Plant Age Identification System of Outdoor Hydroponic Cultivation Based on Digital Image Processing

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***Abstract*—Plant age identification is needed by hydroponic farmer to adjust nutrient solution concentration. Hydroponic plants need different nutrient solution concentration according to their age. Farmers usually adjust it manually based on plants size. It causes plants can't get sufficient nutrition which will have impact on growth. This research aims to identify plants age based on digital image processing. Researh method using segmentation based on color similarity to HSV (Hue, Saturation, Value) method. This method will select plant area, convert to black and white format, calculate pixel number and plant age can be identified based on the standard age categories. The parameters used in this research is the truth age value of 100 image crop cultivation samples based on the number of pixel accounts on the system. Result shows that system has accuracy of 81% on plants age identification.**

Keywords—hydroponic, Digital image processing, HSV color format.

I. INTRODUCTION

Now, agricultural land increasingly narrower is a problem. the current state of agricultural land is widely used for residential and industrial. On the other hand, the demand for agricultural commodities has increased along with the development of the welfare level of the population. To solve these problems used hydroponic techniques. Hydroponic is one of farming method without use soil, but it use water which contain nutrition. In hydroponic techniques the function of soil substitute by water, nutrition, dan oxygen which flow to the plant [1].

On the cultivation of hydroponic techniques there is a problem that is setting the levels of nutrients that are streamed. Nutrient levels settings should be adjusted according to the age of the plant, so that it is proportionate and in line with the intake of nutrients for plant growth. Granting optimal nutrients will enhance the results of high-quality crop production. In reality now, the cultivation of hydroponic is currently setting the levels of nutrition is still adjusted based on estimated quantities the physical age of plant.

Based on these problems, then deeper research to resolve the problem of identification of the age of the plant based on digital image processing. On data processing of digital image acquisition, it takes a picture of the part of the plant used as a sample. On a sample of part of the plant can be used to indicate the parameter characteristic of plant growth according to age categories in general. So the growth of plants according to his age can be tracked until it is ready to harvest.

The rest of the paper is organized as follows. In Section 2, related works are described. Then, in Section 3, the proposed method is described. In section 4, experimental result and discussion is presented in details. Then, in Section 5, there are several conclusion and future works.

II. RELATED WORKS

The idea proposed by Lü et al [4] is the first method wide area measurement research leaves with Hough transformation.To eliminate the influence of holes in the leaf used the technique of contour extraction and then do the calculations of the number of pixels in the contour. However, in this research that has been done is only intended for the destructive methods as well as a homogenous background.

The idea proposed by Kaiyan et al [5] is the research on the measurement of leaves area with a method of HSI (hue, saturation, intensity). The method used in the HSI color filter hue, saturation, and intensity to image segmentation. The intensity of the colors used in the determination of the allowable color threshold. BLOB analysis is also used to eliminate residual noise which is less than the threshold. Residual noise in the form of a small hole will be filled with the same color of the object. However, in the research that has been carried out aimed at destructive methods as well as a homogenous background.

The idea proposed by Glasbey et al [6] is the research on the measurement of leaves area with a combination of stereo and ToF method image. On this research has been discussed widely in non destructive methods of measurement as well as performed on the heterogeneous medium. By changing the images to form images of ToF (Time of Flight), whereas the method of density function for estimating the factor stereo disparity for each pixel. Smoothing methods used to accurately estimate the surface area of the leaf. However, in this study the selection of the area being measured is still done manually.

The idea proposed by Jadon and Agarwal [7] is the research on the measurement of leaves area with RGB filter methods and extents reference objects. Image

acquisition is converted to gray scale. Morphological operation used to remove spotting and then performed the measurement area. However, in this research as there is namely still devoted to destructive methods as well as a homogenous background.

In this paper, we propose system to solve the problem in the growth monitoring and age identification lettuce cultivation hydroponic Based on Digital Image Processing.

