

M. Sc. (AI & ML)

Course Structure & Detailed Syllabi

Department of Computer Science

Faculty of Sciences

Jamia Millia Islamia

New Delhi - 110025, India

Curriculum: M.Sc. (Artificial Intelligence & Machine Learning)-2023

HIGHLIGHTS		
A.	Motivation	<ul style="list-style-type: none"> • Rapidly changing academic and technological scenarios around the world. • Conformance to UGC, AICTE, NEP, and JMI ordinances guidelines. • Keeping abreast with the current and future industrial skill-set requirements, and placement-related tests. • Utilization of available faculty expertise/strength for the benefit of students. • Imminent revision on observations of FM, students and other stakeholders.
B.	Bases and Constraints	<ul style="list-style-type: none"> • Keeping an enhanced set of Core, and Elective courses. • All elective courses are to be open subject to availability of faculty from department or outside.
C.	Course Codes	Unique code to be assigned to each of the typical courses, offered by the Department using the following coding scheme: <ul style="list-style-type: none"> • Core courses (Program-Specific): MS • Computer Science (Elective): CS
D.	Course L-T-P	<ul style="list-style-type: none"> • Theory Courses: 3-1-0/Lab Courses: 0-0-4/Elective Courses: 3-1-0 • Minor Project: 0-1-6/Major Project: 0-4-20
E.	Special Considerations	<ul style="list-style-type: none"> • Accommodation of Computer Science, supportive mathematical and interdisciplinary courses. • Applied computing and the professional nature of the program. • Balancing academic, technological, and industrial imperatives/prospects.
F.	Better Skilling	<ul style="list-style-type: none"> • PG Programs: Dedicated (Lab-courses-6, Minor-Project-1 & Major Project-1).
J.	Evaluation	<ul style="list-style-type: none"> • Internal Assessment: According to the ordinance's provisions, internal assessment will be 40% weightage and semester exam will have a weightage of 60%. Internal assessment will be awarded by conducting two mandatory tests. • Semester examination (except UG courses): Duration for Theory exam will be 3 hours and Lab exam shall be 4 hours.
K.	Seats/Eligibility	<ul style="list-style-type: none"> • M. Sc. (AI & ML): 40 (Forty Seats) • Eligibility: Bachelor's Degree with at least 50% Marks or Equivalent Grade OR Equivalent with Mathematics at 10+2 Level.
L.	Entrance Test	<ul style="list-style-type: none"> • Duration: 120 Minutes (100 MCQs) • Distribution: (10+2 Maths-50%+Computer Science-30%+ Reasoning-20%)
M.	Annual Fee	<ul style="list-style-type: none"> • As this course is being offered in Self-financing mode, a fee of Rs. 50,000 per Annum per student will be charged.
N.	Remarks	<ol style="list-style-type: none"> 1. Students are encouraged to register in courses of their interest/specialization from the bucket list of Electives. 2. Students interested in web developer profile may opt elective on programming with Java in second semester, and then J2EE in third semester. 3. Students interested in security profile may opt cyber security in second semester, and then ethical hacking in third semester. 4. Lab and project courses shall have independent practical and viva-voce examinations. 5. Department may float any other elective, beyond the listed ones, subject to demand, feasibility and approved by BOS.

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MSc (AI & ML): Program Structure-2024					
SEM	CODE	COURSE TITLE	L-T-P	CR	SUMMARY
I	MS11	Foundations of Data Science with Python	3-1-0	4	Periods: 28 Credits: 24
	MS12	Digital Logic and Computer Architecture	3-1-0	4	
	MS13	Data Warehousing & Data Mining	3-1-0	4	
	MS14	Mathematical Foundations for AI	3-1-0	4	
	MS15	Database Management Systems	3-1-0	4	
	MS16	Lab-I (Python)	0-0-4	2	
	MS17	Lab-II (Oracle)	0-0-4	2	
II	MS21	Data Communication & Networks	3-1-0	4	Periods: 28 Credits: 24
	MS22	Artificial Intelligence & Machine Learning	3-1-0	4	
	MS23	Data Structures	3-1-0	4	
	CS24	Elective-I (Data Analytics and Predictive Modelling)	3-1-0	4	
	CS25	Elective-II (Applied Statistics)	3-1-0	4	
	MS27	Lab-III (ML)	0-0-4	2	
	MS28	Lab-IV (Data Structures)	0-0-4	2	
III	MS31	Cloud Computing	3-1-0	4	Periods: 28 Credits: 24
	MS32	Deep Learning	3-1-0	4	
	MS33	Minor Project	0-1-6	4	
	CS34	Elective-III (IOT and Big Data)	3-1-0	4	
	CS35	Elective-IV (MLOps and DevOps)	3-1-0	4	
	MS36	Lab-V (Deep Learning)	0-0-4	2	
	MS37	Lab-VI (Hadoop)	0-0-4	2	
IV	MS41	Major Project	0-4-20	14	Credits: 14
M.Sc. (AI & ML) Program Summary: Courses [Th (15) + Labs(6) + MP (1) + MP(1)] =25				Total Credits=86	
Elective Courses					
II	CS24.1	Data Reduction & Visualization	3-1-0	4	
	CS24.2	Software Engineering	3-1-0	4	
	CS24.3	Compiler Design	3-1-0	4	
	CS24.4	Applied Statistics	3-1-0	4	
	CS24.5	Operating Systems and Shell programming	3-1-0	4	
	CS24.6	Advanced DBMS	3-1-0	4	
	CS25.1	Mobile Application Development	3-1-0	4	
	CS25.2	Modelling and Simulation	3-1-0	4	
	CS25.3	Digital Image Processing	3-1-0	4	
	CS25.4	Information & Data Security	3-1-0	4	
	CS25.5	Programming with Java	3-1-0	4	
	CS25.6	Data Analytics and Predictive Modelling	3-1-0	4	
III	CS34.1	Software Project Management	3-1-0	4	
	CS34.2	IOT and Big Data	3-1-0	4	
	CS34.3	IPR & Ethical Hacking	3-1-0	4	
	CS34.4	Soft Computing	3-1-0	4	
	CS34.5	Cyber Security	3-1-0	4	
	CS34.6	Analysis and Design of Algorithms	3-1-0	4	
	CS35.1	Web development with J2EE	3-1-0	4	
	CS35.2	Business Intelligence	3-1-0	4	
	CS35.3	Cryptography & Network Security	3-1-0	4	
	CS35.4	Systems Programming	3-1-0	4	
	CS35.5	AR & VR	3-1-0	4	
	CS35.6	NLP with Deep Learning	3-1-0	4	
CS35.7	Software Architecture	3-1-0	4		
CS35.8	Software Testing & Quality Assurance	3-1-0	4		

