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New Approach to The Perceptron Algorithm with Quantum Computing for Prediction Analysis of Rice Imports in Indonesia

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*Abstract***—** Rice imports are crucial to ensure a country's food availability, especially when domestic production is insufficient. Because rice is the staple food of Indonesians, a spike in rice prices could cause social unrest. Rice imports have a strategic role in maintaining food stability and reducing the risk of price instability. This research aims to utilize the Quantum Perceptron algorithm to predict rice imports more effectively. Quantum Perceptron is a new approach that combines the principles of quantum mechanics with artificial intelligence to improve prediction performance. Researchers used data on the number of rice imports from the leading countries of origin obtained from the Central Statistics Agency using 7 variables x1 to x7. The research results show that the quantum perceptron algorithm can make predictions very well, proven by a perfect accuracy of 100% with a total of 20 epochs. This result is still better than the classical perceptron, which has 100% accuracy but with a larger number of epochs, namely 50. Quantum perceptron has better performance and shorter time, which can be seen from the smaller number of epochs compared to the classical perceptron.

Keywords— Rice Import Prediction; Quantum Computing; Quantum Perceptron Algorithm.

I. INTRODUCTION

Rice imports are crucial for ensuring food availability in a country, especially when domestic production is insufficient [1]. Rice prices have sharply increased due to inadequate supply from local farmers [2]. Rice is a staple food for the Indonesian people, so any surge in rice prices inevitably leads to public unrest [3]. Rice imports are strategically important in maintaining food stability and reducing price volatility risk.

Despite efforts to predict rice imports, several problems still need to be addressed. One of the main issues is the suboptimal accuracy of predictions. The predictive models used often struggle to identify complex patterns [4]. Additionally, the limited capacity of models to handle large amounts of information is a challenge. Computational speed and efficiency in processing data are also crucial factors [5]. This study proposes the use of the Quantum Perceptron method or algorithm. The Quantum Perceptron is a new approach that combines the principles of quantum mechanics with artificial intelligence to improve prediction performance [6]. The Quantum Perceptron can overcome the complexity of data patterns that are difficult for classical models to identify. Its ability to process information simultaneously and in parallel offers the potential to enhance accuracy and efficiency in predictions, especially when dealing with large and diverse data sets. Using the Quantum Perceptron, data processing can be performed more efficiently and quickly, resulting in more accurate and timely predictions [7][8][9].

Several previous studies that serve as references for this research include utilizing the Multi-Factors High-Order Fuzzy Time Series method to forecast national rice imports [10]. The dataset used was the annual reports from the Indonesian Ministry of Agriculture on rice self-sufficiency from 1970 to 2016. The prediction results showed an almost perfect error rate (NRMSE = 0.28). Another study applied the Quantum Perceptron to estimate the number of visitors to Ucok Kopi [11]. The dataset consisted of visitor data from January to October 2021, with 7 variables from $X1$ to $X7$. The process continued until the temporary value (Y) matched the target (T) or the error value was 0. Another study used the Quantum Neural Network to forecast the Rupiah exchange rate [12]. The dataset used was the Rupiah exchange rate against the Singapore Dollar, Hong Kong Dollar, and Japanese Yen from January 1, 2000, to January 20, 2000. The accuracy obtained was 99.78% against the Singapore Dollar, 99.57% against the Hong Kong Dollar, and 99.60% against the Japanese Yen. However, previous studies have not utilized quantum computing to predict rice imports.

This research aims to apply the Quantum Perceptron algorithm as a more effective solution for predicting rice imports. This study is expected to contribute to the government in making better and more effective decisions in managing rice imports, thus reducing the risk of food supply instability and increasing food availability for the study community.

II. RESEARCH METHODOLOGY

The stages in the research design in Fig.1 begin with collecting data for this research. The data used in this research is secondary data, namely rice import data according to the main country of origin obtained from the Central Statistics Agency website. This data is input and will later be divided into training and testing data. The next step is to separate a

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portion of the dataset to be used in the algorithm training process.

