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FUTURE UNIVERSITY, BAREILLY

(Established under the Uttar Pradesh Private Universities (Third Amendment) Act, 2024)

COURSE CURRICULUM

AND

EVALUATION SCHEME

M. T. R. (A.F.)

For the Students Admitted in Academic Session 2025-26

Effective From

Academic Session 2025-26

Prepared By

Board of Studies

Approved By

Academic Council
Future University, Bareilly

Published By

Office of the Registrar
Future University, Bareilly

Academic Session: 2025-26



(This Curriculum and Evaluation Scheme shall be applicable to all students admitted to the Programme from the Academic Session _____ onwards and shall remain in force until amended or revised by the Academic Council of Future University, Bareilly.)

Faculty of Engineering and Technology

Curriculum and Syllabus
(Applicable to students admitted during (2025-26))

M. Tech – Artificial Intelligence



Diya

Dated: January 31, 2025

Ref. No. FUCSE/Notice/2025/Odd Semester/

Notice/Circular

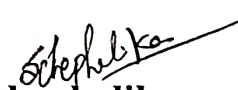
**Subject: Curriculum Development Committee for M.Tech(AI)
2025-26**

The following Curriculum Development Committee has been constituted for the departmental academic course structure/curriculum design considering Industry trends for the session 2025-26.

Curriculum Development Committee (CDC)

This committee has been framed in the department with faculty members:

S.No	Name	Designation	Position
1.	Dr.Schephalika	Associate Professor	Coordinator
2.	Dr.Shivangi	Associate Professor	Member
3.	Mr.Sachin Raj Saxena	Assistant Professor	Member
4.	Mr.Khemendra	Assistant Professor	Member
5.	Mr.Gaurav Trivedi	Assistant Professor	Member


Dr.Schephalika
Head, M.Tech

C.C. :

1. Dean Academics
2. Dean Research
3. Registrar
4. All Faculty Members


Dr. Shash
Dean
Faculty of Engg. & Tech.
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Attendance Sheet -Board of Studies (2025 Batch)

Name of Faculty: Faculty of Engineering and Technology
Program: M.Tech (CSE) and M.Tech. (AI&ML)

Date: 29/03/25

Time: 2:00 PM

S. N.	Position	Designation	Name of member, Designation, Affiliation	Signature
1	Senior Faculty	Member	Dr. Mohd Wazih Ahmad, Dean, Faculty of Engineering and Technology, Future University, Bareilly, UP	
2	HOD	Chairperson	Dr. Shivangi Gildhiyal, HOD, Department of Computer Science and Engineering, Faculty of Engineering and Technology, Future University, Bareilly, UP	
3	Senior Faculty	Member	Mr. Sachin raj Saxena, HoD, Department of AI, Faculty of Engineering and Technology, Future University, Bareilly, UP	
4	Senior Faculty	Member Secretary	Dr. Rajan Prasad, Professor, Department of Computer Science and Engineering, Faculty of Engineering and Technology, Future University, Bareilly, UP	ABSENT
5	Senior Faculty	Member	Mr. Khemendra, Assistant Professor, Department of Computer Science and Engineering, Faculty of Engineering and Technology, Future University, Bareilly, UP	
6	Senior Faculty	Member	Mr. Gaurav Trivedi, Assistant Professor, Department of Computer Science and Engineering, Faculty of Engineering and Technology, Future University, Bareilly, UP	
7	Senior Faculty	Member	Mr. Hemant Kumar, HoD, Diploma in Mechanical Engineering, Faculty of Engineering, Future University, Bareilly, UP	
8	Senior Faculty	Member	Mr. Shubham Saxena, HoD, Diploma in Electrical Engineering, Faculty of Engineering, Future University, Bareilly, UP	
9	Senior Faculty	Member	Mr. Vinay Pratap Sagar, HoD, Diploma in Civil Engineering, Faculty of Engineering, Future University, Bareilly, UP	
10	Academic Expert ME (Member)	Member	Dr. Ravindra Kumar, Associate Professor, Department of Mechanical Engineering, SRMSCET, Bareilly, UP	
11	Academic Expert CSE (Member)	Member	Dr. Anurag Singh Baghel, Department of Computer Science & Engineering, University School of Information and Communication Technology, Gautam Budhha University, Greater Noida	online
12	Academic Expert EE and CSE (Member)	Member	Dr. M. A. Ansari, Professor, Electrical and Computer Engineering School of Engineering, Gautam Budhha University, Greater Noida	online
13	Academic Expert EE (Member)	Member	Dr. SP Singh, School of Engineering, Electrical Engineering, Gautam Budhha University, Greater Noida	online
14	Academic Expert Civil Engineering	Member	Dr. RK Jain, Professor, Department of Civil Engineering, Faculty of Engineering, TMU, Moradabad	

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	(Member)			
15	Industry Expert ME & EE (Member)	Member	Mr. Ankur Tiwari, Director, PRTC Private Ltd, Rudrapur	
16	Industry Expert CSE (Member)	Member	Mr. Mudit Rathore, Technical Product Owner - Digital Transformation, Kenvue Former Consumer Healthcare division of Johnson&Johnson, Bangalore	
17	Industry Expert Civil Engineering	Member	Dr. KK Pandey, retired from NHPC, Faridabad	

Verified by

Head of the Departments
Department of Computer Science and Engineering

Name Dr. Schepalik Date 29/03/2025 Sig

Head of the Department
Department of AI

Name Dr. Shaha Date 29/03/2025 Sig

Head of the Department

Diploma Engineering 1. CSE 2. ME 3. Civil 4. EE

Name _____	Date _____	Sig _____
Name _____	Date _____	Sig _____
Name _____	Date _____	Sig _____
Name _____	Date _____	Sig _____

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FUTURE UNIVERSITY

(Established under Govt. of U. P. Act No. 12, 2024)

Study & Evaluation Scheme Of Master of Technology (AI)

[Applicable w.e.f. Academic Session 2025-26]

Approved by Academic Council



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**18th Milestone, Bareilly-Lucknow Highway NH-24
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MLTech AI Course Scheme

Name of Course: Master Of Technology(M.Tech_AI)

Name of School/Department: Faculty of Computer Science and Engineering

Course Structure: Two Years-Four Semesters (2025-27)

Name of Instructor (s): Prof.(Dr.) Shashi Singh

MLTech(AI) Course Work (Computer Science and Engineering)

MLTech(AI) Course Work (Computer Science and Engineering)											
COURSE			Credit Structure & Total Hours						Evaluation Scheme		
S No	Course Code	Course Title	Course Type	L	T	P	C	CH	CA	EE	TM
1	MAL5101	Research Methodology		3	0	0	3	60	30	70	100
2	MAL5102	Advanced Algorithms & Analysis		4	0	0	4	60	30	70	100
3	MAL5103	Machine Learning & Its Applications		3	0	0	3	30	30	70	100
4	MAL5104	Advanced Deep Learning		4	0	0	4	30	30	70	100
5	MAL5105	Information Retrieval Systems		3	0	0	3	60	30	70	100
6	MAL5106	Internet Of Things		3	0	0	3	60	30	70	100
7	MAL5170	Deep Learning Lab		0	0	2	1	60	30	70	100
8	MAL5160	MOOC I		0	0	0	3	60	30	70	100
Master Of Technology(M.Tech)			Total	20	0	0	24	240	150	350	800

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SUMMARY

Programme: : Master of Technology
M.Tech.(AI)

Duration : Two years full time (Four Semesters)

Medium : English

Minimum Required Attendance : 75 percent

Credit

Maximum Credit : 96

Minimum credit required for the de-
gree : 80

Assessment (Theory)

Internal	External	Total
30%	70%	100%

Assessment (Practical)

Internal	External	Total
50%	50%	100%

Internal Evaluation (Theory Papers)

Class Test I	Class Test II	Assignment(s)	Other Activity (including attendance)	Total
10 Marks	10 Marks	5 Marks	5 Marks	30 Marks

Internal Evaluation (Practical Papers)

Experiment File Viva	Exam	Attendance	Total
10 Marks	30 Marks	10 Marks	50 Marks

Duration of Examination (Theory)

External	Internal
3 hrs.	1 ½ hrs

Duration of Examination (Practical)

: As per the requirement of the practical paper.

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To qualify the course a student is required to secure a minimum of 40% marks in aggregate including the semester end examination and teachers' continuous evaluation. (i.e. both internal and external).
A candidate who secures less than 40% of marks in a course shall be deemed to have failed in that course. The student should have at least 50% marks in aggregate to clear the semester. In case a student has more than 40% in each course, but less than 50% overall in a semester, he/she shall re-appear in courses where the marks are less than 50% to achieve the required aggregate percentage of 50% in the semester.

Question Paper Structure

1. The question paper shall consist of six questions. Out of which first question shall be of short answer type (not exceeding 50 words) and will be compulsory. Question No. 1 shall contain 8 parts representing all units of the syllabus and students shall have to answer any five (weight age 4 marks each).
2. Out of the rest five questions, students shall be required to attempt all five questions, but there will be an internal choice of A or B. Each question will be from one unit of the syllabus. The weight age of Question No. 2 to 6 shall be 10 marks each.

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Faculty of Engineering and Technology

Curriculum and Syllabus
(Applicable to students admitted during (2025-26))

M. Tech – Artificial Intelligence

FUTURE UNIVERSITY

Faculty of Engineering and Technology (Code:05)

Department of Computer Science and Engineering

Master of Technology in AI

Course Structure

Semester-I						
S. No	Course Code	Course Name	L	T	P	C
1	MAL5101	Research Methodology	3	0	0	3
2	MAL5102	Advanced Algorithms and Analysis	4	0	0	4
3	MAL5103	Machine Learning & Its Applications	3	0	0	3
4	MAL5104	Advance Deep Learning	4	0	0	4
5	MAL5105	Information Retrieval Systems	3	0	0	3
6	MAL5106	Internet of Things	3	0	0	3
7	MAL5170	Deep Learning Lab	0	0	2	1
8	MAL5160	MOOC I	0	0	0	3
Total						24

Semester-II						
S. No	Course Code	Course Name	L	T	P	C
1	MAL5201	Optimization Techniques	3	0	0	3
2	MAL5202	Advance Machine Learning	3	0	0	3
3	MAL5203	Cloud Computing and Blockchain Technology	4	0	0	4
4	MAL5204	Data Science	3	0	0	3
5	MAL5205	Generative AI and LLM	3	0	0	3
6	MAL5271	Cloud Computing and Blockchain technology Lab	0	0	4	2
7	MAL5260	MOOC II	0	0	0	3
8		Elective I	3	0	0	3
Total						24

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Semester-III						
S. No	Course Code	Course Name	L	T	P	C
1		Elective II	3	0	0	3
2		Elective III	2	0	0	2
3	MAL5360	MOOC III	0	0	0	3
4	MAL5361	Dissertation – I	0	0	0	16
Total						24

Semester-IV						
S. No	Course Code	Course Name	L	T	P	C
1	MAL5461	Dissertation - II	0	0	2	20
2	MAL5460	MOOC IV	0	0	0	4
Total						24

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Dr. Schephalika
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List of Electives						
Course Code	Course Name	L	T	P	C	
ELECTIVE I						
MAL5160	Speech Processing	3	0	0	3	
MAL5161	Distributed Machine Learning	3	0	0	3	
MAL5162	Neuro Fuzzy Systems	3	0	0	3	
MAL5163	Quantum Computing	3	0	0	3	
ELECTIVE II						
MAL5260	Bio Medical Image Processing	3	0	0	3	
MAL5261	Cognitive Systems	3	0	0	3	
MAL5262	High Performance Computing	3	0	0	3	
MAL5263	Computer Vision	3	0	0	3	
ELECTIVE III						
MAL5360	Deep Reinforcement Learning	2	0	0	2	
MAL5361	Computational Learning Theory	2	0	0	2	
MAL5362	Graphical Models	2	0	0	2	
MAL5363	Unsupervised Deep Learning	2	0	0	2	

Note: Multiple Entry and Multiple Exit options as per NEP 2020 are applicable.