III. SYSTEM CONFIGURATION AND PROPOSED METHOD

A. System configuration

System configuration identification of age of plant cultivation hydroponics is composed of acquisition and image processing module plant, NFT (Nutrient Film Technique) hydroponic module, WLAN access points that are connected to the internet, web and database hosting and PC / gadget as media access to information. The configuration can be seen in Fig. 1 the following:

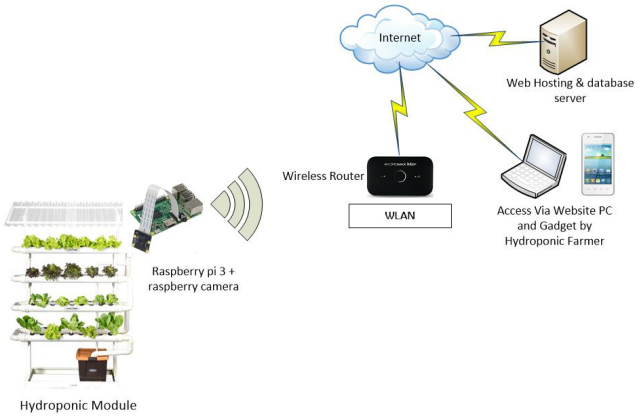

Fig. 1. Plant age identification system hydroponic cultivation.

On Fig. 1 shows the age identification system module, plant lettuce cultivation hydroponics pool is acquisitioning and image processing modules consisting of Raspberry pi 3 and camera module Raspberry. Raspberry pi module 3 module functions as a mini PC for digital image processing by the camera module resulted in Raspberry. Module PC mini Raspberry pi and a camera placed on the NFT hydroponic green house module at an altitude of 130 centimeters.

Digital image processing results by pi Raspberry modules uploaded via a WLAN internet connection is connected to the web and server hosting provider. On the results of the digital image processing and age category information accessible via the website via PC and gadget users.

B. Proposed Method

In this paper discussed the proposed method of color Filter HSV. On Fig. 2 procedure base proposed method displays the system color Filter HSV.

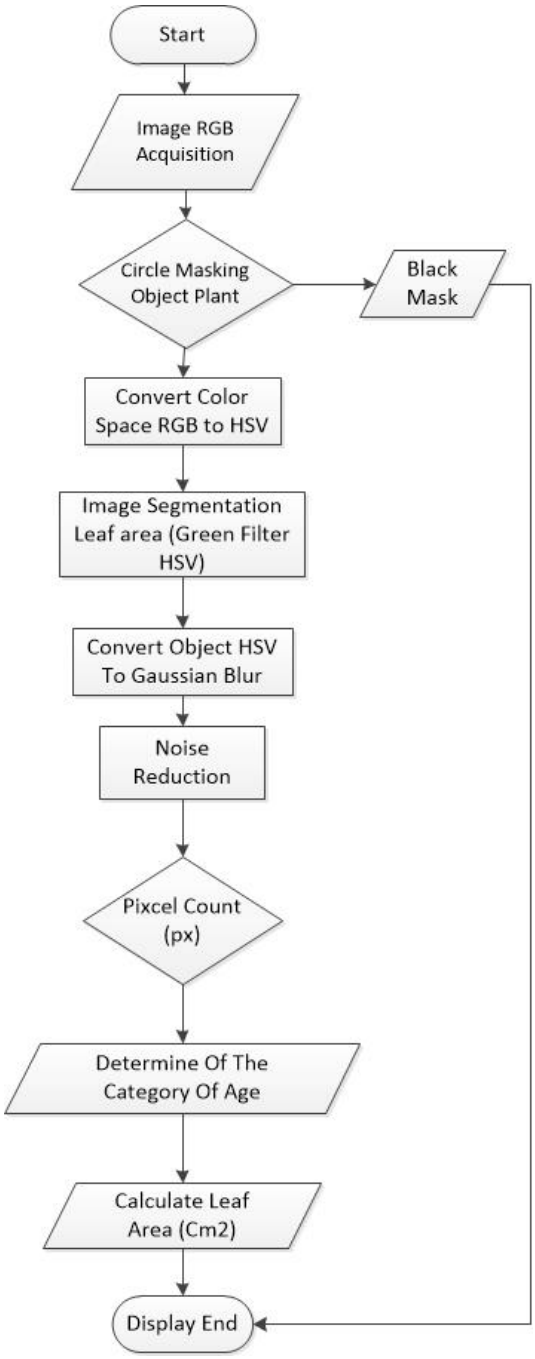

Fig. 2. Block diagram of proposed method.

1) Image RGB Acquisition : Cultivating hydroponic lettuce plants placed on the table module. Module 3 and module pi raspberry camera placed above the plant with a height of 130 centimeters. The paper reference is placed around the lettuce plant. The images were acquired by a camera be displayed as shown below. The images are in JPEG format and color space RGB. Fig. 3 shows RGB image acquisition by module.

