Development of Weeds Density Evaluation System Based on RGB Sensor

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Abstract. Weeds are plant competitors which potentially reduce the yields due to competition for sunlight, water and soil nutrients. Recently, for chemical-based weed control, site-specific weed management that accommodates spatial and temporal diversity of weeds attack in determining the appropriate dose of herbicide based on Variable Rate Technology (VRT) is preferable than traditional approach with single dose herbicide application. In such application, determination of the level of weed density is an important task. Several methods have been studied to evaluate the density of weed attack. The objective of this study is to develop a system that is able to evaluate weed density based on RGB (Red, Green, and Blue) sensors. RGB sensor was used to acquire the RGB values of the surface of the field. An artificial neural network (ANN) model was then used for determining the weed density. In this study the ANN model was trained with 280 training data (70%), 60 validation data (15%), and 60 testing data (15%). Based on the field test, using the proposed method the weed density could be evaluated with an accuracy of 83.75%.

1. Introduction

Weeds are hazardous plants which presence is a competitor for main plants in getting sunlight, water, and soil nutrients. The level of competition depends on rainfall, soil conditions, weed density, weed growth, and age of cultivation plants as weeds begin to compete [1]. One of the weed control efforts is to use herbicide which is a chemical substance to suppress weed growth and can even turn it off [2].

Weed control can be done by chemical (using herbicides) and non-chemicals. Herbicides are chemicals that can kill herbs or weeds. Chemical weed control is biological control, ecology, competition and emphasis in the presence of other plants.

Based on the timing of the administration of the herbicide may be given by: 1) Pre-cultivation, prior to tillage, weeds on the ground are given herbicides to facilitate processing, 2) Pre-planting, after tillage and before planting is given herbicides to inhibit weed growth and facilitate planting, 3) Pre-emergence (pre-emergence), after planting, herbicides are given before the plants and weeds appear, and 4) Post-emergence, herbicides are given after the plant or weed appears [2].

Environmentally sound weed controls no longer apply a single dose method in herbicide spraying activities. Determination of herbicide dose applied to the soil should be adjusted to the spatial and temporal diversity of weeds. Based on this method the effectiveness and efficiency of herbicide use on weed control can be improved so that weed control and land damage can be minimized which result in increased production output. Such a practice is well known as site-specific weed control which is widely adopted [3].

The current problem is that the evaluation of weed density is still done manually so that the precise map base herbicide treatment is difficult to describe. This study aims to develop a red, green, blue (RGB) sensor based to evaluate weed density in precision farming system concepts. The application of precision farming on weed control requires a device capable of identifying the location and degree of weed density in the field. The results of identification can determine the dosage at each location of herbicide spraying. Based on this concept of precision agriculture in weed control can be realized.

2. Materials and methods

2.1. Weed Density Classification

Solahudin [3] in his dissertation classifies that the weed density as a result of the filtering of RGB values is divided into four groups by multilevel method. The staggered group breaks will group the green mean value greater than half the maximum green average into the "Solid" or "Class 4" groups. While the next classes are with the value of the limit of half of the lower limit value of the upper class. Determination of the density class by means of the stratum as seen in table 1 leads the clustering method to a higher level of density, since the higher the weed density class will have a wider range of green width values.

Table 1. Weed density grade classification [3]

Class	Average of Green Value		Definition
	Lower Bound	Upper Bound	
1	0.00	38.22	Clear
2	38.22	76.45	Sparse
3	76.45	114.67	Medium
4	114.67	255.00	Solid

These values can be seen in table 1. Values 1 through 4 are given in the RGB value as a result of weed density classification based on the mean green value of the RGB color values. Value 1 for clean land condition from weed, value 2 for sparse weed, 3 for medium weed, and value 4 for solid weed where 255 is the highest value of green color component. The method used in this research is the prototype development method described in figure 1 and described as follows:
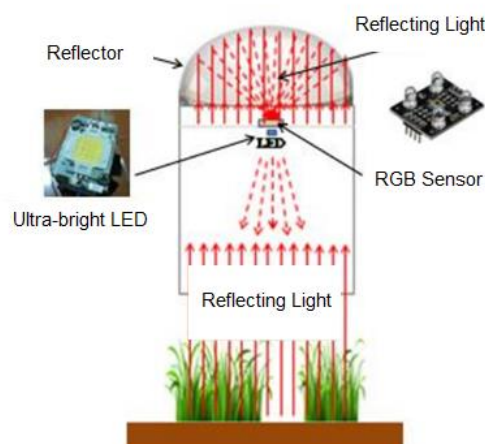