** Approved elective courses as per the Department/University guidelines.

M.Sc. (AI & ML) Program: Detailed Syllabi

Semester I

MS11: Foundations of Data Science with Python
<p>Learning Outcomes:</p> <ul style="list-style-type: none"> • Comprehension of fundamental concepts of data science • Python foundations and programming • Data handling with Python • Understanding various machine learning libraries used in the data science processes • Visualization and presentation of the inference using various Python libraries
<ol style="list-style-type: none"> 1. Data Science Overview: Data Science life cycle; data acquisition, public data repositories, pre-processing, data visualization, Machine Learning algorithms, pattern evaluation, knowledge representation, analytical strategies; Python fundamentals: data types, mutable & immutable types, operators & expressions, standard library modules, the flow of control, etc. 2. Python data structures: String manipulation: string operators, slices, methods; List manipulation: creating & accessing the list, list operations, true copy of lists, nested lists; Tuples: creation, accessing, modifying tuples, nested tuples, methods & functions, tuple slicing; Dictionaries: key-value pairs, creation, accessing, modifying dictionaries, Stack, Queue, data frame, etc. 3. User-defined functions & Classes: modules in Python, importing python modules, name resolution, module aliasing, package/library, locating modules, using Python's standard library, user-defined functions: parameters in functions, passing arrays/tuples/dictionary, and lists to functions, function call, the scope of variables, dynamic typing and dynamic binding, Creating and instantiating classes with attributes and methods, public v/s non-public members, Inheritance, Polymorphism, etc. 4. Data Handling: data file operations: opening & closing a file, reading/writing/appending a file, relative and absolute paths, standard file streams, binary file operations, CSV file handling & pickling, concatenating multiple CSV files/text files, panada's DataFrame, convert pandas data frames to numpy arrays/CSV, etc; introduction to various ML libraries: NumPy, Pandas, Scikit-learn, SciPy, Statsmodels, Matplotlib, Seaborn, Sympy, etc. and their use cases. 5. Scikit-learn library: using sci-kit-learn modules for classification e.g. Support Vector Classifier & Regressor, CART, clustering (k-means), data reduction (PCA), data visualization (box plot), etc. Web Scraping with BeautifulSoup, use cases and case studies: spam detection, drug response, stock price prediction, customer segmentation, etc.
<p>References</p> <ol style="list-style-type: none"> 1. Herbold S. (2020): Introduction to Data Science, led, Jupyter Book 2. O'Neil et.al. (2013): Doing Data Science, Straight Talk from The Frontline. O'Reilly 3. Grus J. (2015): Data Science from Scratch: First Principles with Python, O'Reilly 4. Blum et al. (2018): Foundations of Data Science, Cambridge University Press

MS12: Digital Logic & Computer Architecture
<p>Learning Outcomes</p> <ul style="list-style-type: none"> • The understanding of the concept used to develop the digital circuit. • The student will be able to develop the sequential, combinational circuit as well as various types of counters. • Understand to develop various types of counter design.
<ol style="list-style-type: none"> 1. Number System and Data Representation: Binary, Octal, Decimal, and Hexa-Decimal Number Systems; Base Conversions; Binary Arithmetic; Complements: (r-1)'s and r's Complement, Subtraction using Complements; Floating and Fixed-point Representation, Binary Codes for Decimal Digits: BCD Code, Excess-3 Code, 84-2-1 Code, 2421 Code, Reflected Code; Error Detection Code; ASCII, EBCDIC codes. 2. Boolean Algebra and Logic Gates: Boolean Algebra-Basic Definitions, Huntington's Postulate, Switching Algebra, Basic Theorems, and Properties; Boolean Functions: Basic Definition, Literals, Minimization of Boolean Functions by Algebraic Manipulation, Complement of a Boolean Function; Canonical and Standard Forms: Min-terms and Maxterms, Boolean Function as a Sum of the Minterms, Boolean Function as a Product of Maxterms, Conversion Between Canonical Forms, Standard Form of a Boolean Function; Other Logical Operations; Digital Logic Gates: Basic Gates – AND, OR, NOT; Universal Gates – NAND, NOR; Other Gates – XOR, XNOR, AND-OR-INVERT, and OR-AND-INVERT;

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Implementation of Boolean Functions.

