Comparison of HSV and LAB Color Spaces for Hydroponic Monitoring System

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***Abstract*— Digital image processing can provide significant benefits in various sectors such as agricultural sector. One of digital image processing implementation is plant leaf area calculation in hydroponic monitoring system. A color detection model is required to calculate it. HSV or CIELAB is a color space often used in terms of color image detection. This research aims to compare the accuracy of both methods in reading the number of pixels in the area of plant leaves. The plants used as samples are 3 to 4 weeks old. Results show that CIELAB method has a better accuracy than the HSV method. HSV method has an average accuracy of 75.33% while the CIELAB method has a greater average accuracy of 78.39%.**

***Keywords*— Plant leaf area, Digital image processing, Color detection, HSV color space, CIELAB color space.**

I. Introduction

Recently, knowledge and technology developed very rapidly. One of the technologies that have developed so rapidly is the digital image processing. Digital image processing is the process of manipulating and analyzing images with the help of computer. While the image is a representation or imitation of an object. Image can be regarded as a digital image if the image is stored in a digital format by using a computer.

Digital image processing can provide significant benefits in various technological sectors if used properly. Digital image processing is often used to analyze images to obtain the necessary information. One sector that can be developed with image processing is the agricultural sector. One application of image processing in the agricultural sector is plant leaf area calculation. A color detection model is required to calculate it. But to consider the color detection model, choosing the right type of color space becomes the most important issue. HSV or CIELAB is a color space often used in terms of color image detection [1].

The advantages of HSV or CIELAB color space detection is very similar to the colors seen by the human eye. By using it, an object with a certain color can be detected and reduce the influence of the intensity of light from outside.

In this research, a comparison between the color space of HSV and CIELAB in image processing is used to analyze the performance of both methods in detecting the color of the leaf area of the plant. In the digital image processing system, it takes a sample of data on one part of the plant. The sample will produce an information about the plant leaf area.

II. Review of Literature

In a research Comparing the Performance of L*A*B* and HSV Color Spaces by Appreciating Color Picture Segmentation [1], measured the accuracy between two digital image processing methods namely Lab (LAB Color Model) with CIELAB and HSV (Hue, Saturation, Value) methods to determine the colors that exist in some particular image objects. Results obtained from the HSV method are more accurate than CIELAB.

In the research Color Image Segmentation using Edge Detection and Seeded Region Growing Approach for CIELab and HSV Color Spaces [2], presents a simple and efficient method of image processing using CIELab and HSV color spaces to select seeds automatically. Results obtained from using HSV color space are more precise than using CIELab color space.

In another research, Study and Comparison of Color Models for Automatic Image Analysis in Irrigation Management Applications [3], a widespread data information trial of lettuce green (Lactuca sativa) and soil using various methods of digital image processing. Some methods are used for RGB, XYZ, L*a*b*, L*u*v*, HSV, HLS, YCrCb, YUV, I1I2I3 and TSL. From that experiment, the method that has the highest accuracy is the L*a*b* method. But, the research was still using manual way of capturing crop image by using high resolution camera. Then, the image was processed with some method of image processing on matlab.

In the research of Authentication of Herbal Medicinal Leaf Image Processing using Raspberry Pi Processor [4], to classify the plants according to its medicinal usage using Raspberry pi 2 model B. The plants are captured by raspi camera and stored memory card. The leaves are analyzed and compared with data in Raspberry pi store to find the category of leaf texture.

In the research of Plant Identification Crop Age Cultivation System based on Digital Image Processing [5], to solve plant nutritional problems based on planting time and monitoring of NFT hydroponic. The method applied in this system is segmentation based on HSV color space. In this research, the image was captured using the camera raspi which is processed automatically with python program that has been installed on raspberry pi 3 model B.

In this paper, we propose system to development of the research of Study and Comparison of Color Models for

Automatic Image Analysis in Irrigation Management Applications [3] by using raspberry pi 3 model B and camera raspi to measure the leave area of lettuce plant on NFT hydroponic and to compare the accuracy of HSV method and CIELAB method.

III. System Design and Methods

A. System Design

The monitoring system of NFT hydroponic plant consists of NFT hydroponic module, raspberry pi 3 B and raspberry camera module, WLAN internet connection which connected to web hosting and database server and PC or gadget / smartphone as media access information. Fig. 1 shows the design of monitoring system of NFT hydroponic plant.

