sector in Cyberspace, Cyber Security Standards. The INDIAN Cyberspace, National Cyber Security Policy. (6 Lectures)

Cyber Forensics: Handling Preliminary Investigations, Controlling an Investigation, Conducting disk-based analysis, Investigating Information-hiding, Scrutinizing E-mail, Validating E-mail header information, Tracing Internet access, Tracing memory in real-time. (6 Lectures)

Laboratory

1. Design and implementation of a simple client/server model and running application using sockets and TCP/IP.
2. To make students aware of the insecurity of default passwords, printed passwords and passwords transmitted in plain text.
3. To teach students how to use SSH for secure file transfer or for accessing local computers using port forwarding technique.
4. Comparison between Telnet and SSH for Secure Connection
5. *AVISPA Tool* for the Automated Validation of Internet Security Protocols and Applications

Text Book

C.J. HOOFNAGLE (2016), Federal Trade Commission Privacy Law and Policy, Cambridge University Press, 2016.

Self Learning Material

1. P.W. SINGER, A. FRIEDMAN (2014), Cybersecurity: What Everyone Needs to Know, OUP, 1st Edition.
2. L. THAMES, D. SCHAEFER (2017), Cybersecurity for Industry 4.0, Springer, 1st Edition.
3. N. HASSAN, R. HIJAZI (2017), Digital Privacy and Security Using Windows, Apress, 1st Edition.

Course Title	**Distributed Database Systems**	Course No.	**CSLXXX**
Department	Computer Science & Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Prerequisites	Operating Systems, Database Systems, Computer Networks, Data Communication		

Objective

To understand and appreciate concepts of distributed database design, and its associated issues of consistency, concurrency, optimization, integrity, reliability, privacy, and security.

Learning Outcome

Ability to understand the need for distributed database systems and its related complexities pertaining to fragmentation, replication, availability, concurrency, consistency and recovery.

Contents

Introduction: Distributed data processing concepts, What is a DDBS - advantages, disadvantages and problem areas. (2 Lectures)

Distributed Database Management System Architectures: Transparencies, architecture, global directory concepts and issues. (3 Lectures)

Distributed Database Design: Design strategies, design issues, fragmentation, data allocation. (4 Lectures)

Semantics Data Control: View management, data security, semantic integrity control. (5 Lectures)

Query Processing: Objectives, characterization of processors, layers of processing, query decomposition, data localization. (5 Lectures)

Query Optimization: Factors, centralized query optimization, fragmented query ordering, query optimization algorithms. (5 Lectures)

Transaction Management: Goals, properties, models. (4 Lectures)

Concurrency Control: Concurrency control in centralized systems, concurrency control in DDBSs - algorithms, deadlock management. (5 Lectures)

Reliability: Issues and types of failures, reliability techniques, commit protocols, recovery protocols. (5 Lectures)

Other Avenues: Parallel Database Systems, Multi-databases. (4 Lectures)

Reference Books

1. S. CERI, G. PELAGATTI (2008), Distributed Databases: Principles and Systems, McGraw-Hill, 1st Edition (2017 Reprint).
2. M.T. ÖZSU, P. VALDURIEZ (2011), Principles of Distributed Database Systems, Springer, 3rd Edition.

Title	**Introduction to Blockchain**	Course No.	CSL 7XX
Department	Computer Science and Engineering	Structure (L-T-P [C])	3–0–0 [3]
Offered for	B.Tech, MTech, PhD.	Type	Elective
Prerequisite	Network 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 major components of Blockchain and Identify a use case for a Blockchain application
3. Create their 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. (6 Lectures)
Consensus:Byzantine Fault, Proof of Work, Proof of Stake. (6 Lectures)
Cryptocurrency:Bitcoin creation and economy, Limited Supply and Deflation, Hacks, Ethereum concept and Ethereum classic. (10 Lectures)
Hyperledger Fabric:Hyperledger Architecture, Membership, Blockchain, Transaction, Chaincode, Hyperledger Fabric, Features of Hyperledger, Fabric Demo. (8 Lectures)
Blockchain Applications:Building on the Blockchain, Ethereum Interaction - Smart Contract and Token (Fungible, non-fungible), Languages,, Blockchain-as-a-service. (6 Lectures)

Textbook

A. BAHGA, V. MADISETTI (2017), Blockchain Applications: A Hands-On Approach, VPT.

Self Learning Material

1. M. SWAN (2015), Blockchain: Blueprint for a New Economy, O'Reilly Media.
2. R. WATTENHOFER (2016), The Science of the Blockchain, CreateSpace Independent Publishing Platform.
3. I. BASHIR (2017), Mastering blockchain, Packt Publishing Ltd.
4. K.E. LEVY, Book-smart, Not Street-smart: Blockchain-based Smart Contracts and the Social Workings of Law, Engaging Science, Technology, and Society, vol. 3, pp. 1-15, 2017.

Preparatory Course Material

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

Title	**Soft Computing Techniques**	Course No.	CSL7XXX
Department	Computer Science and Engineering, AI&DS	Structure (L-T-P [C])	3–0–0 [3]
Offered for	B.Tech, M.Tech. 1st Year, Ph.D. 1st Year	Type	Elective
Prerequisite	None		

Objectives

Introduction of different soft computing techniques, their integration and applications.

