Chapter 12
Recent Progress in Quantum Machine Learning

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ABSTRACT

Quantum computing is a new exciting field which can be exploited to great speed and innovation in machine learning and artificial intelligence. Quantum machine learning at crossroads explores the interaction between quantum computing and machine learning, supplementing each other to create models and also to accelerate existing machine learning models predicting better and accurate classifications. The main purpose is to explore methods, concepts, theories, and algorithms that focus and utilize quantum computing features such as superposition and entanglement to enhance the abilities of machine learning computations enormously faster. It is a natural goal to study the present and future quantum technologies with machine learning that can enhance the existing classical algorithms. The objective of this chapter is to facilitate the reader to grasp the key components involved in the field to be able to understand the essentialities of the subject and thus can compare computations of quantum computing with its counterpart classical machine learning algorithms.

INTRODUCTION

In computer science, the machine learning and artificial intelligence are problem solving methods in several research and academic communities. Machine learning spans a wide range of algorithms which are used to uncover the unknown patterns from data. The machine learning algorithms can learn by an interaction and learn from data (Alpaydin, 2020, Marsland, 2015). There are mainly three sub-categories of learning i.e. supervised (task-driven), unsupervised (data-driven) and reinforcement learning (learn from mistakes) (Ayodele, 2010). The applications of machine learning are fraud detection, products

DOI: 10.4018/978-1-7998-6677-0.ch012

recommendation systems, risk assessment in financial sector, spam mail filter, traffic alerts, image recognition, sentiment analysis, social media, customer supports, robot control, weather prediction, medical diagnosis and many more (Jordan et al, 2015). These applications involve an enormous amount of formerly collected data in an input-output pairs so called big data. Hence, machine learning methods need to be highly efficient and effective in order to process the data. Nowadays, it is achievable task due to increase in computational power of systems.

Quantum computing is a compelling research area, that is blend of computer science, physics and mathematics. It has the capability to revolutionize the different scientific fields due to its massive computational power, enabled by entanglement and superposition principle. Quantum computers are known to solve problems which cannot be solved using a classical computer (Gruska, 1999). Quantum computers have shown remarkable improvements in the field of optimization and simulation (Biamonte et al. 2017). It includes computing the properties of partition functions, performing approximate optimization and simulating different quantum systems. Recently, machine learning techniques have been introduced to deal with several quantum information processing (QIP) tasks that consist the exploitation of quantum states (Nielsen and Chuang, 2002). QIP utilizes the concept of superposition principle of states for expedite processing of classical data and its amenable simulation on quantum computers (Ladd et al., 2010). The quantum machine learning techniques provide great potential, better flexibility and efficient performance analogous to classical machine learning techniques.

The rapid development in quantum computing reflects the advancement build in artificial intelligence and machine learning. The HHL algorithm is at center of quantum machine learning, proposed by Harrow, Hassidim, Lloyd in 2009. It is used to solve the linear equations and considered as the most crucial asset in quantum machine learning algorithms. Since the HHL algorithm introduced, the quantum versions of machine learning algorithms have been proposed and witnessed the exponential speed-up over the existing classical machine learning algorithms (Schuld, 2015). The principles of quantum computing can be applied to basic algorithms such as *k*-nearest neighbour algorithm, support vector machine, principal component analysis, classification and many more.

Table 1. Summary of quantum machine learning theories, algorithms and concepts

Quantum machine learning algorithms	Proposed by	Grover's algorithm	Speedup	Quantum data
Quantum k-nearest neighbor method	Wiebe et al., 2015	Yes	Quadratic	No
Quantum principal component analysis	Lloyd et al., 2013	No	Exponential	Yes
Quantum support vector machine	Auguita et al., 2003	Yes	Quadratic	No
	Rebentrost et al., 2014	No	Exponential	Yes
Quantum reinforcement learning	Dong et al., 2008	Yes	-	Yes
Quantum Boltzmann machines	Amin et al., 2018	No	Exponential	No
Quantum neural network	Narayanan & Meneer, 2000	Yes	Numerical	No
Quantum clustering	Aimeur et al, 2007	Yes	Quadratic	No