Figure 1. Illustration of acquisition of RGB value of weeds

2.1.1. RGB Reader Unit. The reading of the RGB value of weeds is done using the TCS3200 color sensor. The sensor consists of 64 sensor arrays that will convert the received reflected light into 4 outputs namely R value, G value, B value and colorless readout value. This sensor is relatively

affordable and easy to use. It's just that this sensor has a shortage of effective distance and a relatively limited reading area. Therefore, the design of the sensor to the effective distance and reading area increases in accordance with the needs of research.

2.1.2. RGB Data Processing Unit. RGB value data processing is done by using open source Arduino Mega platform which has microcontroller unit ATMega 2560 as the data processing of sensor output. The output data from the sensor in the form of RGB value is processed by interpolation method and artificial neural network to classify the level of weed density in the field.

2.1.3. Acquisition of RGB Value. Acquisition of RGB value is a process of retrieving RGB values of objects read by sensors. This process involves a reader unit and a data processing unit operated against a weed object. Figure 1 shows an illustration of the working schema configuration of the RGB retrieval. The sensor device is positioned perpendicular to the color object and as the distance between the edges of the house and the color, object is used three buffers with h cm height. This height is the distance between the sensor house and the object taken. This spacing is done to simulate the position of the sensor with the weed object in the real application in the field. The results of sensor readings in the form of R, G, and B values of each color sample are processed by microcontroller (Arduino) and then sent to computer for further processing for processing by interpolation method and artificial neural network method.

2.2. Artificial Neural Network
In the sensor calibration process the value of RGB sensor readings are used as input ANN which is then used to predict the output of the RGB value. Among these inputs and outputs is placed a hidden layer with six nodes. In the evaluation of weed density, the RGB value of the sensor readings is used as an ANN input to determine the weed density level as output. Among these inputs and outputs is placed a hidden layer with ten nodes. Another important thing related to the ANN created is the activation function on the hidden layer and output layer. In this case, in the hidden layer the activation function used is the sigmoid function which can be expressed as equation 1 while in the output part the function is used linear.

The results of the evaluation of weed density are arranged into 10x50 cm rectangular area where the reading area consists of five parallel horizontal sensor readings which are then averaged as in figure 2.
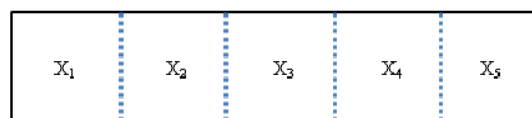

Figure 2. Merging sensor readings

The merger is made to match the spayer unit which has a sprayer width of 50 cm. The result of system reading then averaged using equation:

$$Average\ Reading\ Value = \frac{1}{n}\sum_{1=1}^{n} X_i \tag{1}$$

As figure 3 the results of the system evaluation are interpreted into colors and numbers indicating 4 levels of weed density on open land
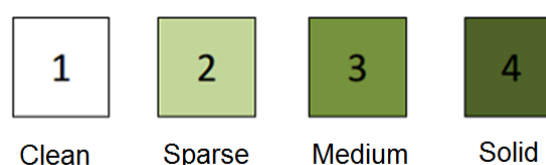

Figure 3. Interpreation of evaluation system results

2.3. Analysis and Testing
To find out the results of system design that has been made, then will be tested by taking data from the system and by analyzing it to obtain the expected results. The tests to be performed are:

2.3.1. Testing the optimum sensor distance. This test is intended to find out how the optimum distance between sensors with objects that have the best output. As a treatment differentiator, two types of type A and type B sensors have distance of sensor with object of 10 cm and 13 cm. The distance is chosen by reason of that distance which allows to be applied to real weed control in the field. In this test, black and white paper is used in black and white color where the color has the lowest RGB value (0, 0, 0) and white color has the highest RGB value (255, 255, 255). Based on the two color samples can be known maximum reading range of each type that is directly proportional to the accuracy of the sensor in discriminating the color.

