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Classification of Organic and Inorganic Waste Types Based on Neural Networks

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ABSTRACT

Waste is the residue of unused industrial production and household consumption. In Indonesia, waste is divided into 2 types, namely organic and inorganic waste. The two types of waste can be recycled in diverse ways, so they must be separated. So far, it is often difficult for the community to sort waste. This paper presents the process of recognizing and sorting waste automatically by utilizing Artificial Intelligence technology, especially Artificial Neural Networks (ANN). The ANN architecture used in this study consists of 4 layers. The number of neurons in each layer consists of 3 neurons in the input layer, 4 neurons in the hidden layer-1, 4 neurons in the hidden layer-2 and 1 neuron in the output layer. The ANN model that has been designed is trained, so that the best weight and bias model will be obtained, which in turn gives the ANN the ability to be able to sort waste properly. The best weights and biases will then be implanted into the Arduino UNO Microcontroller hardware. In this developed system, the microcontroller is given input obtained from 3 kinds of sensors, namely capacitive proximity, inductive proximity, and photodiode. While the input consists of 2 pieces of organic or in organic waste conditions. From the test results, it was found that the system has 100% training accuracy and 100% test accuracy.

Keywords*:* Backpropagation, Artificial Neural Networks, Organic and Inorganic Waste, Waste Classification

INTRODUCTION

Population growth in urban and rural environments is growing rapidly. Along with the increase of the population growth graph, there are several positive and negative impacts. One of the negative impacts caused by the increase in population growth is the increase in the volume of waste generated [1]. Waste is the remnants of industrial production and household consumption that are not used [2]. In Indonesia, in general, waste is often divided into 2 types, namely organic waste and inorganic waste. Organic waste is waste that comes from living things and easily decomposes or decomposes in less than 6 months. Meanwhile, Inorganic Waste is waste that comes from residual materials that cannot be decomposed properly and are difficult to renew [3], [4].

Organic and inorganic waste will be transported and stockpiled at the Final Disposal Site (FDS). The amount of waste that is stockpiled at the FDS can be minimized by recycling [5], [6]. Recycled waste can change items that were previously unusable to have a use value again. Recycling for organic and inorganic waste goes through a different process, so it is necessary to classify it before recycling. Classifying waste in the FDS is more difficult than sorting it in a trash can. Therefore, the waste segregation process needs to be applied to the trash before being brought to the FDS. So far, the available trash bins are only trash bins with sorting done by the community manually [5], [7].

Currently, there are still many people who do not understand the types of waste when disposing of it. Even though organic and inorganic types of waste have been provided, many people make the mistake of disposing of waste in the right place (organic or organic). Until now there is no system that can provide directions to the garbage disposal automatically.

Multi-Layer Perceptron (MLP) is one of the ssupervised learning methods in artificial neural networks. In general, MLP is used to classification especially for classify a certain

pattern [8]–[10]. MLP can also be used to model univariate time series forecasting problems. By detecting patterns and trends in time series data, then formulating them into a model, it can be used to classify future data. Models with high enough accuracy will cause the classification values to be valid enough to be used as support in the decision-making process [11].

Ss Several examples of previous studies used artificial intelligence algorithms for the waste classification process. The classification process carried out by Mao [12] and Rasidi [13] uses a convolutional neural network (CNN) in the waste sorting process. The systems presented in this study each provide accurate results, can carry out the waste classification process. Utilization of proximity sensors in the process of automation of the waste sorting system can be used to detect incoming objects as was done by Fatmawati [14]. The proximity used is capacitive type to classify organic and inorganic waste.

Based on the explanation, it is necessary to develop a system that can assist the community in distinguishing the type of waste before it is put into the FDS with an accurate classification method. The classification process using MLP can be carried out by utilizing a certain device in determining the type of waste. This study is aimed at developing a system that can distinguish between organic and inorganic waste using an artificial neural network with the backpropagation method. This system is expected to run optimally so that inorganic waste can be recycled and the accumulation of waste in the landfill can be reduced.

METHODS

The method used in this study is research and development. After reviewing what the system needs regarding waste classification, then develop a hardware and software system that can sort organic and inorganic waste. The algorithm used in this study is MLP which is a type of artificial neural network (ANN).

MLP system with backpropagation method is developed through a PC based on the Python programming language. The results of MLP training produce the best weights and bias values. The weights and biases obtained are built into the Arduino hardware. Previously, to conduct training, real data was taken from the three sensors in real terms. The readings of each sensor with several types of waste are recorded and used for data training of MLP system with backpropagation method.

