International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 05 | May - 2023 Impact Factor: 8.176 ISSN: 2582-3930

QUANTUM COMPUTING:

IMAGE CLASSIFICATION AND VISUALIATION SYSTEM

[1] Ms E. Padma, [2]Sai Lakshmi Kailash, [3]Senugala Kavya Sree
[1]Assistant Professor, [2]Graduate Students, [3]Graduate students
Department of Computer Science Engineering,
SCSVMV University, Enathur, India

Abstract

The system is a quantum computing based binary image classification and visualization system. It uses the principle of superposition and quantum neural network to achieve an estimated accuracy of 95.5%. The model here is trained using a quantum circuit that is built using cirq and then trained using QNN. The sole purpose of this model is to classify the images into their respective category using quantum programming. It uses principles of image classification and descaling along with python and concepts of TensorFlow. Some key technologies used are Image Classification; Image Visualization; TFQ (Tensorflow Quantum); QNN (Quantum Neural Network); Quantum Computing.

keywords: Image Classification; Image Visualization; TFQ (Tensorflow Quantum); QNN (Quantum Neural Network); Quantum Computing

I. Introduction

Quantum computing is a new and emerging field. Over the last decade the advancement and research related to quantum computing domain has exponentially grown. Quantum computing is a rapidly growing field that is poised to revolutionize the way we process information. Unlike classical computers, which use binary digits (bits) to represent information, quantum computers use quantum bits (qubits) that can exist in a superposition of both 0 and 1 states simultaneously. This allows quantum computers to perform certain calculations exponentially faster than classical computers, particularly for problems involving large amounts of data or complex algorithms. Despite the potential advantages of quantum computing, developing and scaling quantum hardware remains a major challenge. Additionally, the algorithms and software needed to harness the power of quantum computing are still in their infancy. Nonetheless, there has been a surge of interest and investment in quantum computing in recent years, and researchers and companies around the world are working to advance the field and unlock its full potential. Many organizations and companies are slowly investing in understanding and developing a quantum-based computer. This field has great potential in comparison to classical computers as they have claimed and have been theoretically proven to be more efficient and provide better security and create a better user interface and experience. They have a slightly upper hand over classical computers as they are incredibly fast and are known to solve even the most complex mathematical or computational problems in a matter of few seconds or even milliseconds.

II. Literature Survey

[1] A HANDWRITTEN NUMERICAL IMAGE CLASSIFICATION WITH QUANTUM NEURAL NETWORK USING QUANTUM COMPUTER CIRCUIT SIMULATOR [Published in: (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 11, No. 10, 2020]

A Quantum Computer is a type of computer that uses principles of quantum mechanics to perform computations. While Quantum Computers are still in development and have not yet been deployed on a large scale, there are already libraries available for hybrid quantum-classical machine learning, such as TensorFlow Quantum (TFQ). One of the models used in quantum computing is the Quantum Neural Network (QNN), which is adapted from classical neural networks and can process qubit data and pass quantum circuits. This model is particularly useful for classifying image data, which is traditionally classical data that cannot reach a superposition state. However, QNN enables this protocol by transforming the data into a quantum device that provides superposition. The QNN uses supervised learning to predict image data. To classify handwritten numeric image data using a quantum computer circuit simulation, a QNN with a supervised learning method was implemented using the Python 3.6 programming language. The simulation was designed using libraries Cirq and TFQ.

