Project Proposal : Quantum Machine Learning
The Perceptron Model and Nearest Neighbour Algorithms

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Abstract

Machine Learning has been one of the fastest growing interest in the computer science community lately. Having studied multiple classical concepts and algorithms of machine learning, in this project I aim to study learning from a quantum perspective. This project would mainly aim at studying and understanding the quantum versions of some classical machine learning algorithms, that use some new quantum developments unknown in the classical world. I would be illuminating upon the complexity speed-up that these quantum machine learning algorithms provide over their classical counterparts.

1 Introduction

Machine Learning was introduced as a separate field in Computer Science in the 1980s with the work of Leslie Valiant. Now, it has come a long way from it's original state, with increasingly more involved and accurate algorithms being developed. Machine learning in general deals with lots of high-dimensional vectors and "large" matrices, and with computations over them. As quantum systems are generally good at manipulating high dimensional tensors, so the increasing success of quantum techniques in computation gives the motivation to combine machine learning with quantum computation.

A large amount of work has been done on developing quantum versions of classical machine learning algorithms[1]. Much work has been done on quantum algorithms for machine learning problems such as divisive clustering, k-means clustering, support vector machines, Principal Component Analysis, and neural network related problems. These quantum algorithms provide a polynomial speed-up (in cases such as nearest neighbour[3] and perceptron models[4]) as well as exponential speed-up (in clustering[2]). These algorithms utilize various quantum algorithms such as Grover's algorithm, amplitude amplification, and the HHL algorithm for providing 'efficient' and better solutions to the machine learning problems.

2 Plan

With so many advancements having been made in the field of quantum machine learning, it is not possible to cover all the problems in the duration of this project. Therefore, for this project, my work would primarily focus on two specific machine learning problems that have been improved upon by quantum techniques, namely the nearest-neighbour methods and the perceptron model.

2.1 Nearest-Neighbour Methods

N. Wiebe, A. Kapoor and K. M. Svore, in 2014, presented fast quantum algorithms for performing nearest-neighbour learning[3]. This algorithm provides a polynomial reduction in the number of queries required. The algorithm was tested on binary classification problems, where it achieved a accuracy comparable to that achieved by classical algorithms. This polynomial reduction is achieved by using fast quantum techniques to compute distance between vectors. This algorithm for nearest-neighbour learning can directly to utilized to give a quantum k-means clustering algorithm, which also has a polynomial query complexity reduction.

2.2 Perceptron Models

A perceptron is one of the simplest Artificial Neural-Networks, containing only an input and binary output layer, working on a feed-forward mechanism. In 2016, N. Wiebe, A. Kapoor, and K. M. Svore showed how quantum computation techniques can provide a quadratic reduction in the training complexity of the perceptron model of learning[4]. They provide two quantum algorithms that improve upon perceptron learning, by apply-

ing quantum amplitude amplification to the version space interpretation of the perceptron model.

3 Reach of the Project

In this project, the aim would be to understand and fully internalize the quantum methods used by Wiebe, Kapoor and Svore to come up with these algorithms. The two papers that I will be considering to start my study with are [3] and [4], though the research would definitely not be limited to these.
In addition to these papers, I would also try to study more about Quantum Artificial Neural Networks and Quantum Deep Learning, as neural networks generally hold very high potential in the classical world, and it would great to have a fast efficient quantum analogue for the same.

References

[1] ARUNACHALAM, AND WOLF. A Survey of Quantum Learning Theory. *arxiv:1701.06806v3*.

[2] LLOYD, MOHSENI, AND REBENTROST. Quantum Algorithms for supervised and unsupervised machine learning. *arXiv:1307.0411v2*.

[3] WIEBE, KAPOOR, AND SVORE. Quantum Algorithms for Nearest-Neighbor Methods for Supervised and Unsupervised Learning. *arXiv:1401.2142v2*.

[4] WIEBE, KAPOOR, AND SVORE. Quantum Perceptron Models. *arXiv:1602.04799v1*.