A. Hardware Design

The system is designed with three sensors to scan various kinds of garbage, namely the CR18-8DN capacitive proximity sensor, the LJ12A3-4-Z inductive proximity sensor, and the photodiode sensor. Each sensor unit is equipped with signal conditioning. The capacitive proximity sensor is used to detect the presence or absence of water in an object, the inductive proximity sensor is used to detect metallic elements in an object [14], [15], and the photodiode sensor is used to detect the transparency of an object [16]. All data obtained from the sensor is processed by the Arduino UNO microcontroller. This data is labeled which will be used as training data and testing data. Arduino UNO has a working voltage of 5V DC, because the two proximity sensors cannot work well at 5V DC voltage [17], the XL6009E step up module is used. The two proximity sensors work at a voltage of 12V – 36V, so the working voltage is too large to be an analog input on the Arduino Uno, so the output voltage from the sensor will be regulated first using the LM7805 IC so that the output voltage of the two sensors can be processed on the Arduino UNO analog input pin. Arduino will recognize the type of garbage it throws away. The type of garbage detected is displayed in the form of an LED on the Output side. The block diagram of this garbage detection system hardware can be seen in Figure 1 and 2.

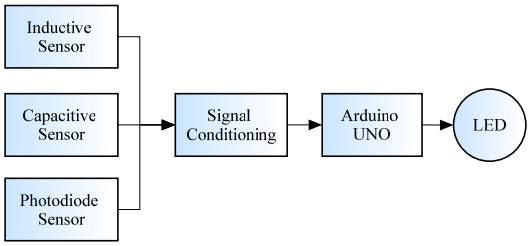

Figure 1. System Block Diagram

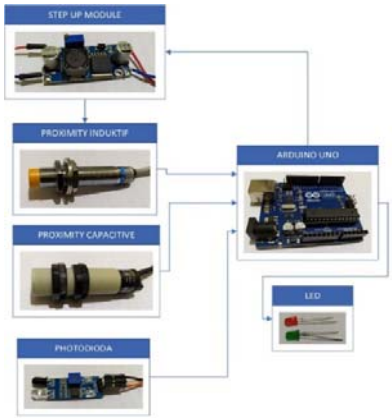

Figure 2. Hardware Block diagram

B. Software Design

Software is developed through a PC based on the Python programming language. Python is a multipurpose interpretive programming language with a design philosophy that focuses on the level of code readability [18], [19]. Python is claimed to be a language that combines capabilities, capabilities, with a clear code syntax, and is equipped with a large and comprehensive library of functionality [20]. Python has libraries that provide a simple and clean way to create deep learning models. Hard code is released under the MIT license [21]. Through Python it is possible to implement MLP in a quite simple and uncomplicated way.

Multi-Layer Perceptron (MLP) is an artificial neural network model that has a multi-layer topology (multilayer) consisting of one input layer, one or more hidden layers, and one output layer [22]. Each layer in the network has units of neurons or nodes. Each neuron in one layer will be connected to other neurons in the next layer. Between neurons are interconnected and each connection has weights and biases. Before being used for identification, MLP needs to be trained first to be able to recognize input patterns correctly [23], [24].

The Multi-Layer Perceptron (MLP) learning used in the research was chosen by the backpropagation method. This method consists of 2 phases, feed forward phase to calculate output and error (difference between target and output) and backpropagation phase to update weights and biases. Sensor reading data will be scaled to a range of 0 and 1. Furthermore, the data is trained with backpropagation training to get the weight of each neuron in each network layer. Figure 3 shows a flow chart for obtaining weights from network training.

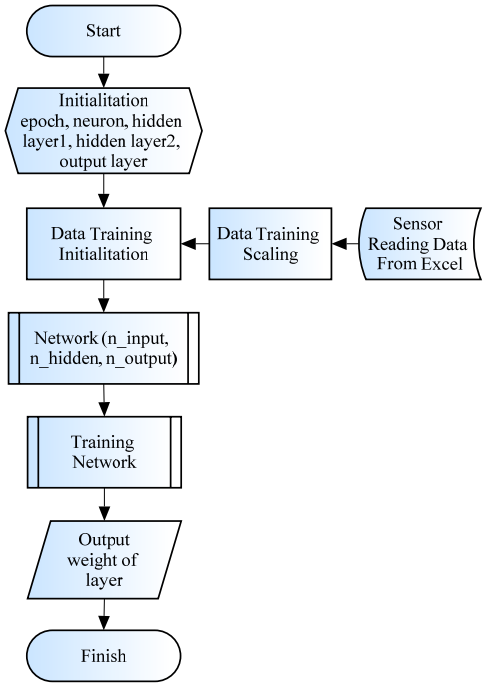

Figure 3. Flowchart of Software

MLP design with architecture as shown in Figure 3 which is implemented through Python software. In MLP, training, validation and testing are carried out through python using the Thony platform and hard libraries, until the resulting weights and biases are best so that they can perform waste type classification properly.

