

Palm Tree Dataset Construction with Plant Height Estimation and Plant Counting Tasks

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Abstract. In this paper, we present the methodology to construct the palm tree dataset from drone images. The two analysis tasks are demonstrated from the derived dataset: Plant height estimation using point cloud processing and tree counting. Open-source software is utilized. WebODM is used to process the drone image data set to construct the orthomosaic image. The 3D point cloud data asset is also derived. We focus on the use of 3D point cloud data and 2D images for further analysis tasks. The data set is located at https://github.com/MambaClaw/Palm-Tree-Height-Estimation-and-Counting-Tasks.git. We demonstrate the use of data sets in two tasks. For plant counting, a 2D image with a template matching can easily be done directly from the orthoimage. For a tree height estimation task, we utilize the 3D dataset. The 3D point clouds of the area are manually selected for each tree, and the tree height in meters is estimated from the measurement tool in WebODM. It is used as a ground truth for the height estimation. On the other hand, Open3D is utilized to remove noises and find the tree bounding box. Linear regression is used to construct the model to estimate the tree height. From the experiments, the accuracy can be up to 97%.

Keywords: Plant height estimation · Plant counting · Drone image processing · WebODM · Open3D · CloudCompare

1 Introduction

In agriculture, a drone is usually utilized for field surveying and data collection. The image data obtained from each flying are used to analyze the plant growth and field yield. After the drone images are collected, they are processed to create orthomosaic photos. The orthomosiac photo stitches all small images obtained from flying in a specified route based on the collected georeference points.

In this paper, we demonstrate the pipeline of drone image analysis with two tasks: tree counting and tree height estimation. The analysis from raw drone images is done using open-source tools. First, we construct the dataset from our field trip, palm trees. The open-source tools are utilized for all the steps. First, the orthomosaic image is created using WebODM [8]. With this software, the other

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related GPS data are extracted. The software can generate 3D point clouds. The point clouds can be exported to be further analyzed. Secondly, the 3D point clouds of trees are cut using CloudCompare [5] while the measurements are performed. The point cloud data are then processed using Open3D [20] to eliminate outlined before using them as training data. At last, OpenCV [4] is used for 2D image processing, i.e., for transforming image channels, binarization, contour finding, etc., for the template matching purpose, for the tree counting task.

2 Backgrounds

WebODM [8]is one of the software for drone image processing. Since it is an open-sourced software, it has a large user community. The processing results include 2D orthophotos and 3D point cloud data created by Structure from Motion (SFM). 2D orthophotos can be used to calculate Normalized Difference Vegetation Index (NVDI) images, and Digital Elevation Model (DEM), contour. 3D point cloud data includes features such as measurement and volume estimation.

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without any human pilot, crew, or passengers on board. UAVs were originally developed through the twentieth century for military missions too "dull, dirty or dangerous" for humans. A drone using a photogrammetry camera system can assemble a point cloud as one of the outputs from the resulting three-dimensional image. In either case, the resulting cloud is a detailed and accurate picture of the scanned area.

Template Matching is a method for searching and finding the location of a template image in a larger image. OpenCV comes with a function cv.matchTemplate() for this purpose. It simply slides the template image over the input image (as in 2D convolution) and compares the template and patch of the input image under the template image. It returns a grayscale image, where each pixel denotes how much the neighborhood of that pixel match with the template.

Linear regression is a supervised machine learning approach. Linear regression analysis is used to predict the value of a variable based on the value of another variable. The variable to predict is called the dependent variable. The other variable used to predict is called the independent variable. The analysis estimates the coefficients of the linear equation involving one or more independent variables that will predict the best value of the dependent variable. Linear regression tries to fit a straight line or a surface which minimizes the error between predicted and actual output values. The simple linear regression measurement is the "least squares" method to find the best-fit line for a set of paired data: the estimated value of dependent variable from the independent variables. Equation (1) presents the example equation where Y is the estimated of dependent variable, β_0 is Y-intercept, β_1 is the gradient of the line, X is the independent variable, and u is an error term.

$$Y = \beta_0 + \beta_1 X + u \tag{1}$$

From the processed images and 3D point clouds, there is much possible analytics to improve precision agriculture. The simplest ones would be tree height estimation, volume estimation, and plant counting. These are common on many commercial drone image processing platforms [7,15] since they imply the growth and resulting yields in the field.