3. Simplification of Boolean Functions: Karnaugh Maps Method: Two Variables K-Map; Three, Four and Five Variables KMaps; Product of Sum Simplification, Don't Care Condition, Simplification of a Boolean Function with Don't Care;

4. Combinational Logic: Design Procedure; Design of Half and Full Adder, Half and Full Subtractor, Code Conversion; Combinational Logic with MSI and LSI: Binary Parallel Adder, Decimal Adder, BCD Adder, Magnitude Comparator, Decoders, Encoder, Multiplexers, De-Multiplexer,

5. Sequential Logic and Computer Architecture: Flip-Flops: RS Flip Flop, Clocked RS, JK Flip Flop, D Type FF, T Type FF; Analysis of Clocked Sequential Circuits: State Table, State Diagram, State Equations, Flip Flop Input Functions; FF Characteristic Tables; FF Excitation Tables; Design of Sequential Circuits; Counter: Binary Counter, BCD Counter, Design of Counters. Registers: Register with Parallel Load, Shift Registers, Bidirectional Shift Register with Parallel Load, Serial Addition using Shift Registers; Counters: Ripple Counters, Binary Ripple Counters, BCD Ripple Counters, Synchronous Counters, Binary Synchronous Counter, Binary Synchronous Up-Down Counter, Binary Counter with Parallel Load, Timing Sequences, and Signals, Johnson Counter. Introduction to Computer Architecture, Addressing mode, pipeline, One address, two address, three address instruction format.

References

1. Alam, M., & Alam, B. Digital Logic Design. PHI Learning Pvt. Ltd.
2. Mano, M. M. Digital logic and computer design. Pearson Education India.
3. Harris, S. L., & Harris, D. Digital design and computer architecture. Morgan Kaufmann.

MS13: Data Warehousing & Data Mining

Learning Outcomes

- Understand the fundamental concepts of data mining and warehousing.
- Learn data preprocessing techniques, multidimensional data models, and association rules.
- Develop applications using data mining concepts and understand the design of data warehouse

1. Data Mining: Introduction, Data warehouses, Transactional databases, Advanced Data Information Systems and Applications, Data Mining Functionalities, Classification of data mining systems, data mining task primitives, Integration of data mining systems with a data warehouse system, Data Preprocessing: Descriptive data summarization, Data cleaning, normalization and standardization, L-p norm, Data Reduction, Data discretization and Concept hierarchy generation.

2. Data Warehouse and OLAP Technology: Multidimensional data model, Data Warehouse architecture and Implementation: OLAP, ROLAP, MOLAP, HOLAP etc., Data Cubes, Indexing OLAP data, OLAP queries, Full Cube Computation, BUC, Star-cubing, Discovery-driven exploration of data cubes.

3. Frequent Patterns, Associations rule mining: Association Rules, Frequent Itemsets, Closed Itemsets, Apriori algorithm, generating association rules from frequent itemsets, Closed & Maximal Sets, Mining Closed Frequent Item sets, Correlation Analysis, Metarule guided mining of Association Rules, Constraint Pushing, FPGrowth, ECLAT, etc., pattern evaluation methods, etc.

4. Classification & Regression: Classification by Decision Tree Induction, Bagging and Boosting, Random forest, Support Vector Machines with linear and non-linear kernel for classification & regression, K- Nearest-Neighbor Classifier, Prediction: Linear v/s Non-linear Regression, Performance and Error measures: Hold-out method, Cross-validation, Bootstrap, estimating confidence intervals, ROC curves, etc.

5. Clustering: Types of data in Cluster Analysis, Categorization of Clustering methods, Partitioning Methods: K-means, K-Medoids, CLARANS, Hierarchical Methods: BIRCH, ROCK, Density-based Methods: DBSCAN, etc.

References

1. Han & Kamber: Data Mining - Concepts and Techniques, Elsevier
2. Witten, Frank & Hall: Data Mining: Practical Machine Learning Tools and Techniques, Elsevier.
3. Mohammed Zaki, Wagner Meira: Data Mining and Analysis: Fundamental Concepts and Algorithms, Cambridge Press

MS14: Mathematical Foundations for AI

Learning Outcomes:

- Understand every mathematical concept very intuitively and you will surely overcome the fear of mathematics, if you have any.
- Master various concepts of Calculus and understand how they are used for optimization of Machine Learning Algorithms.
- Learn Algebraic Equations and how they are used in the Machine Learning
- Understand Linear Algebra including Vectors and Matrices
- You will learn how the matrix transformation is used for various data transformations.
- Get all the basics covered for probability including conditional probability and probability distribution

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1. Algebra Foundations: Algebraic Equations including Linear Equations and how to plot them in Python, Exponents, Logs, Polynomial and quadratic equations, various functions for loss measurement or optimization, continuous and non-continuous functions, activation/transfer function of a neuron

2. Linear Algebra: Scalars, Vector and Matrix Norms, Vectors, Matrices, and Tensors in Python, Special Matrices and Vectors, Eigenvalues and Eigenvectors, Norms and Eigen-decomposition, need for dimensionality reduction, Singular Value Decomposition (SVD), truncated SVD, PCA, ICA, etc. for data reduction.

3. Multivariate Calculus: Introduction to Derivatives, Basics of Integration, Gradients, Gradient Visualization, Optimization, Rate of Change and Limits, Derivative Rules and Operations, Double Derivatives and Finding Maxima or Minima, Double Derivatives examples, Partial Derivatives and Gradient Descent, Integration and Area Under the Curve

4. Image Data handling: reading RGB image in Python workspace, Averaging & Gaussian filtering, Laplacian filter, Convolution operation, Image enhancement using spatial and frequency domain filtering, etc.

5. Probability Theory: Intro to Probability Theory, Probability Distributions, Expectation, Variance, and Covariance, Graphing Probability Distributions in Python, Covariance Matrices in Python, Random variables, Bayes theorem, Bayesian learning, etc.