The results of these best weights and biases will then be used in the implementation of MLP on Arduino Uno Microcontroller

hardware [25] with the C++ programming language. Furthermore, through the microcontroller, the detection/classification of the types of waste will be carried out. This classification process is carried out in real time, so that when waste is detected by the sensor, Arduino can directly determine the type of waste. If the system predicts organic waste, the green LED is active, otherwise if the system detects inorganic waste, the red LED is active. Figure 4 shows a flow diagram of the prediction process that occurs on Arduino.

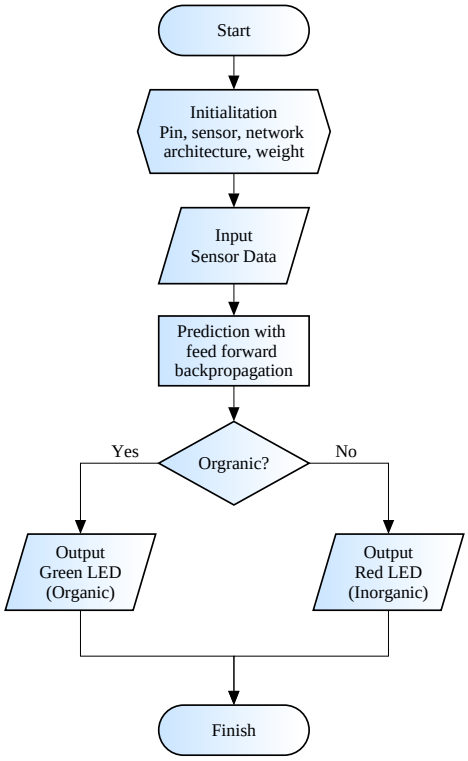

Figure 4. System Flowchart

C. Artificial Neural Network Design

The prototype in this study has 3 parameters to classify based on the nature of the two wastes, including water content, metal content and transparency level. With these three parameters, the input of the artificial neural network has 3 neurons in the input layer which is symbolized by the letter X. This system is expected to be able to distinguish two types of waste: organic and inorganic, therefore two output conditions are needed, these two conditions can be achieved by using 1 neuron in the output layer, the output of this neuron can be in the form of two conditions 0 and 1 so that only 1 neuron is needed. The neurons in this output layer are symbolized by the letter Y. The hidden layer used is 2 layers with each layer having 4 neurons. The number is determined based on trials to find the architecture with the smallest error rate. The structure of the MLP design model used can be seen in Figure 5.

Training data obtained by conducting initial experiments on the sensors used [26], [27]. The training data is stored in a spreadsheet which will be read by the system. The number of training data obtained is 50 data with details of 25 data on organic waste and 25 data on inorganic waste.

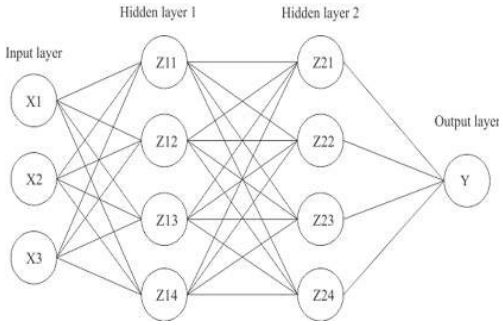

Figure 5. Artificial Neural Network Architecture Used

Researchers conducted training experiments using 2 to 10 neurons in the hidden layer with epoch values: 100, 200, 300, 400, 500, and 600, and by using the Adam optimizer. Optimizer is an algorithm for optimizing weight updates more effectively than the usual learning rate. This optimizer is also a feature of the hard library [28]. Based on these experiments, it was found that the combination of 4 neurons in each hidden layer with the Adam optimizer and epoch 500 has the smallest error rate of 0.57.

RESULT AND DISCUSSION

The results of the developed system were tested which consisted of the Capacitive Proximity Sensor Functional, Inductive Proximity Sensor Functional, Photodiode Functional, and System Performance Testing.

A. Capacitive Proximity Sensor Functional Testing

This test serves to determine the functionality of the capacitive proximity sensor used by looking at the response and accuracy based on the resulting value. From table 1 the detected object has a high capacitance that can be read by the sensor. If the detected object contains water, the sensor readings are close to the maximum value. Wet waste will be detected and metals that do not contain water can still be detected.

Table 1. Capacitive Proximity Sensor Readings

No	Object	Contains Water	Sensor Results
1	White bread	Yes	1003
2	Tempe	Yes	1015
3	Petai Skin	Yes	1020
4	Paperclip	Not	1018
5	Coin	Not	1002
6	Plastic bags	Not	0
7	SIM card	Not	0
8	Cassava leaves	Yes	1020
9	Sheet of paper	Yes	1017
10	Plastic bottles	Not	0
11	Used battery	Not	1023
12	Aluminum foil	Not	1009

B. Inductive Proximity Sensor Functional Testing

This test serves to determine the functionality of the inductive proximity sensor in detecting metal content in a waste object.

