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Development of Quantum Circuit Architecture on Quantum Perceptron Algorithm for Classification of Marketing Bank Data

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Abstract

The creation of quantum circuit architecture based on the quantum perceptron algorithm to classify marketing bank data is proposed in this work. A quantum circuit is a quantum gate made up of two quantum gates. Quantum bits are used in this study's computation. The primary proposed learning method was not ideal, which is the context of this study. The percentage of qubits measurement value is still 90.7 percent. It is essential to raise the value of the qubit rate. Using the IBM Quantum Experience quantum computer, researchers measured, trained, and tested the quantum circuit architecture. Bank marketing data from the UCI Machine Learning Repository was used. A quantum circuit architecture model results from this research the quantum circuit measurement results.

Keywords: classification, quantum computing, quantum perceptron, architecture, quantum circuit.

1. Introduction

One of the most common difficulties in machine learning is data classification. An information file with many types must be organized efficiently and effectively to make ready-to-use details available. There are several algorithms in guided research, one of which is an artificial neural network [1].

Classification helps analyze parts measurements to identify the type they belong to. Analysts use the information to make efficient bonds. For example, before the bank concludes disbursing a loan, the bank assesses the customer's ability to repay the loan. Banks do this by considering factors such as customer income, funds, and financial history. This data is obtained from the analysis and classification of loan information for the past period [2]. The classification strategy is used in a big way in various aspects, one of which is the medical aspect to classify information into different categories according to some limiting the comparative classifier of people. An illustration of research on grouping in the medical part is an estimate of diabetes [3].

Machine learning, a type of artificial intelligence, has made significant progress in classifying data using traditional computers[4]. Each ruler conducts research in research and development centers of giant technology industries, such as Google, IBM, Microsoft, Honeywell, and D-Wave[5].

Quantum computing is a new technique that uses quantum effects to achieve significant gains in some exponential issues and algorithm enhancements over traditional algorithms. Several years ago, numerous researchers used quantum computers to conduct research in machine learning [6].

The quantum computing concept is inspired by the occurrence of elements in quantum mechanics. A superposition occurs when a part in quantum physics has two states simultaneously. The transformation form of a particle's superposition is in bits, with the number of bits consisting only 0 or 1. The quantum computing bit number might be either 0 or 1, or a combination of the two.

This link permits one neuron to send signals to other neurons as data is processed[7]. If there is no connection then the weight is 0.

Three types of neural network learning methods: supervised learning, unsupervised learning, and a hybrid approach. Neural networks, namely: classification, can solve several problems [8], forecasting [9], patern recognition [10], and optimization [11].

All researchers prove their research results if the learning algorithm that uses quantum computing is

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more optimal than the algorithm that uses classical computing[12].

The main reference in this research is YU Zheng's research in 2018. This research results in previous researchers building a quantum perceptron architecture on a perceptron algorithm using a quantum circuit built from a quantum gate. This device shown in figure 1 uses 16 qubits to classify four different data illustrations.

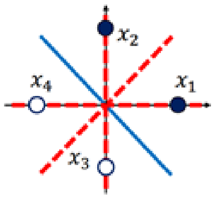

Figure 1. Binary Classifier With Four Samples In Two Dimensional Features

Features in Two Dimensions a similar superposition of 16 candidate weight vectors were obtained in a previous study using IBM Quantum. This weight vector replaces only nine candidates[13].

Test results using IBM Quantum Experience prove the qubit percentage rate of 90.7%. The main problem in this study is that there needs to be an increase in the percentage of qubits in the algorithm studied previously, namely in Yu Zheng's research, in which the researcher built a perceptron quantum architecture on the perceptron algorithm using a quantum circuit. Test result with a quantum computer using the IBM Quantum Experience shows a qubit percentage of 90.7 per cent. Based on the perceptron quantum algorithm testing, increasing the percentage of qubits is still necessary by developing a quantum circuit architecture on the perceptron quantum algorithm to produce a more maximal perceptron quantum algorithm.

This research aims to develop a quantum circuit architecture on a quantum perceptron to classify bank marketing data. This research uses three parameters: architecture, qubit percentage, and error.