References

1. Mathematical Foundation for AI and Machine Learning by Eduonix, July 2018, Publisher(s): Packt Publishing, ISBN: 9781789613209, O'Reilly
2. "The Princeton Companion to Mathematics" edited by Timothy Gowers
3. "Introduction to the Theory of Neural Computation" by John Hertz, Anders Krogh, and Richard G. Palmer
4. "Pattern Recognition and Machine Learning" by Christopher Bishop

MS15: Database Management Systems

Learning Outcomes

- Fundamentals of databases with their advantages and functionalities
- Various database models. Details of RDBMS, its advantages, and usage
- ER Diagrams and EER Diagrams
- Normalization and its various usage in table optimization

1. Basic Concepts: Data, Database and DBMS; Database vs. Traditional File System Approach; Three Schema Architecture of DBMS, Data Independence; Categories of Database Management Systems: Hierarchical, Network and Relational Database Systems.

2. Database Models: Introduction, Categories of Database Models: High-level or Conceptual Data Models, Representational or Implementation Data Models, Low-level or Physical Data Models, Object Data Models. Entity relationship (ER) Model: Basic Concepts and their representations – Entity, Entity Type and Entity Set, Attributes and Keys, Relationships, Relationship Types, and Structural Constraints, Weak Entity, Naming Conventions & Design Issues in ER Model. ER and EER Diagrams.

3. Relational Database Model: Structure of Relational Model; Domains, Attributes, Tuples, and Relations; Characteristics of Relations; Relational Constraints – Domain Constraints, Key Constraints, Entity Integrity, and Referential Integrity Constraints; Relational Database Schema; Relational Algebra Operations – Select, Project, Rename, Union, Intersection, Set Difference, Join, and Division Operations; Aggregate Functions and Groupings.

4. Structured Query Language (SQL): Schema, Table and Domain Creation; Schema and Table Deletion; Table Modification; Insert, Delete, and Update Statements; SELECT- FROM-WHERE Structure; Renaming Attributes; Nested Queries and Set Comparisons; EXISTS and UNIQUE Functions; Aggregate Functions; Creating and Updating Views. Introduction to PL/SQL.

5. Functional Dependencies and Normalization: Informal Design Guidelines for Relation Schemas; Functional Dependencies; Inference Rules for Functional Dependencies; Normalization using Functional Dependencies – First Normal Form (1NF), Second Normal Form (2NF), Third Normal Form (3NF), and Boyce-Codd Normal Form (BCNF); Multi-Valued Dependencies and Fourth Normal Form (4NF); Join Dependencies and Fifth Normal Form (5NF); Relation Decomposition and Insufficiency of Normal Forms; Dependency Preserving and Lossless Join Decompositions; Null Values and Dangling Tuples. Transaction Management and Concurrency Control: Transaction Concept; Transaction State; Concurrent Executions; Serializability and Recoverability; Testing for Serializability. Concurrency Control – Lock-Based Protocols and Timestamp-Based Protocols.

References

1. R. Elmasri, S. B. Navathe: Fundamentals of Database Systems. Pearson
2. A. Silberschatz, H. F. Korth, and S. Sudarshan: Database System Concepts. McGraw Hill
3. J. Casteel: ORACLE 9i Developer: PL/SQL Programming. Thomson
4. Ivan Bayross: SQL, PL/SQL The Programming Language of Oracle. BPB

MS16: Lab I (Python)

Implementation of at least ONE specific assignment concerning each of the following using Python:

1. Drawing different patterns e.g. Pascal triangle, Pyramid of '*', etc. using loop and branching statements
2. Creating a Python class, instantiate 10 objects, save them in csv file, re-open and load them in Python workspace
3. Sorting a student database based on student identification numbers by reading it from csv file
4. Problem related to classification using CART, SVC, K-NN, etc
5. Problem e.g. Market-Basket analysis, related to association mining using Apriori, FPGrowth, etc.
6. Problem related to clustering e.g. image segmentation using K-means,
7. Problem related to regression analysis e.g. electricity load prediction during peak hours using SVR, CART, etc.
8. Problems related to anomaly detection e.g.
9. Training a Machine learning model for a real-life dataset with good practices such as Train/Test split, 10-fold cross validation, reporting performance with RoC plots etc. over a separate test dataset
10. Using all plot libraries to do data pre-processing & visualization e.g. Box plot, Bar chart, probability density function plot, etc.
11. Understanding data processing, reading, pre-processing, cleaning data set, generating Train/Test/Validation datasets, label encoding, one-hot encoding, etc. using Sklearn
12. Importing & using various ML libraries: NumPy, Pandas, Scikit-learn, SciPy, Statsmodels, Matplotlib, Seaborn, Sympy, etc.
13. Creating and using NumPy Array and converting it into other types
14. Creation and usage of panda's data frame and converting it into other types
15. Using various data visualization techniques such as probability density function, box plot, etc.
16. CSV file handling & pickling, concatenating multiple CSV files/text files
17. Implementing a regression algorithm for rain-fall prediction, stock market prediction, wine quality, etc.
18. Implementing a classification algorithm for image classification, breast cancer, etc.
19. Implementing an unsupervised algorithm for grouping data points into meaningful clusters.
20. Implementing a clustering algorithm for data reduction

References

1. Python Machine Learning - Third Edition, by Sebastian Raschka, Vahid Mirjalili
2. Machine Learning, Data Science and Generative AI with Python by Frank Kane
3. Machine Learning with Python for Everyone by Mark Fenner
4. Machine Learning with scikit-learn LiveLessons by David Mertz

MS17: Lab-II (Oracle)

Implementation of at least ONE specific assignment concerning each of the following:

1. SQL statements to create, update, and delete databases and tables
2. SQL statements to insert, update, and delete records from tables
3. SQL statements to create, update, and delete views
4. Nested SQL queries to handle complex information retrieval requirements.
5. Managing changes affecting the data using COMMIT, ROLLBACK and SAVEPOINT.
6. Providing security to databases using GRANT and REVOKE commands.
7. SQL queries using order by, group by and having clauses.
8. SQL sub queries, joins, views, nested queries, inner and outer joins.
9. SQL queries using aggregate functions like count, average, sum, etc.
10. PL/SQL blocks using basic data types, branching and looping constructs
12. Database triggers, functions/procedures and packages using PL/SQL

SEMESTER II

MS21: Data Communication & Networks

Learning Outcomes

- Identify the components required to build different types of networks.
- Choose the required functionality at each layer for a given application.
- Identify solutions for each functionality at each layer.
- Trace the flow of information from one node to another node in the network.