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M.Tech (AI) Detailed Syllabus 2025 Intake

MAL - 5101	Research Methodology	L T P – 3 0 0	3 Credits
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Course Objectives:

CO1	Understand the research process, types of research, and ethics.
CO2	Formulate research problems and hypotheses effectively.
CO3	Apply data collection, analysis, and sampling methods.
CO4	Use statistical tools and software for data analysis.
CO5	Prepare research reports, proposals, and technical papers in a proper format.

Unit □

Introduction to Research: Meaning, Objectives, Types of Research (Basic, Applied, Action, Exploratory, Descriptive, Analytical, Qualitative), Research Process and Methodology, Characteristics of Good Research, Ethics in Research, Plagiarism and Referencing intellectual property rights. Use of Generative AI in research writing, Research summarization using NLP tools, Use of ChatGPT/BARD responsibly in research

Unit □

Research Problem and Design: Defining and Formulating Research Problems, Hypothesis Formation, Literature Review Techniques, Research Design Concepts (Exploratory, Descriptive, Experimental), Sampling Methods. Problem identification and statement, Hypothesis formulation and testing, Literature survey and review techniques (using Scopus, Google Scholar, IEEE Xplore), Research gap identification, Types of research designs – qualitative, quantitative, mixed methods. Patent filing process in India and abroad, Copyrights, Trademarks, IPR tools (WIPO, IPO India).

Unit □

Data Collection and Processing: Primary and Secondary Data, Methods of Data Collection (Surveys, Interviews, Questionnaires, Observation), Data Preparation and Cleaning, Scaling Techniques and Measurement Scales. Types of data (primary and secondary), Data collection tools (questionnaires, interviews, surveys, observations), Sampling methods (probability and non-probability), Data validation and reliability, Case study and field study methods. How to write a grant/funding proposal (DST, AICTE, CSIR), Budgeting and project timeline

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Unit □

Statistical Tools for Research: Descriptive and Inferential Statistics, Hypothesis Testing (t-test, Chi-square test, ANOVA), Correlation and Regression, Use of Tools like SPSS, R, Python (Pandas, SciPy), MATLAB. Descriptive statistics, Inferential statistics (t-test, ANOVA, Chi-square), Correlation and regression analysis, Hypothesis testing, Use of statistical tools (SPSS, R, Python), Data visualization tools (Excel, Tableau, matplotlib/seaborn). Impact Factor, h-index, i10-index, SCImago, Altmetrics.

Unit □

Research Reporting and Presentation: Technical Writing and Report Structure, Formatting Thesis/Dissertation, Writing Research Papers (IEEE/Elsevier/Springer Formats), Presenting Data using Charts/Graphs, Preparing Presentations for Conferences, Patent Filing Basics. Structure of a research paper, Research report, Thesis/dissertation format (IEEE, APA, Springer, Elsevier), Referencing and citation styles (Mendeley, Zotero, LaTeX), Writing abstract, literature review, results and discussion sections, Peer review process, Ethics in publishing. PRISMA framework, Cochrane collaboration, Forest plots

Course Outcomes:

CO1	Understand the research process, types of research, and ethics.
CO2	Formulate research problems and hypotheses effectively.
CO3	Apply data collection, analysis, and sampling methods.
CO4	Use statistical tools and software for data analysis.
CO5	Prepare research reports, proposals, and technical papers in a proper format.

Textbooks:

1. C.R. Kothari & Gaurav Garg, "Research Methodology: Methods and Techniques", New Age International.
2. Ranjit Kumar, "Research Methodology: A Step-by-Step Guide for Beginners", SAGE Publications.

Reference Books:

1. Donald R. Cooper & Pamela S. Schindler, "Business Research Methods", McGraw-Hill.
2. Wayne Goddard & Stuart Melville, "Research Methodology: An Introduction", Juta and Company Ltd.
3. Michael Jay Polonsky & David S. Waller, "Designing and Managing a Research Project", SAGE.

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MAL - 5102	Advanced Algorithms and Analysis	L-T-P: 4-0-0	4 Credits
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Course Objectives:

CO1	Learn advanced algorithm design techniques and their real-world applications.
CO2	Strengthen the understanding of algorithm analysis using mathematical tools.
CO3	Explore the limitations of computation and techniques for solving hard problems.
CO4	Study modern algorithms like randomized, parallel, and online algorithms.
CO5	Investigate advanced graph and geometric algorithms with practical use cases.

Unit □

Algorithm Analysis & Mathematical Foundations: Asymptotic notation (Big-O, Omega, Theta), Recurrence relations (substitution, recursion-tree, master theorem), Amortized analysis, Probabilistic analysis, Basic combinatorics, Time-space trade-offs.

Unit □

Advanced Design Techniques: Divide and Conquer (Karatsuba, Closest Pair of Points), Dynamic Programming (LCS, Knapsack, Edit Distance), Greedy Algorithms (Activity Selection, Huffman Encoding), Backtracking (Sudoku, N-Queens), Branch and Bound (TSP, 0/1 Knapsack).

Unit □

Advanced Graph Algorithms: Graph Traversals (BFS, DFS), MST (Kruskal, Prim), Shortest Path (Dijkstra, Bellman-Ford, A*), Network Flow (Ford-Fulkerson, Edmonds-Karp), Topological Sort, Bipartite Matching, Euler and Hamiltonian Paths.

Unit □

String, Geometry, and Data Structures: KMP, Rabin-Karp, Suffix Trees & Arrays, Trie, Longest Repeating Substring, Geometric algorithms (Convex Hull, Sweep Line, Segment Trees), Range Trees, Quadrees, Binary Indexed Trees (Fenwick Trees), Disjoint Set (Union-Find with path compression).

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Unit □

Complexity Theory & Advanced Topics: NP-Completeness (SAT, Clique, Independent Set), Reductions, Approximation Algorithms (TSP, Set Cover), Randomized Algorithms (Monte Carlo, Las Vegas), Online Algorithms (Caching, Ski Rental), Parallel Algorithms (MapReduce basics, PRAM models), Streaming Algorithms (Count-Min Sketch, Reservoir Sampling), Cache-efficient Algorithms, External memory models.

Course Outcomes:

CO1	Understand and apply advanced algorithmic techniques like divide & conquer, greedy, and dynamic programming.
CO2	Analyze algorithm efficiency using asymptotic notation and recurrence relations.
CO3	Use probabilistic and approximation techniques for intractable problems.
CO4	Explore NP-complete problems and use approximation and randomization when exact solutions are hard.
CO5	Apply parallel, cache-efficient, and streaming algorithms for large-scale data processing.

Textbooks:

1. T. H. Cormen et al., *Introduction to Algorithms*, MIT Press (CLRS).
2. Jon Kleinberg and Éva Tardos, *Algorithm Design*, Pearson.

Reference Books:

1. S. Dasgupta, C. Papadimitriou, and U. Vazirani, *Algorithms*, McGraw-Hill.
2. Sanjeev Arora and Boaz Barak, *Computational Complexity: A Modern Approach*, Cambridge University Press.
3. Michael T. Goodrich and Roberto Tamassia, *Algorithm Design and Applications*, Wiley.

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MAL -5103	Machine learning and its Applications	L-T-P: 3-0-0	3 Credits
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Course Objectives:

CO1	Build a strong mathematical foundation to understand machine learning algorithms.
CO2	Apply linear algebra, probability, and statistics to real-world data problems.
CO3	Understand and use calculus and optimization in learning algorithms.
CO4	Connect mathematical theories to algorithmic and model design.
CO5	Prepare students for advanced topics like deep learning and probabilistic models.

Unit □

Introduction: Objective, scope and outcome of the course.

Artificial Neural Network: Neural network representation, Neural Networks as a paradigm for parallel processing, Linear discrimination, Pairwise separation, Gradient Descent, Logistic discrimination, Perceptron, Training a perceptron, Multilayer perceptron, Back propagation Algorithm. Recurrent Networks, Dynamically modifying network structure.

Unit □

Decision Tree Learning: Decision tree representation, appropriate problems for decision tree learning, Univariate Trees (Classification and Regression), Multivariate Trees, Basic Decision Tree Learning algorithms, Hypothesis space search in decision tree learning, Inductive bias in decision tree learning, Issues in decision tree learning.

Unit □

Genetic Algorithms: Basic concepts, Hypothesis space search, Genetic programming, Models of evolution and learning, Parallelizing Genetic Algorithms.

Unit □

Bayesian Learning: Bayes theorem and concept learning, Bayes optimal classifier, Gibbs algorithms, Naive Bayes Classifier, Bayesian belief networks, The EM algorithm. **Design of Machine Learning:** Guidelines for machine learning experiments, Factors, Response, and Strategy of experimentation **Statistics, Information Theory & Advanced Topics:** Descriptive statistics (mean, median, mode, std), Hypothesis testing, Confidence intervals, Maximum Likelihood Estimation (MLE), Maximum A Posteriori Estimation (MAP), Bias-Variance Tradeoff, Entropy and cross-entropy, KL divergence, Mutual Information, Information gain, Feature selection using information theory, Basics of Bayesian networks.

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Unit □

Complexity Theory & Advanced Topics: NP-Completeness (SAT, Clique, Independent Set), Reductions, Approximation Algorithms (TSP, Set Cover), Randomized Algorithms (Monte Carlo, Las Vegas), Online Algorithms (Caching, Ski Rental), Parallel Algorithms (MapReduce basics, PRAM models), Streaming Algorithms (Count-Min Sketch, Reservoir Sampling), Cache-efficient Algorithms, External memory models.

Course Outcomes:

CO1	Understand and apply advanced algorithmic techniques like divide & conquer, greedy, and dynamic programming.
CO2	Analyze algorithm efficiency using asymptotic notation and recurrence relations.
CO3	Use probabilistic and approximation techniques for intractable problems.
CO4	Explore NP-complete problems and use approximation and randomization when exact solutions are hard.
CO5	Apply parallel, cache-efficient, and streaming algorithms for large-scale data processing.

Textbooks:

1. T. H. Cormen et al., *Introduction to Algorithms*, MIT Press (CLRS).
2. Jon Kleinberg and Éva Tardos, *Algorithm Design*, Pearson.

Reference Books:

1. S. Dasgupta, C. Papadimitriou, and U. Vazirani, *Algorithms*, McGraw-Hill.
2. Sanjeev Arora and Boaz Barak, *Computational Complexity: A Modern Approach*, Cambridge University Press.
3. Michael T. Goodrich and Roberto Tamassia, *Algorithm Design and Applications*, Wiley.

