Team 5 - Quantum Neural Networks

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Introduction

The present project aims to apply quantum kernels implemented with IBM’s quantum computing framework, Qiskit, to classify simple image patterns. Specifically, distinguishing between images of circles and crosses, each represented as 8x8 pixel images. This classification task provides a straightforward yet insightful exploration into the capabilities and practical usage of quantum kernels in supervised learning contexts.

The central objective of this project is to leverage quantum kernel estimation, an innovative method that encodes classical data into quantum states to exploit quantum computational advantages, potentially enhancing classification accuracy or reducing computational complexity compared to classical approaches.

Structure and Workflow

This project will follow a structured and clear workflow composed of several distinct phases: dataset preparation, quantum feature mapping, quantum kernel construction and training, classical classification, and model evaluation. Each step ensures coherence, practicality, and efficient resource utilization within the project's two-week timeline.

Step 1: Data Preparation

Initially, we will construct a balanced and representative dataset, comprising two categories: circles and crosses. Each image (8x8 pixels) will be flattened into a 64-dimensional feature vector. The dataset will then be divided into training (approximately 40 images: 20 circles and 20 crosses) and testing subsets (approximately 10 images: 5 circles and 5 crosses).

To ensure the computational manageability of quantum circuits, dimensionality reduction via Principal Component Analysis (PCA) might be employed to reduce the initial 64 dimensions to a lower-dimensional representation (e.g., 4-8 principal components), significantly simplifying the quantum circuit implementation.

Step 2: Quantum Feature Mapping

The next step is to translate classical data into quantum states via quantum feature maps. We will use `ZZFeatureMap`, suitable for embedding classical features into entangled quantum states.

Step 3: Quantum Kernel Construction and Training

We will compute the kernel matrices using Qiskit's QuantumKernel class, which simplifies the process of kernel estimation by encapsulating both quantum state preparation and measurement in a high-level abstraction.

Step 4: Classical Classification Using SVM

With the computed quantum kernels, a classical machine learning algorithm, specifically a Support Vector Machine (SVM), will be trained.