ARTIFICIAL NEURAL NETWORK IN AGRICULTURE

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Abstract: Agriculture is a very important sector in the development of national economy. The agribusiness-based activities and business will become the main trend in national development. Climate change, soil, and irrigation factors are all uncertain in almost regions. To deal with this, a dependable technique, such as artificial intelligence implementation, is required. Several research have been undertaken, one of which used artificial neural networks (ANN). This research looks at the backpropagation of modified artificial neural networks using the Smart Agriculture dataset, which includes variables like temperature, humidity, wind speed, solar radiation, and soil water tension.

Index Terms - artificial, neural, network, irrigation, precision, agriculture

I: INTRODUCTION

Crop growth and production in a specific region are heavily influenced by the interaction of climatic, soil, plant, and management aspects.

ANN has been discussed in certain agricultural studies. For example, an ANN-based controller can be used to design an autonomous water irrigation scheduler. Using characteristics such as temperature, humidity, and solar radiation, Matlab is utilized to train the model and implement ANN backpropagation to the controller. From this research it has been found that the model is used for artificial neural network, is good for maximising the water utilization of the agricultural system. Then, through a research implementing the artificial neural networks were excellent in use to detect some patterns by farmers manually by adjusting of alignment. But these two studies have not solved the problem of data processing in smart agriculture optimally.

Artificial Neural Networks (ANN) is a computational model to perform task like decision making, forecasting, or modeling. It is a part of AI that can learn and generate rules or operations from multiple entries. Artificial Neural Networks are made up of groups of artificial neurons that are connected together to execute calculations on input patterns and generate output patterns. Back-propagation is an ANN algorithm for supervised learning to solve data pattern problems from dataset.

This paper will research how to optimize ANN backpropagation algorithm with a combination of Smart Agriculture data to maximize the agriculture productivity by acquiring the pattern data and predicting the future condition such as water or soil.

II.BACKPROPAGATION

Backpropagation is one of the methods on Artificial Neural Networks and has supervised type training where it uses a weight adjustment pattern to achieve the minimum error values between the output of the predicated and the actual output.

Backpropagation also includes MLP (Multi-Layer Perceptron) network for having many layer screens to change the weights in its hidden layer, takes the slow training time, through the testing is fast. This algorithm

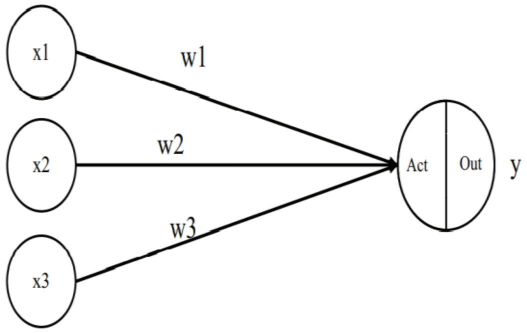


Fig. 1. Neural network representation.

performs two computational stages: forward propagation (feed forward) and backward propagation. In each iteration, the network will adjust the values of weight and bias on all neurons in the network.

The formation of nodes and layers is required prior to performing the calculations, which is followed by the initialization of parameters such as learning rate, threshold, and maximum iteration. The weight value of an artificial neural network is initialized as a random value, causing the result to vary.

The next step is to connect input to output. In the input layer, the input node x is multiplied by the initial weight (w) on each connection from k node to the hidden layer i, prior to be summed to obtain the net value. The value to obtain output of node of the next layer can be formulated as follows:

$$\text{net} = \sum_{k=1}^{n} w_k \times x_{ki} \quad \ldots(1)$$

To calculate how much the output of y is, an activation function such as logistic function or tan-h is used. Once the value is obtained, the process is repeated for another node and layer to obtain the output value, and the feedforward step is completed.

The following step is to compute the error calculation and weight change. Error signal of i^{th} node or es_i can be obtained by calculating the target c_i minus by value of output node o_i then by multiplying by the transfer derivative of output node tdi .

$$es_i = (c_i - o_i)\ t\ d_i \quad \ldots\ldots (2)$$

The weight between i^{th} and k^{th} nodes times is summarized for the error signal of hidden layers, and the error signal of k^{th} node is then multiplied again with transfer derivative of i^{th} node.

$$es_i = \left(\sum_{k=1}^{n} w_{ik} \times es_k\right) t\ d_i \quad \ldots.. (3)$$

After obtaining all of the error signal values, the error derivative of each node is computed. The error derivative value is used to calculate the updated weight of each layer and node.