The data is then used as a data collection in the machine learning data processing process using the perceptron algorithm. However, the use of quantum circuit design and the development of qubits and superpositions as important aspects in this study can change the learning accuracy and architecture contained in the perceptron [15] using big data[14].

2. Research Method

This research builds on previous research. The quantum circuit architecture that the author designed has used quantum computing as a whole. The quantum circuit architecture will be measured, trained, and tested to see how optimal the architecture is by looking at the error rate from the training and testing process. The error rate is received from the target, and the output difference is how to train and test using the IBM Quantum Experience quantum compute.

2.1. Research Stages

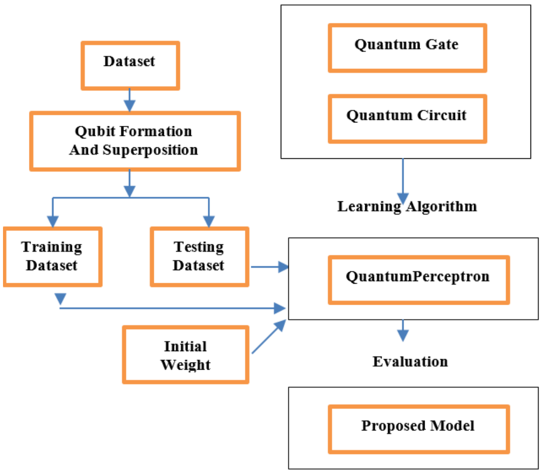

Figure 2. Research Framework

Information on figure 2 are, Dataset: This stage is the data preparation stage. The data used is bank marketing data; Qubit Transformation And Superposition: This stage transforms data into binary form, namely 0 or 1; Training And Testing Dataset: This stage is the stage of dividing the data into training data and testing data; Quantum Gate: Element of Quantum Circuit; Quantum Circuit: A collection of quantum gate elements to form a single unit ;Quantum Circuit Model: A model built on the quantum perceptron architecture; Evaluation: Evaluation of the built model; Proposed Model: The proposed model on the quantum perceptron architecture.

2.2. Qubit Formation And Superposition

The dataset used in this research is a bank marketing dataset to determine the eligibility of customers who are authorized to receive offers to become depositors obtained from the UCI Machine learning repository, which consists of seven the attributes. The dataset is divided into two parts: the training dataset and the test dataset. The dataset is transformed into qubits. The dataset can be seen in table 1, and the transformation results can be seen in table 3.

Table 1. Marketing Bank Dataset

No	Age	Job	Status	Education	House Credit	Bank Loan	Agreement
1	59	Admin.	Married	Secondary	TRUE	FALSE	TRUE
2	56	Admin.	Married	Secondary	FALSE	FALSE	TRUE
3	41	Technici an	Married	Secondary	TRUE	FALSE	TRUE
4	55	Services	Married	Secondary	TRUE	FALSE	TRUE
5	54	Admin.	Married	Tertiary	FALSE	FALSE	TRUE
6	42	Manage ment	Not Married	Tertiary	TRUE	TRUE	TRUE
7	56	Manage ment	Married	Tertiary	TRUE	TRUE	TRUE
8	60	Retired	Divorce	Secondary	TRUE	FALSE	TRUE
9	39	Technici an	Not Married	Unknow	TRUE	FALSE	TRUE
10	37	Technici an	Married	Secondary	TRUE	FALSE	TRUE
11	34	Admin.	Married	Secondary	FALSE	FALSE	TRUE
12	55	Unempl oyed	Divorce	Secondary	TRUE	FALSE	TRUE