Learning Outcomes

The students are expected to have the ability to:

1. Identify and describe soft computing techniques
2. Understand soft computing approaches in problem solving
3. Formulate real-world methodologies to data mining using soft computing tools

Contents

Introduction to Soft Computing: Difference between soft and hard computing, Fuzzy Computing, Neural Computing, Genetic Algorithms, Associative Memory, Adaptive Resonance Theory, Applications (4 Lectures)

Fuzzy Sets and Fuzzy Systems: Membership functions, Fuzzy operations, Fuzzy relations, Fuzzy proposition, Fuzzy implication, Fuzzification, Fuzzy inference, Fuzzy rule based systems, Defuzzification (7 Lectures)

Genetic Algorithm: Representation, Fitness function, Population, Operators – Selection, Mutation, Crossover, Others, Multi-objective optimization problems (8 Lectures)

Metaheuristic and Swarm Intelligence: Ant colony optimization, Bee colony optimization, Particle swarm optimization, Cuckoo search algorithm and others (6 Lectures)

Rough Sets, Knowledge representations, Rough decision making and data mining techniques, Granular Computing (5 Lectures)

Hybrid Systems: Neuro-fuzzy systems, Rough-neural computing, Fuzzy logic and Genetic Algorithm, GA based back propagation networks, Fuzzy associative memories, Hybrid systems using fuzzy and rough sets (9 Lectures)

Big Data Challenges and Soft Computing Opportunity: Uncertainties in Big Data Inputs, Uncertainties in Big Data Decisions (3 Lectures)

Reference Books

1.S.N. SIVANANDAM, S.N. DEEPA (2018), Principles of Soft Computing, Wiley India, 2018, 3rd Edition.
2.F.O. KARRAY, C. De SILVA (2004), Soft Computing and Intelligent Systems Design: Theory, Tools and Applications, Pearson Education.
3.Z. PAWLAK (1991), Rough Sets: Theoretical Aspects of Reasoning about Data, Springer Netherlands.

Self Learning Material

1.Computer Science and Engineering - NOC: Introduction to Soft Computing: https://nptel.ac.in/courses/106105173/
2.Soft Computing — IT60108: http://cse.iitkgp.ac.in/~dsamanta/courses/sca/index.html.
3.Soft Computing: http://www.myreaders.info/html/soft_computing.html.

Course Title	**Randomized Algorithms**	Course No.	**CSL7xxx**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech CSE, AI&DS	Type	Elective
Prerequisite	DAA, PSSP		

Objectives

This course presents basic concepts in the design and analysis of randomized algorithms.

Learning Outcomes

1. Familiarity with several of the main thrusts of work in randomized algorithms.
2. Ability to read current research publications in the area
3. Ability to design and analyze algorithms for solving real problems.

Contents

Tools and Techniques: Basic probability theory; randomized complexity classes; game-theoretic techniques; Markov, Chebyshev, and moment inequalities; limited independence; tail inequalities and the Chernoff bound; conditional expectation; the probabilistic method; Markov chains and random walks; algebraic techniques; probability amplification and derandomization. (22 Lectures)

Applications: Sorting and searching; data structures; combinatorial optimization and graph algorithms; geometric algorithms and linear programming; approximation and counting problems; parallel and distributed algorithms; online algorithms. (20 Lectures)

Text Books

R. MOTWANI, P. RAGHAVAN (1995), Randomized Algorithms, Cambridge University Press, 1st Edition.

Reference Books

1. M. MITZENMACHER, E. UPFAL (2017), Probability and Computing: Randomized Algorithms and Probabilistic Analysis, Cambridge University Press, 2nd Edition.
2. W. FELLER (2008), An Introduction to Probability Theory and Its Applications, Volumes I and II, John Wiley, 2nd Edition.
3. P. BILLINGSLEY (2012), Probability and Measure, John Wiley.

Self Learning

https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-856j-randomized-algorithms-fall-2002/lecture-notes/.

Title	**Video Processing**	Course No.	CSLXXXX
Department	CSE, EE	Structure (L-T-P [C])	3–0–0 [3]
Offered for	B.Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	Linear Algebra		

Objectives

1. To make the students familiar with several issues and challenges involved in the task of video processing
2. To enable students to formulate problems related to video processing and explore solutions

Learning Outcomes

The students are expected to have the ability to:

1. Address the challenging issues of video processing and to come with new solutions by their own
2. Handle multi-dimensional signals other than videos

Contents

Digital Images and Video*:*Human Visual Systems, Analog Video, Digital Video, 3D Video, Video Quality (2 Lectures)

Multi Dimensional Signals and Systems*:* Multi-dimensional Signals, Multi-dimensional Systems, Multi-dimensional transforms, Multi-dimensional Sampling Theory (7 Lectures)

Motion Estimation*:* Camera Models, Motion Models, Motion Estimation, Differential Methods, Matching Methods, Non-linear Optimization Methods, 3-D Motion and Shape Estimation (10 Lectures)

Video Segmentation and Tracking*:* Basics of Segmentation, Video based Segmentation Algorithms Change Detection, Motion Segmentation, Motion Tracking, Performance Evaluation (10 Lectures)

Video Filtering:Spatio-temporal Filtering, Video Format Conversion, Multi-Frame Noise Filtering, Multi-Frame Restoration (6 Lectures)

Video Compression: Motion JPEG 2000, MPEG-4, HEVC, SHVC, H.264 (3 Lectures)

Modern Topics in Video Processing: Ego-centric Video Processing, 360-degree Video, Streaming Video (4 Lectures)

Textbooks

1. A.M. TEKALP (2015), Digital Video Processing, Prentice Hall Signal Processing Series, 2nd Edition.
2. A. BOVIK (2009), The Essential Guide to Video Processing, Academic Press, 2nd Edition.