In this work, we focus on utilizing the drone image data set and constructing analytic services, which help improve future agricultural yields and can be extended to support WebODM extension. The methodology from obtaining the data, preprocessing, and cleaning, and the model construction is described. The dataset can be shared for further studies.

First, we studied the works for drone image analysis. Li et al. proposed a method for estimating crop height for rice based on moving surface and point clouds [11]. The acquired data are from GNSS, IMU, and LiDAR. The data were captured in Jingkou District, Zhenjiang, Jiangsu Province, China. The sampling area was 1m $\times$ 1m divided into 100 grids in a pattern of 10$\times$10 using a soft rope. The moving surface fitting elevation approach is used to classify the ground and crop point clouds.

Sun et al. estimated the plant height from the point clouds from RGB images since RGB camera is low-cost compared to LiDAR[17]. The RGB images were transformed into point clouds using SFM. Then, the point clouds were segmented into the ground layer and plant layer. The ground layers were removed, and the plants were segmented based on orthophotos. The height was computed by inverse distance weighting. Ground height estimation achieves sub-10 cm accuracy.

Valente et al. utilized machine vision and convolutional neural network to do plant counting with high-resolution images[19]. The approach has counted ten weeks old spinach plants in an experimental field with a surface area of 3.2 ha. Validation data of plant counts were available for 1/8 of the surface area. The approach can count plants with an accuracy of 95%

David et al. performed plant detection and counting from high-resolution RGB images [6]. The comparison between deep-learning and handcrafted methods with application to plants: maize, sugar beet, and sunflower was done. The data set contains a total of 16,247 plants. Faster RCNN was used to create ROI for each plant. The dataset was cleaned manually to remove weeds on the ground. RMSE below 5% was obtained.

Mushar et al. applied the machine learning approach for tree volume estimation [12]. The work uses the real tree data that had been gathered from Compartment 37 in the Cherul Forest Reserve, Terengganu, Malaysia. The ground truth data were measured from both the standing and felled trees. The volume is calculated based on Huber's formula. The total number of trees used is 241. The data set was divided into train and test sets at the ratio of 70:30. Three estimation methods were done: regression, SVR, and ANN.

Sreeram utilized OpenCV library to count the number of palm trees [16]. The work counts the number of palm trees in the top-view picture. One palm tree was cropped from a top view and used as a template. After preprocessing, the

work utilized the OpenCV function matchTemplate() to search for a matching between a top view picture that has many palm trees and an input image and used the OpenCV function findContour() that helps in extracting the contours from the image and counted palm trees those matched the condition.

3 Materials and Method

Our process starts from dataset constructions, preprocessing, and model construction.

3.1 Dataset Collection

The data set was obtained by flying the drone (DJI Maverick III) on the private area of the oil palm owned by the Faculty of Agriculture, Kasetsart University (14.26156, 10.90700). The selected area covers 20,000 square meters in this work.

First, the drone was flying at a speed of 4.0 m per second and 100 m in height from the ground. The pictures were collected by CMOS camera sensor from multiple angles. The realistic 3D model point cloud was auto-generated by combining pictures using the overlapping images by WebODM.

WebODM was utilized to process the raw drone images. WebODM has many processing steps as in [18]. Figure 1 is the steps extracted from the software. The user can also start from any step to reprocess the data. These are the typical steps in most software such as ArcGIS [1]. After loading the data set, the structure from motion (SFM) is processed. Next is point filtering, meshing, and georeferencing. At steps 8 and 9, DEM and orthophoto were constructed. The orthophotos and point clouds from meshing are the ones we utilized.