Table 2. Inductive Proximity Sensor Readings

No	Object	Contains Metal	Sensor Results
1	Wooden pencil	Not	0
2	Used battery	Yes	1015
3	Cardboard box	Not	0
4	Paperclip	Yes	1020
5	Coin	Yes	1023
6	Glass of mineral water	Not	0
7	Cable	Yes	1023
8	Cherry leaves	Not	0
9	Rubber band	Not	0
10	Old newspaper	Not	0
11	Milk cans	Yes	1020
12	Aluminum foil	Yes	1018

Based on table 2, it can be seen the working pattern of the proximity sensor. When the sensor detects waste with metal content, the read value ranges from 1020 and if it detects waste without metal content, the value reads 0.

C. Inductive Proximity Sensor Functional Testing

This test aims to determine the functionality of the photodiode in detecting the transparency of an object.

Table 3. Photodiode Reading Results

No	Object	Trans-parency	Sensor Results
1	Iron ruler	Not	23
2	Glass jar (clear)	Yes	267
3	Cardboard box	Not	45
4	Glass of mineral water (clear)	Yes	324
5	Coin	Not	34
6	Sprite bottle	Yes	102
7	Tissue	Not	51
8	cherry leaves	Not	18
9	Used sandals	Not	22
10	Gallons of water	Yes	378
11	Plastic bag (clear)	Yes	426
12	Glass (clear)	Yes	440

From table 3, the photodiode can detect the transparency of objects. For objects that are not transparent, the value obtained is below 50 and for objects that are transparent, the value obtained is high, the higher the transparency, the higher the value produced by the photodiode.

D. System Performance Testing

This test serves to determine the level of accuracy of the prototype in classifying the type of waste using a backpropagation artificial neural network created using the Keras library. Waste to be classified is placed on the three sensors directly. This test is carried out with 12 types of waste.

Table 4. System Conformity Feature Test

No	Waste	Feature 1 (Cap.)	Feature 2 (Induc.)	Feature 3 (Photo.)
1	Basil leave	1019	0	41
2	AA battery	1020	1023	18
3	Sponge	0	0	20
4	Mango seeds	1022	0	36
5	Clear insulation	0	0	389
6	Chicken bones	1015	0	11
7	Cassava leaves	1023	0	55
8	Eggshell	1018	0	33
9	Aqua bottle	0	0	401
10	Insect repellent	0	0	27
11	Tempe	1023	0	26
12	Metal coins	1018	1023	21

Table 5. System Conformity Test Results

No	Waste	Prediction Class	Target Class	Suita-bility
1	Basil leave	Organic	Organic	Yes
2	AA battery	Inorganic	Inorganic	Yes
3	Sponge	Inorganic	Inorganic	Yes
4	Mango seeds	Organic	Organic	Yes
5	Clear insulation	Inorganic	Inorganic	Yes
6	Chicken bones	Organic	Organic	Yes
7	Cassava leaves	Organic	Organic	Yes
8	Eggshell	Organic	Organic	Yes
9	Aqua bottle	Inorganic	Inorganic	Yes
10	Insect repellent	Inorganic	Inorganic	Yes
11	Tempe	Organic	Organic	Yes
12	Metal coins	Inorganic	Inorganic	Yes

Based on the test results shown in table 5, a confusion matrix was made to calculate the performance of the prototype classification of organic and inorganic waste. Table 6 is a confusion matrix based on the experimental results in table 4.

Table 6. Analysis of The Results on The Confusion Matrix

f_{ij}		Prediction Class (j)	
		Inorganic	Organic
Target Class (i)	Inorganic	6	0
	Organic	0	6

Based on the confusion matrix, the accuracy of the prototype can be known by using equation (1).

$$Accyracy = \frac{f00+f11}{f00+f01+f10+f11} \quad (1)$$

So that accuracy can be calculated:

$$Accuracy = \frac{6+6}{6+0+0+6} = \frac{12}{12} = 1$$

Then the accuracy obtained based on the above calculation is 1 or in percentage namely 100%.

CONCLUSION

From the results of training and network experiments, it can be concluded that the waste classification system can detect and classify several samples of organic and inorganic waste with 100% accuracy. Study results show that the system can be applied as an appropriate tool, especially in waste classification. This study also gives the result that the network created in Python programming can be implemented on the Arduino platform so that it can create better opportunities in making artificial neural networks on Arduino. The designed system is expected to be a reference for making an accurate waste classification device.

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