MDS572B: Quantum Machine Learning

Total Teaching Hours for Trimester: 60 Hrs.
No of hours per week: 6(3+3) **Credits: 3**
Max Marks: 100
Course Type: Elective

Course Description
This course explores the intersection of quantum computing and machine learning, introducing students to the fundamental principles of quantum mechanics and their application in designing quantum algorithms for machine learning tasks. Students will gain hands-on experience in implementing quantum machine learning algorithms using relevant programming frameworks. The course aims to equip students with the knowledge and skills necessary to navigate the rapidly evolving field of quantum machine learning.
Course Outcomes: Upon completion of the course students will be able to

No.	Course Outcomes
CO1	Understand the basics of quantum mechanics and quantum computing.
CO2	Implement and analyze quantum machine learning algorithms using Qiskit
CO3	Apply quantum algorithms to solve machine learning problems.
CO4	Critically evaluate the advantages and limitations of quantum machine learning approaches.

Unit 1 **Teaching Hours: 12**
Introduction to Quantum Mechanics (2 Weeks)

Introduction and overview, Global perspectives, Quantum bits, Quantum computation, Quantum algorithms, Quantum information processing.
Introduction to Quantum Mechanics - The postulates of Quantum Mechanics, Application: superdense coding, The density operator.

LAB Exercise

1. Install Qiskit and set up the development environment.

Unit 2 **Teaching Hours: 12**
Introduction to Quantum Computation (2 Weeks)
Quantum Circuits - Quantum algorithms, Single Qubit operations, Controlled operations, Measurement, Universal Quantum gates. Simulation of Quantum systems.

LAB Exercise

2. Basic operations on Qubit and measurements on Bloch Sphere
3. Create a simple quantum circuit using basic gates
4. Visualize and simulate the quantum circuit using Qiskit
5. Quantum Solution to the Deutsch-Josza Problem

Unit 3 **Teaching Hours: 12**
Clustering Structure and Quantum Computing (2 Weeks)
Quantum Random Access Memory, Quantum Principal Component Analysis, Quantum K-Means, Quantum Hierarchical Clustering.

LAB Exercise

6. Implement a quantum clustering algorithm using Qiskit or a similar library.
7. Apply the quantum algorithm to a dataset and visualize the cluster structure.

Unit 4 **Teaching Hours: 12**

Quantum Classification (2 Weeks)

Nearest Neighbors, Support Vector Machines with Grover's Search, Support Vector Machines with Exponential Speedup, Computational Complexity

LAB Exercise

8. Implement Quantum Kernels and Support Vector Machines
9. Design a Training Parameterized Quantum Circuits

Unit 5 **Teaching Hours: 12**

Quantum Pattern Recognition (2 Weeks)

Quantum Associative Memory, The Quantum Perceptron, Quantum Neural Networks, Physical Realizations. Variational quantum algorithms and their applications

LAB Exercise

10. Implement a simple quantum neural network and evaluate the performance

Essential Reading

1. Quantum Computation and Quantum Information by Michael Nielsen and Isaac Chuang
2. Quantum Machine Learning: What Quantum Computing Means to Data Mining by Peter Wittek

Recommended Reading

1. Quantum Computing for Computer Scientists by Noson S. Yanofsky and Mirco A. Mannucci
2. Quantum Machine Learning: A Gentle Introduction by Jacob Biamonte, Peter Wittek, and Nicola Pancotti
3. Quantum Machine Learning: Theory and Experiments" by Maria Schuld and Francesco Petruccione
4. Learn Quantum Computing with Python and Q# by Sarah C. Kaiser and Christopher Granade"

Online learning and Lab References:

- Introduction to Quantum Computing: Quantum Algorithms and Qiskit - Course (nptel.ac.in)
- **IBM Quantum Learning**
- **Qiskit Foundations - Coding with Qiskit - YouTube**
- Quantum Machine Learning - Qiskit - YouTube