2.3.2. Sensor calibration. Sensor calibration is done to compare the result of reading RGB sensor value with R, G, and B value of actual object. The color sample used is a combination of several R, G, and B values. For each color component selected 5 levels of 0, 65, 130, 195 and 255. In total obtained 125 color combinations. Testing and calibration are intended to ensure that the developed system can extract the color components of the observed object precisely before it is later used to detect weeds in the field. From 125 data then grouped into dataset for training, validation and test with each consist of 87 data (70%), 19 data (15%), and 19 data (15%) on processing with ANN method. Further analysis of the results obtained to see the improvement of the performance of each calibration method in improving the accuracy of sensor readings.

In this case, the analysis is done in two ways: 1) visually by comparing the color resulting from the combination of obtained RGB value and the reference color, and 2) quantitatively based on the delta-E (ΔE) value that represents the Euclidean distance between the obtained color and the reference color. To calculate the ΔE, first the obtained RGB value must be converted to L^*, a^*, b^* color space where each variable represents lightness, color opponents green–red and color opponents blue–yellow respectively. The ΔE value then can be calculated using the following equation:

$$\Delta E = \sqrt{(L_1^* - L_2^*) + (a_1^* - a_2^*) + (b_1^* - b_2^*)} \qquad (2)$$

The smaller the delta-E value shows the closer / similar a color to another color (reference). For convenience, the mean and standard deviation values of delta-E are calculated in groups according to the reference to the dataset distribution used in the training, validation and ANN tests.

2.3.3. Real condition test. The test was conducted with a sample of field weed object that had been prepared in the form of grid measuring 10 cm x 10 cm of 1 m x 4 m. The test is done in the morning around 09.00-10.00 WIB which is the actual spraying time of weeds in the field where the wind speed is relatively low and the intensity of sunlight is not too high so that the sprayed herbicide does not drift by the wind or evaporate into the air.

The normalization process is done each time the acquisition process of RGB value (per grid). This is intended for adaptive sensors to weather changes (sunny cloudy) so the sensor works better under various conditions. The results of the evaluation of weed density of the sensors were then validated with the evaluation results of the weed density estimation application developed and used in [4] with some modification according to the research needs. The testing stages of the field weed density evaluation field are shown in figure 4.
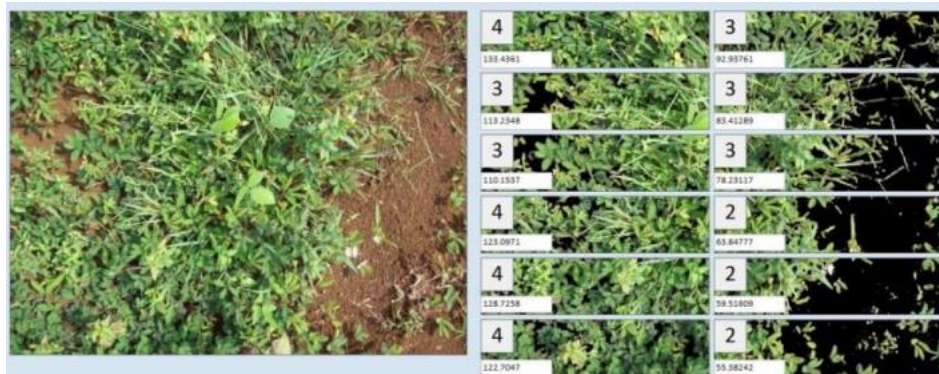
Figure 4. Image processing for weed density evaluation

3. Result and discussion

The sensors used in this study were the TCS3200 color sensor, which was then redesigned to improve the accuracy and optimal range of sensor readings. The design of the sensor is done with the aim of extending the reading range by increasing the light intensity received by the sensor up to a certain point. Light source of the original sensor comes from four Light Emitting Diode (LED) is usually substituted using 10 Watt ultrabright LED. As shown in figure 5 the sensor is positioned upright perpendicular to the center of the dome and the LED lamp is arranged perpendicular to the bottom to the weed object in line with the sensor's home-making design described in the next section. The result of the design of the sensor is the optimal distance of the sensor to the original object $\pm$ 2 cm is increased 5-fold to $\pm$ 10 cm and the accuracy of the sensor in differentiating the color increased significantly along with the increase of RGB sensor value reading range.
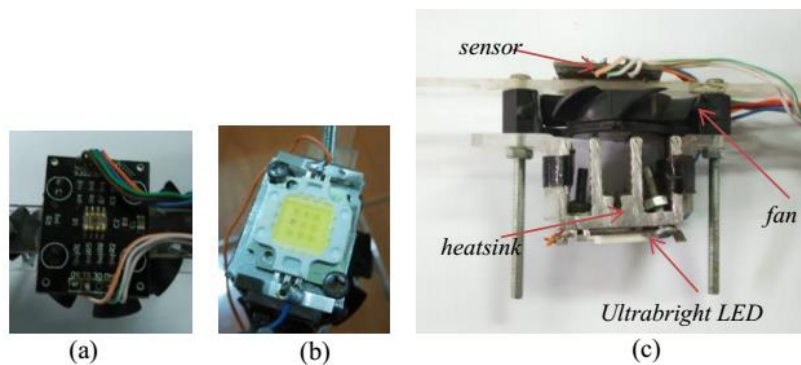