Reference Books

1. E. MAGGIO, A. CAVALLARO (2011), Video Tracking: Theory and Practice, Wiley and Sons.
2. M. WOHL (2017), The 360° Video Handbook.
3. Research literature

Title	**Digital Image Processing**	Course No.	CSLXXX
Department	CSE, EE	Structure (L-T-P [C])	3–0–0 [3]
Offered for	B.Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	Linear Algebra		

Objectives

1. To introduce the origin and formation of digital imaging.
2. To develop the understanding of different types of imaging techniques for different purposes.
3. To equip the students with various possible applications of the image analysis.

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 and compression.

Contents

Digital Image Fundamentals*:* Image modeling, Sampling and Quantization, Imaging Geometry, Digital Geometry, Image Acquisition Systems, Different types of digital images (3 Lectures)
Image Transforms*:* Basic transforms: Spatial and Frequency Domain Transforms (8 Lectures)
Image Enhancement*:* Point processing, interpolation, enhancement in spatial domain, enhancement in frequency domain (7 Lectures)
Color Image Processings*:*Color Representation, Laws of color matching, chromaticity diagram, color enhancement, color image segmentation, color edge detection (3 Lectures)
Image compression*:* Lossy and lossless compression schemes, prediction based compression schemes, vector quantization, sub-band encoding schemes, JPEG compression standard (4 Lectures)
Morphology:Dilation, erosion, opening, closing, hit and miss transform, thinning, extension to grayscale morphology, Euler technique (5 Lectures)
Segmentation: Segmentation of grey level images, Watershed algorithm for segmenting grey level imag***e*** (6 Lectures)
Feature Detection:Fourier descriptors, shape features, object matching/features (6 Lectures)

Textbook

1. C. GONZALEZ, R.E. WOODS (2018), Digital Image Processing, Prentice Hall, 4th Edition.
2. A.K. JAIN (1989), Fundamentals of Digital Image Processing, Prentice Hall.

Reference Books

Research literature

Online Course Material

https://nptel.ac.in/courses/117104020/

Course Title	**Speech Understanding**	Course No.	**CSLXxx**
Department	EE	Structure (L-T-P-C)	3-0-0 [3]
Offered for	B.Tech CSE, AI&DS	Type	Elective
Prerequisite	PR-ML		

Objectives

1. To provide insights into fundamental concepts and algorithms related to speech processing and understanding
2. Impart working expertise by introducing practical problems.

Learning Outcomes

1. Building a speech recognition system
2. Design and implement basic speech based application

Contents

Introduction to Speech processing:Digitization and Recording of speech signal, Review of Digital Signal Processing Concepts, Human Speech production, Acoustic Phonetics and Articulatory Phonetics, Different categories speech sounds and Location of sounds in the acoustic waveform and spectrograms. (14 Lectures)
Speech recognition: Analysis and Synthesis of Pole-Zero Speech Models, Short-Time Fourier Transform, Analysis:- FT view and Filtering view, Synthesis:-Filter bank summation (FBS) Method and OLA Method, Features Extraction, Extraction of Fundamental frequency, Speech Enhancement, Clustering and Gaussian Mixture models, Speaker Recognition.(14 Lectures)
Speech based applications:HMM and Neural models for speech recognition, Speech generation, Question answering, Dialogue systems, Other Speech based Applications.(14 Lectures)

Text Books

1. T.F. QUATIERI (2002), Discrete-Time Speech Signal Processing, Prentice-Hall, New Jersey.
2. D. JURAFSKY, J.H. MARTIN, Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition (3rd Edition Draft), 2019.

Reference Books

1. Y. GOLDBERG (2016), A Primer on Neural Network Models for Natural Language Processing, Journal of Artificial Intelligence Research.
2. I. GOODFELLOW, Y. BENGIO, A. COURVILLE (2016), Deep Learning, The MIT Press, 1st Edition.
3. S.K. PATRA (2011), Digital Signal Processing: A Computer-Based Approach, McGraw-Hill, 4th Edition.

Title	**Statistical Inference and Simulation Techniques**	Number	MAL4XXX
Department	Mathematics	L-T-P-D [C]	3–0–0–0 [3]
Offered for	B.Tech	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Provide background in the area of Statistics.
2. Provide sufficient knowledge of the subject which can be used by students for further applications in their respective domains of interest.
3. Provide understanding of simulation techniques with applications

Learning Outcomes

The students are expected to have the ability to:

1. Provide basic understanding of the Point and Interval Estimation, Testing of Hypotheses, Non-parametric Estimation
2. Impart knowledge in Random Sampling, Unbiased Estimation, Bias-Variance Tradeoff, and Goodness of Fit.
3. Apply simulation techniques in their domain of interest.

