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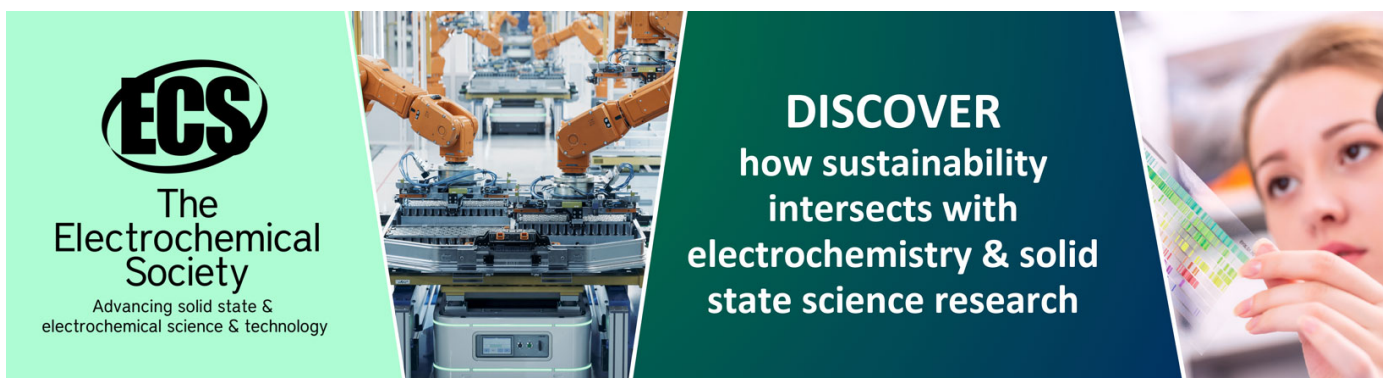
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Backpropagation artificial neural network for prediction plant seedling growth

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Abstract. Prediction of the growth of plant seedlings is one of the important problems in the world in order to fulfill the availability of food for all residents. At this time Greenhouse technology has been developed which is one of the technologies that support plant growth. Unfortunately, prediction technology is still done manually so the results are not accurate. This paper proposes the Neural Network Backpropagation method to evaluate the growth of plant seedlings in the greenhouse area. Data collected from the internet network system from temperature sensors, soil humidity, environmental humidity, light intensity and cameras to monitor growth. Seedling prediction is done by building a computer program using the neural network backpropagation algorithm based on time series that has input layer, hidden layer and output prediction architecture. Training data is used to carry out the training process before the program is used to perform predictions. Furthermore, the program is used to make predictions. The results of applying the neural network backpropagation algorithm to predict the growth of plant seedlings in the greenhouse get good results based on the first iteration Mean Squared Error (MSE) of 0.0112, with computing time 0.0193 seconds and data accuracy of 92.79%, which means that the prediction generated approximates actual data for the application of backpropagation neural network algorithms to the evaluation of plant seedling growth.

1. Introduction

Food is a very important problem in the world, food shortages can have an impact on malnutrition. These impacts greatly affect the growth of young people and children and cause death in infants. A very serious problem in the food crisis is global hunger [1]. Efforts to increase agricultural land productivity in all countries are needed to prevent hunger. The development of agricultural technology is needed to maximize various farming methods. Plant matching technology requires efforts in developing agriculture supported by information systems and technologies that help to improve crop yields and quality so as to supply the world's food needs [2].

Greenhouse is a model of developing agricultural techniques that are able to increase agricultural production by adapting to climate conditions that are needed in controlled indoor plants. The room can



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help protect plants from external physical influences such as rain, wind, pests and low temperatures [3]. Plant growth in the greenhouse can be used computer technology and remote automatic control techniques with wireless sensor networks (WSN) in the greenhouse area [4]. Control of the condition of the greenhouse through a wireless sensor network can be done on environmental conditions that are required on parameters by plants. Some important chemical and physical content parameters to be controlled for example: temperature, CO₂ (carbon dioxide), air flow, humidity, light intensity, and supply of nutrients that require proper attention for the development of plant seeds. Monitoring parameters in the greenhouse are used to protect plants from disturbance that can damage plant conditions [5]. Greenhouses that use wireless sensor network technology are proven to be able to conserve water usage. The integration of Wireless Sensor Networks (WSN) for greenhouses has been a new phenomenon as a technology that can increase crop production [6].