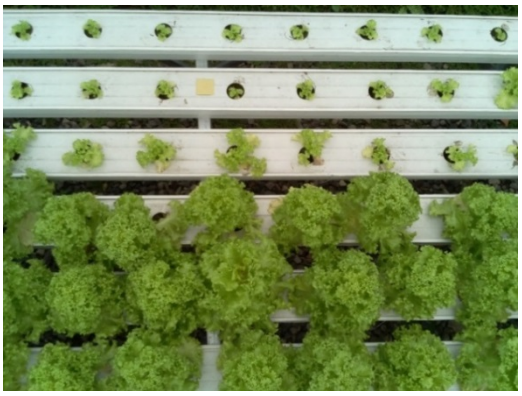

Fig. 3. RGB image acquisition.

2) Circle Masking Object Plant: the acquired image was a picture of a majority. Selection needs to be done to observe selected lettuce area. Masking a circle shaped area. Determination of the center point of a circle is done manually using a paint application. Fig. 4 shows the object masking by the module.

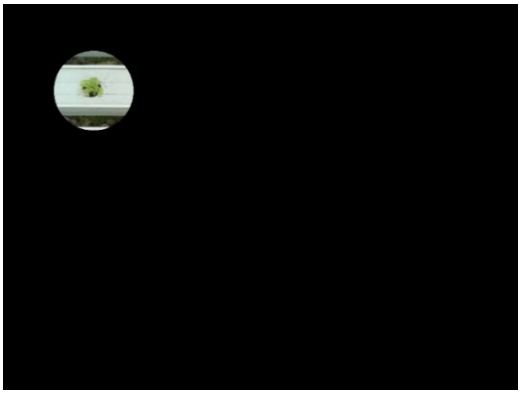

Fig. 4. Circle of masking object plant.

3) Black Masking: The area that is not selected is a black mask. The Black areas of the mask will not be processed further, so its worth a bit value "0".

4) *The Conversion of RGB to HSV Color Space:* color conversion of RGB to HSV is done to facilitate the segmentation of the image of the dominant color of the leaves green using the equation below [6].

$$R' = \frac{R}{255};\quad G' = \frac{G}{255};\quad B' = \frac{B}{255} \tag{1}$$

$$max = \max(R', G', B');\ Cmin = \min(R', G', B');\quad and\ \Delta = C_{max} - C_{min} \tag{2}$$

$$H = \begin{cases} 60° \times \left(\frac{G'-B'}{\Delta}\right) & , Cmax = R' \\ 60° \times \left(\frac{B'-R'}{\Delta}\right) + 2 & , Cmax = G' \\ 60° \times \left(\frac{R'-G'}{\Delta}\right) + 4 & , Cmax = B' \end{cases} \tag{3}$$

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

And $V = Cmax$ (5)

Where the H, S, V declared the value of the hue, saturation, and brightness image. On the technique of method of approach used hue tresholding uti-lized Otsu [7]. From equation (1), we can see the hue is the color degree movies value expressed in 360 degree of color. We can see on Fig. 5 the hue shown in 360 degree movies color wheel. Saturation levels of color clarity is expressed in value 0-255. While the value stated the value of the expression for the relative bandwidth output seen from the light source.

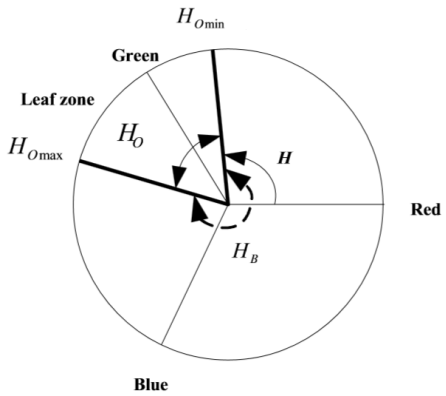

Fig. 5. Hue range of green leaf.

5) Leaf Area Image Segmentation (HSV color space green Filters) : To be able to display the object in the form of leaf area then do segmentation with green area threshold technique. Shown in Fig. 5, where the 3 primary colors (red, green and blue) are expressed respectively in the 120 degree movies color [3]. On Fig. 3 Ho is the area of green color of the leaves, while the *[Ho max,Ho min]* threshold hue leaves stated threshold value is expressed in 2. At Saturation is done setting the value min = 0 and max = 255 and value done setting the min value = 0 and max = 255. On the value of "value" is the value of the maximum approach will give effect to the white light. Fig. 6 shows the image segmentation by a green color filter HSV.