[2] QUANTUM MACHINE LEARNING: A REVIEW AND CURRENT STATUS [Published in: IEEE 2021]

The field of quantum machine learning is an exciting intersection of two highly sought-after areas of research: quantum computing and classical machine learning. Its goal is to leverage quantum phenomena to solve problems in machine learning more efficiently. As the amount of data required to train a classical model continues to grow, it is reaching the limits of what traditional computing devices can handle. Quantum computation has the potential to aid in processing huge amounts of data more efficiently. The aim of quantum machine learning is to create learning algorithms that are faster than their classical counterparts. Classical machine learning involves identifying patterns in data and using those patterns to make predictions. However, quantum systems can produce unique patterns that cannot be generated by classical systems, suggesting that quantum computers may be able to outperform classical computers on certain machine learning tasks. There are three main specializations within the field of quantum technologies: quantum computing (which uses quantum phenomena to perform computational tasks), quantum information (which uses quantum phenomena to facilitate the transfer, storage, and reception of information), and quantum cryptography (which uses quantum phenomena to develop more secure cryptography techniques). The power of quantum computation lies in the vast number of permutations that become available with each additional qubit, allowing quantum computers to become exponentially more memory-intensive. In contrast to classical systems that use only two definite states (0 and 1), quantum systems allow for superposition of quantum states, which leads to quantum parallelism and enables probabilistic tasks to be performed much more quickly than with classical methods. A Turing machine is a mathematical model of computation that consists of an automaton, a strip with symbols, a read-write head, and a set of rules for manipulating symbols on the strip. Quantum computers are universal Turing machines, and their ability to perform probabilistic tasks at faster speeds is rooted in quantum mechanics.

[3] QUANTUM NEURON: AN ELEMENTARY BBUILDING BLOCKFORMACHINE LEARNING ON QUANTUM COMPUTER [Published in: Springer Nature Singapore 2020]

Artificial neural networks are constructed by combining identical units known as neurons. These neurons receive various signals, combine them, and apply a non-linear function to the weighted sum. While attempts have been made to extend neurons to the quantum domain, they have been unsuccessful due to the difficulty of implementing non-linear activation functions in the linear framework of quantum mechanics. However, a solution to this issue has been proposed in the form of a quantum circuit that simulates neurons with threshold activation. This "quantum neuron" is a building block that preserves quantum coherence and entanglement while reproducing classical neural network structures. By arranging these quantum neurons in feedforward networks, numerical evidence suggests that the network can learn a function when trained with superpositions of inputs and their outputs, and this training is sufficient to learn the function for all individual inputs. When arranged as Hopfield networks, quantum neural networks exhibit properties of associative memory, demonstrating attractor dynamics from corrupted inputs. Moreover, the close similarity between our quantum model and traditional neural network dynamics implies that the extensive body of literature and results on neural networks become directly applicable in the context of quantum machine learning.

III. Proposed Methodologies

1. The needed packages and dataset is to be imported.
2. The dataset is to be filtered to avoid any computational overflow.
3. Deduce the size of the image to (2,2).
4. Encode original pixel values to make them readable by the quantum model.
5. The circuit; the base for how the whole quantum system should perform.
6. Train the quantum neural network based on the circuit created.

A. Existing System

There is research based on this concept. The development is in early stages. Different companies have taken initiative and are researching and developing quantum based applications and processors. Quantum Computing is a vast niche. It is a field that has enormous potential. If developed right, it will bring about a impactful revolution in computing.

B. Motivation and Problem Statement

The system classifies classical images into their respective categories using a quantum model that is designed and programed by a quantum algorithm. It is a small step towards creating full fletched quantum models and a fully functional quantum computer that can be accessed by everyone in the future. It is designed to be effective and useable in the real world too. It is not just hypothetical and textual. It has a real world application, and with the advancement and betterment in quantum domain, it can be scaled up to the required proportion.

C. Proposed System

This system is built on an online IDE called google colab. In this system, we classify classical images into their respective category using a quantum model. We build a environment that is pretty accurate to a quantum computer and then classify the image based on the quantum classical machine learning hybrid model we have built. The images that have to classified are filtered from a wider dataset that is selected. The filtered data is then altered in a way that it is easy for a quantum computer to take as its input. A quantum circuit, which acts as a blue print is built using cirq and this is then visualized using SVGcircuit tool. Based on this, a QNN is built and the filtered data is trained and tested. After multiple train and tests, the model is ready to categorize any given data on its own into its respected category.