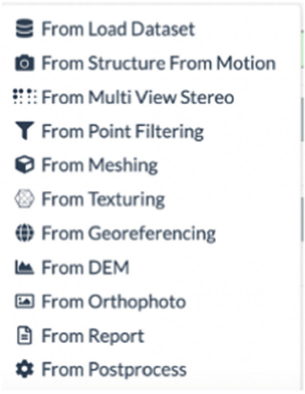


Fig. 1. WebODM processing steps.

Figure 2(a) presents an example orthophoto obtained in 2D from WebODM. For plant height estimation, we view the mesh in 3D as in Fig. 2(b). The point clouds are extracted as a ply file. From the dataset, the annotation can be done depending on the task goal.



(a) (b)

Fig. 2. (a) Orthophoto example (palm fields). (b) 3D point clouds.

3.2 Tree Height Estimation Task

The first goal is to find the relationship between the actual tree height and the tree height from 3D point cloud geometry. As a prototype, we selected a linear regression model to use the 3D point cloud tree height to predict the tree height.

To estimate the tree height, we utilize the tree point clouds obtained from WebODM. First, the ground truth must be constructed. In WebODM, there is a measurement tool on the left side panel of Fig. 3. Zooming in on the point clouds, we use the measurement tools for measuring the height as shown in Fig. 3 The height of each palm tree is collected as ground truth in a meter unit.

On the other hand, the saved *ply* file was edited using CloudCompare [5]. The corresponding tree point clouds from Fig. 3 are selected and cut using the software. Totally, 30 palm trees were manually extracted. The cut tree point clouds may embed the grounds or pixels of neighbors as in Fig. 4(a). The noise reduction process was performed. We utilized Open3D for processing the point cloud data [20]. The Open3D statistical outlier removal was performed as in Fig. 4(b).

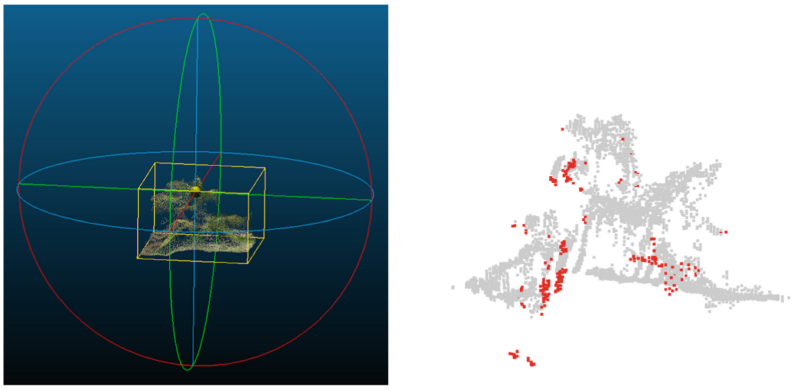
On the other hand, the bounding box of the palm tree in pixels was collected using the Open3D function as ground truth. Figure 5(a) shows two kinds of bounding boxes: AxisAlignedBoundingBox (red) and OrientedBoundingBox (green). We used OrientedBoundingBox in our dataset. The bounding box has eight coordinates.

Table 1 shows the measurement from WebODM and from Open3D.

Once obtained both pixel height and meter height, we constructed the linear regression model to estimate the transformation in pixels to meters. We divide the train set: test set as 70:30. Figure 5(b) shows the model constructed for the



Fig. 3. Height measurement tool in WebODM.



