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A DISCUSSION ON THE MODELING OF SUPERVISED MACHINE LEARNING USING THE QUANTUM COMPUTING MECHANISM

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Abstract:

The mechanism of quantum computing provides support for the proposal of several tasks involving machine learning in quantum technology. Quantum computing incorporates concepts from quantum physics, such as superposition and entanglement, in order to create a new standard of computation that is significantly distinct from that of conventional computers. The qubit is the fundamental building block of quantum technology and aids in the use of quantum mechanisms for a variety of applications. Quantum computing enables the solution of problems that cannot be addressed by traditional computing machines. These problems are notoriously difficult to answer using traditional computing methods and are referred to as complicated computations. Machine learning based on classical models works very well, but it comes with increased computing needs due to the processing of a complicated and large number of data. Feature selection, parameter encoding, and the development of parameterized circuits are all aspects of the work that goes into supervised machine learning modelling using quantum computing. This work focuses on the integration of quantum computing with machine learning, which will make sense when applied to the modelling of quantum machine learning. The modelling of quantum parameterized circuits, as well as the design and implementation of quantum feature sets for sample data, are also topics of discussion. The concept of supervised machine learning is stated via the use of quantum mechanisms like as superposition and entanglement. The many traditional approaches to machine learning may be improved with the aid of quantum machine learning, which allows for more accurate analysis and prediction based on complicated measurements.

Keywords: Supervised, Machine Learning, Quantum Computing

Introduction:

Quantum observables serve as a measurement of the system's current state. As the particle moves from place X1 to position X2 and so on, its state is changing. There are an infinite number of possible states that a particle may adopt, denoted by X1, X2, etc., all the way up to Xn. The energy of a particle might be used as a unit of measurement. The momentum and condition of the particle at the given instant will determine how long it stays in that state. All of these things are referred to as particle quantities, and we may utilise them in quantum mechanisms. These measurements are also referred to as physics measurements in terms of the state of particles and their momentum. The particle state that will be used by the quantum process is one that is a superposition of several states. The state of superposition is referred to as an arbitrary state since it may be used in subsequent computations. This is how the quantum mechanism is incorporated into the field of particle physics. The following section provides an overview of fundamental quantum concepts and mechanisms, including entanglement, superposition, and qubits. [7]. Integration of quantum mechanics with a wide variety of different fields such as cryptography, molecular biology, and chemistry [10]

Quantum Bit or Qubit:

The information carried by a notion that is referred to as a "bit" or as a "ON as 1" and "OFF as 0" bit is termed the "classical bit" information that is used by the mechanism of traditional computers to represent data in terms of 0's and 1's. At any given point in time, the state of a classical bit may either be a zero or a one. A quantum computer has suggested a new method for the standard, and it is referred to as a "qubit." This bit will replace the traditional binary digits 0 and 1. In order to accurately represent data, a quantum bit will be in both the 0 and 1 states at the same time. However, a bit will only hold a single state at any one time. The ability of a qubit to take on both the 0 and 1 states concurrently at any given time is referred to as superposition. In a similar manner, two qubits that are in this state may simultaneously supply the values of all four states, which are 00, 01, 10, and 11, while three qubits can be in a superposition of eight states such as (000,001......111). The Bloch sphere is a representation of a single qubit, as seen in Figure 1. The Bloch sphere is a representation of a single qubit space, in which the activation state of an electron spinning in the up position is represented as 1, and an electron spinning in the down position is represented as 0. The Bloch sphere is a well-known depiction of the qubit in the form of a sphere, and it may be used to display the state of a single qubit. The depiction of a 1-qubit Bloch sphere with real value amplitudes is shown in Figure 1 [16]. The interests of State |0i will be defended by,

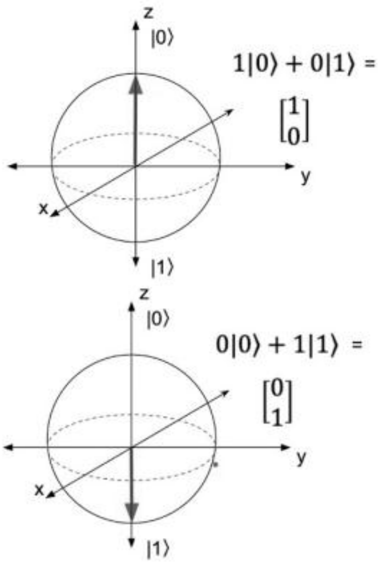

Figure 1. Bloach Sphere

Quantum Mechanism:

The information carried by a notion that is referred to as a "bit" or as a "ON as 1" and "OFF as 0" bit is known as the "bit" that is used by a classic computer mechanism, which represents data in terms of classical bit 0's and 1's. At any one time, the state of a classical bit may either be 0 or 1, depending on which is selected. Instead of the traditional binary digits 0 and 1, a quantum computer has suggested a new mechanism known as a "qubit," which is short for "quantum bit." In order to accurately represent data, a quantum bit will be in both the 0 and 1 states at the same time. However, a bit will only hold a single state at any one time. The ability of a qubit to hold both the 0 and 1 states concurrently at any given time is referred to as superposition. In a manner analogous to this, two qubits in this state are able to simultaneously supply the state values of 00, 01, 10, and 11, while three qubits are able to be in a superposition of eight states such as (000,001......111). As can be seen in Figure 1, a Bloch sphere is a representation of a single qubit. When an electron is in the up position, the activation state is represented by the number 1, and when an electron is in the down position, the activation state is represented by the number 0. A Bloch sphere represents one qubit space. The Bloch sphere is a well-known representation of the qubit that may depict the state of a single qubit. This representation of the qubit takes the form of a sphere. Figure 1 displays a visualisation of a 1-qubit Bloch sphere with real value amplitudes [16]. The representation for State |0i will be,

$$|\Psi\rangle = \alpha|0\rangle + \beta|1\rangle \quad (1)$$

Ψ state represents superposition of 0 and 1. Ψ state will measured for multiple qubits as per mechanism. Eq (1), (2), (3) represents 1qubit, 2qubit, 3qubit. 2- qubit state is represented in following manner, four states and shown in Figure 2.

$$|\Psi\rangle = \alpha 1|00\rangle + \alpha 2|01\rangle + \alpha 3|10\rangle + \alpha 4|11\rangle \quad (2)$$

Eq. (1) in which α and β are the complex values. a n-qubit is superposition of 'n' states at a moment of time shown below in Eq(3).

$$|\Psi\rangle = \alpha 1|00..\rangle + \alpha 2|01..\rangle + \alpha 3|10..\rangle + ... + \alpha n|11..\rangle \quad (3)$$

Entanglement is a phenomena in quantum physics, and it is one of the most important advantages of the process underlying quantum physics. The theory of entanglement connects all of the different qubits together. Quantum systems may be used to describe the correlations between states that are included inside a superposition. Once qubits have been intertwined with one another, it is impossible to separate them again. Entanglement on many particles It is expected that qubits would behave and respond with one another in accordance with their entangled rule, which is being applied. The superposition of four states is called quantum entanglement, and it occurs when two qubits are entangled. Entanglement in quantum systems is one of the fundamental principles of quantum physics, yet it is also one of the most difficult concepts to grasp. The term "entanglement" refers to the linking of many qubits together in order to demonstrate superposition states on higher dimensions. The activity of the laser that connects the qubits causes them to get entangled with one another. Once they have been entangled with one other, they will behave in an intermediate manner with one another. However, when the qubits have been entangled, they may be separated by any distance, but they will still be connected to one another. [16][18].

QML Benefits:

The traditional approaches to machine learning will be given a significant boost by quantum computers. Computing on the quantum level will allow for the completion of tasks that traditional computers are unable to complete due to limitations in their machine capabilities. Quantum machine learning is able to take into consideration feature spaces of increasing dimensions, up to and including n-dimensional feature spaces [2]. The traditional approach to machine learning may plot data on several dimensions, but doing so requires more time and often results in the learning algorithm being unable to keep up with the demands placed on the system. On traditional computers, machine learning has been around for quite some time, but academics are still hard at work refining various machine learning algorithms. In the first portion of the article, a short introduction is given to the idea of qubit in quantum computing as well as several quantum processes, such as superposition and entanglement. In the next part of the article, a comprehensive and comparative study of quantum machine learning and its need will be presented. In terms of the operating procedures of a classical computer, classical machine learning presents several computational challenges that must be overcome. Using quantum processes, the proposed solutions in the quantum computing domain will be able to overcome the computational challenges that now exist and represent data on extremely high dimensional feature spaces. Quantum mechanical concepts such as superposition and entanglement will be of assistance in the representation and processing of data in higher dimensional space. This will help make sense of how quantum machine learning will replicate superior outcomes compared to traditional ml methods. In order to have a grasp on the quantum notion, let's quickly go over the following points: Quantum Qubit, Superposition, Entanglement. The many advantages offered by quantum computers serve as the impetus for the establishment of this standard, which involves the introduction of a qubit, also known as a quantum bit. On a traditional computer, the value 0 or 1 is used to denote the status of a bit. A single number can only have one of these values. The following points have been recognised as operating abilities that classical machines might be attained utilising quantum hardware, based on the literature study described above. Machine learning, when seen from a quantum point of view, will unquestionably be of assistance in solving and optimising difficult problems and obtaining the answer or prediction in a shorter amount of time. Processing massive data in quadratic time, as opposed to the more traditional approaches, is the subject of very few research articles.