Fig. 6. Image segmentation by a green color filter HSV.

6) *Converting Objects to HSV Gaussian Blur :* To facilitate the process of the reduction of noise on the image do morphological operation with gaussian blur. Gaussian blur is the technique of changing the format of the HSV colors have filtered into a grayscale format and continued

with the technique of blurring. Gaussian blur techniques results will then be converted to a form of binary image. Fig. 7 shows the conversion object HSV to gaussian blur.

Fig. 7. *Gaussian Blur* process.

7) *Noise Reduction :* To improve the quality of the image data, done the reduction of noise with noise reduction operation. On the techniques of reduction of noise made up of erosion and dilation techniques. On Fig. 8 showing the results of the process of erosion. Operation of erosion can be displayed as follows [3] :

$$X\Theta B = \{x|(B_x) \subseteq X\} \quad (6)$$

Fig. 8. Erosion process.

Dilation is engineering a majority area returns eroded by erosion processes. The process of dilation is done with iteration 6 times will return the form area leaves back like in the beginning. On Fig. 9 showing the process of dilation. The process of dilation is revealed with the following operating [5]:

$$X \oplus B = \{B_x \cap X \neq \emptyset\} \quad (7)$$

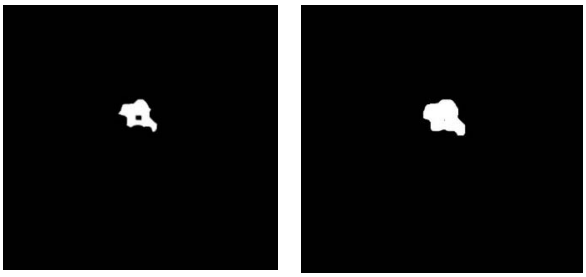

Fig. 9. Dilation process.

8) *Pixcel Count :* After getting a perfect form of leaf area performed calculations of the number of pixels of the leaf area have been converted into binary format. Where a value of 1 color white cell "1 bit" will be worth 1 pixel.

9) *The Daily Average Pixel :* in determining pixel daily average data growth required for 3 times. The following equation is used in the calculation of :

$$pixel\ day - n\ \bar{x} = \frac{pixel\ x_1 + pixel\ x_2 + pixel\ x_3}{3} \quad (8)$$

In the equation above pixel day $-n\ \bar{x}$ stating the average pixel value on the day - n while $pixel\ x_{1,2,3}$ the pixel value is expressed daily on day - n on seedling period 1,2, and 3.

10) *Determining of The Category of Age :* The number of pixels calculated based on age category determination conducted standard categories of age, shown in TABLE I. Standard age category is based on the observation of the number of pixels for 3 times for planting lettuce cultivation until harvest.

11) *Calculate Leaf Area* : On Fig. 10 showing segmentation paper references used for calibration the measured area on leaf area , real leaf area is expressed with the following equation [5] :

$$\text{Ax} = \frac{Px}{Pr} \text{ x Ar} \quad (8)$$

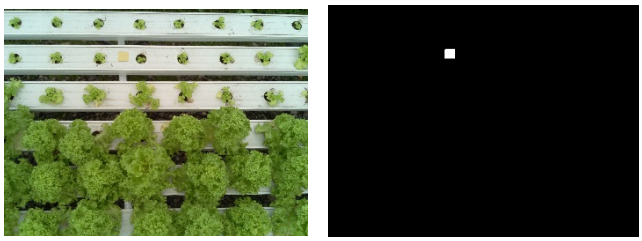

Fig. 10. Segmentation of reference paper.

On Fig. 10 display reference paper sized 5 x 5 centimeters. n the calculation of the number of pixels of the method steps 1 to 8 are known to have a number of pixel 9103 px. So the Pr value in equation 13 is 9103 with Ar is 25 centimeters.