Contents

Review of Probability and Statistics [3 Lectures]: Sampling Distributions (Chi-square, t, F, Normal) and random sampling

Parametric Estimation [10 Lectures]: Unbiasedness and Consistency, Sufficiency and Completeness, Minimum Variance Unbiased Estimators, Method of Moments and Maximum Likelihood,

Testing of Hypothesis [8 Lectures]: Interval Estimation, Neyman Pearson Theory for Testing of Hypotheses, Likelihood Ratio Test

Non-parametric Estimation [5 Lectures]: Bayesian Approach of Estimation, Non-parameteric Estimation, Sequential Hypotheses Testing

Random Variate Generation [5 Lectures]: Random numbers, properties of random numbers, random number generation, and random variate generation.

Simulation Techniques [8 Lectures]: Simulating a Two Dimensional Poisson Process, Multivariate Distribution, Generating Variables from Copula Models

Markov Chain, Monte Carlo Methods [3 Lectures]

Textbooks

1. Rohatgi, V. K. (2003), Statistical Inference, Dover Publications Inc.
2. Hogg, R. V., McKean, J. W., Craig, A. T. (2009), Introduction to Mathematical Statistics, Pearson
3. Ross, S. M. (2013), Simulation, Academic Press, Elsevier.

Reference Book

1. Casella, G. and Berger, R. L. (1990), Statistical Inference, Brooks/ Cole Publishing Company
2. Rao, C. R. (2006), Linear Statistical Inference and Its Applications, Wiley

Online material:

Zhou Fan, Introduction to Statistical Inference, Stanford University, http://web.stanford.edu/class/stats200/.

Title	**Introduction to Financial Engineering**	Number	MA4XX
Department	Mathematics	L-T-P [C]	3–0–0 [3]
Offered for		Type	
Prerequisite	Probability, Statistics and Random Processes		

Objectives

1. Technical Analysis of Financial Data
2. Securities Pricing
3. Risk Management
4. Portfolio Optimization – Balancing risk and return
5. Modeling – Pricing of derivatives

Learning Outcomes

1. Understand the Market
2. Understanding Derivatives and Securities
3. Pricing and Valuation in Discrete Case
4. Using the Binomial Model for Option Pricing

Contents

Risk free Assets:Introduction to Financial Markets and Financial Instruments, Technical and Fundamental Analysis, Time Value of Money, Different Compounding Periods, Bonds, Bond Pricing. (6 Lectures)

Mean Variance Theory:Risky Assets, Risk and Return, Mean Variance Analysis, Markowitz Theory for Portfolio Optimization, Inclusion of Risk Free Asset, Capital Asset Pricing Model, Security Market Line. (8 Lectures)

Derivative Securities: Spot and Forward Rates, Forward and Futures, Arbitrage Pricing Theory, Options (call and put), European and American Options, Put-call parity, Binomial Tree, Discrete Time Models for Option Pricing, Risk Neutral Probabilities, Option Greeks. (12 Lectures)

Exotic Options and Greeks: Pricing of American Options, Path Dependent and Other Exotic Options, Option Greeks (Delta, Gamma, Vega, Sigma and Rho), Delta Hedging, Delta-Gamma Hedging. (6 Lectures)

Interest Rate Derivatives: Black Scholes Model, CRR Model, Interest Rate Models (Hull-White, Cox-Ingersoll-Ross, Vasicek). (10 Lectures)

Textbooks

1. M. CAPINSKI, T. ZASTAWNIAK (2010). Mathematics for Finance: An Introduction to Financial Engineering, Springer.
2. D.G. LUENBERGER (1998). Investment Science, Oxford University Press.

Reference Book

J.C. HULL, S. BASU (2014), Options, Futures and Other Derivatives, Pearson.

Title	**Introduction to Game Theory**	Number	MAL4XXX
Department	Maths	L-T-P-D [C]	3–0–0–0 [3]
Offered for	B.Tech	Type	Elective
Prerequisite	None		

Objectives

1. To provide basic understanding of Game Theory and its applications.
2. To equip the students with sufficient knowledge in Game theory which can be used by the students in their respective fields.

Learning Outcomes

1. Understanding of basic of Non-cooperative games and Nash Equilibria
2. Understanding of Dual Simplex method and concept of Duality with applications to game theory.
3. Understanding of Nash Model with security point, stable strategies and Bayesian Games.

Contents

Game Trees, Choice Functions and Strategies, Choice Subtrees, Equilibrium N-tuples Strategies. (4 Lectures)

Normal Forms, Non-cooperative games, Nash Equilibrium and its computation, The von Neumann Minimax Theorem, Mixed strategies, Best Response Strategies. (8 Lectures)

Matrix Games and Linear Programming, Simplex Algorithm, Avoiding cycles and Achieving Feasibility, Dual-Simplex Algorithm, Duality Theorem. (10 Lectures)

2x2 Bimatrix Games, Nonlinear Programming Methods for Non-zero Sum Two-Person Games, Coalitions and Characteristic Functions, Imputations and their Dominance. (4 Lectures)

The Core of a game, Strategic Equivalence, Stable Sets of Imputations, Shapley Values, N-Person Non-Zero Sum Games with continuum of strategies – Duels, Auctions. (8 Lectures)

Nash Model with Security Point, Threats, Evolution, Stable Strategies, Population Games, Bayesian Games. (8 Lectures)

Textbook

1. M. MASCHLER, E. SOLAN, S. ZAMIR (2013), Game Theory, Cambridge University Press.
2. M.J. OSBORNE, A. RUBINSTEIN (1994), A Course in Game Theory, The MIT Press.

Reference Book

P.D. STRAFFIN (Jr.) (1993), Game Theory and Strategy, The Mathematical Association of America.