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MAL-5104	Advance Deep Learning	L-T-P: 4-0-0	3 Credits
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Course Objectives:

CO1	To understand the advanced architectures and training methods in deep neural networks.
CO2	To explore convolutional, recurrent, and attention-based deep models.
CO3	To study generative modeling, unsupervised and self-supervised learning.
CO4	To implement real-world applications in vision, NLP, and multimodal systems.
CO5	To analyze recent research trends and challenges in deep learning systems.

UNIT □

Deep Neural Network Optimization: Review of DNNs, vanishing/exploding gradients, weight initialization, batch/layer/group normalization, dropout and regularization, learning rate schedules, optimizers (SGD, RMSprop, Adam, AdaBelief, Lookahead), loss landscape visualization. Vanishing/exploding gradients, initialization strategies (Xavier, He), optimizers (SGD variants, AdamW, Lookahead, AdaBelief), learning rate schedulers (cosine annealing, cyclical learning rate), batch/layer/group normalization, label smoothing, sharpness-aware minimization (SAM).

UNIT □

Convolutional and Recurrent Networks: Deep CNN architectures (ResNet, DenseNet, EfficientNet), object detection (YOLO, SSD), segmentation (U-Net, DeepLab), RNNs, LSTMs, GRUs, attention mechanisms in sequence models, vanishing gradients in RNNs, temporal modeling. Deep CNNs (ResNet, DenseNet, EfficientNet), semantic segmentation (U-Net, DeepLab), object detection (YOLOv5, Faster R-CNN), recurrent networks (RNNs, LSTMs, GRUs), bidirectional and hierarchical RNNs, temporal convolutions, hybrid CNN-RNN models.

UNIT □

Attention and Transformers: Self-attention and multi-head attention, Transformer architecture (encoder-decoder), positional encoding, pretraining (BERT, GPT), transfer learning, vision transformers (ViT, Swin Transformer), applications in NLP and CV. Scaled dot-product attention, self-attention vs. cross-attention, multi-head attention, transformer architecture (BERT, GPT, T5),

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Dr. Chaitanya

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vision transformers (ViT, Swin), attention visualization, encoder-decoder models for seq2seq tasks, Transformer tuning (LoRA, Adapters, PEFT).

UNIT IV

Generative Deep Learning: Generative Adversarial Networks (GANs), conditional GANs, CycleGAN, style transfer, Variational Autoencoders (VAEs), Diffusion Models (overview), comparison and use cases in image generation and augmentation. GANs (vanilla, DCGAN, CycleGAN, StyleGAN), VAEs and β -VAEs, Diffusion models (DDPM, Stable Diffusion – overview), contrastive learning (SimCLR, MoCo), clustering with deep autoencoders, masked modeling (MAE, BERT-style).

UNIT V

Emerging Topics and Applications: Self-supervised learning (SimCLR, BYOL, MoCo), contrastive learning, multimodal deep learning (CLIP, Flamingo), zero-shot and few-shot learning, model compression, pruning, quantization, federated learning, ethical issues in DL (bias, fairness, explainability), interpretability methods (Grad-CAM, SHAP). Transfer learning and fine-tuning, Zero-shot/Few-shot learning (CLIP, GPT-3 prompt engineering), Multimodal deep learning (Vision+Language, LLM+speech), Multitask learning, Domain adaptation & generalization, Active learning, Continual/Lifelong learning, Deep reinforcement learning (DQN, A3C – basics).

Course Outcomes:

CO1	Demonstrate a strong grasp of deep learning theory and optimization techniques.
CO2	Implement and experiment with advanced models such as ResNet, ViT, Transformer, GPT, and GANs.
CO3	Analyze the mathematical foundations behind attention, transformers, and variational methods.
CO4	Develop scalable models for cross-domain applications and address bias, robustness, and interpretability.
CO5	Evaluate and critique cutting-edge research in deep learning from top-tier conferences.

Textbooks:

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville – *Deep Learning*, MIT Press
2. François Chollet – *Deep Learning with Python*, Manning
3. Aurélien Géron – *Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow*, O'Reilly.

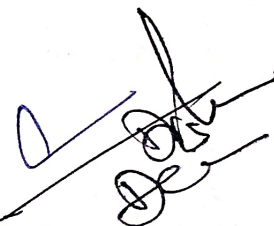
Reference Resources:

1. Papers with Code: <https://paperswithcode.com>
2. HuggingFace Docs: <https://huggingface.co/docs>
3. OpenAI & Meta AI Blogs for cutting-edge model development
4. ArXiv preprints (NeurIPS, ICLR, ACL, CVPR)

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MAL-5105	Information Retrieval Systems	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To provide foundational and advanced understanding of information retrieval systems.
CO2	To explore mathematical models and machine learning techniques for search and ranking.
CO3	To implement indexing, document representation, and relevance scoring methods.
CO4	To apply modern IR strategies in web, semantic, neural, and multilingual environments.
CO5	To evaluate IR systems using standardized performance metrics and address ethical issues.

Unit I

Fundamentals of Information Retrieval: Overview and Evolution of IR, Components of an IR System, Text Preprocessing: Tokenization, Stemming, Lemmatization, Stop-word Removal, Term Frequency (TF), Inverse Document Frequency (IDF), TF-IDF; Document Representation: Bag of Words, Vector Models; Zipf's Law, Heaps' Law, Vocabulary Growth; Boolean Retrieval and Ranked Retrieval Models; Introduction to Relevance and User Intent.

Unit II

Indexing and Retrieval Models: Inverted Index Construction; Document Parsing and Tokenization Strategies; Index Compression: Variable-Length Coding, Gamma and Delta Coding; Signature Files and Skip Pointers; Vector Space Model and Cosine Similarity; BM25 Scoring Function and Variants; Probabilistic Retrieval Models: Binary Independence Model; Language Modeling for IR: Query Likelihood, Smoothing Techniques (Jelinek-Mercer, Dirichlet); Divergence from Randomness Models.

Unit III

Web IR and Evaluation: Web Crawling: Architecture, Scheduling, Politeness, Duplicate Elimination; Link Analysis: PageRank, HITS Algorithm; Metadata and Structured Document Retrieval (HTML, XML); Query Processing and Query Expansion; Relevance Feedback: Rocchio Method; IR Evaluation Metrics: Precision, Recall, F1-Score, Mean Average Precision (MAP), Mean Reciprocal Rank (MRR), NDCG; A/B Testing and Click Models; TREC and CLEF Benchmarks.

Unit IV

Semantic, Contextual and Domain-Specific IR: Word Embeddings: Word2Vec, GloVe, FastText; Document Embeddings: Doc2Vec, Universal Sentence Encoder; Knowledge Graphs in IR (e.g., Google's KG); Ontology-based Search and Semantic Ranking; Query Reformulation and Context-aware Retrieval; Personalized Search and User Behavior Modeling; Domain-Specific IR:

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Legal, Medical, Scientific, E-commerce; Cross-lingual and Multilingual IR; Zero-shot IR using Pretrained Models (XLM-R, mBERT).

Unit V

Neural and Advanced IR Techniques: Neural Ranking Models: DSSM, KNRM, DRMM; Dense Retrieval with DPR, ColBERT, SPLADE; Transformers in IR: BERT, T5, DistilBERT for reranking; Retrieval-Augmented Generation (RAG, RETRO); Contrastive Learning for IR (SimCSE, CLEAR, DenseContrast); Open-Domain QA Systems and IR; Federated IR Systems and Edge-based Retrieval; Privacy, Fairness, and Ethics in Search Systems; Interpretability and Explainable Search Models.

Course Outcomes:

CO1	Understand IR concepts and components such as indexing, ranking, and document retrieval.
CO2	Apply vector space, probabilistic, and neural models to search tasks.
CO3	Design web-scale IR systems with effective crawling, compression, and duplicate removal.
CO4	Employ advanced IR techniques in domains like QA, semantic search, and RAG.
CO5	Evaluate IR systems using metrics like MAP, NDCG, and address fairness and privacy.

Textbooks:

1. Introduction to Information Retrieval, Manning, Raghavan, Schütze – Cambridge University Press.
2. Search Engines: Information Retrieval in Practice Croft, Metzler, Strohman – Pearson.
3. Modern Information Retrieval, Baeza-Yates, Ribeiro-Neto, Addison-Wesley.

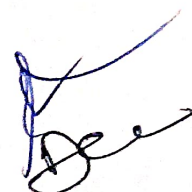
Reference Materials and Tools:

1. Research: NeurIPS, SIGIR, ACL, ArXiv IR Papers.
2. Datasets: MS MARCO, TREC, BEIR Benchmark, SQuAD.
3. Tools: Pyserini, Haystack, Elasticsearch, Faiss.
4. Frameworks: HuggingFace Transformers, OpenAI APIs, LangChain.
5. Online Platforms: PapersWithCode, HuggingFace Spaces, TensorBoard.dev.

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MAL -5106	Internet of Things (IoT)	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To introduce the foundational concepts and architecture of IoT systems.
CO2	To explore IoT hardware components, sensors, microcontrollers, and interfacing.
CO3	To analyze IoT communication protocols, networking models, and wireless technologies.
CO4	To evaluate IoT data handling, security measures, and edge/cloud integration.
CO5	To investigate practical applications of IoT in various domains and study emerging trends.

Unit I

Introduction to IoT: Definition, vision and characteristics of IoT; IoT architecture: perception, network, middleware, application, and business layers; IoT vs M2M vs CPS; IoT enabling technologies: RFID, WSN, cloud computing, AI, big data; Functional blocks of an IoT system; IoT ecosystems: stakeholders, business models, and value chains; Real-world use cases (overview): smart home, smart health, smart agriculture

Unit II

IoT Hardware, Devices, and Embedded Systems: Overview of IoT hardware platforms: Arduino, Raspberry Pi, ESP32, BeagleBone; Microcontrollers vs Microprocessors; Sensors: classification, working principles, interfacing examples (temperature, motion, humidity, gas, etc.); Actuators: types and interfacing; GPIO, ADC, DAC, timers, PWM; Interfacing protocols: UART, SPI, I2C; Low-power design and energy harvesting in IoT; Introduction to embedded operating systems (FreeRTOS, RIOT)

Unit III

Communication Protocols and Networking in IoT: Communication models: request-response, publish-subscribe, push-pull; Protocol stack: application, transport, network, link, physical; Application layer protocols: HTTP/HTTPS, MQTT, CoAP, XMPP, AMQP; Transport protocols: TCP, UDP; Network protocols: IPv4, IPv6, 6LoWPAN; Link/physical layer technologies: Zigbee, Bluetooth/BLE, Wi-Fi, LoRaWAN, NB-IoT, RFID, NFC; Network topologies in IoT: star, mesh, hybrid; IoT gateways and edge routers.

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Unit IV

IoT Data Management, Edge Computing and Security: Data acquisition and preprocessing; Time-series data and streaming analytics; Cloud-based IoT platforms: AWS IoT Core, Google Cloud IoT, Azure IoT Hub; Introduction to fog and edge computing; Edge analytics vs cloud analytics; Challenges in IoT data storage and retrieval; Security threats: physical, network, software; Encryption: symmetric, asymmetric, AES, RSA; Authentication and authorization protocols: OAuth, JWT; Privacy and ethical considerations; Introduction to blockchain in IoT for trust and traceability.

