Estimation of Paddy Plant Population Using Aerial Image Captured by Drone

M. Saifizi, M.A Syauqi, R. Vinoth, Wan Azani Mustafa, Syed Zulkarnain Syed Idrus, Mohd Aminudin Jamlos

1Department of Electrical Engineering Technology, Faculty of Engineering Technology, University Malaysia Perlis
2Center of Excellence Geopolymer and Green Technology, Universiti Malaysia Perlis, 01000 Kangar, Perlis, Malaysia.

Abstract. Monitoring of rice plants population density is important for crop setting and fertilizer management to achieve high target yield. Currently, the population density is determined by manually counting the tiller number of total rice plants in a 25 cm x 25 cm square frame. Generally, several random sampling locations of a paddy plot are selected to perform tiller counting. This is time-consuming, labour intensive and costly. An automatic counting tiller number method using digital image processing technique is introduced to overcome the problem. Monitoring paddy population can be done by using Unmanned Aerial Vehicle (UAV) or Drones. The use of drones can take a wider picture, save time and be more efficient. For this research, the DJI Mavic Pro Drone is used to scout the areas. The drone has captured the image from the air and sending to the computer via wireless. The image is processed in different technique such as filtering, enhancement, segmentation and thresholding. As a result, the image processing technique is practical, feasible and effective in estimating tiller number for monitoring of rice plant population density.

1. Introduction
Rice (Oryza sativa L.) is the most important and staple food for more than half of the world’s population. Rice is a type of grains, which is the most consuming food in the world. It is the third major crop in the world in terms of production after sugarcane and maize. That around 90% of the world’s rice was produced and consumed in Asia. In 2012 the total area under rice cultivation in Malaysia was 701,821 hectares, distributed in Peninsular Malaysia and Borneo Islands [1]. Malaysia is ranked 24th among the rice producing countries with an annual production of 2.750 million tonnes at an average of 3.97 tonnes/ha [2]. In terms of production, rice is the third major commodity in Malaysia after oil palm and rubber.

The average Malaysian citizen consumes 82.3 kilograms of rice per year and accordingly, increasing population demand for more research and technological advancement to increase rice production. Rice production in Malaysia is not sufficient to meet the requirements of the local population. Presently the local rice production only fulfills 73% of the demand, whereas the rest is imported from different countries and the government has set a target of 2015 to achieve 100% self-sufficiency in rice. However, there are many problems to achieve that target and include low yield (3.76 ton /ha) that has to be increased to 5 ton/ ha at present area under cultivation or area under cultivation has to increase up to 1.14 million hectares from present 0.678 hectares [3].

The total area under rice cultivation was 673,745 hectares in Malaysia of which more than 50% were planted in eight granary area in Peninsular Malaysia, 32.3% outside the granary areas and the
remaining 10.4% representing the upland paddy, especially in Sabah and Sarawak. Kedah has the biggest paddy fields in Malaysia with an area of 213,193 hectares in 2010. The national average yield is about 3.5 t/ha. The average yield in the granary area is 4.2 t/ha, while the average yield of other areas is 3.2 t/ha [1]. Generally, Malaysian rice production is not cost effective as compared to other countries such as Vietnam and Thailand.

Many researchers have done in the area of image segmentation to obtain the best method that can be used for segmentation. According to [4], resolutions of 7 cm/pixel permit the identification of gaps as small as 1m². Gap maps obtained from UAV-acquired orthophotos and a manned LIDAR flight can be compared. Different segmentation techniques are also used to extract pure canopy pixels. Besides, both paper [5] and [6] has applied a thresholding algorithm to mask pixels associated with the cloud, soil, and shadow, and obtain only directly illuminated canopy pixels. Meanwhile, [7] obtained consistent results using the watershed algorithm for rows extraction in vineyards, where the differences between vines in terms of vigour made a thresholding selection difficult. Watershed transformation is based on the gradient magnitude, with pixels having the highest gradient intensity corresponding to region boundaries.