$$es_i = \left(\sum_{k=1}^{n} es_i \times x_k\right) \quad \ldots.. (4)$$

The new weight is calculate by multiplying the error derivative of k^{th} node with the value of learning rate *lr*, then it is appended with initial weight. Random values can be used to determine the value of the learning rate. Smaller learning rate means slower training time, but has high accuracy, high learning rate means fast training time, but low accuracy.

$$W_i\,(t+1) = w_i(t) + (ed_k \times lr) \quad (5)$$

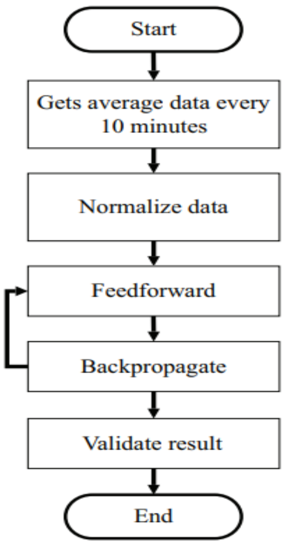


Fig. 2. Proposed method flowchart.

To find the best weight that fits the data pattern, the neural network must be iterated many times. Once the minimum error threshold or maximum iteration is reached, the iteration will be terminated. The next stage is to validate the data. If the obtained error is very small, the artificial neural network is said to be successful and usable; however, if the obtained error is still too large, it must be retrained.

III. DESIGN AND MODELING

Artificial neural networks are in high demand in agriculture and plantations as a way to improve the quality of plantation products. Among them is to make predictions and determine the suitability. The dataset of the Smart Agriculture system developed by the Lab Sistem Elektronis Universitas Gadjah Mada was used in this study.

The dataset included wind speed, temperature, soil water tension, humidity, and solar radiation. The data sent by the sensor had some unique characteristics, such as data sent by the sensor at 3 minute intervals with erratic intervals. To solve this issue, the data was collected at 10-minute intervals on a single day of recording. The data would be more generalized if too much for the input. Data was also divided by about 75% of data for training, 25% data for testing. To detect the pattern of the dataset, input had to be organized into a different class;

for example to detect the pattern of soil water tension, then the soil water tension had to be configured as the target of ANN. As shown on Fig. 3, the system had 4 inputs in the form of temperature, humidity, wind speed, and solar radiation (A, B, C, D) ; then the output (O) is a soil water tension.

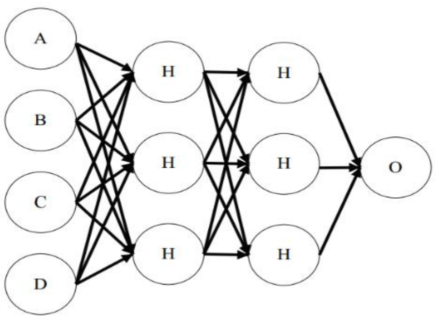
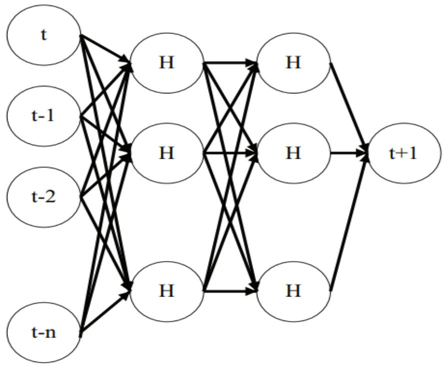


Fig3: Backpropagation Architechture



<u>Fig4</u>: Time series form of ANN

To forecast the data, the input of backpropagation needed to be modified into the time series form that only consisted of one type of data such as predicting temperature only. The input of the data consisted of time sequence data using past value to predict future value. t value is present data, t-n is past data, and t+1 is future data. The form of ANN is shown in Fig. 4.

Two hidden layers were proposed. The choice of two hidden layers was made because with one layer it could estimate any function, but with two layers it could estimate smooth mapping for any accuracy. There was no theoretical reason to use more than two layers. The number of neurons in each hidden layer was determined using the rule of thumb in which the number should be between the size of input and output layer, the number of neurons in hidden layers is 2/3 of number of input layers plus the number of output layers and the number of neurons should be less than twice of the size of input layer. In this study, the input layer was divided into 6 from t to t-6 to predict t+1 which would have 5 hidden neurons based on calculation.