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No	Age	Job	Status	Education	House Credit	Bank Loan	Agreement
13	28	Services	Not Married	Secondary	TRUE	FALSE	TRUE
14	30	Technici an	Married	Secondary	TRUE	FALSE	TRUE
15	36	Technici an	Married	Secondary	TRUE	TRUE	TRUE
16	37	Admin.	Not Married	Secondary	TRUE	TRUE	TRUE
17	45	Blue-Collar	Married	Secondary	TRUE	FALSE	TRUE
18	53	Services	Divorce	Primary	TRUE	TRUE	TRUE
19	38	Admin.	Not Married	Secondary	TRUE	FALSE	TRUE
20	30	Blue-Collar	Married	Secondary	TRUE	FALSE	TRUE
21	29	Manage ment	Married	Tertiary	TRUE	TRUE	TRUE
22	46	Blue-Collar	Not Married	Tertiary	TRUE	FALSE	TRUE
23	31	Technici an	Not Married	Tertiary	TRUE	FALSE	TRUE
24	39	Blue-Collar	Married	Primary	FALSE	FALSE	TRUE
25	35	Manage ment	Divorce	Tertiary	TRUE	FALSE	TRUE
26	32	Blue-Collar	Not Married	Primary	TRUE	FALSE	TRUE
27	49	Services	Married	Secondary	TRUE	FALSE	TRUE
28	41	Admin.	Married	Secondary	TRUE	FALSE	TRUE
29	49	Admin.	Divorce	Secondary	TRUE	TRUE	TRUE
30	28	Admin.	Divorce	Secondary	TRUE	FALSE	TRUE
31	43	Manage ment	Not Married	Tertiary	TRUE	FALSE	TRUE
32	43	Manage ment	Divorce	Tertiary	TRUE	FALSE	TRUE
33	43	Blue-Collar	Married	Primary	TRUE	FALSE	TRUE
34	37	Unempl oyed	Not Married	Secondary	TRUE	FALSE	TRUE
35	35	Blue-Collar	Not Married	Secondary	TRUE	FALSE	TRUE
...	...	...	...	...	...	...	...
...	...	....	....	....	....	...	...
45211	72	Retired	Married	Secondary	FALSE	FALSE	True

The Bank Marketing dataset consists of Age (X1), Job (X2), Status (X3), Education (X4), House Credit (X5), Bank Loans (X6) and Agreement (Target). The Bank Marketing dataset is transformed into binary form 0 and 1 with the rules according to table 2.The data transformation rules can be seen in table 2.

Table 2. Terms of Data Transformation

No	Attribute	Information	Weight
1	Age (X1)	0 – 20 years (adults) >= 21 years (children)	0 1
2	Job (X2)	Low income or no income or unknown High or medium income	0 1
3	Status (X3)	Divorced or unknown Not Married or Married	0 1
4	Education(X4)	Primary or unknown Secondary or Tertiary	0 1
5	House Credit(X5)	Have a home loan (True) Don't have a home loan (False)	0 1
6	Bank loan (X6)	Have a loan (True) Don't have a (False)	0 1
7	Agreement (Target)	Worthy (True) Not feasible (False)	1 0

Furthermore, the data is converted into binary code as written in table 3.

Table 3. Transformation data

No	Age	Job	Status	Education	House Credit	Bank Loan	Agreement
1	1	1	1	1	0	1	1
2	1	1	1	1	1	1	1
3	1	1	1	1	0	1	1
4	1	1	1	1	0	1	1
5	1	1	1	1	1	1	1
6	1	1	1	1	0	0	1
7	1	1	1	1	0	0	1
8	1	0	0	1	0	1	1
9	1	1	1	0	0	1	1
10	1	1	1	1	0	1	1
11	1	1	1	1	1	1	1
12	1	0	0	1	0	1	1
13	1	1	1	1	0	1	1
14	1	1	1	1	0	1	1
15	1	1	1	1	0	0	1
16	1	1	1	1	0	0	1
17	1	1	1	1	0	1	1
18	1	1	0	0	0	0	1
19	1	1	1	1	0	0	1
20	1	1	1	1	0	1	1
21	1	1	1	1	0	0	1
22	1	1	1	1	0	0	1
23	1	1	1	1	0	1	1
24	1	1	1	0	1	1	1
25	1	1	0	1	0	1	1
26	1	1	1	0	0	1	1
27	1	1	1	1	0	1	1
28	1	1	1	1	0	1	1
29	1	1	0	1	0	0	1
30	1	1	0	1	0	0	1
31	1	1	1	1	0	1	1
32	1	1	0	1	0	1	1
33	1	1	1	0	0	1	1
34	1	0	1	1	0	1	1
35	1	1	1	1	0	1	1
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
45210	1	0	1	0	1	1	1

Before the data is processed into the proposed model, the information is simplified into four input qubits using "And" logic gates as seen in table 4. The age attribute with the job attribute produces $\boldsymbol{x_1}$, the status attribute with the attribute produces $\boldsymbol{x_2}$, the house credit attribute creates $\boldsymbol{x_3}$, and the bank loan attribute produces $\boldsymbol{x_4}$.