Online Course Material

M.O. JACKSON, K.L. BROWN, Y. SHOHAM, Game Theory, Coursera Course Material: https://www.coursera.org/learn/game-theory

Title	**Reliability Engineering and Life Testing**	Number	MAXXX
Department	Mathematics	L-T-P [C]	3-0-0
Offered for	B.Tech.	Type	Elective
Prerequisite	Basic Probability & Statistics		

Objectives

To understand the basic concepts of statistical reliability theory and their various real life applications.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the basic notion of systems, different reliability measures and different lifetime models
2. Understand the basic concepts of life testing and inference
3. Gain the ability to handle different issues in software reliability

Contents

Introduction:Importance of reliability, Definition of reliability and its measures, Concept of failure, Mean time to failure. (2 Lectures)

System Reliability:Components and systems, Series, parallel, k-out-of-n system and their reliability block diagrams; Coherent system, path sets and cut sets; Structural importance of components; Reliability of coherent system with independent components; Reliability importance of components; Bounds on system reliability. (7 Lectures)

Lifetime Models: Notion of aging, concept of hazard rate, reliability and mean residual life functions, IFR and DFR class of life distributions; Bath-tub failure curve; Lifetime distributions: exponential, Weibull, gamma, etc. (5 Lectures)

Redundancy, Load Sharing and Stress-Strength Models: Systems with hot, cold and warm standby components; Reliability of shared load parallel system; Stress- strength models; Cumulative damage model, Virtual age model. (6 Lectures)

Life Testing and Inference:Life testing, Complete data and censored data; Type-I, Type-II, hybrid and random censoring schemes, Parametric inference based on complete and censored data using asymptotic likelihood theory, Nonparametric estimate (Life table and Kaplan-Meier) of reliability; Graphical methods (PP, QQ and TTT plots) and standard statistical tests for model validation, Life test acceptance sampling plans in exponential case; Basic concept of accelerated life testing. (14 Lectures)

Software Reliability:The basic concept and definition, Difference between hardware and software reliability, Jelinski-Moranda Model and some other relevant models, The problem of optimal release time, Software Reliability predictions using artificial neural networks, Some recent models. (8 Lectures)

Textbooks

1. H. PHAM (2003), Handbook of Reliability Engineering, Springer.
2. J.V. DESHPANDE, S.G. PUROHIT (2005), Life Time Data: Statistical Models and Methods, World Scientific, Singapore.
3. H. PHAM (2006), System Software Reliability, Springer-Verlag.

Reference Books

1. W.Q. MEEKER, L.A. ESCOBAR (1998), Statistical Methods for Reliability Data, John Wiley.
2. J.F. LAWLESS (2003), Statistical Models and Methods for Lifetime Data, John Wiley.
3. W. NELSON (1982), Applied Life Data Analysis, John Wiley.
4. R.E. BARLOW, F. PROSCHAN (1983), Statistical Theory of Reliability and Life Testing Probability Models, Holt, Rinehart and Winston.
5. R.E. BARLOW, F. PROSCHAN (1965), Mathematical Theory of Reliability, John Wiley.

Title	**Stochastic Calculus for Finance**	Number	MA4XX
Department	Mathematics	L-T-P [C]	3–0–0 [3]
Offered for		Type	
Prerequisite	Probability, Statistics and Random Processes		

Objectives

1. To develop an understanding of change of measure, Martingales and Brownian motion
2. To develop an understanding of Ito's calculus with Stock Market applications

Learning Outcomes

1. Understanding Derivatives and Securities
2. Pricing and Valuation in Discrete Case
3. Ito's Integral and Ito Process
4. Black Scholes Model
5. Various Interest Rate Models

Contents

Discrete Time Models: General probability spaces, Gaussian and log-normal distribution, filtration, martingales and stopping times, Binomial model for option pricing, conditional expectation given a sigma field, Brownian motion and its properties. (8 Lectures)

Continuous Time Models: Continuous approximation of Binomial model, Ito's integral and martingales, properties of Ito's integral, continuous time financial market models, Geometric Brownian motion, Black-Scholes-Merton model, Black-Scholes PDE and formulas. (10 Lectures)

Applications for Option Pricing*:* Risk-neutral valuation, option pricing, the Greeks, put-call parity, Risk-neutral valuation, Girsanov's theorem for change of measure, martingale representation theorems, representation of Brownian martingales. (10 Lectures)

Stochastic Differential Equation: Feynman-Kac formula and its applications, models with stochastic volatility, pricing and hedging in incomplete markets, bond markets, term-structures of interest rates, bond pricing, Short rate models, martingale models for short rate, Vasicek, Cox-Ingersoll-Ross and Hull-White models. (14 Lectures)

Textbooks

1. S.E. SHREVE (2004), Stochastic Calculus for Finance I: The Binomial Asset Pricing Model, Springer-Verlag.
2. S.E. SHREVE (2004), Stochastic Calculus for Finance II: Continuous-Time Model, Springer-verlag.

Reference books

F.C. KLEBNER (2005), Introduction to stochastic Calculus with Applications, Imperial College Press.