Figure 5. Sensor design, (a) RGB sensor module (b) Ultrabright LED (c) sensor device design result

Table 2. Corelation between Height of sensor and RGB Value

Sensor Height	Color Object	R	G	B
Tipe A (10 cm)	White	87	71	100
	Black	27	20	24
	Range	60	51	76
Tipe B (13 cm)	White	70	56	77
	Black	29	20	25
	Range	41	36	52

From table 2 it can be seen that the largest difference of white and black color readings on RGB values occurs in type A (10 cm) sensors. This is because the reflectance of the reflected light received by the sensor on type A is larger than the light reflectant in type B. In this case the larger the RGB

value the resolution of the sensor in differentiating one color with the other color will be better. Based on these considerations, type A sensor (10 cm) is selected as the optimum distance between the sensor with the object. Calibration is performed to compare the readings of RGB sensor values with actual object RGB values. In this research, 2 calibration methods are tested with interpolation and ANN to improve the accuracy of RGB value reading with ANN structure of RGB value of sensor readings as input and RGB value of predicted result as output. Among the inputs and outputs are placed one hidden layer with six nodes and from 125 data 70% data is used as training data, 15% as validation data, and 15% data as test. The results of the tests are then visualized as shown in figure 6 showing the color comparisons made based on the original RGB value of sensor readings, interpolated processing, processing with artificial neural network and reference value.

Visually as shown in figure 6 it is clear that sensor readings are relatively different from references (actual colors). The use of interpolation method can improve the reading result of this just the color is darker than the reference. The best results are shown by the results of the processing with ANN.
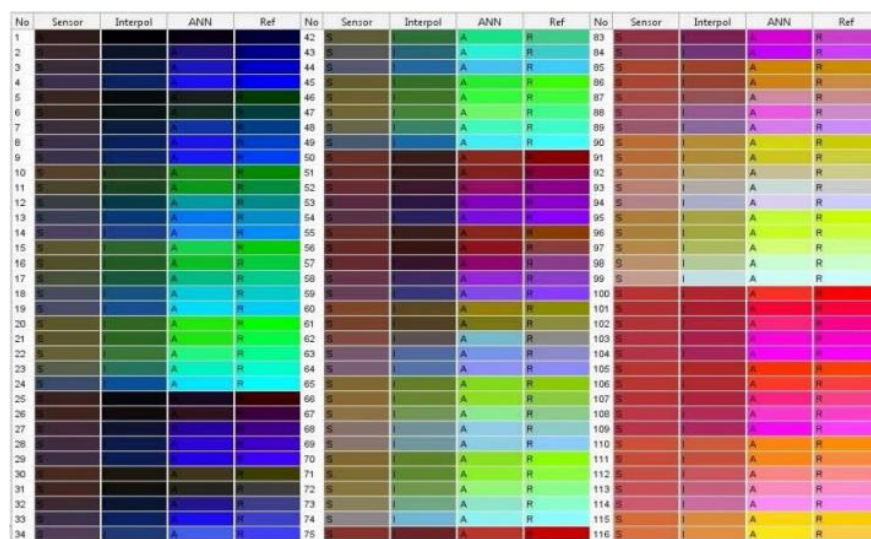

Figure 6. Color comparison result

Visually the resulting color is quite close to the reference color. Further this can be confirmed quantitatively on the basis of the E-delta-E value that represents the Euclidean distance of one color with another color referenced by the color component L *, a *, b * as shown in table 3. Based on the mean and standard deviation values of the delta- E shows that interpolation can reduce the distance between the colors produced by reference but the ANN gives better results. These results indicate that the developed system (sensors and calibrations) can read the color components of the observed object quite well.