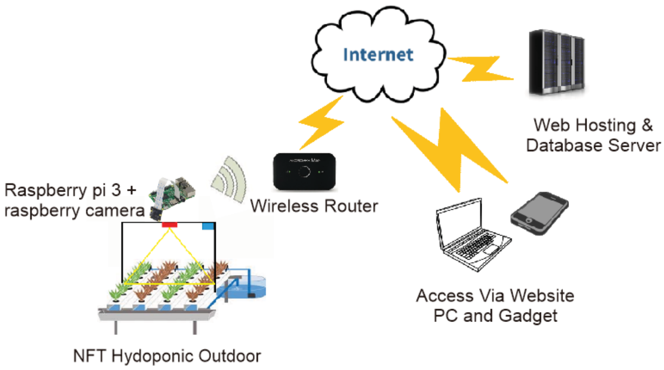

Fig. 1. Monitoring system of NFT hydroponic plant.

Based on Fig. 1, lettuce cultivation plant is captured by raspberry camera and continued with image processing process by raspberry pi 3 B. Raspberry pi 3 B module and Raspberry Pi camera installed on the NFT hydroponic module at a height of 120 centimeters.

Image processing results will be uploaded to the web hosting and can be accessed via the website on PC or gadgets which connected with internet.

B. Image Processing Methods

This research will discuss the performance comparisons of HSV and CIELAB color filters. Fig. 3 shows diagram block between HSV and the CIELAB methods.

1) Image Acquisition: The first step to get digital images. The will captured by raspberry camera and produce a RGB (Red, Green, Blue) image in JPEG format. Fig. 2 shows the result of image acquisition by raspberry camera module.

Fig. 2. Image acquisition.

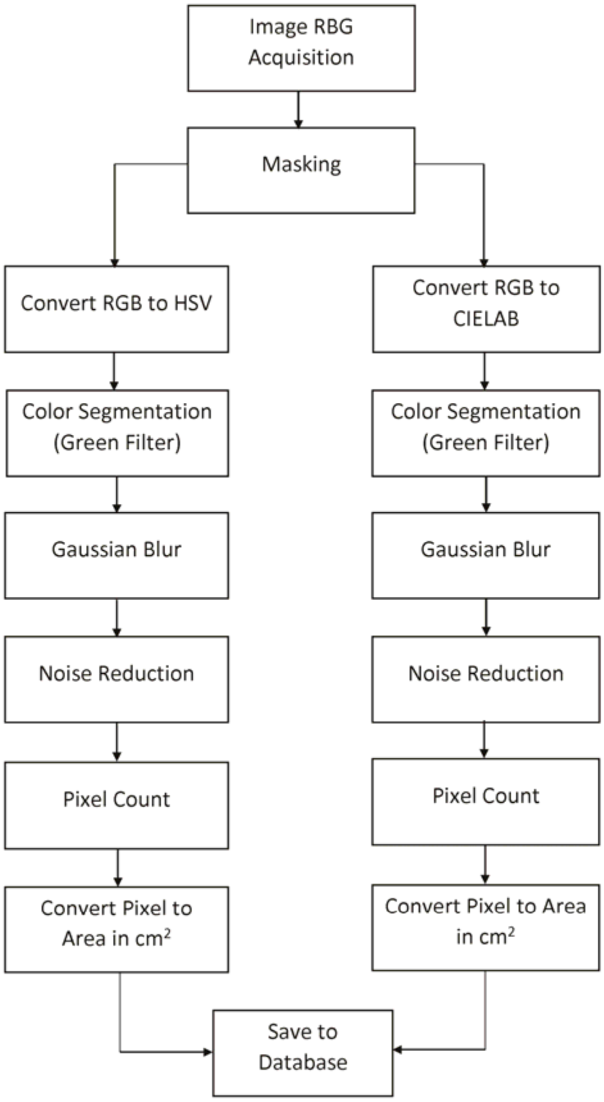

Fig. 3. Diagram block of HSV and CIELAB methods.

2) Circle Masking (Black Masking): Object selection is needed to observe the selected plant area. Selection of the plant is done manually using a paint application. The unselected area will be masked by black area. The black mask area will not be processed, so the bit value is "0". Fig. 4 shows the area masking by the module.

Fig. 4. Area masking.

3) The Conversion of RGB Image to HSV and CIELAB Color Spaces: Color conversion of RGB Image to HSV and CIELAB is done to determine green color boundary of plant leaf. The number of green color boundary of plant leaf in RGB is about [0,0,0] to [130, 255, 155].

