Optimizing Healthcare Predictive Models Using Quantum-Inspired Learning Algorithms

1. Introduction and Background

   Artificial Intelligence (AI) and Machine Learning (ML) have revolutionized healthcare by enabling predictive analytics and early diagnosis. However, classical ML algorithms face challenges in processing large-scale, high-dimensional biomedical datasets, often leading to suboptimal accuracy and computational inefficiency. Recent advances in Quantum Machine Learning (QML) offer a potential paradigm shift — combining quantum computing's ability to handle complex feature spaces with the learning capabilities of classical AI models.

   This research proposes the development of a hybrid quantum–classical framework for enhancing disease prediction accuracy and scalability, focusing on Chronic Kidney Disease (CKD) as a primary case study due to its growing prevalence and need for early intervention.

2. **Problem Statement**

   Traditional machine learning models for CKD prediction are limited by computational bottlenecks and difficulties in capturing nonlinear feature relationships within clinical data. Although QML techniques show theoretical advantages, practical implementations in healthcare remain underexplored due to algorithmic constraints and limited hybrid frameworks. Therefore, there is a need to design an optimized **quantum-enhanced learning model** that bridges classical ML efficiency with quantum computing's high-dimensional representation power.

3. **Research Objectives**

   The proposed research aims to:

   - Design a hybrid QML framework integrating classical preprocessing and quantum feature embedding for CKD prediction.
   - Evaluate the model's performance against state-of-the-art classical ML techniques.
   - Explore quantum kernel methods and variational circuits to enhance feature representation.
   - Extend the framework to other medical datasets for generalization and scalability.
   - Develop interpretability and explainability measures for quantum-based medical predictions.

4. **Proposed Methodology**

   - ✓ Dataset: Publicly available CKD datasets (e.g., UCI CKD dataset, hospital clinical data with ethical clearance).
   - ✓ Preprocessing: Feature selection and normalization using classical ML techniques.
   - ✓ Quantum Feature Encoding: Use quantum circuits to map classical data into high-dimensional Hilbert spaces.

- ✓ Model Design: Implement hybrid algorithms (e.g., Quantum Support Vector Machines, Variational Quantum Classifiers) using frameworks like Qiskit or PennyLane.
- ✓ Comparative Study: Compare hybrid models with classical counterparts such as Random Forests, SVM, and Deep Neural Networks.