Unit V

Applications, Case Studies, and Future Trends: Smart home: automation, security, energy management; Industrial IoT (IIoT): predictive maintenance, digital twins; Smart cities: waste management, traffic control, water monitoring; Healthcare: wearable IoT, remote patient monitoring; Agriculture: precision farming, soil monitoring, irrigation systems; Logistics and supply chain: fleet tracking, RFID inventory systems; AI and machine learning in IoT: anomaly detection, edge intelligence; Sustainable IoT: green computing, energy-efficient networking; Open research challenges and emerging trends: interoperability, scalability, standardization, 6G and IoT convergence.

Course Outcomes:

CO1	Explain the layered architecture and building blocks of IoT systems.
CO2	Select and interface appropriate sensors, microcontrollers, and embedded platforms.
CO3	Apply suitable communication protocols and standards for different IoT use-cases.
CO4	Analyze the storage, analytics, and security aspects in IoT ecosystems.
CO5	Design application-specific IoT solutions and evaluate recent advancements.

Textbooks:

1. Internet of Things: A Hands-On Approach: Arshdeep Bahga & Vijay Madisetti – Universities Press
2. Internet of Things: Principles and Paradigms : Rajkumar Buyya, Amir Vahid Dastjerdi – Elsevier
3. IoT Fundamentals: Networking Technologies, Protocols and Use Cases : David Hanes et al. – Cisco Press

Reference Tools & Platforms:

1. Development Boards : Arduino, Raspberry Pi, ESP32.
2. Platforms : Node-RED, Blynk, ThingsBoard, AWS IoT, Google Cloud IoT
3. Simulators : Cisco Packet Tracer (IoT mode), IoT-LAB, Cooja
4. Communication Tools : Mosquitto MQTT broker, Wireshark

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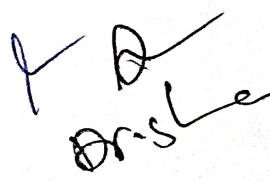
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MAL-5170	Deep Learning Lab	L-T-P: 0-0-2	Credits: 1
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Deep Learning Lab Practical Questions:

1. Implement Perceptron Learning Algorithm for binary classification
2. Build a Feedforward Neural Network for digit classification using MNIST dataset
3. Implement a Convolutional Neural Network (CNN) for image classification
4. Develop a Recurrent Neural Network (RNN) for text generation
5. Build an Autoencoder for image noise reduction or feature extraction
6. Perform sentiment analysis on movie reviews using word embeddings
7. Create a deep learning model for handwritten digit recognition using PyTorch
8. Train a CNN to detect cats vs. dogs
9. Implement a face mask detection system using MobileNet or a lightweight CNN
10. Apply Batch Normalization and Dropout in a neural network and compare

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MAL-5201	Optimization Techniques	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To provide a solid foundation in classical and modern optimization methods.
CO2	To introduce mathematical modeling for decision-making and real-world problem solving.
CO3	To analyze linear and nonlinear programming, integer programming, and constraint optimization.
CO4	To explore advanced techniques such as dynamic programming, evolutionary algorithms, and convex optimization.
CO5	To apply optimization strategies to machine learning, engineering design, and operational problems.

Unit I

Introduction to Optimization: Definition and types of optimization problems, Classification: linear, nonlinear, constrained, unconstrained, deterministic, stochastic, Optimization problem formulation, Applications in AI, engineering, economics, operations research, Optimality conditions and problem-solving strategies, Graphical method for 2-variable LP problems.

Unit II

Linear Programming and Duality: Linear programming formulation, Simplex method (standard and Big M method), Duality theory: primal-dual relationships, Dual simplex method, Sensitivity analysis and shadow prices, Revised simplex method (overview), Applications in supply chain and resource allocation.

Unit III

Nonlinear Programming (NLP): Unconstrained optimization: single-variable and multivariable problems, Constrained optimization with equality and inequality constraints, Karush–Kuhn–Tucker (KKT) conditions, Lagrange multipliers, Convex and non-convex optimization, Penalty and barrier methods, Numerical methods: gradient descent, Newton's method, trust region methods.

Unit IV

Dynamic Programming and Integer Programming: Bellman's principle of optimality, Forward and backward recursion, Applications in inventory control, shortest path, resource allocation, Integer programming: Branch and Bound, Cutting Plane method, 0–1 integer programming, Mixed-Integer Programming (MIP), Binary optimization in combinatorial problems.

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Unit V

Metaheuristics and Modern Techniques: Introduction to evolutionary and population-based optimization, Genetic Algorithms (GA): encoding, selection, crossover, mutation, Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Simulated Annealing and Tabu Search, Multi-objective optimization (Pareto front, NSGA-II), Convex optimization and interior point methods (overview), Optimization in ML: regularization, hyperparameter tuning, loss minimization.

Course Outcomes:

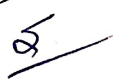
CO1	Formulate and solve optimization problems using appropriate techniques.
CO2	Apply simplex and duality methods in linear programming scenarios.
CO3	Solve nonlinear and constrained optimization problems analytically and numerically.
CO4	Use dynamic programming, evolutionary, and heuristic techniques in uncertain or multi-stage environments.
CO5	Implement optimization models for engineering, AI/ML, logistics, and decision sciences.

Textbooks:

1. Engineering Optimization: Theory and Practice, S.S. Rao – New Age International
2. Operations Research, H.A. Taha – Pearson
3. Introduction to Operations Research Hillier & Lieberman – McGraw Hill

Reference Books & Tools:

1. Modern Text Boyd & Vandenberghe – Convex Optimization (Cambridge)
2. Tools MATLAB, SciPy.optimize (Python), Pyomo, CVXPY
3. Applications ML/DL: TensorFlow, PyTorch (gradient-based optimization)
4. Online Optimization tutorials – NPTEL, MIT OCW, Stanford EE364a

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MAL-5202	Advanced Machine Learning	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To strengthen core ML concepts and extend knowledge to advanced supervised, unsupervised, and semi-supervised techniques.
CO2	To explore ensemble learning, structured prediction, and probabilistic graphical models.
CO3	To develop practical understanding of scalable ML using kernels, optimization, and model selection.
CO4	To introduce online learning, active learning, and reinforcement learning basics.
CO5	To understand and apply current research trends such as self-supervised, multi-task, and meta-learning.

Unit I

Advanced Supervised Learning: Review of basic ML algorithms, Bias-variance trade-off, model complexity, Ensemble methods: Bagging, Boosting (AdaBoost, Gradient Boosting), Stacking, Model calibration, class imbalance handling (SMOTE, cost-sensitive learning), Evaluation metrics: ROC, AUC, F1-score, confusion matrix, Regularization: L1, L2, ElasticNet.

Unit II

Kernel Methods and Support Vector Machines: Kernel trick and Mercer's theorem, Kernelized SVMs, hard/soft margin classifiers, Common kernels: polynomial, RBF, sigmoid, Model complexity and capacity (VC dimension), Support Vector Regression (SVR), Kernel PCA and applications, Hyperparameter tuning using cross-validation |

Unit III

Probabilistic Models and Graphical Models: Bayesian inference and MAP/MLE estimation, Naive Bayes, Bayesian networks, Hidden Markov Models (HMMs), Conditional Random Fields (CRFs), Variational inference (overview), EM Algorithm, Gaussian Mixture Models (GMM) and clustering, Latent Dirichlet Allocation (LDA).

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Unit IV

Unsupervised, Semi-supervised & Online Learning: Advanced clustering: spectral clustering, DBSCAN, Manifold learning (t-SNE, UMAP, Isomap), Dimensionality reduction: PCA, ICA, autoencoders, Semi-supervised learning techniques: self-training, label propagation, Online learning algorithms: Perceptron, Passive-Aggressive, Bandit algorithms, Active learning and sampling strategies, Streaming data and concept drift.

Unit V

Reinforcement and Meta Learning: Reinforcement learning basics: Markov Decision Processes (MDP), Q-learning, SARSA, policy gradients (overview), multi-armed bandits, Meta-learning model-agnostic meta-learning (MAML), Reptile, Few-shot learning, zero-shot learning, Self-supervised learning paradigms (SimCLR, BYOL), Multi-task and transfer learning concept.

Course Outcomes:

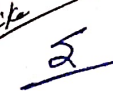
CO1	Apply and analyze advanced ML algorithms for classification, regression, and clustering.
CO2	Design robust predictive models using ensemble, probabilistic, and kernel methods.
CO3	Implement scalable ML solutions using dimensionality reduction and optimization tools.
CO4	Understand modern learning paradigms including online, active, and semi-supervised learning.
CO5	Explore current literature and apply meta-learning and self-supervised techniques to real-world problems.

Textbooks:

1. Pattern Recognition and Machine Learning, Christopher Bishop – Springer
2. Machine Learning: A Probabilistic Perspective, Kevin P. Murphy – MIT Press
3. Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow Aurélien Géron – O'Reilly

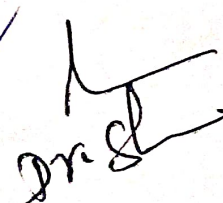
Reference Books & Resources:

1. Advanced Reference Deep Learning – Goodfellow, Bengio, Courville (MIT Press)
2. Libraries & Tools: Scikit-learn, XGBoost, LightGBM, CatBoost, PyTorch, TensorFlow, HuggingFace
3. Datasets: UCI ML Repository, Kaggle, OpenML, ImageNet, OpenAI Gym
4. Research: ArXiv preprints, NeurIPS, ICML, ICLR, JMLR papers

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MAL-5203	Cloud Computing and Blockchain Technology	L-T-P: 4-0-0	Credits: 4
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Course Objectives:

CO1	To provide a comprehensive understanding of cloud computing models, architecture, and services.
CO2	To introduce virtualization and containerization as enablers of scalable cloud platforms.
CO3	To explore the design and working of blockchain technology and its integration with cloud.
CO4	To understand consensus protocols, smart contracts, and distributed applications.
CO5	To analyze real-world applications of cloud and blockchain in industry, finance, and IoT.

Unit I

Introduction to Cloud Computing: Definition and characteristics of cloud computing, Evolution of cloud computing and comparison with traditional computing, Service models: IaaS, PaaS, SaaS, Deployment models: public, private, hybrid, community clouds, Cloud architecture: front-end, back-end, cloud storage, Benefits and challenges of cloud adoption, Case studies: AWS, Microsoft Azure, Google Cloud Platform.

Unit II

Virtualization and Containerization: Virtualization fundamentals: types, hypervisors (Type 1 and 2), Server, storage, and network virtualization, Virtual Machine Monitor (VMM), VirtualBox, VMware, KVM, Containerization: Docker architecture, containers vs VMs, Orchestration with Kubernetes: pods, deployments, services, Autoscaling, load balancing, and service discovery in containers, Cloud resource provisioning and management.

Unit III

Introduction to Blockchain Technology: Fundamentals of blockchain, structure of a block, linked blocks, Distributed ledger and peer-to-peer (P2P) networks, Hashing, digital signatures, Merkle trees, public vs private blockchain, permissioned vs permissionless blockchain, Blockchain platforms: Ethereum, Hyperledger Fabric, Corda, Applications in financial systems, supply chain, digital identity.