The color conversion of RGB to HSV can be used the following equation [6] :

$$\text{And } V = Cmax \tag{1}$$

$$H = \begin{cases} 60^\circ \times \left(\frac{G-B}{\Delta}\right) & , Cmax = R \\ 60^\circ \times \left(\frac{B-R}{\Delta} + 2\right) & , Cmax = G \\ 60^\circ \times \left(\frac{R-G}{\Delta} + 4\right) & , Cmax = B \\ Undifined, & Cmax = Cmin \end{cases} \tag{2}$$

Where,

$$Cmax = \max(R, G, B);\ Cmin = \min(R, G, B);$$
$$\text{And } \Delta = Cmax - Cmin \tag{3}$$

$$S = \begin{cases} 0, & Cmax = 0 \\ \frac{\Delta}{Cmax}, & Cmax \neq 0 \end{cases} \tag{4}$$

The HSV model shows the color space in the form of three color components, there are Hue, Saturation, and Value (brightness). Hue is a color grade value from 0^o to 360^o where the color degree is 0^o is red, 60^o is yellow, 120^o is green, 180^o is cyan, 240^o is blue and 300^o is magenta. On Fig. 5 shows the hue range of green leaf [7]. Saturation stated the amount of white light mixed in Hue that is 0-255 value, worth towards "0" if more white light content or saturation is 0%. While the value or brightness stated the value of light intensity in ranges from “0” or black until “255” white.

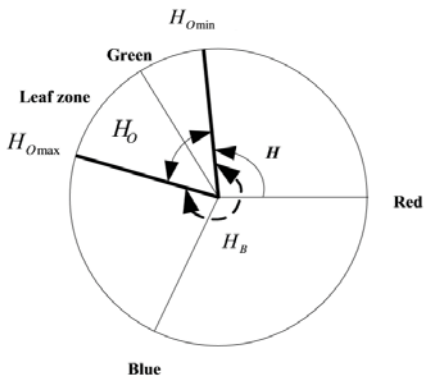

Fig. 5. Hue range of green leaf.

The color conversion of RGB to CIELAB required color conversion of RGB to XYZ that used the following equation [8] :

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.607 & 0.174 & 0.200 \\ 0.299 & 0.587 & 0.114 \\ 0.00 & 0.066 & 1.116 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{5}$$

The color conversion of XYZ to CIELAB can used the following equation [9] :

$$L^* = 116\,(Y/Yn)^{1/3} - 16, \text{ for } Y/Yn > 0.008856 \tag{6}$$

$$L^* = 903.3\ Y/Yn, \text{ for another } Y/Yn > 0.008856 \tag{7}$$

$$a^* = 500\,(f(X/Xn) - f(Y/Yn)) \tag{8}$$

$$b^* = 200\,(f(Y/Yn) - f(Z/Zn)) \tag{9}$$

Where,

$$f(x) = \begin{pmatrix} x^{1/3} & x > 0.008856 \\ 7.787\,x + 16/116 & x \leq 0.008856 \end{pmatrix} \tag{10}$$

The L*a*b* color space or CIELAB is the most complete color space set by the International Commission on color illumination (French Commision Internationale de l'eclairage, known as CIE). Where the L, a, b stated the value of Luminance (Lightness) and Chromatic color (a, b). Based on Fig. 6, we can see that the L* Axis shows the brightness or lightness value from 0 (dark) to 100 (white). The axis a* shows the type of green (-a) and red (+ a), while the axis b* shows the type of blue (-b) and yellow (+ b).

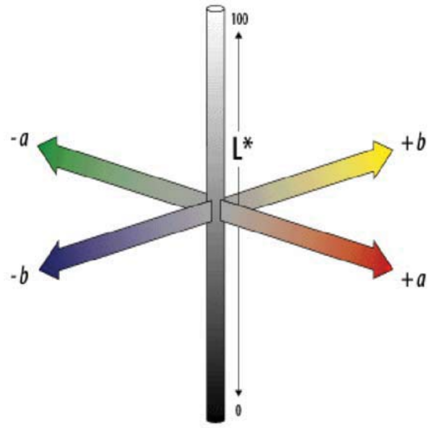

Fig. 6. L*a*b* color space (CIELAB).

4) Image Segmentation: Green color segmentation is done in order to take the object in the form of leaf area. The image segmentation requires a minimum and maximum treshold value of green color to filter the form of plant leaf with the background. Fig. 7 shows the form of plant leaf by CIELAB color filter.

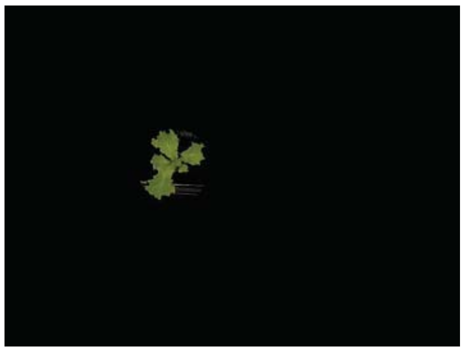

Fig. 7. Image segmentation by CIELAB.

