Project: Implement and Analyze Quantum Search Algorithms Using Qiskit

Project Description

Students will implement two quantum search algorithms— **Grover's Search Algorithm** and **Deutsch-Jozsa Algorithm**— using Qiskit. They will compare these algorithms with their classical counterparts to observe speedup and efficiency in solving specific problems.

Learning Objectives

- Gain hands-on experience implementing quantum algorithms in Qiskit.
- Understand how quantum speedup works by comparing quantum and classical solutions.
- Apply quantum gates and circuits to real-world problem-solving.
- Visualize quantum states and results using Qiskit tools.

Project Tasks

1. **Introduction & Setup**
    - Install Qiskit and set up the environment.
    - Review the necessary quantum gates (Hadamard, X, Z, CNOT, etc.).
2. **Classical Baseline Implementation**
    - Implement a classical function to solve a search problem (e.g., unstructured search for an element in a list).
    - Implement a classical algorithm to determine if a function is balanced or constant (for comparison with Deutsch-Jozsa).
3. **Quantum Implementation**
    - Implement Grover's algorithm in Qiskit to search for a specific marked element.
    - Implement the Deutsch-Jozsa algorithm in Qiskit.
    - Simulate the circuits and obtain measurement results.

4. **Analysis & Comparison**
    - Compare runtime and complexity between classical and quantum approaches.
    - Analyze the circuit depth and number of qubits used.
    - Discuss practical challenges in quantum computation (e.g., noise, decoherence).
5. **Report & Presentation**
    - Prepare a short report explaining the methodology, results, and conclusions.