Once collected, the data was then normalized. Normalization was performed to equalize each category of value of the sensor to be equivalent. In this research the Min Max method was used to convert the data value to a value between 0.5 and -0.5. First, the minimum min(x) and maximum max(x) values of a dataset were calculated, followed by calculating the value of normalization z in n^{th}

data by subtracting x in n^{th} data with min(x) and dividing the result by the difference of max(x) and min(x) values. To get a value between 0.5 and -0.5, the result was subtracted with -0.5.

$$Z_n = \frac{x_n - \min(x)}{\max(x) - \min(x)} - 0.5 \qquad (6)$$

Momentum (μ) was also used in this algorithm. Momentum is a value that will assist backpropagation to reach global minima that improve the speed and accuracy of training. Momentum was implemented by multiplying momentum value by i^{th} layer's past weight. Then, the result value was added with new weight equation refer to 5. Momentum value determined by trial and error and can range from 0 to 1.

$$w_i(t+1) = w_i(t) + (ed_k \times lr) + w_i^{n-1}\mu \quad \ldots\ldots (7)$$

So iterations would be stopped after one of two conditions was obtained. The minimum error was less than the threshold error of 0.01 and maximum iteration of 100000 iteration has been reached. If the minimum error has been reached then it would go into the data validation phase. Otherwise it needed to be retraced until the minimum error could be reached. Error was obtained using MSE (mean squared error) for every epoch of data by calculating the average of squared difference of target o and output neural $o^\wedge$ in every n data.

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (o^\wedge - o)^2 \qquad (8)$$

Common problem in backpropagation is overfitting. It occurs when the training algorithm runs too long, resulting in output that perfectly matches the training data but performs poorly when applied to new data. As a result, it must be validated. Each epoch of training is validated by implementing a trained neural network to the test data set. Each error will be stored on a variable. If the error variable is less than the previous test error, the copy of the neural network is saved as a copy, also known as a validated neural network, which generalizes a better outside training set. Then as a testing environment, the validated neural network will be used.

IV.TESTING & ANALYSIS

Testing was conducted by making 100 data with sinusoidal pattern. Testing also conducted to determine optimal value for learning rate and momentum value. Firstly, testing is done to generate optimal value of learning rate. Optimal value determined by which value has fastest iteration with minimum failure of training. The process is done by running the algorithm 10 times with initial value of momentum was set to 0. Table I shows that learning rate of 0.1 has fastest iteration with minimum failure.

TABLE II
OPTIMAL MOMENTUM TESTING

No	Momentum	Average Iteration
1	0	15212
2	0.2	9128
3	0.4	8021
4	0.6	7823
5	0.8	3652
6	1	8538

Table 1
Optimal Learning Rate Testing

No	Learning Rate	Average Iteration	Failure
1	0.001	33958	0
2	0.01	15865	0
3	0.1	6235	0
4	0.3	2553	1
5	0.5	2006	3
6	1	1973	7

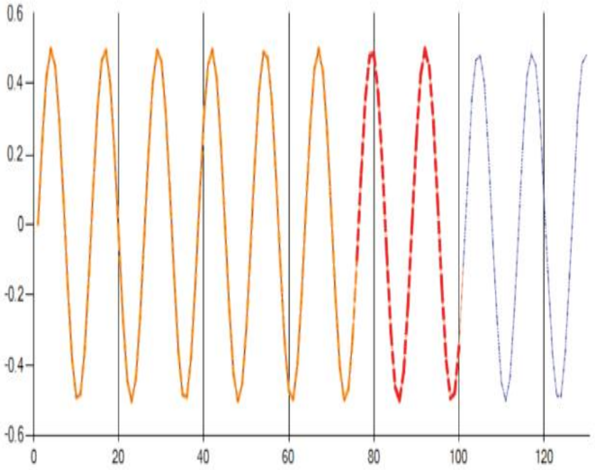
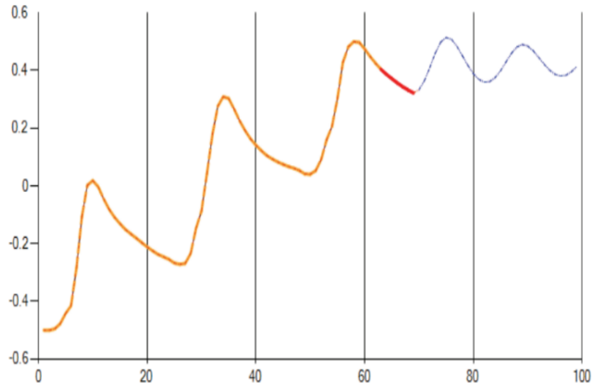


Fig5: Sinusoidal Prediction

Testing was also performed to determine the optimal momentum value by running the algorithm 10 times in which each momentum value then obtained how much average iteration using optimal learning rate above. A better momentum value indicates that the neural network requires smaller iterations to achieve the minimum possible error. Table II shows that momentum has the smallest average iteration with a value of 0.8.