1. Data Communication and Networking Overview: Communication Model; Data Communications; Data Transmission and Related Concepts – Guided Media, Unguided Media, Direct Link, Point-to-Point and Multipoint Guided Configuration, Simplex, Half-Duplex, and Full-Duplex Transmission, Frequency, Spectrum, Bandwidth; Time Domain and Frequency Domain Concepts; Analog and Digital Data Transmission; Transmission Impairments – Attenuation and Attenuation Distortion, Delay Distortion.

2. Computer Networks and Reference Models: Computer Networks and their Applications; Broadcast and Point-to-Point Networks; Personal Area Networks; LAN; MAN; WAN; Wireless Networks; Internetworks; Network Layers, Protocols, and Interfaces; Connection-Oriented and Connectionless Services. OSI Reference Model; TCP/IP Reference Model; Comparison of OSI and TCP/IP Models; Problems with OSI and TCP Models; Internet and its Usage; Internet Architecture; Connection-Oriented Networks – X.25, Frame Relay, and ATM.

3. Transmission Media: Twisted Pair, Coaxial Cable, Optical Fiber; Wireless Transmission – Antennas, Terrestrial Microwave, Satellite Microwave, Broadcast Radio, and Infrared; Wireless Propagation; Line of-Sight Transmission. Communication Satellites – Geostationary Satellites, Medium-Earth Orbit Satellites, Low-Earth Orbit Satellites; Satellites versus Fiber.

4. Data Link Layer: Design Issues; Error Detection and Correction; Elementary Data Link Protocols – Unrestricted Simplex Protocol, Simplex Stop-and-Wait Protocol; Sliding Window Protocols – One-Bit Sliding Window Protocol, Protocol Using Go Back N, Multiple Access Protocol – ALOHA (Pure and Slotted), Carrier Sense Multiple Access (CSMA) Protocols (Persistent and Nonpersistent), CSMA with Collision Detection, Collision-Free Protocols, Wireless LAN Protocols, etc.; Ethernet; Wireless LANS – 802.11 Protocol Stack, 802.11 Physical Layer, 802.11 MAC Sublayer Protocol, 802.11 Frame Structure, and Services.

5. The Network and Application Layer: Design Issues; Routing Algorithms – Optimality Principle, Shortest Path Routing, Flooding, IP Protocol; IP Addresses; Subnets; Subnet Mask; Internet Control Protocols, Domain Name System (DNS); DNS Name Space; Name Servers, Simple Mail Transfer Protocol (SMTP), POP3; World Wide Web and Hyper Text Transfer Protocol.

References

1. S. Tanenbaum: Computer Networks. PHI
2. William Stallings: Data and Computer Communications. Pearson
3. Behrouz A. Forouzan: Data Communications and Networking (SIE). TMH

MS 22: Artificial Intelligence & Machine Learning

Learning Outcomes

- Understand design of AI and Deep learning based systems
- Designing AI based expert systems using Prolog
- Solve different AI puzzles such as Sudoku, 8-puzzle etc. using Prolog.
- Build, train and apply fully connected deep neural networks.
- To train SOM for data reduction/clustering etc.

1. AI Techniques: History, AI techniques, Problem solving using Search, Uninformed v/s Informed Search, Heuristic Search Techniques: Hill Climbing, Simulated Annealing, Best First Search: OR Graphs, Heuristic Functions, A* Algorithm, AND-OR Graphs, Adversarial Search: Zero-sum perfect information Games, Optimal Decisions and Strategies in Games, Mini-max Algorithm, Alpha-beta Pruning, Solving game puzzles: NIM, Chess, Chinese Checkers, etc.

2. Knowledge Representation & Reasoning: Propositional logic, Inference in First order logic, Forward v/s Backward chaining, Resolution, Resolution-refutation; PROLOG: Logic Programming and Horn Clauses; CUT and FAIL operators, Built-in Goals, Negation, recursive rules, recursive Lists processing, CLP library, PROLOG programs for solving puzzles such as Sudoku, Cryptarithmic, etc.

3. Feed-forward Neural network: Machine learning (m/l) types & applications, Artificial Neural Networks: Activation Functions; Loss functions; Training/learning functions, Different Models: McCulloch and Pitts Model; Perceptron Learning, Multi-layer Feed-forward model for classification and regression: Delta rule and error Backpropagation learning; performance measures & RoC plots.

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4. Convolutional Neural Network: Deep learning, CNN architecture, convolution and pooling layers, strided convolutions, padding v/s non-padding, learning, & applications. Loss Function, error backpropagation for training CNN, etc.

5. RNN & Unsupervised Neural Networks: RNN, LSTM, GRU, text classification with RNN, Error Backpropagation through time; Unsupervised methods: Self organizing maps (SOM): Competitive Learning, Feature maps, Implementation and training; Autoencoders, Reconstruction loss, anomaly detection, etc.