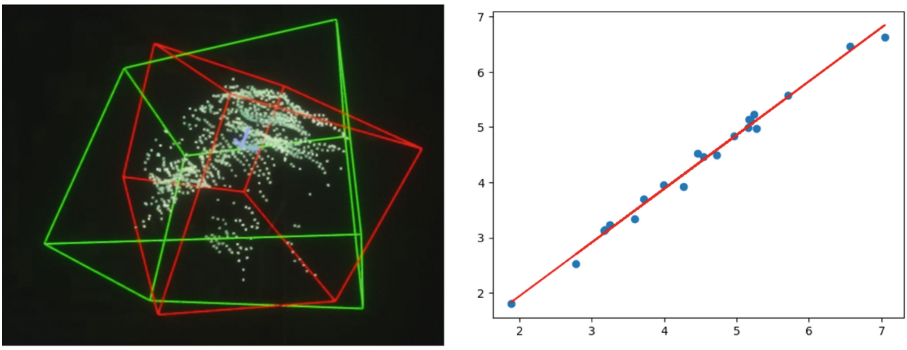
(a) (b)

Fig. 4. (a) Example tree on CloudCompare. (b) Noise reduction in Open3D.

Table 1. Ground truth from WebODM and Open3D.

Plant ID	Real Height (Meters)	Pixel Height (Pixels)
1	3.95	3.99
2	6.47	6.57
3	7.71	7.99
4	5.58	5.71
5	5.15	5.17
6	4.46	4.54
7	4.52	4.46
8	5.23	5.24
9	3.23	3.25
10	4.84	4.97
11	4.48	4.8
12	3.7	3.72
13	6.63	7.05
14	2.67	2.93
15	4.99	5.16
16	4.5	4.73
17	4.98	5.27
18	5.02	5.12
19	3.34	3.6
20	4.39	4.44
21	3.93	4.27
22	4.81	4.92
23	4.59	4.89
24	5.12	5.19
25	4.35	4.57
26	2.53	2.78
27	3.14	3.18
28	3.49	3.49
29	1.8	1.89
30	3.13	3.17

test data. With the test data, the model can estimate with 97.431% accuracy maximum and 93.507% minimum. In effect, the error estimation is about 18.4, as shown in Table 2.



(a) (b)

Fig. 5. (a) Bounding box finding (Open3D). (b) Linear regression model.

Table 2. Error comparison for test set.

Plant ID	Real Height(Meters)	Predict Height(Meters)	Accuracy(%)	Error(Meters)
3	7.71	7.76	99.34	0.05
11	4.48	4.66	95.89	0.18
14	2.67	2.84	93.51	0.17
18	5.02	4.97	98.99	–0.05
20	4.39	4.31	98.21	–0.08
22	4.81	4.78	99.41	–0.03
23	4.59	4.75	96.42	0.16
25	4.35	4.46	98.03	0.09
28	3.49	3.39	97.09	–0.10

3.3 Palm Trees Counting Tasks

We implemented the palm tree counting process on our dataset. For counting the number of trees, it is easy to work with 2D data, which is orthophoto. The 2D palm image was exported from WebODM.

Most approaches utilize a machine vision approach with the OpenCV library. We tested the approach in [16]. The step begins with choosing proper HSV thresholds for color filtering [14]. Figure 6 shows a part of the orthophoto we worked on. Figure 7(a) shows the template of the selected palm tree. Figure 7(a) is the template before adjusting, and Fig. 7(b) shows the HSV after the adjustment. We adjusted the HSV so that the color filtering threshold is easy to select. In Fig. 9, the HSV filtering threshold can be varied with the scrollbar. Afterward,



Fig. 6. Top view of palm trees.