Conducting activities to predict plant seeds is one of the food problems with the greatest difficulty in evaluating the growth of plant seeds in a greenhouse. Plant growth can be adjusted through monitoring environmental parameters of the greenhouse [7]. To support growth observation can be done by artificially intelligent by measuring physical indices such as stem length, number of leaves, plant weight, and plant height and width. Measurement of plant indexes aims to control plants [8]. Neural network algorithm can also predict fruit from pepper plants from the stage of planting seedlings in a greenhouse by measuring plant characteristics, namely plant height, canopy width, number of fruits per plant, yield of fresh fruit per plant (weight of each fruit plant), and dried fruit yields per plant [9]. Neural network algorithm in processing data with time series can choose the number of observations based on past data. Neural network algorithm with time series is a clear, simple method for determining this parameter by testing many networks of varying amounts of input and hidden units estimate each generalization error and selecting the network with the lowest generalization error [10].

2. Related Work

The backpropagation Artificial Neural Network (ANN) architecture model that was developed consisted of inputs that had several variables that had growth correlations from the plants tested [11]. The environmental condition monitoring system uses a wireless sensor network that is applied to high-precision agriculture in a controlled environment. In addition, to minimize environmental impacts and maximize yields with significant yields compared to traditional cultivation systems [12]. The application of neural network algorithms can make prediction models easier and more accurate with many inputs. By designing a network that studies plant factors effectively estimates the production of plant seeds in the long or short term [13].

Neural network algorithms have been widely used for forecasting and forecasting functions. One of the most significant advantages of ANN compared to other prediction models is that predictions using ANN can approach a high level of accuracy supported by information from data. Neural network algorithm in processing data with time series is done by selecting the number of observations based on past data. Neural network algorithm with time series is a clear, simple method for determining this parameter by testing many networks of varying amounts of input and hidden units estimating each generalization error and selecting the network with the lowest generalization error [10].

Practicing networks provides the advantage of unsupervised grouping of supervised learning with its ability to adapt. Different data sets taken from different plant growth can give different characteristics. Backpropagation has three stages in training the network namely forward feed (feedforward) of the input pattern, calculation of errors and adjustment of weights. Artificial neural network units such as input units, hidden units, and output units that are interconnected. Artificial neural network algorithms with supervised learning do learning based on certain weight values with results that can be determined [14]. The architecture of artificial neural networks is shown in Figure 1.

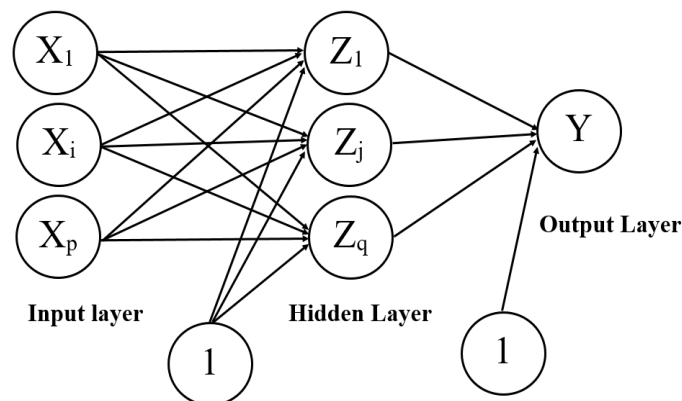


Figure 1. Architecture of artificial neural networks.

Backpropagation artificial neural networks explain how the input layer receives data from the input vectors (X_1 , X_i , and X_p) send it to the hidden layer (Z_1 , Z_j , and Z_q). Then the units in the hidden layer (Z_1 , Z_j , and Z_q) accept the input weights and transfer these weights to the output layer (Y) with a transfer function. Information is disseminated into the network with every input manipulation and the results are calculated in each process unit. Each unit in the output layer calculates weight and error. The back spread from the output layer returns to the hidden layer to see the calculated error and weight values then returns to the hidden layer to update the weights. Internet of Things (IoT) is integrated into the Wireless Sensor Network (WSN) to support taking real-time data and monitoring environmental parameters of plant growth in the greenhouse.

WSN is able to control by monitoring remote plants connected to the internet. WSN nodes consisting of temperature, soil moisture, environmental humidity, light intensity and actuators connected to Arduino and WIFI devices send data through the cloud to the gateway or router for transfer to the cloud server. WSN provides data and controls the environment to provide optimal conditions for plant growth. WSN provides sensor and actuator information stored in the cloud via WIFI to share information and monitor with remote devices [15]. Sensors on WSN are used to provide information about temperature, pressure, humidity and light levels in plants. All of these are connected using the IoT cloud server to access data and provide a cost-effective solution for farmers [16]. The main components of IoT include sensor networks that directly contact objects, gateways to send sensor data, and clouds to record, store and process these data [17,18].

3. System Realization

The selection of backpropagation network in this study has 6 input variables indicated by the x symbol and 6 hidden layers with z symbols and output with the y symbol. After the network is formed, the training process is computationally carried out. The developed of backpropagation artificial neural network architecture is shown in Figure 3. Plant seed growth prediction system with backpropagation neural network algorithm is developed with computer programming for data calculation and displays the plant seed growth prediction information system. This system is made in the form of desktop-based Graphical User Interface (GUI) and the information generated in the form of a prediction table graph so that it can help in seeing the predicted results of the growth of seedlings in a greenhouse.