References

1. Tom M. Mitchell: Machine Learning. McGraw Hill
2. E. Rich & K. Knight: Artificial Intelligence. TMH
3. Michael Nielsen: Neural Networks and Deep Learning (free online book)
4. Stuart Russel & Peter Norvig: Artificial Intelligence– A Modern Approach. Pearson, 4th edition, 2023
5. Padhy: Artificial intelligence and intelligent systems. Oxford University Press
6. Prolog Programming for Artificial Intelligence, August 2011, by Ivan Bratko, Addison-Wesley; 4th edition
7. Deep Learning (Adaptive Computation and Machine Learning series) Illustrated Edition, by Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press, London

MS23: Data Structures

Learning Outcomes

- Illustrate terminology and concepts of data structures.
- Derive the mapping functions to map the indices of multi-dimensional arrays to the index of 1D array.
- Design efficient algorithms for different matrix operations for various special matrices.
- Design algorithms for various operations of different data structures.
- Applications of various data structures to solve different problems.

1. List and Matrices: Data Structure, Linear Data Structure, Array Data Structure, Multi-Dimensional Array, Mapping of Indices of 2D and 3D Arrays to the Index of 1D Array, Matrix, Mapping of Indices of Matrix Elements to One Dimensional (1D) Array Index, Special Matrices, Triangular, Diagonal, Tri-Diagonal, Representation in Row Major and Column Major Order, Mapping of non-null Elements in 1D Array, Sparse Matrix, Single Linked List, Circular Linked List, Doubly Linked List, Circular Doubly Linked List, Applications of Linked Lists: Bin Sort, Radix Sort, Convex Hull.

2. Stacks and Queues: Stack Data Structure, Various Stack Operations, Representation and Implementation of Stack using Array and Linked List, Applications of Stack: Conversion of Infix to Postfix Expressions, Parenthesis Matching, Towers of Hanoi, Rat in a Maze, Implementation of Recursive Functions, Queue Data Structure, Various Queue Operations, Circular Queue, Representation and implementation of queues using Array and Linked List, Applications of Queue Railroad Car Rearrangement, Machine Shop Simulation, Image-Component Labeling, Priority Queues: Priority Queue Using Heap; Max and Min Heap; Insertion into Heap; Deletion from a Heap; Applications of Priority Queue: Heap Sort.

3. Trees: Binary Trees and their Properties; Representation of Binary Trees: Array-Based and Linked Representations; Binary Tree Traversals; Binary Search Trees (BST); Operations on BST: Search, Insertion and Deletion; BST with Duplicates; Applications of BST: Histogramming, Best-Fit Bin Packing, AVL Trees; AVL Tree Representation; Introduction to Red-Black and Splay Trees, B-Trees and their Representation; Operations on B-Tree: Search, Insertion and Deletion; B+-Trees.

4. Sorting, Searching, and Hashing: Insertion Sort, Bubble Sorting, Quick Sort, Merge Sort, Shell sort, Sequential search, binary search, Introduction to Hashing, Hash Table Representation, Hash Functions, Collision and Overflows, Linear Probing, Random Probing, Double Hashing, and Open Hashing.

5. Graphs and Disjoint Sets: Graph Terminology & Representations, Graphs & Multi-graphs, Directed Graphs, Representations of Graphs, Weighted Graph Representations; Graph Traversal Methods: Breadth-First Search and Depth-First Search; Spanning Tree and Shortest Path Finding Problems, Disjoint Sets, Various Operations of Disjoint Sets, Disjoint Sets Implementation.

References

1. Sartaj Sahni: Data Structures, Algorithms and Applications in C++. Universities Press
2. D. Samanta: Classic Data Structures, PHI
3. Narasimha Karumanchi: Data Structures and Algorithms Made Easy. CareerMonk

CS24: Elective –I

will be decided at the starting of the semester

CS25: Elective -II

MS27: Lab III (AI & ML)

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Implementation of at least ONE specific assignment concerning each of the following:

1. Implementing different PROLOG language features e.g.; recursive rules, cut and fail operators, knowledge base, LIST processing, etc to build an expert system.
2. Solving puzzles e.g.; Sudoku, water-jug problem using PROLOG.
3. Solving Cryptarithmic puzzle using PROLOG.
4. Build, train, apply fully connected feed-forward network for MNIST data classification.
5. Build, train, apply fully connected feed-forward network for Regression problem.
6. Build, train and apply convolutional neural network for image classification in Python.
7. To fine-tune AlexNet or VGG net for skin image data classification in Python.
8. To train SOM for clustering application in Python.
9. To do clustering using K-means in Python.
10. To train SOM/Autoencoder for data reduction in Python.
11. Implement optimization functions using GA.
12. Use Fuzzy logic in reasoning using Prolog.
13. Implement Fuzzy logic based expert system.
14. Implement Transfer Learning using ResNet50 and CIFAR-10.
15. Implement a hand written digit recognizer using FFNN for MNIST dataset.
16. Implement an image classifier using CNN for ImageNet dataset.

MS28: Lab-IV (Data Structures)

Implementation of at least ONE specific assignment concerning each of the following:

1. Creation of Matrix and Special Matrices classes OR Implementation of the different functions of the Matrix and Special Matrices.
2. Creation of Array class OR implementation of the different functions of the Array D.S.
3. Creation of the Different types of Linked list classes OR Implementation of the various functions of the Different types of Linked list D.S.
4. Implementation of the bucket and radixSort algorithms using single linked list D.S. and convex hull using doubly circular linked list D.S.
5. Creation of the Generic Stack class and implementation of the infixToPostfix, EvaluatePostfix, tower of Hanoi problem, Rat on maz problems, and recursive functions such as factorial(n), Fib(n), gcd(m, n), DecimalToBinary(n) using Stack D.S.
6. Creation of the Generic CircularQueue class and implementation of the Railroad Car Rearrangement, Image-Component Labeling using Queue.
7. Creation of Array and linked representation of the tree data structure class; linked representation of the Expression tree data structure.
8. Creation of the Heap tree data structure and implementation of the heapsort and priority Queue D.S.
9. Creation of the binary search tree data structure.
10. Implementation of various functions of the graph; depth-first search and breadth-first search of a graph.