IV. EXPERIMENT AND NUMERICAL RESULT

A. Experiment of Age Category-Standard

Experimental data on the age category standard lettuce plant growth, number of observations performed the pixels daily growth for 3 times of seedling period. Observation of the number of pixels using method 1 to 8.The number of pixels are calculated per day on 1 x 24 hours. Here are a number of pixel data daily for 3 times of harvest period :

TABLE I. Number of pixel calculations data daily for 3 times the harvest

Age in days	Pixel Seedling Period -1	Pixel Seedling Period -2	Pixel Seedling Period -3
1	1429	1080	1356
2	3397	3873	3299
3	7342	6032	7252
4	10738	8336	9634
5	13921	10425	12998
6	20753	17631	18041
7	33738	20236	22034
8	37289	25534	31097
9	35915	28502	33212
10	41402	30722	36719
11	42733	55575	59337
12	56733	70663	63354
13	62645	71800	78004
14	70542	73566	86110
15	86391	85122	85457
16	91469	95379	98610
17	92157	102375	122119
18	93064	102741	151220
19	94141	101537	153298
20	97743	103240	153913
21	99472	106510	154628
22	109684	109675	157936
23	115776	111273	161075
24	116105	113714	165131
25	118254	120729	173904
26	131752	127879	183731
27	140763	136834	187342
28	152371	149494	196327

From TABLE I it can be produced the amount of pixels on average for 28 days with a lettuce plant growth using the equation in step 9 method as follows :

TABLE II. Standard age category based on the number of pixels the average daily

Average pixels	Age Categories	Age Information
1288	0 - 1288	1 day
3523	1289 - 3523	2 day
6875	3524 - 6875	3 day
9569	6876 - 9569	4 day
12448	9570 - 12448	5 day
18808	12449 - 18808	6 day
25336	18809 - 25336	7 day
31307	25337 - 31307	8 day
32543	31308 - 32543	9 day
36281	32544 - 36282	10 day
52548	36283 - 52548	11 day
63583	52549 - 63583	12 day
70816	63584 - 70816	13 day
76739	70817 - 76739	14 day
85657	76740 - 85657	15 day
94486	85658 - 94486	16 day
114550	94487 - 114550	17 day
115675	114551 - 115675	18 day
116325	115676 - 116325	19 day
118299	116326 - 118299	20 day
120203	118300 - 120203	21 day
125765	120204 - 125765	22 day
129375	125766 - 129375	23 day
131650	129376 - 131650	24 day
133245	131651 - 133245	25 day
136728	133246 - 136728	26 day
140178	136729 - 140179	27 day
166064	140179 - 166064	28 day

Based on data of TABLE II can be shown the graph of the number of pixels the average daily on Fig. 12 following :

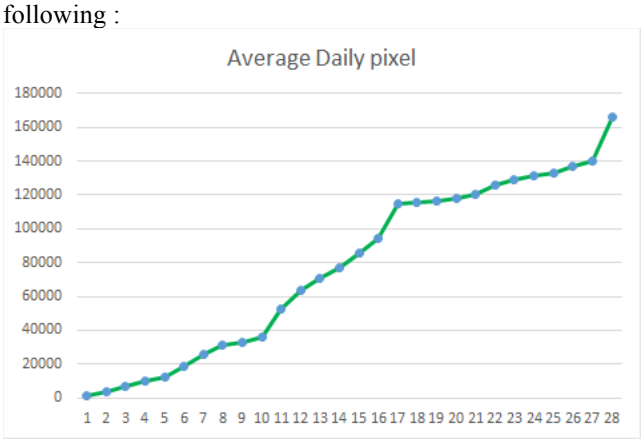

Fig. 12. Graphic of the number of the daily average pixel

In addition, based on TABLE II number of daily average pixel can be converted into polygons in square centimeters (cm^2) on TABLE III below :

TABLE III. Conversion table average number of pixels to the unit area (in cm^2)

Day	Pixel Average	Area (cm^2)
1 day	1288	3.537295397
2 day	3523	9.675381742
3 day	6875	18.88113809
4 day	9569	26.27979787
5 day	12448	34.18653191
6 day	18808	51.65330111
7 day	25336	69.58145666
8 day	31307	85.97989674
9 day	32543	89.37438207
10 day	36281	99.6402285
11 day	52548	144.315061
12 day	63583	174.6210041
13 day	70816	194.4853345
14 day	76739	210.7519499
15 day	85657	235.2438756
16 day	94486	259.4913765
17 day	114550	314.5940899
18 day	115675	317.6837306
19 day	116325	319.4688564
20 day	118299	324.8901461
21 day	120203	330.1191915
22 day	125765	345.3943755
23 day	129375	355.3086894
24 day	131650	361.5566297
25 day	133245	365.9370537
26 day	136728	375.5025816
27 day	140178	384.97748
28 day	166064	456.0694277