Title	**Time Series Analysis**	Number	MA4XX
Department	Mathematics	L-T-P [C]	3–0–0 [3]
Offered for		Type	
Prerequisite	Probability, Statistics and Random Processes		

Objectives

1. To provide working knowledge of time series and forecasting methods
2. To provide with techniques and receipts for estimation and assessment of quality of economic models with time series data

Learning Outcomes

To develop the skills needed to do empirical research in fields operating with time series data sets

Contents

Stationary Processes:Strong and weak, autocorrelation function, linear processes, estimation of mean and covariance functions, Wold decomposition Theorem. (8 Lectures)
ARMA Models: ARMA (p, q) processes, ACF and PACF, Modeling using ARMA processes, estimation of parameters, testing model adequacy, Order estimation. (8 Lectures)
Forecasting: Prediction in stationary processes, special reference to ARMA processes, Frequency domain analysis – spectral density and its estimation, transfer functions. (8 Lectures)
Non-stationary Models: ARMAX, ARIMAX models and introduction to ARCH models. (10 Lectures)
Multivariate Time Series: Multivariate Time Series, State Space Models. (8 Lectures)

Textbooks

1. P.J. BLOCKWELL, R.A. DAVIS (2017), Introduction to Time Series and Forecasting, Springer, 2nd Edition.
2. C. CHATFIELD (2004), The Analysis of Time Series – An Introduction, Chapman and Hall / CRC, 4th Edition.

Reference book

G.E.P. BOX, G. JENKINS, G. REINSEL (1994), Time Series Analysis-Forecasting and Control, Pearson, 3rd Edition.

Online Learning material

https:// ocw.mit.edu/courses/economics/14-384-time-series-analysis-fall-2013/recitations/.

Course Title	**Differential Geometry**	Course No.	**MAL4XX0**
Department	Mathematics	L-T-P-D [C]	3–0–0-0[3]
Offered for	B.Tech	Type	Elective
Prerequisite			

Objectives

1. To introduce the fundamental concepts of differential geometry, In particular, focusing on the local and global properties of curves and surfaces.
2. To learn major topics will include geodesics, parallel transport, curvature, isometries, the Gauss map and the Gauss-Bonnet theorem.

Learning Outcomes

1. Understanding of concrete aspects of geometry, centered on the notion of curvatures.
2. Understanding of major theorems (with proofs), Gauss-Bonnet and Poincare-Hopf Index theorems.

Contents

Introduction [Lectures 8]: Graphs and level sets of functions on Euclidean spaces, vector fields, integral curves of vector fields, tangent spaces.
Theory of Surfaces [Lectures 12]: Surfaces in Euclidean spaces, vector fields on surfaces, orientation, Gauss map, Geodesics, parallel transport, Weingarten map.
Intrinsic Geometry of Surfaces [Lectures 14]: Curvature of plane curves, arc length and line integrals, Curvature of surfaces. Parametrized surfaces, local equivalence of surfaces and Gauss-Bonnet Theorem.
Applications [Lectures 8]: Manifold learning methods applied to data, Network curvature metrics (discrete Ricci curvature and flow), discrete exterior calculus for animation/computer vision, conformal mapping of image data (particularly medical images with Yamabe flow/Ricci flow), data representation in Teichmuller space (particularly video and image data), and machine learning on Riemannian manifolds.

Textbooks

1. M.P. de Carmo (2017), Differential Geometry of Curves and Surfaces, Dover Publications, 2nd Edition.
2. M. Spivak (2005), A Comprehensive Introduction to Differential Geometry, Publish or Perish Inc., 3rd Edition.
3. J.A. THORPE (1979), Elementary Topics in Differential Geometry, Springer.

Reference Books

1. J.J. STOKER (1988), Differential Geometry, Wiley.
2. T.F. BANCHOFF, ST. LOVETT (2015), Differential Geometry of Curves and Surfaces, Chapman and Hall/CRC, 2nd Edition.
3. A.N. PRESSLEY (2010), Elementary Differential Geometry, Springer, 2nd Edition.

Course Title	**Nonlinear Dynamics and Chaos**	Course No.	**MAL4XX0**
Department	Mathematics	L-T-P-D [C]	3–0–0-0[3]
Offered for	B.Tech	Type	Elective
Prerequisite			

Objectives

1. To introduce the concept of linear and nonlinear dynamical systems.
2. To learn the basic concepts in dynamical systems, like, evolution of system, fixed points, periodic points, attractors, bifurcation process and stability of the systems.
3. To understand the nonlinearity in nature and nonlinear models which are present in other areas: Physics, Biology, Chemistry and Engineering.
4. Use Matlab or Mathematics for solving dissipative dynamical systems, which are relevant for engineering models.

Learning Outcomes

1. Construction of phase portraits of linear and nonlinear system and describe the stability of the system.
2. Identification of attractors, like, fixed points, periodic attractors, Cantor set, Chaotic attractors.
3. Understanding the different bifurcations, like, saddle node, transcritical and period doubling etc.
4. Analyzing the dynamics of the system, when the parameter varies.

Contents

One-Dimensional Flows [Lectures 8]: Flows on the Line, Bifurcations, Flows on the Circles.
Two-Dimensional Flows [Lectures 12]: Linear systems and stability, Phase space analysis, Vector field of nonlinear system and stability analysis, Limit Cycles, Saddle-node, Transcritical, Pitchfork bifurcations, and Hopf Bifurcations.
Chaos [Lectures 15]: Lorenz equations, Chaos, Iterated maps, One-Dimensional Maps, period doubling bifurcation, Cantor set, Fractals and strange attractors.
Applications [Lectures 7]: Mechanical vibrations, lasers, biological rhythms, superconducting circuits, insect outbreaks, chemical oscillators, genetic control, systems, chaotic waterwheels, and using chaos to send secret messages.