5) Converting Objects to Gaussian Blur: To reduce the noise on the image by using a morphological operation. Gaussian blur is a blurred image detection technique that combines images with low-pass filter to remove noise and reduce detail or smooth objects. This operation will detect noise and edge easily. Gaussian blur techniques results will be converted to a form of binary image. Fig. 8 shows the conversion object to gaussian blur.

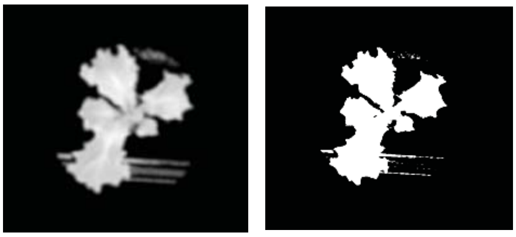

Fig. 8. *Gaussian Blur* process.

6) Noise Reduction: To improve the form of plant leaf in order to produce more accurate data by using noise reduction operations. Noise reduction techniques include erosion and dilation. Erosion is a morphological filter which used to remove or reduce the surface area of a minority object. On Fig. 9 shows the result of erosion process. Operation of erosion can be displayed as follows [7] :

$$X\theta B = \{x|(B_x) \subseteq X\} \tag{11}$$

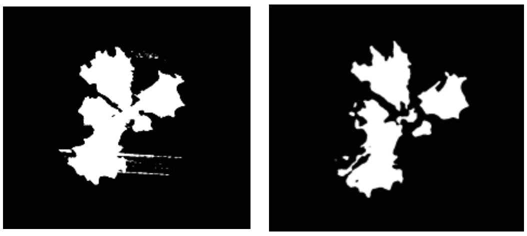

Fig. 9. Erosion process.

Dilation is a morphological filter which used to add or enlarge a surface area of the object. This operation recovers against the removal of noise effects around the plant leaf. On Fig. 10 shows the result of dilation process. The process of dilation is revealed with the following operating [7]:

$$X\theta B = \{B_x \cap X \neq X\} \tag{12}$$

Fig. 10. Dilation process.

7) Pixcel Count: The form of plant leaf area will be calculated the pixel count of the object that has been converted into binary image. A binary image which have 1 cell of white color "1 bit" will be calculated 1 pixel.

8) Leaf Area Calculation: Based on Fig. 11, paper reference is used to calibrate the measured leaf area which expressed in the following equation [10] :

$$\mathrm{Ax} = \frac{Px}{Pr} \mathrm{x\ Ar} \tag{13}$$

Fig. 11. Segmentation of reference paper.

The size of reference paper is 7,6 x 5 centimeters. The number of pixels of the reference paper is calculated by using ImageJ software. The number of pixels of reference paper obtained from ImageJ software is about 13838 with an area of 38 cm2.

IV. Experimental Result and Discussion

A. Experiment of Plant Monitoring System

Monitoring data on the growth of leaf area, observed the number of daily pixels of plant growth at about 3th-4th week for 1 harvest periode. The number of pixels are counted by HSV Color Filter and CIELAB Color Filter. Calculation of the number of pixels proposed methods from proposed method steps 1 until 7. The results of both filters will produced different values. The difference of pixels will produced different leaf area. The result of pixels conversion to the leaf area is seen in the following TABLE I :

TABLE I. Results Data of Plant Growth Monitoring System

Age in days	Pixel Seedling with HSV Color Filter	Pixel Seedling with CIELAB Color Filter
22	77,051	91,117
22	77,412	78,324
23	20,624	51,179
23	81,803	83,371
24	51,862	65,445
24	85,393	86,558
25	93,284	96,548
25	93,415	97,169
26	91,387	95,628
26	85,844	94,588
27	129,022	131,305
27	121,230	122,312
32	288,906	290,717
32	284,071	289,534
33	321,563	323,611
33	262,823	265,465

Based on pixel data obtained on the plant growth monitoring system in Table I, can be shown through the plant growth graph in Fig. 12 :