Quantum Machine Learning Process Model:

In order to model quantum machine learning, a classical-quantum approach will be used. This approach will take input in the form of classical data, and the processing will be done on quantum circuits, as shown in Figure 5. The classical data input has fed to quantum algorithm, which is called training data for machine learning. The first representation of the training data will be done on the quantum feature space. In order to encode the data, the conversion of data from classical to quantum will employ a variety of approaches, such as basis and amplitude encoding [1]. The supervised machine learning technique is currently being investigated by our team. In this level of quantum circuitry, the nature of the circuit may either be parameterized or variational [4]. The next thing that will be done is measuring the output label since this is a supervised technique. After that, a comparison of the output in terms of mean absolute error will be computed, and if necessary, the processing of the model will be modified. Figure 3 provides an overview of the modelling used for the Quantum classifier, which will output the class label as the prediction [6]. A quantum classifier that is applied to intricate data points is an excellent option, but using one needs extensive measurement in order to analyse and understand the behaviour of data. [9]

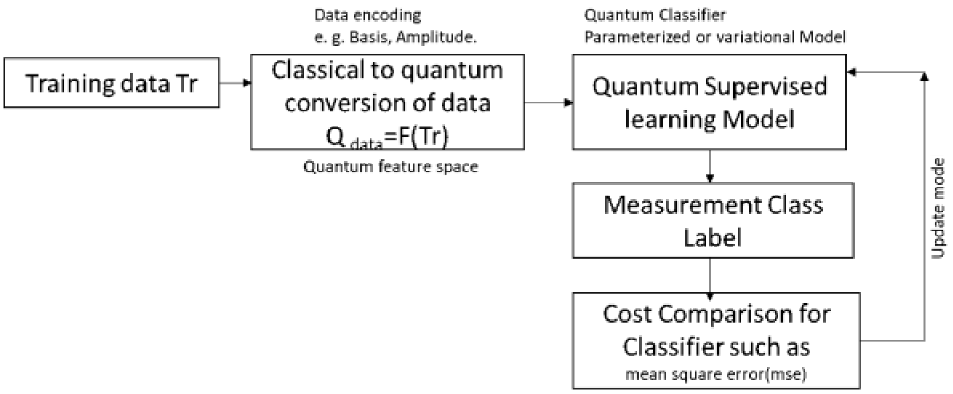

Figure 2. Quantum machine learning model.

Conclusion:

Strange analyses for the development of complicated patterns in data may be built with the help of quantum mechanics. The combination of machine learning with quantum computing might make it easier to tackle difficult machine learning problems. Quantum systems have the ability to build intricate patterns, which are notoriously difficult to produce using the mechanism of conventional devices. Quantum systems, on the other hand, are able to learn and detect patterns that classical systems are unable to perceive. Quantum machine learning may be constructed on a wide variety of different characteristics, such as the formation of hyperplanes on high-dimensional feature spaces, the classification of multiple classes, quicker vector generation, and ML optimization. The modelling of unsupervised learning and reinforcement learning is also helped by this domain integration. In this work, we explored how machine learning would be modelled using quantum technology. We also spoke about the articulation of quantum machine learning utilising classical-quantum models for implementation, based on the cloud quantum services that are already accessible.

References:

[1]. Maria Schuld, Ilya Sinayskiya and Francesco Petruccionea 2014 An introduction to quantum machine learning (Quantum Research Group, School of Chemistry and Physics, University of KwaZulu-Natal, Durban, KwaZulu-Natal, 4001, South Africa)

[2]. Vojtech Havlicek, Antonio D. Corcoles, Kristan Temme, Aram W. Harrow, Abhinav Kandala, Jerry M. Chow, and Jay M. Gambetta 20018 Supervised learning with quantum enhanced feature spaces (IBM T.J. Watson Research Center, Yorktown Heights, NY 10598, USA and Center for Theoretical Physics, Massachusetts Institute of Technology, USA)

