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A Performance Comparison Study of AI algorithms on Classical and Quantum Scenarios

(Independent Study Proposal)

1 Introduction

Machine learning has been an interdisciplinary field that aims to find patterns, or relationships, from data. Generally machine learning techniques could be divided into two categories [4, 3]: supervised learning and unsupervised learning [7]. With supervised learning, labels are given, which means we have a pattern, and want to find more similar patterns from the data we have. Example algorithms such as SVM (Support Vector Machines), DNN (Deep Neural Networks), etc, are successful supervised learning algorithms. While in unsupervised learning scenario, we don't have the labels we want, instead, we want to find patterns among the data we have. Algorithms such as KNN(K-Nearest Neighborhood), EM(Expectation-maximization) algorithms etc, are well-known unsupervised learning methods [2, 8].

However, due to the enormous computing resources requirements of many large machine learning algorithms, such as DNN, computing power has been an emerging bottleneck for the full release of the potential for the machine learning algorithms[1]. Quantum computers, which promise considerable speed-up compared to classical computers, has drawn widely attention from both academia and industry in recent years.

Quantum machine learning is a field growing rapidly in the last years. It aims to run classical machine learning algorithms on a quantum infrastructure. There are a lot of questions remains when applying machine learning techniques in a quantum scenario [9, 5]. For example, the quantum supremacy will still be achieved in machine learning example? The performance of machine learning we achieved in classical setting will be maintained or even better in quantum setting [10]?

In this independent study, we will perform an experimental evaluation and comparison of machine learning algorithms running in a classical computing setting and quantum setting. We're going to evaluate various aspects of the performances such as training loss, classification accuracy, time complexity, space complexity, etc. We'll also study a wide range of machine learning algorithms [6], including both supervised and unsupervised learning algorithms.

2 Hypothesis/Objectives

The objective of this independent study is to explore the performance comparison of machine learning algorithms, including both supervised and unsupervised learning algorithms, running on classical computing settings and quantum computing settings. The aspects we will focus will be on the training loss, classification accuracy, time complexity, space complexity etc.

3 Proposed methods and procedures

We will study all the background information of machine learning and quantum computing during this Fall semester, and then focus on the quantum machine learning algorithms and the performance comparison of the quantum machine learning algorithms in a classical computing and quantum computing settings. The procedures will follow the four stages:

- **Stage 1:** In this stage, we'll mainly focus on the learning of the fundamentals of machine learning algorithms, including supervised and unsupervised learning algorithms. SVM(Support Vector Machines) and DNN(Deep Neural Networks) will be our special focus.

- **Stage 2:** We'll study the fundamentals of quantum computing, including qubits, entanglement, decoherence, quantum supremacy, etc.

- **Stage 3:** In this stage, we'll explore the basic idea of quantum machine learning, study how traditional machine learning algorithms could be converted into their quantum version.

- **Stage 4:** We'll perform comprehensive experiments to evaluate and compare the performance of the machine learning algorithms running in classical computing and quantum computing settings. And conclude the independent study.

4 Project timetable/Faculty meeting

This independent study will lasts for the whole Fall semester 2023. We'll have a weekly meeting with the supervisor, in this case, is Dr. Zhengping Jay Luo. The timetable is scheduled as follows:

Time	Task
Week 1	Listing the goals, finding literature, setting up experimental platforms.
Week 2	Learn and understand the KNN(K-nearest neighbor) algorithm.
Week 3	Study the SVM(Support Vector Machines) algorithm.
Week 4	Implementation and running KNN and SVM in a classical computing setting.
Week 5	Understand and explore the Neural Networks and how it works.
Week 6	Study and learn about the DNN(Deep Nerual Networks).
Week 7	Implementing and running DNN algorithms in a classical computing setting.
Week 8	Learn the fundamentals of quantum computing, including qubits, entanglement, decoherence, etc.
Week 9	Getting used to the IBM Qiskit quantum programming platform.
Week 10	Study on the topic of how to convert the classical machine learning algorithms into quantum machine learning algorithms.
Week 11	Implementing and experimenting on the quantum machine learning algorithms.
Week 12	Collecting data results and analyzing the experimental results.
Week 13	Wrapping up the results and preparing the publication of the results.

5 Project evaluation

This independent study will be evaluated from multiple perspectives. They include but not limited to:

- **Knowledge:** The student are required to understand the fundamentals of machine learning algorithms such as KNN, SVM and DNN etc., and fundamentals of quantum computing and quantum machine learning algorithms.
- **Programming skills:** The participated student will be required to programming and debugging the related machine learning algorithms and their corresponding quantum versions using Python programming language or other preferred language.
- **Research experience:** The student will cooperate with the supervisor on researching the field of quantum machine learning and proposing new ideas novel to this field.
- **Academic Writing:** The student will cooperate and work with the supervisor on getting the potential new ideas or findings published in academic conferences/journals. The

student will help the writing process and other tasks capable of.

The final grade of the independent study will be decided upon the following components with the regarding weight:

- Advisor meeting (10%)
- Platform and program environment set up (10%)
- Algorithm implementation (30%)
- Results/Data analysis (25%)
- Poster and paper writing (25%)

6 Relevant bibliography

References

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