SEMESTER III

MS31: Cloud Computing

Learning Outcomes

- The core concepts of the cloud computing paradigm- how and why this paradigm shift came about, the characteristics, advantages and challenges brought about by the various models and services in cloud computing.
- Apply fundamental concepts in cloud infrastructures to understand the tradeoffs in power, efficiency and cost, and then study how to leverage and manage single and multiple datacenters to build and deploy cloud applications that are resilient, elastic and cost-efficient.
- Discuss system, network and storage virtualization and outline their role in enabling the cloud computing system model.
- Illustrate the fundamental concepts of cloud storage and demonstrate their use in storage systems such as Amazon S3 and HDFS.

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<ul style="list-style-type: none"> Analyze various cloud programming models.
<p>1.Cloud Computing Overview and Origins of Cloud computing: Concept of “cloud computing”, recent history of cloud computing, Roots of Cloud Computing, Layers and Types of Clouds, Features of a Cloud, Cloud Infrastructure Management, Infrastructure as a Service Providers, Platform as a Service Providers, Challenges and Risks.</p> <p>2. Migrating into a Cloud – Introduction, Broad Approaches to Migrating into the Cloud, the Seven-Step Model of Migration into a Cloud, High-performance computing, Utility and Enterprise grid computing, Cloud scenarios – Benefits: scalability, simplicity, vendors, security, limitations – Sensitive.</p> <p>3.Cloud Architecture: Software as a Service (SaaS), features of SaaS and benefits, Platform as a Service (PaaS), features of PaaS and benefits, Infrastructure as a Service (IaaS), features of IaaS and benefits, Service providers, challenges and risks in cloud adoption. Cloud deployment model: Public clouds – Private clouds – Community clouds - Hybrid clouds - Advantages of Cloud computing.</p> <p>4. Data Security and Management in the Cloud: An Introduction to the Idea of Data Security, The Current State of Data Security in the Cloud, Homo Sapiens and Digital Information, Cloud Computing and Data Security Risk, Cloud Computing and Identity, The Cloud Digital Identity and Data Security, Content Level Security—Pros and Cons. Distributed Management of Virtual Infrastructures, Scheduling Techniques for Advance Reservation of Capacity, Capacity Management to meet SLA Commitments.</p> <p>5. Governance and case studies: Organizational Readiness and Change Management in the Cloud Age- Introduction, Basic Concept of Organizational Readiness, Drivers for Changes: A Framework to Comprehend the Competitive Environment, Common Change Management Models, Change Management Maturity Model Organizational Readiness Self-Assessment.</p>
<p>References:</p> <ol style="list-style-type: none"> Cloud computing a practical approach - Anthony T.Velte , Toby J. Velte Robert Elsenpeter, TATA McGraw- Hill , New Delhi – 2020 Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online - Michael Miller - Que 20018 Cloud computing for dummies- Judith Hurwitz , Robin Bloor , Marcia Kaufman ,Fern Halper, Wiley Publishing, Inc, 2010 Cloud Computing (Principles and Paradigms), Edited by Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc. 2011

MS32: Deep Learning

<p>Learning Outcomes</p> <ul style="list-style-type: none"> Understand the concept and need of deep learning Understand different architecture for deep learning Understand various pre-trained deep neural architectures and to be able to use them or fine tune them for your task To implement efficient recurrent neural networks for sequence based data
<ol style="list-style-type: none"> CNN & Variants: review of ANN models covered in previous course: FFNN, Long Short-Term Memory networks (LSTM), Gated Recurrent Units (GRU), Autoencoders, CNN; types of CNN, LeNet, Pre-trained models offered by PyTorch: AlexNet, VGG16, ResNet, Inception Net, MobileNet, GCN, etc.; Training/Fine-tuning pre-trained models with domain specific data, and their applications in Image classification & Biometrics. Generative Models: Generative Adversarial Network (GAN) Architecture, parts of GAN: generator and discriminator, MinMax Loss, generator and discriminator, alternative objective formulations promoting stable convergence, stabilizing GAN training; Variational Autoencoders, Latent Loss, Diffusion Models, Forward v/s Reverse diffusion, etc. and applications for generating new images. Object Detection & Image Segmentation: YOLO, Bounding box, Target vector, and loss for object detection, convolutional sliding windows method, Anchor boxes, IoU, Non-max suppression, Benchmark datasets for object detection, Semantic Segmentation, thresholding, region/edge-based methods, clustering based methods; Encoder-Decoder architecture: UNet, Transposed Convolution; SegNet, etc., Segmentation masks, Tools for mask creation, and their applications in biomedical image segmentation. Transformer model: sequence to sequence tasks, review of RNN, attention mechanisms, transformer architectures, position encoding, absolute vs relative positional embedding options, feedforward networks, residual connections, and layer normalization, multi-head attention; Word embeddings e.g., Word2Vec, Global Vectors (GloVe), FastText, ELMo, and BERT; sentiment analysis, Pre-trained models for NLP tasks: BERT (Bidirectional Encoder Representations from Transformers), GPT-3 (Generative Pre-trained Transformer 3), XLNet (Generalized Autoregressive Pretraining for Language Understanding), DistilBERT, etc. and using them for summarization, image captioning, and dialogue systems, etc. Fuzzy Logic & Hybrid AI models: Genetic Algorithm: Encoding, fitness functions, genetic operators, reproduction,

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evolutionary strategies, Applications of GA, hyperparameter optimization of ANN with GA; Fuzzy Logic: fuzzy sets: properties and operations; Fuzzy logic and fuzzy rules, Mamdani fuzzy rule inferencing mechanism, Fuzzy Systems, Neuro Fuzzy Systems, etc.