[3]. Maria Schuld, Ryan Sweke, and Johannes Jakob Meyer 2020 The effect of data encoding on the expressive power of variational quantum machine learning models (Xanadu, Toronto, ON, M5G 2C8, Canada Dahlem Center for Complex Quantum Systems, Freie Universitt Berlin, 14195 Berlin, Germany arXiv:2008.08605v1)

[4]. Samuel yen-chi chen, chao-han huck yang, jun qi, pin-yuchen, xiaoli ma and hsi-sheng goan 2020 Variational Quantum Circuits for Deep Reinforcement Learning (IEEE Transactions on Information Theory, Digital Object Identifier 10.1109/ACCESS.2020.3010470)

[5]. Somayeh Bakhtiari Ramezani; Alexander Sommers; Harish Kumar Manchukonda; Shahram Rahimi;AminAmirlatifi 2020 Machine Learning Algorithms in Quantum Computing: A Survey (International Joint Conference on Neural Networks (IJCNN) 978-1-7281-6926-2/20/)IEEE.

[6]. Ismael C. S. Araujo; Adenilton J. da Silva 2020 Quantum ensemble of trained classifiers (International Joint Conference on Neural Networks (IJCNN) DOI: 10.1109/IJCNN48605.2020.9207488)

[7]. Giuseppe Carleo, Ignacio Cirac, Kyle Cranmer, Laurent Daudet, Maria Schuld, Naftali Tishby, Leslie VogtMaranto, and Lenka Zdeborov´a 2019 Machine learning and the physical sciences (Reviews of Modern Physics. DOI:

10.1103/RevModPhys.91.04500. Rev. Mod. Phys. 91, 045002)

[8]. M. Schuld, M. Fingerhuth and F. Petruccione 2019 Implementing a distance-based classifier with a quantum interference circuit EPL, Volume 119, Number 6 DOI: 10.1209/0295-5075/119/60002

[9]. Amira Abbas, Maria Schuld, Francesco Petruccione 2020 On quantum ensembles of quan-tum classifiers (Springer Nature Switzerland AG 2020) doi:10.1007/s42484-020-00018-6

[10]. Adriana Marais, Betony Adams, Andrew K. Ringsmuth, Marco Ferretti, J. Michael Gruber, Ruud Hendrikx, Maria Schuld, Samuel L. Smith, Ilya Sinayskiy, Tjaart P. J. Kruger, Francesco Petruccione, and Rienk van Grondelle 2017The future of quantum biology (Journal of Royal Society Interface) 15: 20180640. http://dx.doi.org

[11]. Farid Ablayev, Marat Ablayev, Joshua Zhexue Huang, Kamil Khadiev, NailyaSalikhova, and Dingming Wu 2020 On Quantum Methods for Machine Learning Problems Part I: Quantum Tools" Big Data Mining And Analytics (ISSN 2096-0654 ll04/06llpp 41 – 55 Volume 3, Number 1, March 2020 DOI: 10.26599/BDMA.2019.9020016)

[12]. Farid Ablayev, Marat Ablayev, Joshua Zhexue Huang, Kamil Khadiev, NailyaSalikhova, and Dingming Wu 2020 On Quantum Methods for Machine Learning Problems Part II: Quantum Classification Algorithms" Big Data Mining And Analytics ISSN 2096-0654 ll05/06llpp56–67 Volume 3, Number 1, March 2020 DOI: 10.26599/BDMA.2019.9020018

[13]. Yangyang Li, Mengzhuo Tian, Guangyuan Liu, Cheng Peng, And Licheng Jiao 2020 Quantum Optimization and Quantum Learning: A Survey (Digital Object Identifier 10.1109/ACCESS.2020)

[14]. Marco Fanizza, Andrea Mari, and Vittorio Giovannetti 2019 Optimal Universal Learning Machines for Quantum State Discrimination IEEE Transactions on Information Theory, VOL. 65, No. 9

[15]. Daoyi Dong, Xi Xing, Hailan Ma, Chunlin Chen, Zhixin Liu, and Herschel Rabitz Zhixin Liu, and Herschel Rabitz 1998 Learning-Based Quantum Robust Control: Algorithm, Applications, and Experiments (IEEE Transactions on Cybernetics.)

[16]. P. Wittek 2007 Quantum Machine Learning

[17]. I. S. Maria Schuld and F. Petruccionea 2016 An introduction to quantum machine learning (Springer)

[18]. E. Riefel and W. Polak 2007 Quantum Computing: A Gentle Introduction (Education)