Table 4. Data Processing Results

No	x_1	x_2	x_3	x_4	Target
1	1	1	0	1	1
2	1	1	1	1	1
3	1	1	0	1	1
4	1	1	0	1	1
5	1	1	1	1	1
6	1	1	0	0	1
7	1	1	0	0	1
8	0	0	0	1	1
9	1	0	0	1	1
10	1	1	0	1	1
11	1	1	1	1	1
12	0	0	0	1	1
13	1	1	0	1	1
14	1	1	0	1	1
15	1	1	0	0	1
16	1	1	0	0	1
17	1	1	0	1	1
18	1	0	0	0	1
19	1	1	0	0	1
20	1	1	0	1	1
21	1	1	0	0	1
22	1	1	0	0	1
23	1	1	0	1	1
24	1	0	1	1	1
25	1	0	0	1	1
26	1	0	0	1	1
27	1	1	0	1	1
28	1	1	0	1	1

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No	x_1	x_2	x_3	x_4	Target
29	1	0	0	0	1
30	1	0	0	0	1
31	1	1	0	1	1
32	1	0	0	1	1
33	1	0	0	1	1
34	0	1	0	1	1
35	1	1	0	1	1
...	...	...	...	...	...
...	...	...	...	...	...
45210	0	0	1	1	1
45211	0	1	1	1	1

2.3. Training and Testing Dataset

The research dataset is consisting of 45,211 data. The dataset is divided into 2, namely the nursery training dataset and the testing dataset. The nursery updating dataset was obtained from 60% of the data sample from the bank marketing dataset, and the test dataset was obtained from 40% of the data sample.

2.4. Learning Algorithm

The learning technique is based on a perceptron-based artificial neural network with n quantum operations and a quantum circuit architecture. The architecture is built around a quantum circuit that consists of a series of quantum gates. The quantum course was designed utilizing the form of the quantum circuit created by Yu Zheng in 2018 with 16 qubits.

3. Results and discussion

3.1. Quantum Circuit

Researchers developed a Quantum Circuit from a study built by Yu Zheng in 2018 by improving the Complementary Quantum Circuit Complementary and eliminating the Quantum Circuit Uncomplementary using four qubit data inputs.

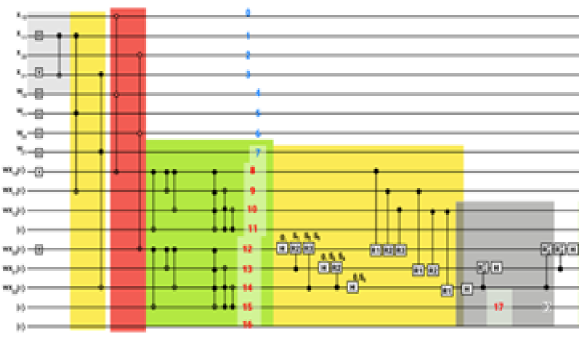

Figure 3. Quantum Circuit

The arrangement of this quantum circuit model as shown in figure 3 consists of the first sequence is the initialization of input data and weight data. There are four qubits of input data, namely $\boldsymbol{x_1}, \boldsymbol{x_2}, \boldsymbol{x_3}, \boldsymbol{x_4}$, and there are four qubits of weight data, namely $\boldsymbol{w_1}, \boldsymbol{w_2}, \boldsymbol{w_3}, \boldsymbol{w_4}$.