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Unit IV

Consensus Protocols and Smart Contracts: Consensus mechanisms: Proof of Work (PoW), Proof of Stake (PoS), Delegated PoS, BFT, Blockchain forks, transaction validation, mining and block rewards, Smart contracts: definition, lifecycle, advantages, Ethereum Virtual Machine (EVM), Solidity programming basics, Smart contract deployment and interaction, Security challenges in smart contracts: reentrancy, overflow, underflow, Introduction to Decentralized Applications (DApps).

Unit V

Integration, Applications and Research Trends: Integrating blockchain with cloud: benefits and challenges, Blockchain as a service (BaaS) platforms (AWS, IBM, Azure), Case studies: healthcare, IoT, energy grid, digital assets, NFTs, Edge computing and fog computing in cloud-blockchain ecosystems, Data privacy, scalability, and regulatory concerns, Research areas: interoperability, layer 2 protocols, zero-knowledge proofs (zk-SNARKs), CBDCs, Future trends: Web3, decentralized finance (DeFi), green blockchain.

Course Outcomes:

CO1	Explain the concepts, models, and architecture of cloud computing systems.
CO2	Apply virtualization and container orchestration in cloud platforms.
CO3	Understand the principles of blockchain, consensus algorithms, and distributed ledgers.
CO4	Implement smart contracts and DApps using platforms like Ethereum or Hyperledger.
CO5	Design use-cases integrating cloud and blockchain for scalable and secure applications.

Textbooks:

1. Cloud Computing: Principles and Paradigms Rajkumar Buyya, James Broberg, Andrzej Goscinski – Wiley.
2. Blockchain Basics: A Non-Technical Introduction Daniel Drescher – Apress.
3. Mastering Blockchain Imran Bashir – Packt Publishing.

Reference Books & Tools:

1. Cloud Platforms: AWS, Azure, Google Cloud, IBM Cloud
2. Virtualization: VirtualBox, Docker, Kubernetes, OpenStack
3. Blockchain Platforms Ethereum (Remix IDE), Ganache, MetaMask, Hyperledger Fabric
4. Research & Development: ArXiv, ACM Digital Library, IEEE Xplore
5. Programming Languages: Python, Solidity, YAML (Kubernetes), Shell scripting

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MAL-5204	Data Science	L-T-P: 3-0-0	Credits: 3
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Course Objective:

CO1	To understand the fundamental principles of data science and its application domains.
CO2	To provide proficiency in data handling, exploration, and preprocessing.
CO3	To apply statistical methods, machine learning, and data modeling techniques.
CO4	To equip students with tools for data visualization and communication of results.
CO5	To explore real-world applications and ethical considerations in data science.

Unit I

Introduction to Data Science: What is Data Science? Data science vs statistics vs machine learning, Data types: structured, semi-structured, unstructured, components of the data science lifecycle, CRISP-DM framework, Data-driven decision making, Applications: healthcare, finance, marketing, IoT, smart cities.

Unit II

Data Wrangling, Exploration, and Preprocessing: Data acquisition from files, APIs, databases, and web scraping, Data formats: CSV, JSON, XML, Excel, Handling missing data, outliers, and noise, Feature engineering: scaling, encoding, binning, transformation, Data integration and reduction, EDA: summary statistics, correlations, visualization with seaborn/matplotlib/plotly, Handling time-series and text data basics.

Unit III

Statistical Analysis and Machine Learning: Probability distributions and sampling, Hypothesis testing and confidence intervals, Correlation, regression, ANOVA, Machine learning pipeline overview, Supervised learning: linear/logistic regression, decision trees, k-NN, SVM, Unsupervised learning: k-means, DBSCAN, PCA, Cross-validation and model evaluation (precision, recall, F1, AUC).

Unit IV

Data Visualization and Communication: Principles of effective data visualization, Tools: Matplotlib, Seaborn, Plotly, Power BI, Tableau (overview), Dashboard creation and storytelling with data, Visualization types: heatmaps, boxplots, histograms, pair plots, bar charts, Reporting results with clarity and integrity, communicating uncertainty and limitations, Interactive plots using Plotly and Dash (intro).

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Unit V

Advanced Topics and Applications: Introduction to deep learning with TensorFlow/Keras (basic neural networks), Natural language processing (text classification, word clouds), Big data tools overview: Spark, Hadoop, PySpark (brief), Model deployment: Flask, FastAPI, Streamlit, Ethical issues: bias in data, privacy, responsible AI, Capstone project planning: end-to-end pipeline with dataset, model, evaluation, and report.

Course Outcome:

CO1	Understand the data science lifecycle, including acquisition, preparation, modeling, and evaluation.
CO2	Clean, preprocess, and explore structured and unstructured datasets effectively.
CO3	Apply supervised, unsupervised, and basic deep learning models to solve analytical problems.
CO4	Visualize and interpret data-driven results using industry-standard tools.
CO5	Work on end-to-end data science projects involving real-world datasets.

Textbooks:

1. Doing Data Science, Cathy O'Neil & Rachel Schutt – O'Reilly.
2. Python for Data Analysis, Wes McKinney – O'Reilly.
3. An Introduction to Statistical Learning, Gareth James et al. – Springer.

Reference Books & Tools:

1. Languages & Libraries: Python (pandas, numpy, scikit-learn, matplotlib, seaborn, plotly)
2. Visualization: Tableau Public, Power BI, Dash, Streamlit
3. ML/DS Platforms: Jupyter Notebooks, Google Colab, Kaggle
4. Datasets: UCI ML Repository, Kaggle, FiveThirtyEight, OpenML
5. Advanced Tools: PySpark, TensorFlow/Keras (basic), Flask/FastAPI (deployment)

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MAL-5205	Generative AI and Large Language Models (LLM)	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To understand the foundations and mathematical background of generative AI.
CO2	To explore generative models such as autoencoders, GANs, diffusion models, and transformers.
CO3	To study architectures and training techniques of Large Language Models (LLMs).
CO4	To apply LLMs to NLP tasks like text generation, summarization, code generation, and QA.
CO5	To understand ethical, legal, and societal implications of generative AI systems.

Unit I

Foundations of Generative AI: Discriminative vs generative models, Types of generative models: explicit, implicit, latent variable models, Mathematical background: probability distributions, KL divergence, entropy, ELBO, Maximum likelihood estimation (MLE), Bayesian inference, Applications of generative AI: image synthesis, text generation, code, audio, data augmentation.

Unit II

Deep Generative Models: Autoencoders and Variational Autoencoders (VAE), GANs: architecture, training dynamics, mode collapse, Types of GANs: DCGAN, CycleGAN, StyleGAN, conditional GANs, Diffusion models: Denoising Diffusion Probabilistic Models (DDPMs), Stable Diffusion, Comparison of VAE, GAN, Diffusion models for content generation.

Unit III

Introduction to Large Language Models (LLMs): Sequence modeling: RNN, LSTM, GRU (overview), Self-attention and Transformers, Transformer architecture (encoder, decoder, encoder-decoder), Pre-training and fine-tuning paradigm, Positional encoding, tokenization techniques (BPE, WordPiece), Introduction to BERT, GPT, T5, BART architectures.

Unit IV

Applications of LLMs: Text generation (GPT-2, GPT-3, GPT-4), Summarization and translation (T5, BART), Conversational AI and chatbots (ChatGPT, Claude), Code generation

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(Codex, CodeLLaMA), Prompt engineering and instruction tuning, Few-shot and zero-shot learning, in-context learning, Retrieval-Augmented Generation (RAG), tool use (LangChain, vector stores).

Unit V

Evaluation, Safety & Ethics: Evaluating generative models (BLEU, ROUGE, FID, perplexity, human eval), Bias, toxicity, hallucinations in LLMs, Adversarial prompting and prompt injection, Alignment techniques: RLHF (Reinforcement Learning with Human Feedback), Open vs closed LLMs (OpenAI, Anthropic, Meta, HuggingFace), Societal impact: misinformation, privacy, regulation, watermarking, Future trends: multimodal models (GPT-4V, Gemini), open-source LLMs, agent-based LLMs.

Course Outcome:

CO1	Explain the theory behind generative models and their role in AI.
CO2	Implement and experiment with architectures like GANs, VAEs, and diffusion models.
CO3	Understand and apply LLMs such as GPT, BERT, T5, and LLaMA.
CO4	Evaluate the capabilities and limitations of LLMs across diverse tasks.
CO5	Analyze and address the ethical concerns associated with generative AI and LLMs.

Textbooks and Reading Materials:

1. Deep Learning Ian Goodfellow, Yoshua Bengio, Aaron Courville – MIT Press.
2. The Deep Learning Revolution, Terrence J. Sejnowski – MIT Press.
3. Attention is All You Need, Vaswani et al., NeurIPS 2017.
4. GPT and Beyond, OpenAI technical blog, HuggingFace docs, arXiv papers.

Tools & Platforms:

1. Libraries: PyTorch, TensorFlow, HuggingFace Transformers, Diffusers.
2. APIs: OpenAI (ChatGPT, Codex), Anthropic (Claude), Cohere, LLaMA (Meta).
3. Platforms: Google Colab, Kaggle, HuggingFace Spaces, LangChain.
4. Datasets: Common Crawl, WikiText, C4, LAION, Stack Overflow.

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MAL-5271	Cloud Computing and Blockchain technology Lab	L-T-P: 0-0-4	Credits: 2
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Cloud Computing – Lab Practical's:

1. Launch and configure a virtual machine (VM) instance on a cloud platform (AWS EC2 / Google Cloud / Azure).
2. Deploy a simple web application on the cloud using PaaS (e.g., Heroku, Google App Engine, or AWS Elastic Beanstalk).
3. Set up a cloud-based storage bucket (AWS S3 / Google Cloud Storage) and perform file upload/download operations.
4. Create a serverless function using AWS Lambda / Google Cloud Functions to respond to HTTP events.
5. Demonstrate autoscaling and load balancing with two or more VM instances running a web server.
6. Write a simple smart contract using Solidity (e.g., "Hello Blockchain") and deploy it on Remix IDE (Ethereum test network).
7. Develop a basic smart contract for a voting system and test it on a local Ethereum blockchain using Ganache.
8. Demonstrate peer-to-peer transactions using MetaMask and a deployed smart contract.
9. Build a basic decentralized application (DApp) using Web3.js and connect it to the Ethereum blockchain.
10. Set up and simulate a private blockchain network using Hyperledger Fabric or Ganache CLI.

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MAL5160	Speech Processing	L-T-P: 3-0-0	Credits: 3
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Course Objective:

CO1	To introduce the fundamentals of human speech production and acoustic phonetics.
CO2	To analyze digital speech signals using time and frequency domain methods.
CO3	To develop algorithms for speech recognition, synthesis, and speaker identification.
CO4	To explore statistical and deep learning approaches in modern speech systems.
CO5	To understand applications of speech processing in real-world scenarios.

Unit I

Introduction to Speech and Phonetics: Human speech production mechanism, Acoustic phonetics: articulatory features, formants, Speech sounds: vowels, consonants, voiced/unvoiced speech, Speech signal characteristics: non-stationarity, coarticulation, Overview of speech applications: ASR, TTS, speaker ID, voice biometrics.