The initial process carried out in this prediction system is to perform data calculations and create a GUI (Graphical User Interface) based information system to display predictions by reading data on temperature, air humidity, soil moisture, light intensity, plants, number of leaves, plant width, and length the stem. The stages in making predictions can be explained by the following:

- a. Initialize parameters for the number of input neurons, hidden neurons, output layer neurons, learning rate, number of iterations and error tolerance with the equation:

$$\text{Value } V = (n_{\text{input}} + 1) * n_{\text{hidden}} \quad (1)$$

$$\text{Value } W = (n_{\text{hidden}} + 1) * n_{\text{output}}$$

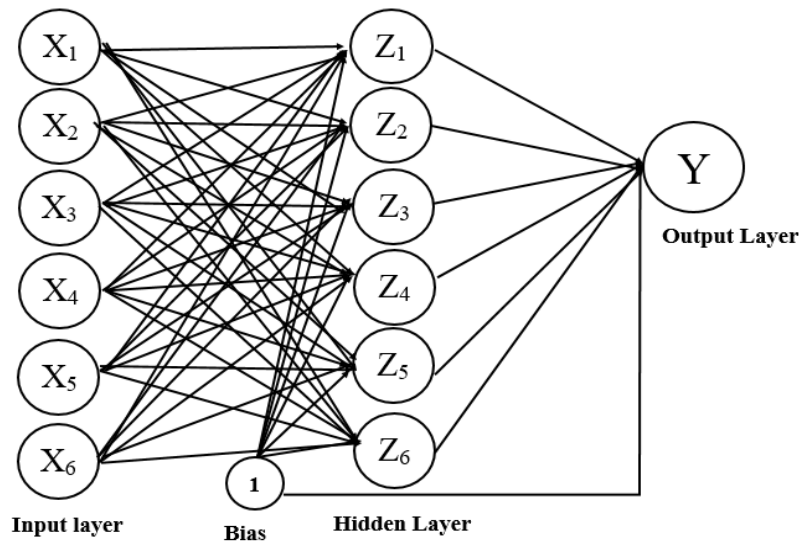


Figure 2. The developed of backpropagation artificial neural network architecture

- b. Calculate the value of neurons in the output layer (Z value) including the calculation of the value of Z_i ($Z_1, Z_2, Z_3, \dots Z_n$) using the following equation:

$$z_{in_j} = v_{oj} + \sum_{i=0}^n x_i v_{ij} \quad (2)$$

$$z_j = f(z_{in_j})$$

- c. Calculate the value of neurons in the output layer (Y value) including the calculation of the value of Y_i ($Y_1, Y_2, Y_3, \dots Y_n$) using the following equation:

$$y_{in_k} = w_{ok} + \sum_{i=0}^n z_j w_{jk} \quad (3)$$

$$y_k = f(y_{in_k})$$

- d. Perform backward propagation calculations from the output layer to the hidden layer to update the weight connecting the output layer and the hidden layer (weight W). The equations used at this stage are as follows:

$$\begin{aligned}w_{jk}(\text{new}) &= w_{jk}(\text{old}) + \Delta w_{jk} \\w_{0k}(\text{new}) &= w_{0k}(\text{old}) + \Delta w_{0k}\end{aligned}\quad (4)$$

- e. Perform backward propagation calculations from the hidden layer to the input layer to update the weight of V using the following equation:

$$\begin{aligned}v_{ij}(\text{new}) &= v_{ij}(\text{old}) + \Delta v_{ij} \\v_{0j}(\text{new}) &= v_{0j}(\text{old}) + \Delta v_{0j}\end{aligned}\quad (5)$$

4. Result and Discussion

In plant growth prediction systems using the backpropagation neural network algorithm make predictions by reading spreadsheets consisting of light intensity, temperature, air humidity, soil moisture, number of leaves, plant width and stem length. Predictions on plant growth are carried out due to internal and external factors that affect growth, one of which is microbial infection which is influenced by temperature differences. Prediction of plant growth using computer software is able to provide a picture between the growth of microbes with different temperature effects based on plant growth parameters. Computer software is able to provide results with accuracy to measure predictions and measurement values with good correlation. The display results of the system that has been built are shown in Figure 3.