Another paper proposed by [8] used object-oriented image classification software to classify mixed rangeland into four primary cover types (bare soil, shrubs, subshrubs, and herbaceous plants). The similar object-oriented strategy is used by [9] with the aggregation of pose information and solar model.

2. Methodology

Firstly the image captured by the drone. The data transfer via wireless and will undergo image processing to extract the image information. Proceed with an estimation of paddy population and testing. Image acquisition is the first step of the project to get the data. Image Acquisition can be defined as the activity of retrieving an image from some source, hence it can be gone through any procedures need to happen subsequently. The image of the paddy field was acquired in this step. The image captured after 15 into 18 weeks the farmer planting the seed. The paddy population is captured by using the drone. 200 images of paddy population with various conditions have been captured for classification proposed. After the image has been obtained, various image processing techniques have been applied in order to segment the paddy plant images.

DJI Mavic Pro Drone is the types of drone used in this project as shown in Figure 1. This drone is already built-in with the high-quality camera with resolution 12 megapixel. DJI Mavic Pro Drone is easy to handle and can capture the good image in any height we applied. The drone and controller are calibrated first before start data captured. Camera conditions and battery rate are also things need to monitor before the drone start flying.

![DJI Mavic Pro Drone](image1)

**Figure 1.** DJI Mavic Pro Drone

The drone can be controlled directly by using the controller without using the Smartphone. The drone also can be controlled through a Smartphone without attached to the controller. For this study, the controller was attached with the Smartphone to control the DJI Mavic Pro Drones.

2.1 Image Processing

Image processing is the next step after images data transferred completely to undergo classification of paddy population. There are several image processing techniques has been proposed to segment the paddy population images. The image segmentation approach is conversion the images into Saturation
components based on the HSV colour model. Then, the S component image is filtered with a median filter. Next, the filtered image is changed into a binary image by used Otsu' thresholding method.

Classification of paddy population images is classified by using the comparison technique[10]. In this project, the goal of image segmentation is to segment the paddy plant. There are several image segmentation techniques that are used to segment the paddy plant from the soil and water. To exploit the colour contents in an image, the colour image segmentation for the nucleus is performed based on the HSV (Hue, Saturation, Value) colour model image. Thus, out of these three colour models, only the S component is used for transforming the RGB (Red, Green, Blue) image.

The median filter is the best-known order statistics filter which the value of a pixel replaced by the median of the gray levels in the neighborhood of that pixel as shown in Equation 1 [11]. Computation of the median is included in the original value of the pixel. The capabilities in noise reduction for certain types of random noise make it the median filters are quite a famous algorithm. Plus, it is less blurring than linear smoothing filters of similar size.

\[
f(x, y) = \text{median } g(s, t)
\]  

Otsu's threshold helps minimize variance within a class and perform the image in a binary image. The optimum threshold is calculated to separate the image that contains two classes of pixels so that their combined spread become equivalents or minimal in order for inter-class variance is maximal. Equation 2 and 3 shows the algorithms of class probability. Weights \( \omega_0 \) and \( \omega_1 \) are the probabilities of the two classes separated by a threshold \( t \) and \( \sigma_0^2 \) and \( \sigma_1^2 \) are variances of these two classes. The class probability \( \omega_{0,1}(t) \) is computed from the histograms.

\[
\omega_0(t) = \sum_{i=0}^{\frac{L}{2}} p(i)
\]

\[
\omega_1(t) = \sum_{i=\frac{L}{2}}^{L} p(i)
\]

2.2 Classification Process

Classification of paddy population is divided into two classes which are compact paddy population and not compact paddy population. The classified of these classes are performed based on the comparison of the accuracy of segmentation between image reference and an input image. Examples, if accuracy above 70 percent will consider as compact paddy population while below than 70 will consider as not compact paddy population. Calculation of accuracy for classification is been made from Equation 4.

\[
\text{Accuracy of application} = \frac{Tp + Tn}{Tp + Tn + Fp + Fn}
\]
3. Result and Discussion

There are two categories of planting paddy technique that was carried out by farmers. The cultivation technique was scattered as shown in Figure 2 (a) and systematically or structurally as Figure 2 (b) shows. The rice plants scattered have less population than the paddy planted systematically or arranged.