Unit II

Speech Signal Processing: Time-domain analysis: short-time energy, zero-crossing rate, Frequency-domain analysis: DFT, FFT, spectrograms, Windowing and framing, pre-emphasis, Cepstral analysis, Mel and Bark scale, Feature extraction techniques: MFCC, PLP, LPC, delta & delta-delta coefficients, Voice activity detection (VAD).

Unit III

Speech Modeling and Recognition: Hidden Markov Models (HMMs) for ASR, Gaussian Mixture Models (GMMs), Viterbi decoding, Baum-Welch training, Dynamic Time Warping (DTW), Phoneme, word, and sentence-level modeling, Acoustic model, language model, pronunciation dictionary, Evaluation metrics: WER, PER.

Unit IV

Deep Learning for Speech Processing: End-to-end ASR systems: CTC, attention-based models, Sequence-to-sequence models with RNN, LSTM, GRU, Transformer-based models for speech (e.g., Whisper, Wav2Vec2, Conformer), Pre-trained speech encoders: HuBERT, TERA, WavLM, Data augmentation techniques: SpecAugment, noise injection, Transfer learning and fine-tuning for low-resource speech.

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Unit V

Speech Synthesis, Speaker Systems & Applications: Text-to-Speech (TTS): formant synthesis, concatenative synthesis, parametric TTS, Deep learning-based TTS: Tacotron, WaveNet, FastSpeech, VITS, Speaker identification and verification systems, Emotion recognition, speaker diarization, Voice conversion and cloning, Open-source toolkits: Kaldi, ESPnet, DeepSpeech, Festival, Coqui, Applications: IVR, voice assistants, subtitle generation, accessibility tools.

Course Outcomes:

CO1	Explain the principles of speech production, perception, and linguistic structures.
CO2	Extract and process features from speech signals for various tasks.
CO3	Apply models for speech recognition, synthesis, and classification.
CO4	Design deep learning-based pipelines for end-to-end speech processing.
CO5	Evaluate speech systems using standard benchmarks and deploy them in practical domains.

Textbooks:

1. Fundamentals of Speech Recognition Lawrence Rabiner & Biing-Hwang Juang – Pearson.
2. Speech and Language Processing, Daniel Jurafsky & James H. Martin – Pearson.
3. Spoken Language Processing Xuedong Huang et al. – Prentice Hall.

Reference Tools & Resources:

1. Toolkits: Kaldi, ESPnet, DeepSpeech, Wav2Vec2 (HuggingFace), Tacotron, WaveGlow.
2. Libraries: Librosa, PyDub, torchaudio, SpeechBrain, Coqui TTS.
3. Datasets: LibriSpeech, Common Voice, TIMIT, VoxCeleb, TED-LIUM.
4. Papers & Benchmarks ACL, Interspeech, ICASSP, NeurIPS (ASR/TTS tracks).

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MAL5161	Distributed Machine Learning	L-T-P: 3-0-0	Credits: 3
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Course Objective:

CO1	To understand the need and challenges of scaling machine learning in distributed environments.
CO2	To explore architectures and frameworks for parallel and distributed ML.
CO3	To implement distributed optimization, parameter updates, and gradient aggregation.
CO4	To examine use cases of federated learning, edge ML, and large-scale model training.
CO5	To evaluate distributed systems for ML using cloud and cluster-based infrastructure.

Unit I

Introduction to Distributed Machine Learning: Motivation and applications, Limitations of traditional ML with big data, Basics of distributed systems: consistency, fault tolerance, scalability, Challenges in distributed ML: communication overhead, synchronization, fault tolerance, Data parallelism vs model parallelism, ML on GPUs, TPUs, clusters, and cloud environments.

Unit II

Distributed Data and Model Processing: Distributed data storage and partitioning, Distributed computing frameworks: Hadoop MapReduce, Apache Spark MLlib, Parameter servers and asynchronous SGD, Ring-allreduce, Horovod, NCCL for GPU clusters, Mini-batch gradient descent in distributed systems, Synchronous vs asynchronous updates, stale gradients, update delays.

Unit III

Distributed ML Algorithms and Optimization: Parallel SGD and its variants, Adaptive learning algorithms in distributed settings: AdaGrad, Adam, Federated averaging (FedAvg), gossip-based optimization, Communication-efficient ML: quantization, sparsification, compression, Elastic averaging SGD, decentralized optimization methods, Case studies: distributed training of SVMs, decision trees, deep neural networks.

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Unit IV

Federated Learning and Edge Intelligence: Concept and architecture of federated learning, Cross-device vs cross-silo training, Privacy-preserving training: differential privacy, secure aggregation, Heterogeneity and personalization in federated models, Challenges in edge-based ML: compute, latency, data drift, Use-cases: mobile personalization, healthcare, IoT devices.

Unit V

Infrastructure, Frameworks, and Case Studies: TensorFlow Distributed, PyTorch Distributed, Spark MLlib, Ray, Kubernetes, Docker, and container orchestration for ML deployment, AutoML in distributed setups, Cloud platforms: GCP Vertex AI, AWS SageMaker, Azure ML, Real-world applications: recommendation systems, fraud detection, speech processing, Benchmarking distributed training (MLPerf), Future trends: distributed reinforcement learning, large foundation models, LLM training pipelines.

Course Outcomes:

CO1	Explain core principles of distributed systems as applied to machine learning.
CO2	Implement scalable ML algorithms using parallelism and distributed optimization techniques.
CO3	Evaluate communication-efficient learning strategies across clusters and edge devices.
CO4	Understand tools such as Hadoop, Spark, TensorFlow, and PyTorch for large-scale ML.
CO5	Design and deploy distributed ML pipelines in real-world cloud-based or federated environments.

Textbooks & Reading Materials:

1. Machine Learning Systems: Design and Implementation, Jeff Smith – Manning.
2. Distributed Machine Learning: Foundations and Algorithms, Qiang Yang et al. – Morgan & Claypool.
3. Hands-On Distributed Computing with PySpark, Pramod Singh – Packt Publishing.

Tools & Platforms:

1. Distributed Frameworks: PyTorch Distributed, TensorFlow MultiWorker, Spark MLlib, Horovod.
2. Deployment & Orchestration Docker, Kubernetes, Ray, Dask.
3. Cloud Platforms: AWS SageMaker, GCP Vertex AI, Azure ML.
4. Datasets: ImageNet, OpenML, CIFAR-100, Reddit, StackOverflow (federated splits)
5. Papers & Benchmarks MLPerf, NeurIPS, ICLR, ArXiv (Federated ML & Distributed Optimization)

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MAL5162	Neuro-Fuzzy Systems	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To introduce fundamental concepts of fuzzy logic and neural networks.
CO2	To study architectures and learning algorithms for neural networks.
CO3	To explore fuzzy inference systems and fuzzy reasoning mechanisms.
CO4	To develop hybrid neuro-fuzzy systems for real-world applications.
CO5	To analyze the design, training, and optimization of neuro-fuzzy controllers.

Unit I

Introduction to Neural Networks: Biological motivation and artificial neurons, Types of neural networks: feedforward, feedback, recurrent, Activation functions: sigmoid, tanh, ReLU, Supervised learning: Perceptron, multilayer perceptron (MLP), backpropagation, Unsupervised learning: Hebbian learning, competitive learning, Self-Organizing Maps (SOMs) and Hopfield networks.

Unit II

Fuzzy Logic and Fuzzy Systems: Classical sets vs fuzzy sets, Fuzzy set theory: membership functions, fuzzification, defuzzification, Fuzzy rules and inference systems, Fuzzy operations: union, intersection, complement, Fuzzy implications and reasoning, Mamdani and Sugeno fuzzy models, Applications of fuzzy systems.

Unit III

Learning and Adaptation in Neural Networks: Error correction learning, Hebbian learning, Boltzmann learning, Gradient descent and backpropagation algorithm, Training and testing neural networks, Overfitting, underfitting, early stopping, regularization, Performance evaluation: accuracy, MSE, confusion matrix, Introduction to deep neural networks (overview only).

Unit IV

Adaptive Neuro-Fuzzy Inference Systems (ANFIS): Architecture of ANFIS, learning algorithms for ANFIS: hybrid learning (least squares + backpropagation), ANFIS training using

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data, Membership function tuning and optimization, Rule base generation from data, Comparison with pure NN and fuzzy systems, MATLAB-based implementation of ANFIS.

Unit V

Applications of Neuro-Fuzzy Systems: Control systems and system identification, Function approximation and time-series prediction, Pattern recognition and classification, medical diagnosis, fault detection, intelligent robotics, Decision support systems and expert systems, Case studies using real-world datasets, Challenges and recent research directions in neuro-fuzzy systems.

Course Outcomes:

CO1	Explain the theoretical background of fuzzy logic and neural network models.
CO2	Design and train neural networks using supervised and unsupervised learning.
CO3	Develop fuzzy inference systems using Mamdani and Sugeno models.
CO4	Implement adaptive neuro-fuzzy inference systems (ANFIS) for modeling and control.
CO5	Apply neuro-fuzzy models in classification, prediction, and intelligent control problems.

Textbooks:

1. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, J.-S. R. Jang, C.-T. Sun, E. Mizutani – Pearson.
2. Fuzzy Logic with Engineering Applications Timothy J. Ross – Wiley.
3. Neural Networks: A Comprehensive Foundation Simon Haykin – Pearson.

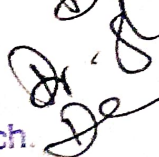
Tools & Platforms:

1. Simulation Tools: MATLAB Fuzzy Logic Toolbox, ANFIS Editor GUI.
2. Programming Python: (NumPy, SciPy, Scikit-fuzzy, PyTorch).
3. Visualization TensorBoard, Matplotlib, Seaborn.
4. Datasets: UCI ML Repository, Kaggle for classification/regression tasks
5. Research: IEEE Xplore, SpringerLink, Elsevier (Neurocomputing, Fuzzy Sets and Systems)

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MAL5163	Quantum Computing	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To introduce the principles of quantum mechanics underlying quantum computation.
CO2	To understand quantum gates, circuits, and computational models.
CO3	To study key quantum algorithms like Deutsch-Jozsa, Grover's, and Shor's algorithm.
CO4	To explore concepts of quantum information theory, quantum cryptography, and quantum error correction.
CO5	To analyze the differences between classical and quantum computation, and their practical implications.

Unit I

Fundamentals of Quantum Mechanics: Introduction to quantum computation, Qubits and quantum states, Dirac notation, superposition and entanglement, Bloch sphere representation, Quantum measurement and postulates, Unitary transformations, Classical vs quantum information.

Unit II

Quantum Circuits and Gates: Quantum logic gates: X, Z, H, S, T, Y gates Multi-qubit gates: CNOT, Toffoli, SWAP, controlled gates, Quantum circuit model, Circuit equivalence and simplification, No-cloning theorem, Quantum parallelism and measurement collapse, Introduction to IBM Qiskit, QcTIP for simulation.

Unit III

Quantum Algorithms: Deutsch and Deutsch-Jozsa algorithm, Bernstein-Vazirani algorithm, Simon's algorithm, Grover's quantum search algorithm, Shor's algorithm for integer factorization, Quantum Fourier Transform (QFT), Complexity classes: P, NP, BQP, and their relevance.