D. Modules

➢**Import module:** the needed packages such as python, cirq, tensorflow, tensorflow quantum, numpy, simpy, keras, svgcircuit, and other visualization and classification tools and the dataset that is needed is to be imported.

➢ **Filter module:** the dataset is to be filtered to avoid any computational overflow. in this system we filter only the data that is needed for the system. the quantum computer can only identify boolean values, so the dataset needed to be filtered so that it could be operated on quantum circuits.the needed data is filtered using hepler function. this system uses two out of ten datasets from the fashion mnist dataset, that is imported from keras.

➢ **Descale module:** the filtered data is not instantly readable by the quantum circuit and the module. this is so because the original image is in (28,28) pixels. if it is taken 12 directly as it is, this will require 784 qubits. this much amount of qubits is a little too much. this will increase the computational power as well as the complexity of the system. and at this stage of the advancement it is not advisory. hence we descale by reducing the size of the image to (2,2). this will need only 4 qubits. hence it makes the system more efficient and qualitative.

➢ **Data encoding module:** the original train and test values are not directly readable by the quantum model. hence we have to encode it in such a way that it is understandable by the model. this methodology is undertaken to encode original pixel values to make them readable by the quantum model.

➢ **Quantum circuit module:** this is an important module. this module creates a base or a blueprint for the whole system. this system is designed based on the system's requirement. to design this circuit, basic understanding of the principles of entanglement and superpositions and the basic concept of quantum computing and mechanics. in this, we design the circuit using cirq using different combinations o quantum gates as the software system demands.

➢ **QNN train module:** After the model is established and declared, we now create a class for the quantum neural network and train the given dataset based on this model using the QNN. The filtered data is further divided into train, test and validation data. In this system, we use 12,000 train data, 10200 test data and 1800 validation data.

E. Implementation Process

The mentioned software system is built to classify the given image input into its respective category. This system is built in an online IDE called google colab. This was chosen to avoid errors and difficulties caused due to hardware specification errors. It is an IDE primarily for python. It was released by Google in 2017. Colab is an excellent tool for data scientists to execute Machine Learning and Deep Learning projects with cloud storage capabilities. It makes it easy to install the required tools and packages at ease. The dataset used is Fashion dataset. Fashion industry is huge and all scaled up. Hence we use it to show real time uses and other related applications that are possible because of it. This can be easily collected and imported using Keras. It is a large freely available database of fashion images that is commonly used for training and testing various machine learning related or based projects and works. It is a strictly balanced dataset with each class having the same training and test sample count as other classes. Deep neural network models owe their representational power to the high number of learnable parameters. It has a training set of 60,000 examples and a test set of 10,000 examples. Each example is a 28x28 grayscale image, associated with a label from 10 classes. After the dataset is imported, we have to filter out the needed data alone. The computational and the algorithmic power of a quantum computer is not yet advanced enough to deal with large dataset in a classical computer. Hence, the needed class of data is filtered. Here we choose 2 distinct class of data o make the classification process evident and to make the computational work of the machine a little tough. The filtering is done using Helper function. It is as given bellow.

```
def Filter_36(x, y):
keep = (y == 3) | (y == 6)
x, y = x[keep], y[keep]
y = y == 3
return x, y
```

Once the data is filtered, the image has to be processed. This step is important as the quantum machine is not capable of processing the classical image as it is. The image has to be descaled to reduce the number of qubits used, which in turn reduces the computational complexity and prevents the overflow of data. The unwanted and not applicable data if any is removed. Then the classical image is converted into a quantum readable data. The descaled image is visualized and shown.