References

1. Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville (MIT Press)
2. Deep Learning with PyTorch, by Eli Stevens, Luca Antiga, and Thomas Viehmann, July 2020, ISBN 9781617295263
3. Deep Learning with PyTorch: A practical approach to building neural network models using PyTorch by Vishnu Subramanian, Packt publisher, 2018
4. Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow by Aurélien Géron (O'Reilly Media)
5. Deep Learning with Python by Francois Chollet (Manning Publications)
6. Speech and Language Processing by Dan Jurafsky and James H. Martin (Pearson)
7. Computer Vision: Algorithms and Applications by Richard Szeliski (Springer)

MS33: Minor Project	<i>will be decided at the starting of the semester</i>
CS34: Elective –III	
CS35: Elective -IV	

MS36: Lab V (Deep Learning)
<ol style="list-style-type: none"> 1. Implement sequence data classifier using a long short-term memory (LSTM) network for Japanese Vowels dataset. 2. Implement sequence to sequence model using GRU. 3. Train CNN for classifying Flower images 4. Train a CNN for classifying 7 types of skin cancer from ISIC skin cancer dataset 5. Train LSTM for time series data classification 6. Train autoencoder for anomaly detection 7. Train GAN for face image generation 8. Train Transformer for Image captioning 9. Train Transformer for sentiment analysis 10. Fine tune pre-trained model for medical diagnosis 11. Use pre-trained BERT model for creating chatbot for health monitoring of a smartphone user 12. Use pre-trained model for describing surroundings to a smartphone user

MS37: Lab VI (Hadoop)
<ol style="list-style-type: none"> 1. Install Hadoop on a single-node or multi-node cluster depending on the available resources. and Verify the installation and ensure that all components are running correctly. 2. Perform basic Hadoop operations such as starting and stopping Hadoop services, checking cluster status, and interacting with HDFS (Hadoop Distributed File System) using command-line utilities like hadoop fs. 3. Implement the Word Count program using MapReduce to count the occurrences of each word in a given text file. And Test the program with different input files and analyze the results. 4. Create an index of words appearing in a set of documents using MapReduce. Test the program with a collection of documents and verify the generated index. 5. Modify the Word Count program to find the top N most frequently occurring words in a given text file. 6. Calculate the average length of words in a given text file using MapReduce. 7. Implement matrix multiplication using MapReduce to multiply two matrices. And Test the program with small matrices and verify the correctness of the result.

8. Perform a join operation on two datasets using MapReduce based on a common attribute.
9. Implement the K-Means clustering algorithm using MapReduce to cluster a set of data points.
10. Implement the PageRank algorithm using MapReduce to rank web pages based on their importance.

MS41: Major Project

6 Months Industrial Project Training starting from January (M.Sc. IV Semester)

Detailed Syllabi of Elective Courses

Elective Course Title: IoT and Big Data

1. Introduction to IoT and Enabling Technologies: Basics of IoT: definitions, evolution, applications, IoT elements: sensors, actuators, communication modules, Enabling technologies: RFID, ZigBee, Wi-Fi, BLE, 6LoWPAN, Wireless Sensor Networks (WSN): basics and protocols, Communication protocols: HTTP, MQTT, CoAP. overview IoT standards, cloud computing and data management issues Challenges, security and privacy concerns in IoT

2. IoT Middleware, Interoperability and Services: Role of middleware in IoT, Middleware platforms: Kaa, ThingsBoard, FIWARE, Service orchestration, data filtering, and preprocessing Device discovery and registry services, RESTful APIs and resource constrained device integration Semantic interoperability, ontology, and RDF/JSON-LD in IoT

3. IoT Architectures, Protocols and Integration: IoT architecture: perception, network, middleware, application layers, IoT reference models: ITU-T, ETSI M2M, oneM2M, Application layer protocols: MQTT, CoAP, AMQP, IoT frameworks: ThingsBoard, Kaa, Azure IoT, Introduction to Edge and Fog Computing: design, components, use cases, Cloud-IoT integration: (AWS, Azure, Google Cloud IoT)

4. Big Data Fundamentals and Ecosystem Overview Introduction to Big Data: definitions, characteristics (5Vs), limitations of existing architectures, Big Data lifecycle: generation, collection, ingestion, storage, Overview of Big Data architectures and challenges, Introduction to structured/unstructured data formats (CSV, Avro, JSON)

5. Hadoop Framework and Big Data Analytics: Introduction to Hadoop: Origin, motivation, and role in Big Data, overview of Hadoop Architecture: HDFS and MapReduce, HDFS design principles: block level storage, replication mechanisms and fault tolerance, YARN, Hadoop Ecosystem Components: Hive, Pig, HBase, Zookeeper, Sqoop, Flume

References:

1. Rajkumar Buyya, Amir Vahid Dastjerdi, Internet of Things: Principles and Paradigms, Elsevier/Morgan Kaufmann, 2016.
2. Arshdeep Bahga, Vijay Madiseti, Internet of Things: A Hands-on Approach, VPT, 2014.
3. Kazem Sohraby, Daniel Minoli, Taieb Znati, Wireless Sensor Networks: Technology, Protocols and Applications, John Wiley & Sons, 2007.
4. Seema Acharya, Subhashini Chellappan, Big Data and Analytics, Wiley India, 2015.
5. Tom White, Hadoop: The Definitive Guide, O'Reilly Media, 2015.