Unit IV

Quantum Information and Cryptography: Quantum entropy and von Neumann entropy, Bell states and entanglement, Quantum teleportation, Superdense coding, Quantum key distribution (QKD): BB84 protocol, Quantum coin flipping and bit commitment, Quantum communication protocols.

Unit V

Quantum Error Correction and Current Research: Introduction to quantum noise and decoherence, Shor's 9-qubit code, Bit-flip, phase-flip, and combination error models, Stabilizer codes and CSS codes, Fault-tolerant quantum computation, Quantum supremacy and NISQ devices, Trends in quantum computing platforms (IBM, Google, Rigetti, IonQ), Introduction to quantum machine learning (overview).

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Course Outcomes:

CO1	Understand and apply the postulates of quantum mechanics to quantum computing.
CO2	Design and simulate quantum circuits using basic and advanced quantum gates.
CO3	Implement and analyze key quantum algorithms for search and factoring problems.
CO4	Explain quantum entanglement, teleportation, and no-cloning theorem.
CO5	Examine challenges in quantum error correction and the future scope of quantum computing.

Textbooks:

1. Quantum Computation and Quantum Information, Michael A. Nielsen & Isaac L. Chuang – Cambridge University Press.
2. Quantum Computing: An Applied Approach Jack D. Hidary – Springer.
3. Quantum Computing Explained, David McMahon – Wiley IEEE Press.

Tools & Platforms:

1. Quantum Simulators: IBM Qiskit, Google Cirq, Microsoft Q#, QuTiP.
2. Platforms: IBM Quantum Experience, Braket (AWS), Xanadu's Strawberry Fields.
3. Programming: Python, Jupyter Notebook, QASM.
4. Learning Resources: Qiskit Textbook, MIT OCW, edX Quantum Courses, ArXiv.org.

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MAL5260	Biomedical Image Processing	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To understand the fundamentals of digital image processing and its applications in biomedical domains.
CO2	To study various medical imaging modalities like MRI, CT, and ultrasound.
CO3	To apply image enhancement, segmentation, and feature extraction techniques to biomedical data.
CO4	To develop algorithms for analysis, classification, and visualization of medical images.
CO5	To explore deep learning approaches in medical image interpretation and diagnostics.

Unit I

Introduction to Biomedical Imaging: Biomedical image formation principles, Overview of medical imaging modalities: X-Ray, CT, MRI, Ultrasound, PET, SPECT, Characteristics of biomedical images, Noise sources and acquisition challenges, DICOM format and PACS systems, Applications of biomedical imaging in diagnosis and therapy.

Unit II

Image Preprocessing and Enhancement: Image representation, resolution, histograms, point processing: contrast stretching, histogram equalization, Spatial filtering: smoothing, sharpening filters, Frequency domain filtering: DFT, FFT, Butterworth, Gaussian, Noise reduction: median, bilateral filters, Edge detection: Sobel, Prewitt, Canny, Intensity transformations specific to CT and MR data.

Unit III

Image Segmentation and Feature Extraction: Thresholding: global, local, Otsu's method, Region-based segmentation: region growing, watershed, Edge-based segmentation: active contours, snakes, Morphological operations: dilation, erosion, opening, closing, Texture analysis: GLCM, LBP, Shape-based descriptors, statistical and structural features, Feature selection and dimensionality reduction (PCA, LDA).

Unit IV

Image Registration and Classification: Image registration: rigid, affine, elastic registration, Mutual information, feature matching, landmark detection, Classification techniques: k-NN, SVM, decision trees, Performance evaluation: ROC, AUC, sensitivity, specificity, 3D reconstruction from 2D slices, Image fusion techniques for multimodal analysis.

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Unit V

Deep Learning in Medical Imaging: CNN architecture for image classification and segmentation, medical image datasets: NIH ChestX-ray, BraTS, ISIC, LUNA16, U-Net, ResNet, V-Net for biomedical segmentation, Transfer learning and data augmentation, Explainable AI in healthcare: Grad-CAM, SHAP, Challenges in AI for healthcare: interpretability, bias, regulation. Case studies: tumor detection, organ segmentation, disease diagnosis.

Course Outcomes:

CO1	Explain the characteristics of biomedical images and the fundamentals of medical imaging systems.
CO2	Implement preprocessing and enhancement techniques suitable for medical images.
CO3	Apply segmentation and feature extraction to detect anomalies in medical data.
CO4	Analyze and classify biomedical images using ML/DL techniques.
CO5	Design and evaluate complete biomedical image processing pipelines for specific clinical tasks.

Textbooks:

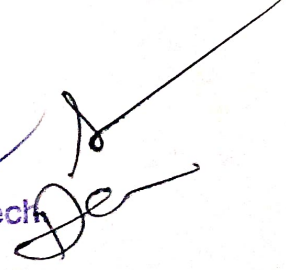
1. Digital Image Processing, Rafael C. Gonzalez & Richard E. Woods – Pearson.
2. Medical Image Processing, Reconstruction and Analysis Jiri Jan – CRC Press.
3. Biomedical Image Analysis Rangaraj M. Rangayyan – CRC Press.

Reference Tools & Platforms:

1. Programming: Python (OpenCV, NumPy, SciPy, PyTorch, TensorFlow, MONAI)
2. Libraries: SimpleITK, scikit-image, Pydicom, ITK-Snap
3. Visualization: Matplotlib, VTK, 3D Slicer
4. Datasets: TCIA, NIH ChestX-ray14, BraTS, ISIC, DRIVE (retinal images)
5. Research: IEEE Transactions on Medical Imaging, MICCAI, Nature Biomedical Engineering:

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MAL5261	Cognitive Systems	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To understand the fundamentals of cognition and cognitive modeling.
CO2	To explore theories of perception, learning, memory, and reasoning in human and artificial systems.
CO3	To study computational models and architectures for simulating human-like intelligence.
CO4	To integrate AI, machine learning, and neuroscience concepts into cognitive computing systems.
CO5	To examine applications of cognitive systems in robotics, NLP, decision-making, and healthcare.

Unit I

Introduction to Cognitive Science and Systems: Overview of cognition: perception, attention, memory, learning, reasoning, Interdisciplinary nature: AI, neuroscience, psychology, linguistics, philosophy, Cognition in human's vs machines, Emergence of cognitive systems in computing, Key components: sensory processing, representation, decision making, Applications in assistive tech, robotics, and intelligent agents.

Unit II

Models of Cognitive Processes: Cognitive architectures: SOAR, ACT-R, CLARION, Symbolic vs sub-symbolic representations, Production systems and rule-based reasoning, Working memory and long-term memory modeling, Perception models (visual, auditory, multimodal), Attention mechanisms in biological and computational systems.

Unit III

Learning and Adaptation in Cognitive Systems: Learning paradigms: supervised, unsupervised, reinforcement learning, Hebbian learning and neuroplasticity, Concept learning, generalization, analogy-making, Adaptive systems and feedback mechanisms, Cognitive maps and schema theory, Human-like learning in neural-symbolic systems.

Unit IV

Machine Learning for Cognitive Computing: Deep learning and cognitive representations, Neuro-symbolic AI: integration of logic and learning, Explainable AI in cognitive systems,

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Language understanding: parsing, semantics, and pragmatics, Cognitive NLP: conceptual spaces, grounding language in perception, Decision-making under uncertainty (Bayesian cognition, fuzzy logic).

Unit V

Applications and Future Directions: Human-computer interaction (HCI) and user modeling, Emotion-aware cognitive systems, Cognitive robotics and embodied intelligence, Brain-computer interface (BCI) systems, Cognitive agents in education, defense, and therapy, Ethical issues in cognitive system design, Research trends: digital twins, cognitive IoT, neuro-symbolic reasoning.

Course Outcomes:

CO1	Explain the basic principles of human cognition and their relevance to intelligent systems.
CO2	Model cognitive tasks using symbolic and sub-symbolic approaches.
CO3	Design systems that exhibit perception, reasoning, and adaptive learning.
CO4	Apply machine learning and neuro-symbolic methods in cognitive simulations.
CO5	Evaluate cognitive architectures in real-world applications such as robotics and decision support.

Textbooks:

1. Cognitive Science: An Introduction to the Study of Mind, Jay Friedenberg & Gordon Silverman – Sage Publications.
2. Artificial Cognitive Systems David Vernon – MIT Press.
3. The Cambridge Handbook of Artificial Intelligence Keith Frankish, William M. Ramsey – Cambridge University Press.

Reference Tools & Resources:

1. Cognitive Frameworks: ACT-R, SOAR, OpenCog, Spaun.
2. Programming : Python (TensorFlow, PyTorch, NLTK, spaCy), Prolog.
3. Simulation: OpenAI Gym, CARLA, AirSim, ROS (for cognitive robotics).
4. Research Papers, NeurIPS, AAAI, IJCAI, Cognitive Science Journal, Cognitive Computation.

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MAL5262	High Performance Computing (HPC)	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To introduce the fundamentals of parallel and high-performance computing.
CO2	To study the architectures and performance aspects of shared and distributed memory systems.
CO3	To explore various models and programming paradigms used in HPC, such as MPI, OpenMP, and CUDA.
CO4	To understand parallel algorithm design, scalability, and optimization techniques.
CO5	To develop and analyze HPC applications for real-world scientific and engineering problems.

Unit I

Introduction to HPC and Parallel Computing: Motivation and applications of HPC, Flynn's taxonomy (SISD, SIMD, MISD, MIMD), Types of parallelism: data, task, instruction-level, HPC architectures: multicore, SMP, MPP, clusters, grids, and cloud-based HPC, Amdahl's Law and Gustafson's Law, Speedup, efficiency, scalability, and performance bottlenecks.

Unit II

Shared Memory Programming (OpenMP): Introduction to multithreading and shared memory, OpenMP directives, parallel regions, work sharing, synchronization, Critical sections, barriers, and reductions, Loop parallelism and nested parallelism, Performance tuning and profiling in OpenMP, Case studies using OpenMP in scientific computing.

Unit III

Distributed Memory Programming (MPI): Introduction to message passing paradigm, MPI environment and basic communication functions, Point-to-point and collective communication, Synchronous vs asynchronous communication, Derived data types, communicators, and topology, Deadlocks and debugging MPI programs, Performance considerations and hybrid (MPI+OpenMP) models.

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Unit IV

GPU Computing and CUDA Programming: GPU architecture and memory hierarchy, CUDA programming model: kernels, threads, blocks, and grids, Memory management: shared, global, constant, and texture memory, Synchronization and thread divergence, Performance optimization in CUDA, Comparison of CUDA with OpenCL, Applications in image processing, matrix computations.

Unit V

Performance Analysis, Parallel Algorithms & Case Studies: Tools for performance profiling: gprof, nvprof, perf, Intel VTune, Cache coherence and memory consistency, Parallel algorithms: prefix sum, matrix multiplication, FFT, sorting, Load balancing and scheduling strategies, Real-world HPC applications in weather forecasting, bioinformatics, physics, and ML, Introduction to HPC clusters and job schedulers (SLURM, PBS), Exascale computing and future trends in HPC.