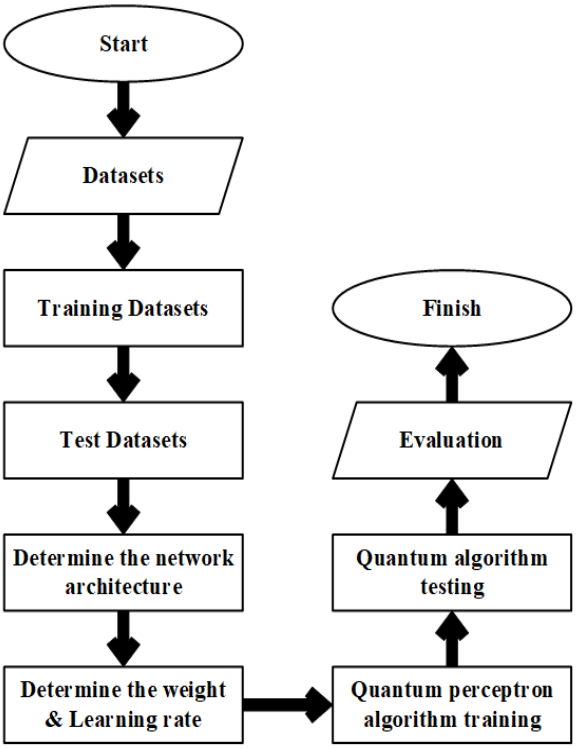

Fig.1. Research Design

Training data is used to train the model to recognize patterns in the data. Then, some of the datasets will be left for testing. This test data will test the model performance after the training is complete. After dividing the dataset, the next step is designing the structure or architecture of the network that will be used in the quantum perceptron algorithm, such as the number of neurons and layers in the model. Then, the initial weight and learning rate value used in algorithm training will be determined.

The learning rate determines how quickly the model adjusts its weights during training. After determining the initial weights and learning rate, the model training process uses the quantum perceptron algorithm on the training data. The model will adapt based on the predetermined weights and learning rate. Once training is complete, the model is tested using test data to evaluate how well the model performs. Evaluate model performance based on test results to see the accuracy and effectiveness of the model in recognizing data patterns. After the evaluation, the research stage is completed, and the final results can be analyzed or concluded.

A. Datasets

The dataset in this study comprises secondary data, specifically the quantity of rice imports from main source countries obtained from the Central Statistics Agency. The data covers the period from 2017 to 2023.

The dataset is divided into training and testing data based on the research data. Data from 2017 to 2022 (x1-x6) are used as input, and data from 2023 (x7) are used as the target.

TABLE I
RESEARCH DATA

Country Of Origin	Year (Ton)						
	2017	2018	2019	2020	2021	2022	2023
India	32209,7	337999	7973,3	10594,4	215386	178534	69715,7
Thailand	108945	795600	53278	88593,1	69360	80182,5	1381921
Vietnam	16599,9	767181	33133,1	88716,4	65692,9	81828	1147705
Pakistan	87500	310990	182565	110517	52479	84407	309310
Myanmar	57475	41820	166701	57841,4	3790	3860	141204
Japan	72,1	0,2	90	0,3	230,291	56,087	61,5
China	2419	227,7	24,3	23,8	42,601	6	7

B. Data Transformation

The data in Table I is initially converted into binary form, represented by 0 and 1. The transformation into binary form follows specific rules outlined in Table II.

TABLE II
TERMS OF TRANSFORMATION

Year	Provision	Weight
2017	Total < 1000	00
	Total ≥ 1000 & Total ≤ 100000	01
	Total ≥ 100001 && Total ≤ 500000	10
	Total > 500000	11
2018	Total < 1000	00
	Total ≥ 1000 && Total ≤ 100000	01
	Total ≥ 100001 && Total ≤ 500000	10
	Total > 500000	11
2019	Total < 1000	00
	Total ≥ 1000 && Total ≤ 100000	01
	Total ≥ 100001 && Total ≤ 500000	10
	Total > 500000	11
2020	Total < 1000	00
	Total ≥ 1000 && Total ≤ 100000	01
	Total ≥ 100001 && Total ≤ 500000	10
	Total > 500000	11
2021	Total < 1000	00
	Total ≥ 1000 && Total ≤ 100000	01
	Total ≥ 100001 && Total ≤ 500000	10
	Total > 500000	11
2022	Total < 1000	00
	Total ≥ 1000 && Total ≤ 100000	01
	Total ≥ 100001 && Total ≤ 500000	10
	Total > 500000	11
	Total < 1000	00
	Total ≥ 1000 && Total ≤ 100000	01
2023	Total ≥ 100001 && Total ≤ 500000	10
	Total > 500000	11

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Subsequently, the data is converted into binary form based on these rules. The conversion results can be seen in Table III.