After the data image is processed, the model is built. The model is built using Cirq. *Cirq* is a Python software library for writing, manipulating, and optimizing quantum circuits, and then running them on quantum computers. It is used for writing quantum algorithms for noisy intermediate scale quantum (NISQ) devices. Roughly speaking, NISQ devices are those with O(100) qubits that can enact O(1000) gates. The quantum neural network (QNN) model that is built will be used to recognize images. This model uses two qubit gates, with continuously readout qubit. Thus, this model use layered approach; each layer will pass through the same gate. Each qubit data plays a role in the qubit readout. The model is wrapped into the tfq-keras Model. Here, the Keras model is built with quantum components. This model uses quantum data by using the Parameterized Quantum Circuits (PQC) layer for training circuit models on quantum data. Describing training procedures to the model is carried out using the compile method. Image data originating from conventional computers will enter through the PQC layer, then the image data will be quantum processed and the processed data will be sent again to a conventional computer to display the output.

Once the quantum circuit model is completed, setup and declares, A QNN class is created and trained. All the filtered is then trained. The data is divided into test, train and validation. Once this process is done, the data is encoded. The values from the new test, train dataset in not readable as it is by the quantum machine. Hence the data has to be encoded. To encode this data we using Binary encoding algorithmic method.

The Model is then trained by using trained image data and the output to be validated. Classic image data handwritten which was trained will be tested by image. The output in the form of Boolean number where value of 1.0 or true represents sandals and value of - 1.0 or false represents T-shirts. Testing of the model is performed using image test data. The testing is recorded by observing the results of the QNN testing process which is processed using the supervised learning method to predict classical handwritten image data. Meanwhile, the hinge accuracy value from the training results is 0.8603 for the accuracy value on the training data and 0.8669 for the validation hinge accuracy value. The graph of the training accuracy and validation accuracy values can be seen. Testing is performed by providing several images; the model will predict the answer. Image number 3 will be represented as true with an answer output of 1.0 and image number six 6 will be represented as false with an answer output of -1.0.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 05 | May - 2023 Impact Factor: 8.176 ISSN: 2582-3930

$$\text{Accuracy Percentage} = \frac{\text{The Quantity of True Testing Data}}{\text{The Quantity of Testing Data}} \times (100\%)$$

Finally, as we give an image at random, the system takes the input and based on the test and train that is done, figures of to which group the given image belongs to and then the category of the image along with the descaled and processed version of the image is displayed.