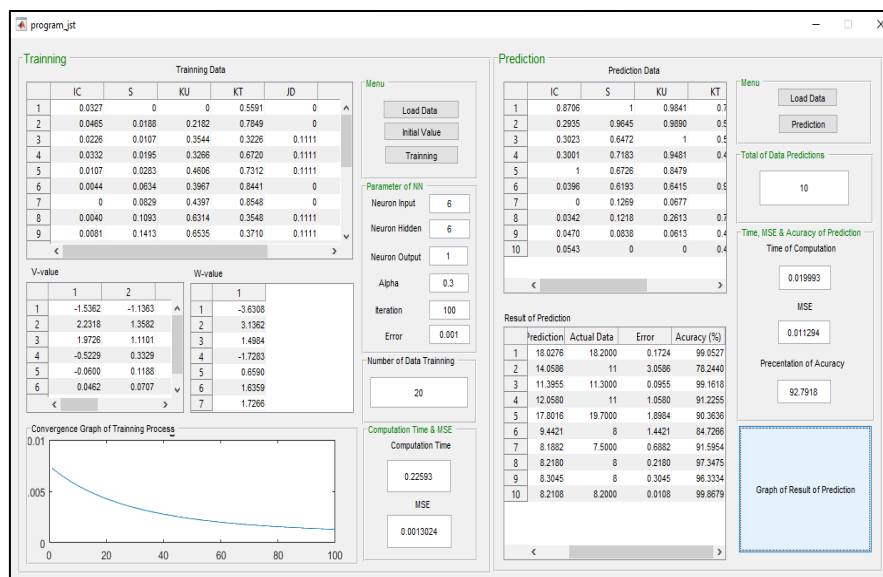


Figure 3. The display results of the system that has been developed

The results of computer programming that have been shown in the figure consist of two parts, namely the unit used to conduct training (the left side) and the unit used to make predictions (the right side). In the training section done to enter training data, these data are input data and growth data that have been generated. Training data come from daily data whose growth results are known. The amount of training data and the distribution of data variations determine the accuracy in predictions [19].

System testing in this study was carried out by entering test data as a result of predictions. Validation is done by comparing the predicted values issued by the computer system to the actual values

obtained from field measurements. Learning data is adjusted to the parameters of 6 input layers, 6 hidden layers, 1 output layer, learning rate (alpha) as much as 0.3, iteration as much as 100 and error tolerance as much as 0.001. The test results are shown in Table 1.

Table 1. Validation results of growth predictions

Result of prediction data	Actual data	Error	Accuracy (%)
18.1	18.2	0.2	99.1
14.1	11	3.1	78.3
11.4	11.3	0.1	99.2
12.1	11	1.1	91.3
17.9	19.7	1.9	90.4
9.5	8	1.5	84.8
8.2	7.5	0.7	91.6
8.3	8	0.3	97.4
8.4	8	0.4	96.4
8.3	8.2	0.1	99.9

Prediction data will be predicted which results in predictive data with a computational time of 0.0193 seconds, Mean Squared Error (MSE) of 0.0112 and an accuracy value of 92.79%. MSE value reflects the quality of the performance of the system that has been built. The smaller the MSE value, the greater the accuracy of the prediction results [11]. A comparison graph between the predicted data and the actual data obtained from the test results of the developed system is shown in Figure 4. From the figure it is shown that the prediction pattern is the same as the actual data pattern. This shows that the data system has visually worked well. The accuracy value of 92.79% indicates this system can be predicted accurately.

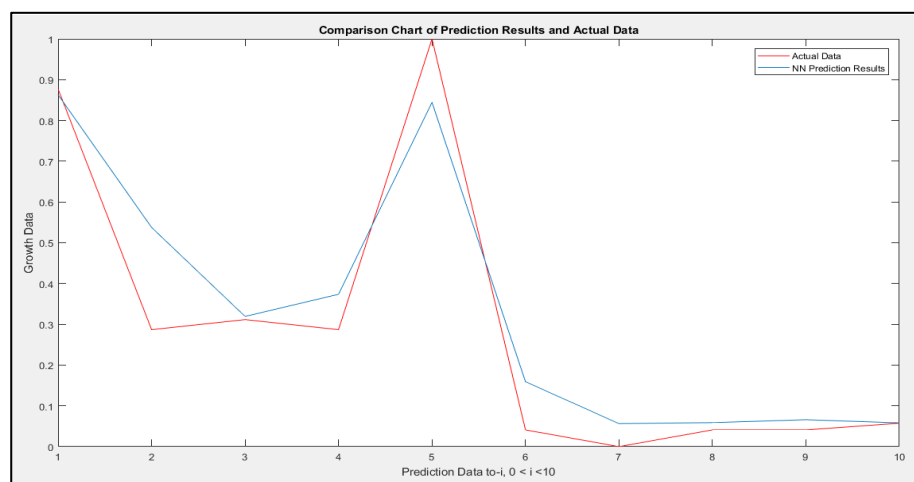


Figure 4. A comparison graph between the predicted data and the actual data obtained from the test results of the developed system

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