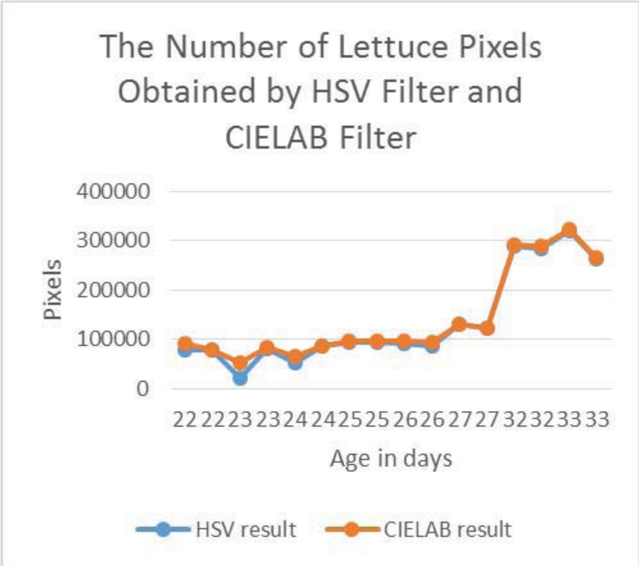

Fig. 12. Graphic of the number of lettuce pixels.

B. Error Rate and Accuracy of Plant Monitoring System

Based on the result of plant monitoring system, calculated the error value and accuracy of the monitoring system by comparing the calculation of pixel value manually with monitoring result data. The manual calculation of pixel leaf area is done by using ImageJ software. The calculation of error data and accuracy of HSV method based on manual calculation is given in Table II below :

TABLE II. THE CALCULATION ERROR DATA AND ACCURACY OF HSV METHOD

Age in days	Pixel Seedling with HSV Color Filter	Pixel Seedling with ImageJ software	Value of Error	Error Rate %	Accuracy %
22	77,051	54,474	22,577	0.41	58.55
22	77,412	52,988	24,424	0.46	53.91
23	20,624	63,877	43,253	0.68	32.29
23	81,803	64,221	17,582	0.27	72.62
24	51,862	78,055	26,193	0.34	66.44
24	85,393	77,901	7,492	0.10	90.38
25	93,284	100,354	7,070	0.07	92.95
25	93,415	101,019	7,604	0.08	92.47
26	91,387	119,110	27,723	0.23	76.72
26	85,844	119,577	33,733	0.28	71.79
27	129,022	142,117	13,095	0.09	90.79
27	121,230	142,202	20,972	0.15	85.25
32	288,906	247,588	41,318	0.17	83.31
32	284,071	235,341	48,730	0.21	79.29
33	321,563	242,001	79,562	0.33	67.12
33	262,823	242,050	20,773	0.09	91.42
Overall test results				24.67	75.33

While the calculation of error data and accuracy of CIELAB method can be shown in table III below :

TABLE III. THE CALCULATION ERROR DATA AND ACCURACY OF CIELAB METHOD

Age in days	Pixel Seedling with CIELAB Color Filter	Pixel Seedling with ImageJ software	Value of Error	Error Rate %	Accuracy %
22	91,117	54,474	36,643	0.67	32.73
22	78,324	52,988	25,336	0.48	52.19
23	51,179	63,877	12,698	0.20	80.12
23	83,371	64,221	19,150	0.30	70.18
24	65,445	78,055	12,610	0.16	83.84
24	86,558	77,901	8,657	0.11	88.89
25	96,548	100,354	3,806	0.04	96.21
25	97,169	101,019	3,850	0.04	96.19
26	95,628	119,110	23,482	0.20	80.29
26	94,588	119,577	24,989	0.21	79.10
27	131,305	142,117	10,812	0.08	92.39
27	122,312	142,202	19,890	0.14	86.01
32	290,717	247,588	43,129	0.17	82.58
32	289,534	235,341	54,193	0.23	76.97
33	323,611	242,001	81,610	0.34	66.28
33	265,465	242,050	23,415	0.10	90.33
Overall test results				21.61	78.39

Based on the test data generated can be seen that changes in the number of pixels obtained on each plant growth is not always increased. This is caused by the position of plant leaves that are always changing, the condition of wilt or absence of plants and sunlight that can affect the results of sampling by raspi camera module. In the pixel reading data using HSV color filter method has the accuracy level of 75.33% while the pixel number reading using CIELAB color filter method has a greater accuracy of 78.39%. the results prove that the CIELAB color filter method has greater accuracy than the HSV color filter method in reading the number of pixels of the lettuce area even though the difference in accuracy value is very small.

V. CONCLUSION AND FUTURE WORK

The application of digital image processing methods to outdoor hydroponic plant growth monitoring using CIELAB method has better accuracy than HSV method. Based on the results of the research, HSV method has an average accuracy of 75.33% while the CIELAB method has a greater average accuracy rate of 78.39%. The use of HSV and CIELAB methods on reading the leaf area of outdoor hydroponic plants with heterogeneous backgrounds needs to be observed to the effect of ideal light intensity by using higher resolution cameras in order to produce better image processing.

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