Hadamard Gate, Pauli-X, CNOT Gate and CCNOT Gate. Hadamard Gate allows us to escape the axis of the block sphere with the formula $H = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$. Hadamard Gate can carry out the transformation H 0⟩=+⟩ as well as H 1⟩=−⟩. Gate-X serves to change the amplitude of the condition, and with the formula $|0\rangle = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix}\begin{bmatrix}1\\0\end{bmatrix} = \begin{bmatrix}0\\1\end{bmatrix} = |1\rangle$, On the other hand, the CNOT Gate is in charge of 2 qubits carrying out the Not operation on the second qubit when the qubit is |1>. Gate can be represented by gate |a,b> to |a>, a ⊕ b>. The CCNOT gate applies the X gate to the third bit when the first 2 bits are in the condition |1>.

The second arrangement of quantum circuit forms is a quantum multiplier arrangement whose role is to multiply between inputs and weights with the formula y> = $|w_1 >.|x_1 >$. The quantum multiplier array consists of the Hadamard gate and the gate Rϕ. Hadamard Gate does the transformation H | 0⟩ = | +⟩ and H | 1⟩ = | −⟩ with formula $H = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$. While the gate Rϕ carries out rotation ϕ around the Z-axis, which has a matrix Rϕ = $\begin{bmatrix}1 & 0\\0 & e^{i\phi}\end{bmatrix}$.

The third arrangement of the quantum circuit is the quantum adder which is useful for adding up all the multiplications between the inputs and the weights with the formula |y> = $\sum |w_i >.|x_1 >$. The quantum adder arrangement consists of a complementary quantum arrangement. The complementary circuit consists of the CNOT and the CCNOT.

3.2. Development of Quantum Circuit Architecture

This quantum circuit model architecture develops from the architecture created by the previous researcher Yu Zheng in 2018. The architecture uses 16 qubits consisting of 4 input data qubits, four qubit information weights, and 6 data qubits for multiplication between input qubit data and weight data. Two ancilla qubits as control qubits. In this quantum circuit architecture, it was developed by improving complementary circuits and eliminating uncomplimentary circuits. In the complementary circuit that is changed is a topfolio 4 gate with the method of reversing the shape of a topfolio 4 gate with a layer of qubit lines q_{11} , q_{10} , q_9, dan q_8 be a row array of qubits q_8 , q_9 , q_{10}, and q_{11} and gate toffoli 4 with qubit row arrangement q_{15} , q_{14} , q_{13}, and q_{12} be a row array of qubits q_{12} , q_{13} , q_{14}, and q_{15}. Gate tofolio 4 operates on 4 qubits.

3.3. Quantum Circuit Architectural Measurement

The measurement of the researcher's quantum circuit model revealed that there is only one output binary, namely the 10001000000000000 binary with a 100% qubit percentage. The amplitude of each state that isn't |10001000000000000 is 0, as expected, implying that we have a 100% chance of measuring |10001000000000000.

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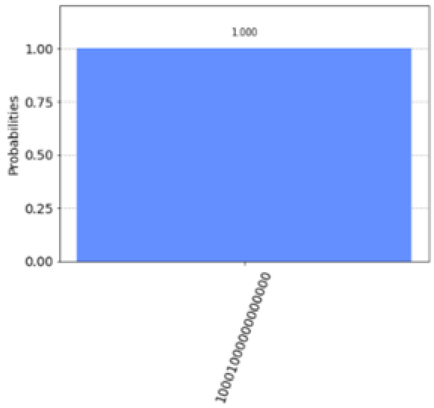

Figure 9. Quantum Circuit Model Measurement

After measuring, training, and testing, the training and testing results prove that error = 0 because there is no difference between the percentage of target qubits and the percentage of output qubits.

This model can be derived into the form of an algorithm. Then, a program can be made from the algorithm to perform data classification.

4. Conclusion

The conclusion of this study is that the results of the training and testing of the Quantum Circuit Architecture that we developed show a 100% percentage of qubits with one binary data output. The percentage of qubits obtained has increased significantly compared to the previous architecture built by Yhu Zeng in 2018. There was an increase of 9.3% from 90.7%. In general, there is no difference in the percentage of qubits during training and testing

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