Course Outcomes:

CO1	Understand the architecture of modern HPC systems and classify types of parallelism.
CO2	Implement parallel programs using MPI, OpenMP, and GPU-based computing.
CO3	Analyze performance metrics and optimize parallel programs for efficiency.
CO4	Design scalable algorithms suitable for distributed and heterogeneous environments.
CO5	Apply HPC techniques to solve large-scale computational problems in various domains.

Textbooks:

1. Introduction to High Performance Computing for Scientists and Engineers Georg Hager & Gerhard Wellein – CRC Press.
2. Parallel Programming in C with MPI and OpenMP Michael J. Quinn – McGraw Hill.
3. CUDA by Example: An Introduction to General-Purpose GPU Programming Jason Sanders, Edward Kandrot – Addison-Wesley.

Tools & Platforms:

1. Parallel Programming: OpenMP, MPI, CUDA, OpenACC.
2. Profiling Tools: gprof, nvprof, Nsight, Intel VTune, Valgrind.
3. Libraries: BLAS, LAPACK, cuBLAS, Thrust, FFTW.
4. Platforms: Linux HPC clusters, NVIDIA GPUs, Cloud-based HPC (AWS ParallelCluster, Azure Batch).
5. Languages: C/C++, Python (mpi4py, numba.cuda), Fortran.

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MAL5263	Computer Vision	L-T-P: 3-0-0	Credits: 3
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Course Objectives:

CO1	To introduce the fundamental concepts and mathematical techniques of computer vision.
CO2	To study classic image processing techniques and 2D/3D vision models.
CO3	To implement vision algorithms for object detection, recognition, and tracking.
CO4	To explore the integration of deep learning into vision applications.
CO5	To analyze and evaluate performance of vision systems in real-world scenarios.

Unit I

Introduction and Image Formation: Introduction to computer vision and its applications, Digital image formation and camera models, imaging geometry: pinhole camera, perspective projection, Color models: RGB, HSV, Lab, Image sampling, quantization, and transformations, Image filtering: convolution, smoothing, sharpening, Gaussian, Laplacian filters, edge detection (Sobel, Canny).

Unit II

Feature Detection and Matching: Interest point detection: Harris, FAST, Corner detection, Blob detection (LoG, DoG), Feature descriptors: SIFT, SURF, ORB, Feature matching: distance metrics, RANSAC, Homography and geometric transformations, Camera calibration and stereo vision basics, Epipolar geometry and fundamental matrix.

Unit III

Segmentation, Recognition, and Tracking: Thresholding, region growing, graph-based segmentation, Watershed segmentation and GrabCut, Contour detection and shape analysis, Object detection and recognition (traditional methods), Object tracking: optical flow, Kalman filter, mean-shift, Background subtraction and motion segmentation.

Unit IV

Deep Learning in Vision: Introduction to CNNs: architecture and components, Popular models: LeNet, AlexNet, VGG, ResNet, Inception, Object detection: R-CNN, Fast R-CNN, Faster R-CNN,

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YOLO, SSD, Semantic and instance segmentation: FCN, U-Net, Mask R-CNN, Transfer learning and fine-tuning, Data augmentation and preprocessing for DL-based CV tasks.

Unit V

Applications and Emerging Topics: Face detection and recognition systems, Human pose estimation, Image captioning and scene understanding, 3D vision: structure from motion, depth estimation, point clouds, medical image analysis, autonomous driving, industrial inspection, Vision transformers and diffusion models (overview), Challenges: occlusion, illumination, dataset bias, fairness in vision.

Course Outcomes:

CO1	Understand and apply image processing techniques for feature extraction.
CO2	Develop algorithms for image segmentation, motion analysis, and object recognition.
CO3	Work with 2D and 3D geometry in computer vision.
CO4	Build deep learning-based solutions using CNNs for image classification and detection.
CO5	Evaluate and improve vision algorithms using standard benchmarks and metrics.

Textbooks:

1. Computer Vision: Algorithms and Applications, Richard Szeliski – Springer.
2. Multiple View Geometry in Computer Vision, Richard Hartley, Andrew Zisserman – Cambridge.
3. Deep Learning for Computer Vision Rajalingappaa Shanmugamani – Packt Publishing.

Tools & Platforms:

1. Programming: Python (OpenCV, scikit-image, PIL).
2. Deep Learning: PyTorch, TensorFlow, Keras, Detectron2, YOLOv8.
3. Datasets: COCO, ImageNet, Pascal VOC, LFW, KITTI.
4. Evaluation: IoU, mAP, Precision-Recall, confusion matrix.
5. Applications: OpenCV, MediaPipe, RoboFlow, NVIDIA DeepStream.

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MAL5360	Deep Reinforcement Learning	L-T-P: 2-0-0	Credits: 2
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Course Objectives:

CO1	Understand foundational RL principles including MDPs, value functions, and the RL paradigm.
CO2	Gain hands-on experience implementing both tabular and function approximation RL methods.
CO3	Explore deep reinforcement learning architectures including DQN, policy gradients, and actor-critic models.
CO4	Understand the role of exploration, variance reduction, and stability in training RL agents.
CO5	Analyze and apply RL in real-world environments including robotics, simulation, and games.

Unit I

Reinforcement Learning Foundations: Introduction to RL vs supervised/unsupervised learning, Components of RL: agents, environments, actions, states, rewards, Episodic vs continuing tasks, Bellman equations for state-value and action-value functions, Exploration strategies: ϵ -greedy, Boltzmann, UCB, Thompson sampling, Case study: GridWorld and FrozenLake environments (OpenAI Gym).

Unit II

Model-Free Control and Temporal Difference Learning: TD (0), TD(λ), and n-step bootstrapping, Batch learning vs online learning, Q-learning and SARSA (on-policy vs off-policy learning), Exploration vs exploitation trade-offs, Limitations of tabular methods in large state spaces, Function approximation: linear and non-linear (with neural nets), Case study: Cliff Walking, Taxi-V2, MountainCar.

Unit III

Deep Q-Networks (DQN) and Variants: Vanilla DQN architecture: input encoding, Q-function approximator, Instability problems in Q-learning with function approximation, Experience replay buffer design, Target network and soft updates, Extensions: Double DQN, Dueling DQN, Prioritized Experience Replay (PER), NoisyNet exploration, Rainbow DQN (combining all variants), Case study: CartPole, Atari Pong.

Unit IV

Policy Optimization and Actor-Critic Algorithms: Stochastic vs deterministic policies, REINFORCE algorithm with baseline, Variance reduction with advantage functions, Actor-Critic

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framework, A2C vs A3C: synchronous vs asynchronous, PPO: clipped surrogate loss, DDPG (Deep Deterministic Policy Gradient), TD3 (Twin Delayed DDPG), Soft Actor-Critic (SAC) for continuous action spaces, Case study: Bipedal Walker, MuJoCo Humanoid.

Unit V

Advanced Topics and Applications: Reward shaping and curriculum learning, Imitation Learning and Behavioral Cloning, Multi-agent Reinforcement Learning (MARL), Hierarchical RL and Options framework, Inverse RL and preference learning, Meta-RL and few-shot RL, Offline RL: Batch-Constrained Q-Learning (BCQ), CQL, Applications: Game playing (Atari, AlphaZero, Dota 2), Autonomous vehicles and drones, Robotics manipulation, financial trading strategies.

Course Outcomes:

CO1	Explain and implement foundational RL algorithms from scratch.
CO2	Use deep learning models to approximate policies and value functions.
CO3	Design reward functions and explore strategies to handle sparse and delayed rewards.
CO4	Evaluate and optimize agents using techniques like PPO, DDPG, and SAC.
CO5	Apply DRL to simulation platforms such as Gym, MuJoCo, or Unity ML-Agents.

Textbooks:

1. Reinforcement Learning: An Introduction (2nd Edition), Sutton & Barto – MIT Press.
2. Deep Reinforcement Learning Hands-On, Maxim Lapan – Packt Publishing.
3. Grokking Deep Reinforcement Learning, Miguel Morales – Manning.

Reference Materials and Tools:

1. Frameworks: TensorFlow, PyTorch, Keras-RL, Stable-Baselines3, RLlib.
2. Environments: OpenAI Gym, MuJoCo, Unity ML-Agents, CARLA, Roboschool.
3. Visualization: TensorBoard, Matplotlib, Weights & Biases.
4. Practice Platforms: Coursera DRL Specialization (DeepMind), RL Zoo, HuggingFace Datasets.

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MAL5361	Computational Learning Theory	L-T-P: 2-0-0	Credits: 2
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Course Objectives:

CO1	To understand formal models of machine learning and their theoretical foundations.
CO2	To analyze what makes a concept class learnable and what limits learning.
CO3	To explore complexity measures like VC-dimension, Rademacher complexity, and margins.
CO4	To study the connections between learning theory, optimization, and generalization.
CO5	To analyze and compare the learnability of different algorithms under various models.

Unit I

Introduction to Learning Models: Overview of computational learning theory, Formalizing the learning problem, Types of learning: supervised, online, statistical, active learning, Notion of concepts, hypotheses, labels, and instances, Deterministic vs probabilistic learning, Consistency and realizability assumption.

Unit II

PAC Learning Framework: Probably Approximately Correct (PAC) model, Sample complexity for finite hypothesis spaces, Union bound and Hoeffding's inequality, Agnostic PAC learning and realizable PAC learning, Learning conjunctions, decision lists, Limitations of PAC model.

Unit III

VC Dimension and Capacity Control: Vapnik-Chervonenkis (VC) dimension, Sauer's Lemma and shattering coefficient, Structural Risk Minimization (SRM), Examples: VC-dimension of linear classifiers, axis-aligned rectangles, Generalization bounds with VC dimension, Rademacher complexity and covering numbers.

Unit IV

Online and Margin-Based Learning: Online learning model and mistake bounds, Halving algorithm, Perceptron convergence theorem, Winnow and regret analysis, Large-margin classifiers: motivation and generalization, Support Vector Machines (SVM) theory, Kernel trick and dual representations.

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Unit V

Advanced Topics and Limitations of Learnability: Boosting and weak learnability (AdaBoost theory), No Free Lunch Theorem, Hardness of learning: cryptographic assumptions, Compression schemes and sample compression bounds, Learning deep neural networks: generalization and complexity (overview), Open questions in learning theory and recent trends.

Course Outcomes:

CO1	Explain key theoretical frameworks like PAC learning, VC dimension, and uniform convergence.
CO2	Analyze sample complexity and its dependence on the hypothesis class.
CO3	Understand bounds for generalization and overfitting using complexity measures.
CO4	Apply learning theory to evaluate real-world algorithms (SVM, boosting, deep nets).
CO5	Examine limitations of learning under computational and statistical constraints.

Textbooks & Readings:

1. Understanding Machine Learning: From Theory to Algorithms: Shai Shalev-Shwartz, Shai Ben-David – Cambridge University Press.
2. Foundations of Machine Learning: Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar – MIT Press.
3. An Introduction to Computational Learning Theory: Michael Kearns & Umesh Vazirani – MIT Press.

Reference Tools & Resources:

Category	Resources
Notes	Shai Ben-David's Lecture Notes, MIT OCW (6.86x), CMU Learning Theory Slides.
Exercises	COLT Conference Papers, UCI Datasets for empirical testing.
Tools	Python, Jupyter Notebooks, scikit-learn (for empirical generalization testing).

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