Here Fig. 5 shows that the algorithm was successful in obtaining the data pattern and predicting the data with error less than 0.01. The first line of the graph is training data, the second is validation data, and the last line is the way of making prediction. Following that, the configuration of the artificial neural network was applied to real-world data. The water tension data from the smart agriculture was used. Water tension is the amount of force required by crops and plants to extract water from soil. Which is included as one of the factor that affect the growth of plant and crops. When testing was started, the backpropagation algorithm was able to recognize patterns to predict how the state of water tension would change in the coming days with an error of less than 0.01 after 7032 iterations, as shown in Fig. 6.

Algorithm was also used to predict the water tension data per month. Iteration succeeded in 5819 iteration with error 0.009. The results can be seen in Fig 7 Which means the proposed method was able to predict how much water



tension needed in the future.

Fig6: Daily Water Tension Prediction

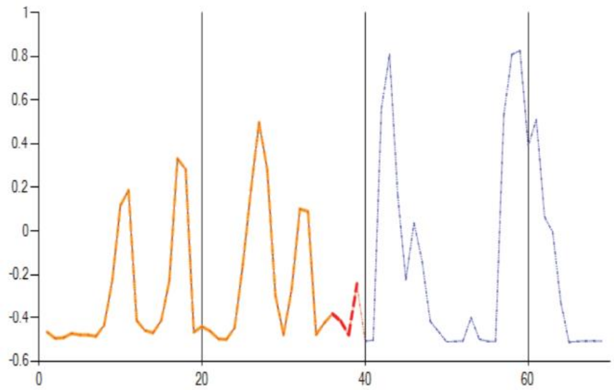


Fig7: Monthly Water Tension Prediction

V: ANN in Predicting Crop Yield

Presently, ANN has become a well-liked method to most authors because of its ability of prediction, forecasting and classification in biological science fields. Although regression model consumes more time to be developed, an ANN model can produce more consistent yet accurate crop yield prediction rather than regression models. Since there are a lot of factors which influence crop production, the use of ANN in predicting crop yield using direct and indirect factors will be presented.

3.1 ANN in Environmental Factors

Agricultural plants such as paddy, corn, soybean and wheat have strong response to their environment to determine the yield at the end season. The environment factors such as temperature, photoperiod and water stress [11] are among the most important factors that control plant development, growth and yield.

3.2 ANN in Soil And Soil- Plant Hydrology

Drummond et al. applied a feed-forward neural network to estimate nonlinear relationship between soil parameters and crop yield. The dataset is not only reasonably accurate but also at the same time, the model retained good generalization characteristics. Although the model tended to overestimate low yielding points while underestimating the higher yielding ones, the estimated yield maps generated by neural network method tended to be very similar to the actual yield map.

3.3 ANN in Sensing Technologies

Sensing technologies have become important for site specific management in agriculture. A lot of sensing systems have been developed such as in yield mapping and prediction, irrigation control, etc., using diverse types of sensors and instruments such as field-based electronic sensors, spectroradiometers, machine vision, airborne multispectral and hyperspectral remote sensing, satellite imagery, thermal imaging, etc. These technologies provide a broad usage in measuring variety factors such as crop nutrient, water content as well as soil properties.

3.4 ANN in Biomass Factor

Chtioui et al. designed generalized regression neural network (GRNN) for leaf wetness prediction model which later compared the result obtained with multiple linear regression (MLR). Leaf wetness is predicted based on temperature, relative humidity, wind speed, solar radiation and precipitation in order to warn of disease in agricultural crop which would affect crop yield production sooner or later.

3.5 ANN in Controlled Environment

ANN models also have been applied in controlled environments like greenhouse and glasshouse. Similar to the outside environment, greenhouse is also classified as complex system since it always deals with environmental factors such as temperature, humidity, radiation intensity and carbon dioxide concentration for optimization of plant growth and production. Apart of the above factors, In et al. used a neural network to develop a vase life prediction model of cut roses grown in greenhouse.

VI: CONCLUSION

Smart agriculture is a solution to solve the problems on agriculture by monitoring the agriculture data. This problem can be solved by embedding a smart algorithm that is able to help in reading patterns. Backpropagation is one of the algorithms that can be optimized to be used for smart agriculture systems to predict data by recognizing smart agriculture data patterns. Optimization is done in several forms by changing how to integrate the data input in the input layer. From the simulation result, backpropagation is able to provide good predictions. Optimal learning rate of 0.1 was obtained with minimum iteration needed without failure on testing. Momentum also help neural network reach threshold faster with optimal value of 0.8. Neural network also can be used to predict data water tension of smart agriculture data with minimum mean squared errors below threshold 0.01.

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