TABLE III
TRANSFORMATION RESULT

Country	X1	X2	X3	X4	X5	X6	X7
India	01	10	01	01	10	10	01
Thailand	10	11	01	01	01	01	11
Vietnam	01	11	01	01	01	01	11
Pakistan	01	10	10	10	01	01	10
Myanmar	01	01	10	01	01	01	10
Japan	00	00	00	00	00	00	00
China	01	00	00	00	00	00	00

C. Quantum Computing

Quantum computing is a field of computer science that uses the principles of quantum mechanics to process information. It can potentially revolutionize computing compared to classical computing [13]. The basic unit of information in quantum computing is the qubit, which differs from classical bits' ability to exist simultaneously in states of 0, 1, or a superposition of both [14]. Superposition allows qubits to perform many calculations in parallel, while quantum entanglement enables entangled qubits to instantly influence each other, even over long distances [15][16]. Quantum computing shows significantly higher speed and efficiency in solving certain problems than classical computers.

D. Artificial Neural Network

Artificial Neural Networks are a type of artificial intelligence inspired by the way the human brain processes information [17][18][19]. Artificial Neural Networks are composed of numerous neurons that receive input from other neurons, combine it with specific weights, and apply an activation function to determine their output. The learning process involves training the network with data and adjusting the weights and biases to minimize the error between the network output and the desired target value. Artificial Neural Networks can handle complex and large datasets, demonstrate flexibility across various applications, and adapt to different data types.

E. Perceptron

The perceptron is the simplest and most fundamental machine-learning algorithm for binary classification tasks [20][21]. It is often seen as the foundation for more complex learning models. The perceptron comprises neurons that take input as feature vectors, combine them with corresponding weights, and apply an activation function to produce output [22][23].

F. Quantum Perceptron

The Quantum Perceptron adapts the classical perceptron model into quantum computing. It utilizes the principles of quantum mechanics to enhance the processing capabilities and efficiency of the perceptron [24]. The Quantum Perceptron combines superposition, interference, and entanglement elements to accelerate the training and classification processes.

III. RESULT AND DISCUSSION

Dirac notation is critical in the quantum perceptron process because it makes it easier to represent and manipulate quantum states and the operators used in quantum computing [25]. Quantum perceptron is a learning model designed based on the principles of quantum mechanics. Dirac notation is essential for formulating complex and abstract mathematical operations in a compact and intuitive form. Dirac notation, also known as bra (>) – ket (<) notation, is a notation system developed by physicist Paul Dirac to describe vectors in Hilbert space, which is a vector space used in quantum mechanics to represent the states of quantum systems [26]. This notation is very efficient and intuitive for performing calculations in quantum computing.

TABEL IV
DIRAC NOTATION

Notation	Matrix						Ordo
Bra (>)	1>	=	$\begin{matrix}0\\1\end{matrix}$	0>	=	$\begin{matrix}1\\0\end{matrix}$	2x1
Ket (<)	<1	=	0 1	<0	=	0 1	1x2

Table IV outlines Dirac notation, commonly used in quantum mechanics to represent vectors in Hilbert space. It consists of two components: bra (<|), representing row vectors or dual vectors, and ket (|>), representing column vectors or state vectors. For example, <1| corresponds to the row vector [0 1]. Bra vectors have dimensions of 1x2, while ket vectors are 2x1. This notation is crucial in expressing quantum states, probabilities, and operators, with the inner product <1|0> yielding a scalar. This study uses a 12-2-2 architecture with a learning rate of 0,1. The first step is to assign random weight values *w* and *v* from {0,1}, namely:

$$W_{1,1} = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix},\ W_{1,2} = \begin{bmatrix}0 & 0\\1 & 1\end{bmatrix},\ W_{2,1} = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix},\ W_{2,2} = \begin{bmatrix}0 & 0\\1 & 0\end{bmatrix},$$
$$W_{3,1} = \begin{bmatrix}0 & 0\\0 & 1\end{bmatrix},\ W_{3,2} = \begin{bmatrix}1 & 0\\1 & 1\end{bmatrix},\ W_{4,1} = \begin{bmatrix}0 & 1\\1 & 1\end{bmatrix},\ W_{4,2} = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix},$$
$$W_{5,1} = \begin{bmatrix}1 & 0\\0 & 0\end{bmatrix},\ W_{5,2} = \begin{bmatrix}0 & 1\\0 & 1\end{bmatrix},\ W_{6,1} = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix},\ W_{6,2} = \begin{bmatrix}0 & 0\\1 & 1\end{bmatrix},$$
$$W_{7,1} = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix},\ W_{7,2} = \begin{bmatrix}0 & 0\\1 & 0\end{bmatrix},\ W_{8,1} = \begin{bmatrix}0 & 0\\0 & 1\end{bmatrix},\ W_{8,2} = \begin{bmatrix}1 & 0\\1 & 1\end{bmatrix},$$
$$W_{9,1} = \begin{bmatrix}0 & 1\\1 & 1\end{bmatrix},\ W_{9,2} = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix},\ W_{10,1} = \begin{bmatrix}1 & 0\\0 & 0\end{bmatrix},\ W_{10,2} = \begin{bmatrix}0 & 1\\0 & 1\end{bmatrix},$$
$$W_{11,1} = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix},\ W_{11,2} = \begin{bmatrix}0 & 0\\1 & 1\end{bmatrix},$$
$$W_{12,1} = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix},\ W_{12,2} = \begin{bmatrix}0 & 0\\1 & 0\end{bmatrix},$$
$$V_{1,1} = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix},\ V_{1,2} = \begin{bmatrix}0 & 0\\1 & 1\end{bmatrix},$$
$$V_{2,1} = \begin{bmatrix}0 & 0\\1 & 0\end{bmatrix},\ V_{2,2} = \begin{bmatrix}1 & 0\\0 & 0\end{bmatrix}.$$

The testing begins with data number 1, using 011001011010 as input and 01 as output. The next step is to

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determine the output values at Z_1 and Z_2 using Equation (1) and Equation (2).

$$Z_1 = W_{1,1}.|X_1> + W_{2,1}.|X_2> + W_n.|X_n> \quad (1)$$

$$Z_2 = W_{1,2}.|X_1> + W_{2,2}.|X_2> + W_n.|X_n> \quad (2)$$

The outputs Z_1 and Z_2 in a quantum perceptron result from quantum operations that apply weights and activation functions to the inputs in different layers. Although similar in concept to classical neural networks, quantum perceptrons use quantum operations on qubits to produce output values at each layer, which can then be used for classification or prediction. The next step is to find the output from Y_1 and Y_2 using Equations (3) and (4), usually referring to the output produced by neurons after each layer's activation process. If Z_1 and Z_2 are the output before the activation function on the first and second layers, then Y_1 and Y_2 are the output after the activation function is applied to each layer. Y1 and Y_2 are the final output of the quantum perceptron.

$$Y_1 = V_{1,1}.|Z_1> + V_{2,1}.|Z_2> \quad (3)$$

$$Y_2 = V_{1,2}.|Z_1> + V_{2,2}.|Z_2> \quad (4)$$

After the outputs Z_1, Z_2, $Y1$, and $Y2$ are obtained, the next step is changing W and V weights using Equations (5) and (6).

$$W(new) = W(old) + \alpha\ .\ (|Y_1> - |T_1>)\ .\ <X_n| \quad (5)$$

$$V(new) = V(old) + \alpha\ .\ (|Y_1> - |T_1>)\ .\ <Z_n| \quad (6)$$

The model will get closer to the optimal solution by updating the weights at each iteration, reducing errors, and increasing prediction accuracy. The next step is to adjust the weights. The process continues with data number 2 after the weight adjustments are completed. The process will proceed by iteratively adjusting the weights until the output (*Y*) matches the target output (*T*) or the error value is 0. After all stages have been carried out up to the last data, the result is that the quantum perceptron prediction has perfect accuracy, namely 100%, with the number of epochs of 20 epochs. This result is still better than the classical perceptron, which has an accuracy of 100% but with a larger number of epochs, namely 50.

TABEL V
COMPARISON RESULT

Model	Accuracy	Epoch
Perceptron	100%	50
Quantum Perceptron	100%	20

Based on Table V, after carrying out the implementation phase results, it can be concluded that the quantum perceptron performs better and takes a shorter time, which can be seen from the smaller number of epochs compared to the classical perceptron.

IV. CONCLUSION

The research results show that the Quantum Perceptron algorithm can be used to predict the amount of rice imports. After carrying out the training stage on all the tested data, the results show that the quantum perceptron algorithm can make predictions very well, proven by perfect accuracy, namely 100%, with a total of 20 epochs. This result is still better than the classical perceptron, which has 100% accuracy but with a larger number of epochs, namely 50. Quantum perceptron has better performance and shorter time, which can be seen from the smaller number of epochs compared to the classical perceptron.

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