GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Branch: Computer Engineering (Artificial Intelligence And Data Science)

Course / Subject Code : ME01095071

Subject Name: Optimization

WEF Academic Year :	2024-25
Semester :	1st Semester
Category of the Course :	PEC

Prerequisite :	Linear Algebra, Calculus, Probability and Statistics, Programming Skills in R or Python
Rationale :	This course covers the fundamental optimization techniques used in artificial intelligence and data science, including linear programming, integer programming, dynamic programming, gradient descent, conjugate gradient, quasi-Newton methods, stochastic optimization, evolutionary algorithms, convex optimization, unconstrained optimization, and constrained optimization. The course will also cover applications of optimization techniques in machine learning, deep learning, and data science.

Course Scheme :

Teaching Scheme			Total Credits	Assessment Pattern and Marks				Total Marks
				Theory		Practical		
L	T	PR	C	ESE (E)	PA(M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Course Content:

Sr. No.	Course Content	No. of Hours	% of Weightage
1	Introduction to Optimization Definition of optimization, types of problems (linear, nonlinear, discrete, continuous), optimization vs. machine learning vs. search algorithms. optimization in reinforcement learning, optimization in natural language processing	12	26

2	Unconstrained & Constrained Optimization: Gradient descent methods (batch, mini-batch, stochastic), Newton's method and variants, convergence analysis, stochastic gradient descent. Lagrange multipliers, Karush-Kuhn-Tucker (KKT) conditions, penalty methods, interior point methods Metaheuristic Optimization Techniques: Genetic algorithms (encoding, selection, crossover, mutation), particle swarm optimization, ant colony optimization, simulated annealing,	**12**	**26**
3	Evolutionary Algorithms and Optimization in Machine Learning: Evolutionary strategies, genetic programming, differential evolution, Optimization in neural networks (backpropagation, stochastic gradient descent, Adam optimizer), support vector machines (dual and primal optimization) Feature selection, dimensionality reduction (PCA, LDA), hyperparameter tuning (grid search, Bayesian optimization),	**9**	**22**
4	Ethical consideration for Optimization Optimization for interpretable AI, fairness and bias reduction in optimization, optimization in federated learning, Bias and fairness issues in optimization algorithms, ethical implications of optimization in AI and data science	**6**	**13**
5	Optimization applications and case studies in data science: Resource Allocation, Recommendation Systems , Energy Optimization, Route Optimization, Supply chain Optimization. Case Studies : Netflix, Amazon, Google, Facebook, Uber, Microsoft, Walmart, Disney	**6**	**13**
	Total	**45**	**100**

Reference Book:

1. “Optimization Techniques in Artificial Intelligence and Data Science”
2. “Numerical Optimization” by Jorge Nocedal and Stephen J Wright
3. “Convex Optimization” by Stephen Boyd and Lieven Vendenberghe

4. "Optimization for Machine Learning" by Suvrit Sra, Sebastian Nowozin and Stephen j Wright
5. Rahul Dubey, "An Introduction to Internet of Things: Connecting Devices, Edge Gateway, and Cloud with Applications", Cengage India Publication
6. Raj Kamal, "Internet of Things: Architecture and Design Principles, Mc Graw Hill Education
7. Hanes et al "IoT Fundamentals", Cisco Press
8. Vijay Madisetti and Arshdeep Bahga, "Internet of Things (A Hands-on-Approach)", , Paperback, 2015.
9. . McEwen, H. Cassimally, "Designing the Internet of Things", Wiley, 2013.
10. Yashwant Kanetkar, "21 Internet of Things Experiments", Kindle edition
11. Adeel Javed, "Building Arduino projects for Internet of Things", Apress publication
12. Donald Noris, "The Internet of Things: Do it yourself Projects with Arduino, Raspberry PI and BeagleBone Black" Mc Graw Hill Publication
13. [9] Adrian McEwen & Hakim Cassimally, "Designing the Internet of things", Willey publication
14. [1] Rahul Dubey, "An Introduction to Internet of Things: Connecting Devices, Edge Gateway, and Cloud with Applications", Cengage India Publication
    Raj Kamal, "Internet of Things: Architecture and Design Principles, Mc Graw Hill Education
    Hanes et al "IoT Fundamentals", Cisco Press
15. Vijay Madisetti and Arshdeep Bahga, "Internet of Things (A Hands-on-Approach)", , Paperback, 2015.
16. A. McEwen, H. Cassimally, "Designing the Internet of Things", Wiley, 2013.
17. Yashwant Kanetkar, "21 Internet of Things Experiments", Kindle edition
18. Adeel Javed, "Building Arduino projects for Internet of Things", Apress publication
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20. Adrian McEwen & Hakim Cassimally, "Designing the Internet of things", Willey publication
21. [1] Rahul Dubey, "An Introduction to Internet of Things: Connecting Devices, Edge Gateway, and Cloud with Applications", Cengage India PublicatioCourse Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level*
01	Define and explain optimization techniques and algorithms.	RM
02	Apply optimization techniques to solve real-world problems.	UN
03	Implement optimization algorithms using programming languages.	AP
04	Compare and contrast optimization techniques and algorithms.	AN
05	Assess the strengths and limitations of optimization techniques and algorithms.	EL

*RM: Remember, UN: Understand, AP: Apply, AN: Analyse, EL: Evaluate, CR: Create

Suggested Course Practical List:

1. Implement a simple calculator using Python or MATLAB to demonstrate basic mathematical operations.
2. Write a program to solve a system of linear equations using Gaussian elimination or LU decomposition.
3. Develop a graphical user interface (GUI) to visualize mathematical functions and relations.
4. Implement a basic algorithm for sorting and searching data structures.
5. Use a computer algebra system (CAS) to solve symbolic mathematics problems.
6. Develop a program to compute the determinant, inverse, and eigenvalues of a matrix.
7. Implement a numerical method for solving ordinary differential equations (ODEs).
8. Create a data visualization project using a library like Matplotlib or Seaborn.
9. Develop a machine learning model using a library like scikit-learn to classify or regress data.
10. Implement a cryptographic algorithm like RSA or elliptic curve cryptography to demonstrate number theory applications.

List of Laboratory/Learning Resources Required:

Online Courses:

-"Optimization Techniques for AI and Data Science" by IBM on Coursera
- "Optimization Methods for Machine Learning" by Stanford University on Stanford Online
- "Convex Optimization" by MIT OpenCourseWare

Websites:

- Optimization for AI and Data Science by Microsoft Research
- Optimization Techniques for Machine Learning by Google AI
- Convex Optimization by Stanford University

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