Textbook

Steaven, S., *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*, 1st Ed., Levant Books, 2007

Reference Books

1. Alligood K., Sauer, T., and Yorke, J., *Chaos: An Introduction to Dynamical Systems*, Second Edition, Springer, 2008
2. Stephen Wiggins, *Introduction to Applied Nonlinear Dynamical Systems and Chaos,* 2nd Edition, Spriger.

Online course Material

Banerjee S., IIT Kharagpur, NPTEL Course on "*Chaos, Fractals and Dynamic Systems*",https://nptel.ac.in/courses/108105054/

Course Title	**Artificial Intelligence in Transportation**	Course No.	**CS6XX**
Department	Computer Science and Engineering	Structure (L-T-P [C])	3-0-0 [3]
Offered for	B.Tech, MTech, PhD	Type	Elective
Pre-requisites	Computer Networks		

Objectives

1. The course is intended to provide students with an understanding of the applications of AI in transportation systems.
2. The course would have a Computer Science flavor to transportation rather than Civil engineering perspective.

Learning Outcomes

At the end of this course, students would be able to appreciate the tremendous AI-driven impact on transportation systems worldwide.

Contents

Traffic flow basics (3 Lectures)
Continuum models of traffic flow(4 Lectures)
Traffic modeling and control of freeways (3 Lectures)
Network-level traffic management (4 Lectures)
Control of traffic signals (4 Lectures)
ITS (Intelligent Transportation Systems) applications and case studies (4 Lectures)
Sensor technologies and data requirements of ITS(3 Lectures)
Overview of Autonomous Systems (4 Lectures)
Driverless Vehicles (3 Lectures)
Vehicular localization techniques (3 Lectures)
Future trends in transportation systems (3 Lectures)
Paper discussions **(flipped mode)** (4 Lectures)

Note:

Please note that the course material would not be taken from a single book or resource. It would be a combination of textbook material, research papers, and other sources.

Textbooks:

1. Alam, M., Ferreira, J., & Fonseca, J. (2016). Introduction to intelligent transportation systems. In Intelligent Transportation Systems (pp. 1-17). Springer, Cham.
2. Lipson, H., &Kurman, M. (2016). Driverless: Intelligent Cars and the road ahead. MIT Press.

Reference Books:

1. Chowdhury, M. A., &Sadek, A. W. (2003). Fundamentals of intelligent transportation systems planning. Artech House.
2. Recent relevant RFCs, Internet drafts, selected research papers from relevant venues: Mobicom, MobiSys, SIGCOMM, Infocom, IEEE TMC, ACM MC2R.

Self-learning Material:

1. https://www.edx.org/course/intro-to-traffic-flow-modeling-and-intelligent-tra
2. Relevant research papers.

Title	**Introduction to Industry 4.0**	Course No.	AIDSLXXX
Department	AI & DS, ME	Structure (L-T-P [C])	3–0–2 [4]
Offered for	B.Tech (AI & DS)	Type	Compulsory
Prerequisite		Antirequisite	OS, CN

Objectives

The Instructor will:

1. Provide an understanding of the fundamentals of operating systems and networking
2. Explain the transformation of industrial processes through the integration of modern technologies such as sensors, communication, and computational processing

Learning Outcomes

The students will have the ability to:

Apply technology in industries to modify the various existing industrial systems

Contents

Introduction: Introduction: Sensing & actuation, Communication and Networking, Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Smart and Connected Business Perspective, Smart Factories (7 Lectures)

Industry 4.0: Cyber-Physical Systems and Next Generation Sensors, Collaborative Platform and Product

Security: Cybersecurity in Industry 4.0, Basics of Industrial IoT: Industrial Processes, Industrial Sensing & Actuation, Industrial Internet Systems.

Industrial IoT: Introduction, Industrial IoT, Business Model, Reference Architecture, IIoT-Business Models, IIoT Sensing, IIoT Processing, Security and Fog Computing: Cloud Computing in IIoT

Data Analytics: Big Data Analytics and Software Defined Networks: IIoT Analytics - Introduction, Machine Learning, and Data Science, Data Management with Hadoop

Case Study: Application in the areas: Factories and Assembly Line, Food Industry, Healthcare, Power Plants, Inventory Management & Quality Control, Plant Safety and Security (Including AR and VR safety applications), Facility Management, Oil, chemical and pharmaceutical industry, Applications of UAVs in Industries, Real case studies.

Text Books

A. Gilchrist (2016), *Industry 4.0: The Industrial Internet of Things*, APresss.

Reference Books

S.Jeschke, C. Brecher, H. Song, D. B. Rawat (2017), Industrial Internet of Things: Cyber Manufacturing Systems, Springer Series in Wireless Technology.

Online Material

NPTEL Lectures, Introduction to Industry 4.0: Industrial Internet of Things, https://nptel.ac.in/courses/106105195/

Title	**Visual Computing Lab**	Number	CSE/EE XXX
Department	CSE, EE, ME	L-T-P [C]	0–0–4 [2]
Offered for	BTech. CSE, AI&DS, EE, ME	Type	Specialization Core
Prerequisite			

Objectives
The Instructor will introduce students to the importance of human centered visual computing.