![Figure 2. Planting paddy techniques are (a) Scattering paddy plant and (b) Systematic paddy plant](image)

In this project, the image captured was started with a 4-meter height above the paddy plant. With the 4 meter height, Figure 3 shows the difference between of paddy plant and not paddy plant. However, scattering paddy plant image produced not too accurate because of the strong wind from the drone.

![Figure 3. 4 meter height for (a) Scattering paddy plant and (b) Systematic paddy plant](image)

Next, an image captured at 5-meter height. Figure 4 shows the image of both categories which were scattered and systematic paddy plant can be seen clearly in 5-meter height image. This research more focus on the scattered paddy plant. For systematic paddy plant, at 12 to 17 weeks paddy will growth higher than scattered paddy plant. At 5 meter height, the paddy still can be compared to the differences between the paddy plant and non-paddy plant.
Figure 4. 5-meter height for (a) Scattering paddy plant and (b) Systematic paddy plant

Image from height 1 meter up to 3 meters also had been tried to captured but the images taken were not suitable for this project studies. This was because of the strong wind from the drone caused the paddy plants not in a proper state cause the result of unseen paddy plant images. As a result, a 5-meter image was the best-recommended height to use as the image test for this project.

3.1 Segmentation of image paddy population

Figure 5 was presented the original image of a paddy plant. The researcher needs to resize the image to make data is more accurate. The colour segmentation based on the HSV components method was applied. S components were chosen from other two-component colour models. This decision had been made because of the result produced of paddy image more accurate other than H and V components. The image produce between these three colours component was shown in Figure 6.

Figure 5. Original image

The image produce between these three colours component was shown in Figure 6. After HSV component is chosen, the selected image was S component was doing the enhancement process. The enhancement process was to filter the image.
Figure 6. The different of image color models for (a) H component, (b) S component and (c) V components.

After HSV component is chosen, the selected image was S component was doing the enhancement process. The enhancement process was to filter the image. Figure 7 shows the filtering process was to make the image more to clear to get accurate data. The filtering method used in this segmentation is a median filter.

Figure 7. Median filter

After filtering the image, the image was converted into a binary image by used Otsu's Thresholding technique. Converted into binary image used for the accuracy calculation process where only can be read in the binary image. The image produced was shown in Figure 8.

Figure 8. Otsu's Thresholding

3.2 Classification of paddy population performance

Classification of paddy population had been done based on the accuracy of image references and image uploaded. One perfect image was used as a benchmark or reference pictures. The reference picture was divided into two classes which were compact paddy plant and non-compact paddy plant. The reference images already finish all the segmentation process to make it easier to compare. Figure 9 (a) and Figure 9 (b) shows the image references used for this project.
Table 1 shows the result of accuracy performance of estimation paddy plant system for compact paddy plant and not compact paddy plant. Both results were for individual image tested for each class based on the reference image.

| Images             | Total Average Accuracy (%) |
|--------------------|----------------------------|
| Compact paddy plant| 52.89                      |
| Not compact paddy  | 48.61                      |

The total accuracy for compact paddy plant was 52.89% while not compact paddy was 48.61%. Thus, the accuracy performance for both classes was successfully achieved.

4. Conclusion

The main objective of this project is to determine the captured technique and data transfer technique by using the drone. This aim has successfully achieved with capturing images with the height of the difference between drone and paddy field. At 5 meter height, the images captured more to accurate and easy to identified the classes of paddy population.

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