Table 3. Mean and standard deviation values of delta-E

Data Set	Mean of delta-E		
	Sensor	Interpolation	ANN
Training	58.4 ± 24.5	45.8 ± 21.7	15.2 ± 10.1
Validation	60.1 ± 22.3	45.7 ± 19.1	13.2 ± 9.1
Test	57.1 ± 30.1	45.3 ± 25.0	13.9 ± 7.0

Evaluation test of Weed Density is intended to determine the ability of the system to evaluate the real weed density level in the field. Sudden weather changes in the evaluation process (sunny to cloudy or otherwise) potentially interfere with sensor performance. Therefore the normalization process is done on each grid during the acquisition process of RGB value so that the RGB value

obtained is not affected by the solar intensity change in the field so that the sensor has adaptive ability on the weather change.

The result of RGB value from sensor reading is then processed by interpolation method and ANN with RGB value of sensor reading as input and weed density level as output and between input and output placed one hidden layer with ten nodes. From all of data taken 70% data composed as data training, 15% data as validation data, and 15% data as test data. The validation process is performed between the value of the weed density of the sensor evaluation result and the weed density value of the evaluation of weed density equation estimation application as a reference (figure 7).
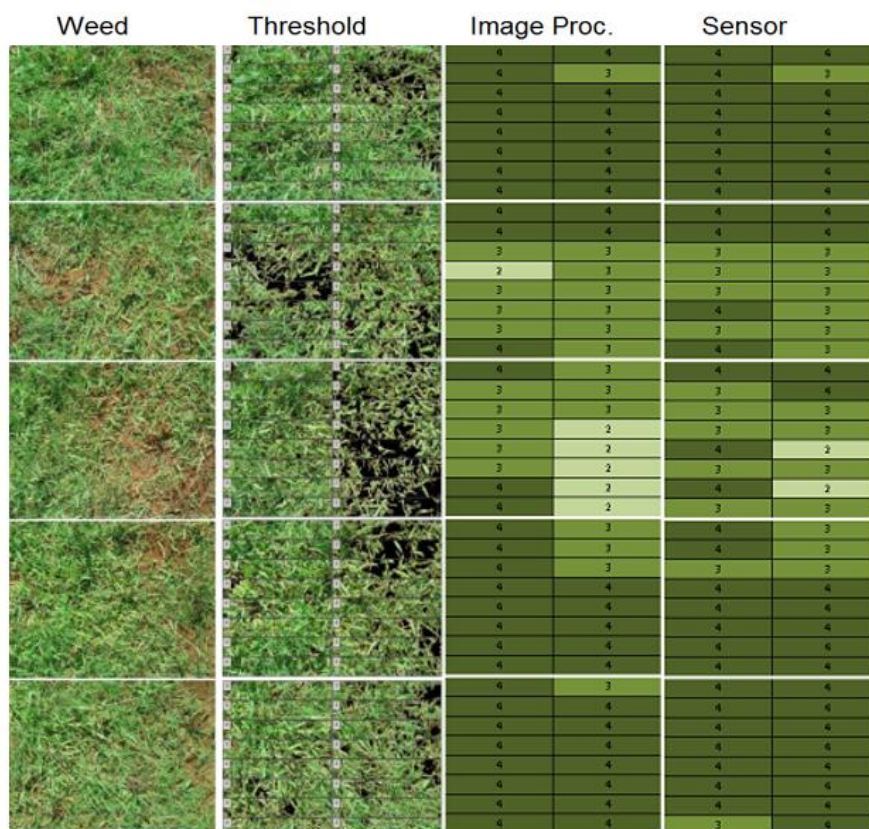

Figure 7. Modification of weed density estimation application

As shown in figure 7 on weed density evaluation testing, the field trials were able to evaluate weed density with an accuracy of 83.75% against density evaluation by weed density estimation applications. The errors that occur in the estimation of weed density levels occur only on one level only (eg weed level 2 density is read as 3) so the system can still be said to work pretty well. Based on this it can be concluded that the system is able to do a good weed density evaluation in the field.

4. Conclusions
Based on the sensor calibration obtained the result that the interpolation method and the ANN method can improve the accuracy of sensor readings in the process of color identification and the ANN method gives better results. These results can be confirmed visually and quantitatively based on the delta-E value so that the developed system is able to read the color components of the observed object well enough and sufficient to be used to detect weed density levels. An algorithm has been developed to evaluate the density of weeds using the ANN method with the input of weed RGB value and the output of weed density level which has an accuracy of 83.75% in field trial.

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