Learning Outcomes
The students are expected to have the ability to design applications that explicitly consider human perception.

Contents
Sensing Devices: Concept of dynamic range, HDR displays, Event Based Camera, Time of Flight Camera, Coded Apertures, LIDAR, 3D Reconstruction, Kinect Scanner, Laser Scanner (4 weeks)
Mini-project in Recognition (2 weeks)
Mini-project in Navigation (2 weeks)
Mini-project in Action (2 weeks)
Mini-project in Mixed Reality (2 weeks)
Mini-project in Trustable Decision (2 weeks)

Textbooks
Szeliski, R. (2010). *Computer Vision: Algorithms and Applications*. Springer-Verlag New York Inc. Available Online.
Reinhard, E., Heidrich, W., Debevec, P., Pattanaik, S., Ward, G., &Myszkowski, K. (2010). *High Dynamic Range Imaging: Acquisition, Display, and Image-based Lighting*. 2nd Edition. Morgan Kaufmann**.**

Self Learning Material
Prof.Ioannis (Yannis) Gkioulekas, Computational Photography, Carnegie Mellon University,http://graphics.cs.cmu.edu/courses/15-463/
Prof. Silvio Savarese, Computer Vision, From 3D Reconstruction to Recognition, Stanford University,http://web.stanford.edu/class/cs231a/

Preparatory Course Material:
Prof. Gilbert Strang, Linear Algebra and Learning from Data, Massachusetts Institute of Technology,https://math.mit.edu/~gs/learningfromdata/

Title	**Bio-Imaging**	Number	
Department	CS, AI&DS, EE	L-T-P [C]	3–0–0 [3]
Offered for		Type	Elective
Prerequisite			

Objectives

The Instructor will:

The Instructor will provide an overview of different imaging modalities.

Learning Outcomes

The students will have ability to:

1. The students will have the ability to choose appropriate imaging modality to visualize biological samples.
2. The students will be able to interpret and analyse the images in a quantitative way.

Contents

Introduction to Bio-imaging [1 lecture], Light microscopy [1 Lectures], Basic configuration of modern light microscopes [3 Lectures], Fluorescence and fluorescence microscopy [3 Lectures], Super-resolution light microscopy [1 Lectures], 3D imaging techniques in microscopy: confocals and mesoscopic techniques [3]
Total: 12 lectures

Transmission Electron Microscopy - principles [6 Lectures], Scanning Electron Microscopy (SEM) [4 Lectures]
Total: 10 lectures

Digital Imaging In Biology; Image acquisition devices: CCDs vs CMOS cameras; High-speed & time-lapse acquisition, Thermography, UV, Gamma & X-ray cameras
Total: 6 lectures

Medical imaging: Principles, instrumentation and applications of X-ray [3 Lectures], Computed Tomography [3 Lectures], PET and Ultrasonography [4 Lectures], MRI, and fMRI [4 Lectures].
Total: 14 lectures

Text Books

1. Murphy (2001) Fundamentals of light microscopy and electronic imaging. John Willey & Sons.
2. Pawley (2006) Handbook of Biological Confocal Microscopy. 3rd ed. Springer.

Self-Learning Material

Bioimaging by Prof. Lu Lei at NTU Singapore:
http://www.sbs.ntu.edu.sg/prospective/undergraduate/Curriculum%20and%20Course%20Descriptions/Pages/Major-PE/Table%20A/BS2010.aspx

Title	**Medical Image Analysis**	Number	
Department	CS, AI&DS, EE	L-T-P [C]	3–0–0 [3]
Offered for		Type	Elective
Prerequisite	Fundamental knowledge of Digital Image Processing or Computer Vision, Machine Learning/PRML, Deep Learning		

Objectives

The Instructor will provide an in-depth understanding of classical and machine learning based techniques for medical image analysis.

Learning Outcomes

The students will have ability to:

1. interpret and analyse the images in a quantitative way.
2. apply the learned techniques for novel disease diagnosis and prognosis.

Contents

Classical Approaches: *[1-0-0]*

Introduction to image processing and medical imaging modalities, denoising and enhancement [4 Lectures]
Tissue and Cell Segmentation: clustering, active contours and level sets based approaches [5 Lectures]
Medical Image alignment: rigid and deformable registration [5 Lectures]

Machine Learning and Deep Learning Approaches*: (2-0-0)*

Fundus Image analysis, Retinal Vessel Segmentation [4 Lectures]
MRI image analysis and segmentation, 3D brain reconstruction from and MRI slices and analysis [5 Lectures]
Microscopic image analysis and interpretation [5 Lectures]
Ultrasonography image analysis [4 Lectures]
X-Ray and CT image segmentation, diagnosis and prognosis of various diseases [5 Lectures]
Correlation between different medical imaging modalities and conversions, augmenting clinical measurements with medical imaging modalities for diseases diagnosis and prognosis [5 Lectures]

Text Books

1. Prince, J. L., & Links, J. M. (2006). *Medical imaging signals and systems*. Upper Saddle River, NJ: Pearson Prentice Hall.
2. Suetens, P. (2017). Fundamentals of medical imaging. Cambridge university press.

Self-Learning Material:

Medical Image Processing by Prof. Jeff Orchard at University of Waterloo:
https://cs.uwaterloo.ca/~jorchard/cs473/CS473/Welcome.html