Data TABLE III area generated through the equation in step 11 method. Then the graph area is displayed in Fig. 13 the following :

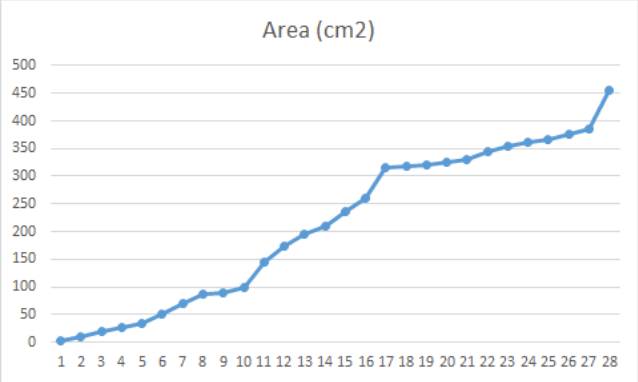

Fig. 13. Graphic of Conversion area on daily average

B. *Experiment Result of the determination of the age of 100 Sample Pictures*

According to standard testing done pixel growth toward 100 sample image crop of lettuce which consists of 4 categories of age are the age of 1 week, 2 week, 3 week and 4 week. In each category the age of the plant sample amounted to 25. On the results of the experiment are generated as follows on TABLE IV :

TABLE IV. Identification result per class for proposed method

No.	Age Category	No image used for test	No Error data	Value of Error	Accuracy %
1.	1 Week	25	0	0	100
2.	2 Week	25	4	0.16	84
3	3 Week	25	9	0.36	64
4.	4 Week	25	6	0.24	76
Overall test results		100	19	0.19	81

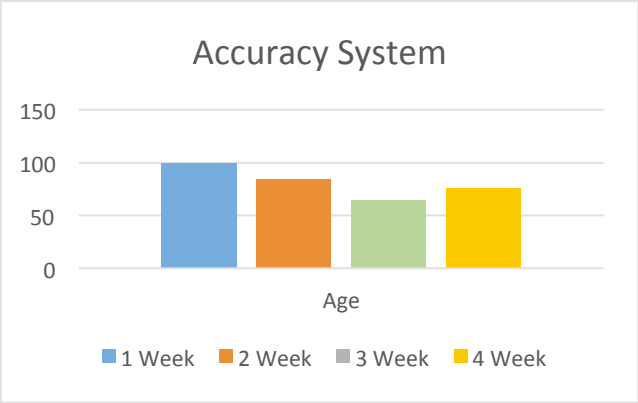

Fig. 14 – Accuracy results per class for proposed method.

Based on experimental data sample picture above 100 can be found at TABLE IV the amount of error in the amount of 25 plants known age on 1 week was 0. The amount of error in 25 number of plant age 2 weeks was 4. The amount of error in 25 number of plant age 3 weeks was 9. The amount of error in 25 number of plant age of 4 weeks is 6. In Fig. 14 display accuracy system against the identification in each age category lettuce plants. Based on that data then the data error rate can be known identification of age with the following equation :

$$Error\ Rate = \frac{Total\ error\ data}{Total\ image\ used\ for\ test} = \frac{19}{100} = 0.19$$

$$Overall\ Accuracy = (1 - Error)x\ 100\%$$

$$= (1\text{- }0.19)\text{ x }100\% = 81\%$$

V. CONCLUSION AND FUTURE WORK

Identification of the age of the plant through digital image processing plant that is part of the leaf is the right solution for plant growth monitoring. This is because the leaf is the main organ in the plant, indicating the growth in plants. Through the filter method of the HSV color components are applied, hue, saturation and value with the approach of the Otsu tresholding eases in the segmentation of the image of the leaves with the heterogeneous background. It also added a noise reduction techniques consist of erosion and dilation so give a clean image results. based on the research of the truth values of age against 100 samples of the plant will result in accuracy of 81% with an error rate 0.19. For further development can be discussed on the influence of light intensity that is efficient in image processing dan analysis of the use of multiple camera resolutions.This method is easy to implement and it takes a lot of cost.

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