F. Proposed Architecture

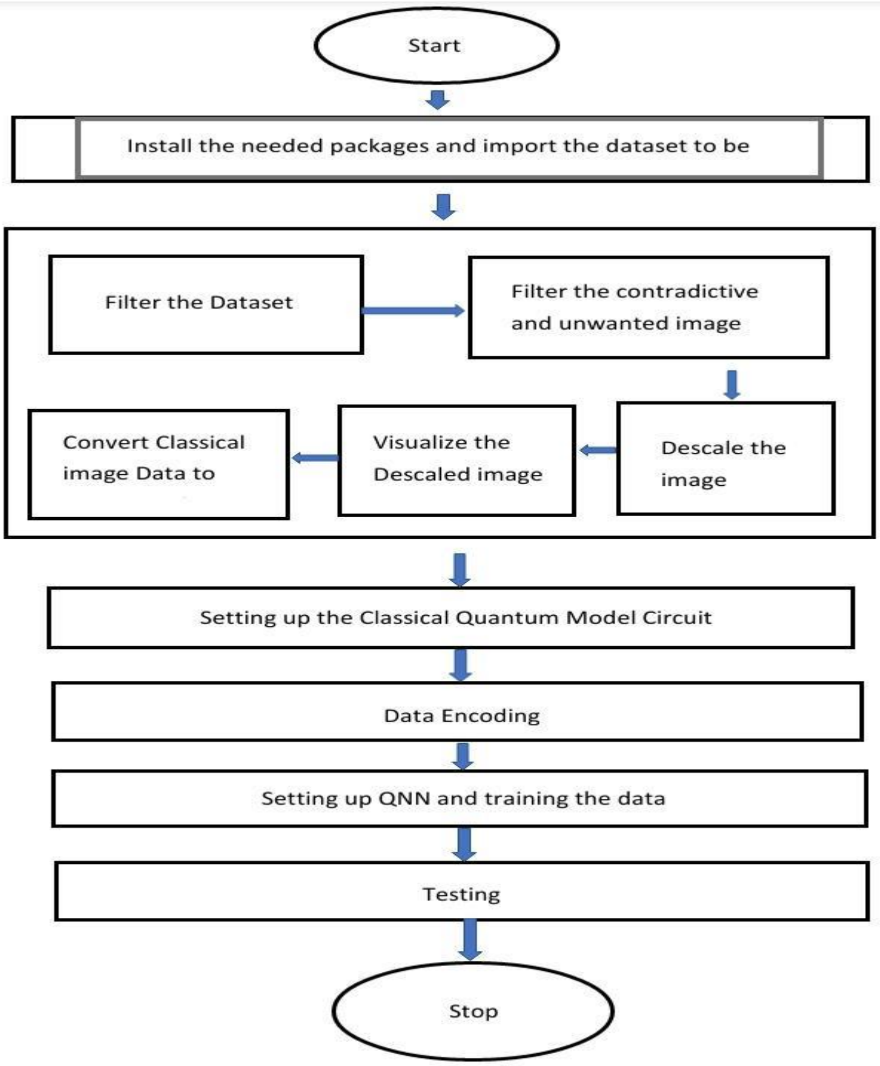

Figure 1: System architecture

G. Algorithms used

1. Collecting classical data images.
2. Preprocessing the collected image data.
3. Filtering the needed data.
4. Downscaling and resizing images to fit the quantum circuit.
5. Setting up a model for quantum classification and visualization.
6. Training the model.
7. Testing and Implementation.
8. Result obtained.

V. Conclusion

From the results of tests that have been carried out using the fashion image data with the Quantum Neural Network (QNN) model, it shows that the accuracy results too. From this quantum binary image classification and visualization software system, we conclude that we can collect and classify classical images into their respective categories using quantum programming in a virtually setup quantum computer like environment.

The implementation of the supervised learning method to classify handwritten numeric image data on the Quantum Neural Network (QNN) model in order to achieve a superposition state has been successful and the data can be read on a quantum computer circuit simulator.

The future of quantum computing is incredibly promising, as researchers and companies continue to make significant strides in advancing the technology. As quantum computers become more powerful and sophisticated, they will be able to tackle increasingly complex problems that are beyond the capabilities of classical computers. This could include everything from simulating complex chemical reactions to optimizing financial portfolios to developing new drugs and materials. Additionally, quantum computers are expected to play a major role in advancing artificial intelligence, as they can process large amounts of data in parallel and potentially provide more efficient solutions to complex optimization problems. However, there are still significant challenges that must be overcome before quantum computing can reach its full potential. These challenges include developing error-correcting codes to account for the high error rates of current quantum hardware, improving the scalability of quantum systems, and developing new algorithms and software that can effectively harness the power of quantum computers. Despite these challenges, the future of quantum computing is incredibly exciting, and it has the potential to revolutionize the way we process information and solve problems in the years and decades to come.

VI. References

1. Improved Image Classification Algorithm Based on Convolutional Neural Network [Published in: Scientific research Vol.8 No.12, December 2021]

2. Comparative analysis of deep learning image detection algorithms [Published in: Springer 10 May 2021]

3. Quantum Neuron: an elementary building block for machine learning on quantum computers [Published in: Department of Chemistry and Chemical Biology, Harvard University, Cambridge]

4. Handwritten Numeric Image Classification with Quantum Neural Network using Quantum Computer Circuit Simulator [Published in: (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 11, No. 10, 2020]

5. Quantum Image Processing [Published in: Academia 2022]

6. Quantum image processing: and challenges [Published in: Hidawi 5 jan 2021]

7. An improved novel quantum image representation and its experimental test on IBM quantum experience [Published in: Scientific reports 6 July 2021]