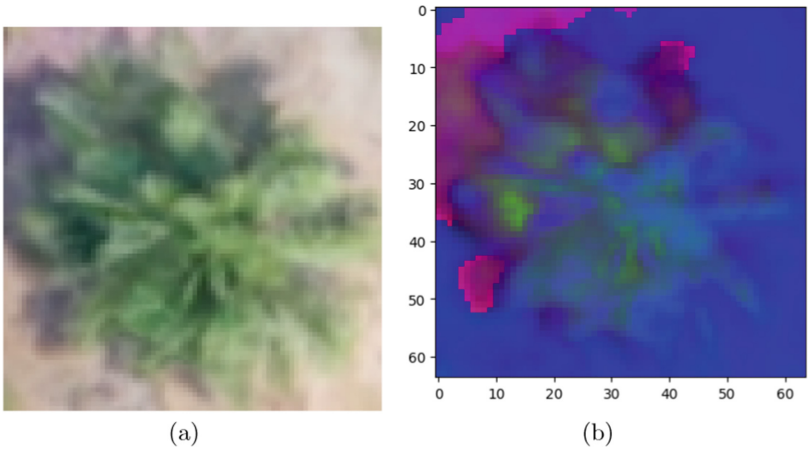


Fig. 7. (a) Template of palm tree (b) HSV palm tree template

the ground and the grasses can easily be seen. Figure 9 is the setting we chose to remove grounds from palm trees. For this area, we particularly selected Hmin = 42, Smin = 41, Vmin = 90, Hmax = 81, Smax = 240 and Vmax = 233.

After we did the same for the binary template in Fig. 8(a), we denoised it to reduce the hole inside or the noise outside and add a border. The denoised binary template is shown in Fig. 8(b). Then, we used the distance transform from the template in Fig. 8(c).

We applied the same process to the palm image set but added the morphological transformations before doing the distance transform to make the edges sharpen to reduce some connected contours, which may accidentally combine 2 or 3 palm trees into one tree. After that, we did template matching, and the proper threshold to make it the binary image was found. Figure 10 and Fig. 11 show the matching template in greyscale and in binary which is used to find the contours, respectively. Those with more than 1,000 contour areas were selected as the trees.

Figure 12 presents the resulting output. The template matches near perfectly in our images. This setting results in 312 trees out of 317 trees in the picture (98.42% accuracy). This is because two uncounted trees are too small, and three uncounted trees were cropped to make this photo not too long, making 5 of them have less than 1,000 contourArea. We may reduce the parameter contourArea to 600 to make the perfect match, but in the large field, it will be sensitive to small trees or noises.

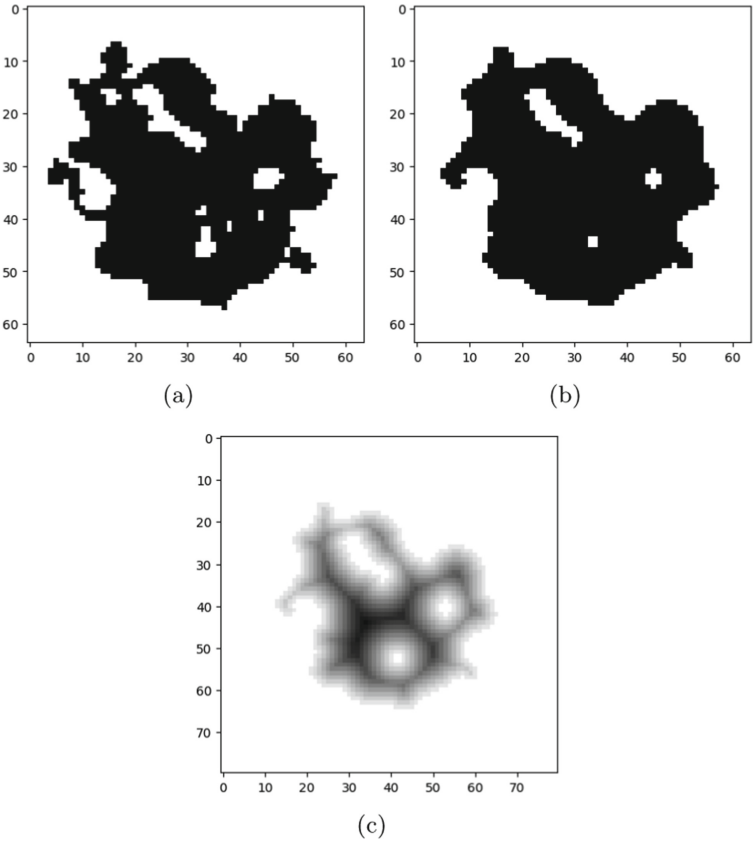


Fig. 8. (a) Binary palm tree template (b) Denoised binary palm tree template (c) Distance transform palm tree template.

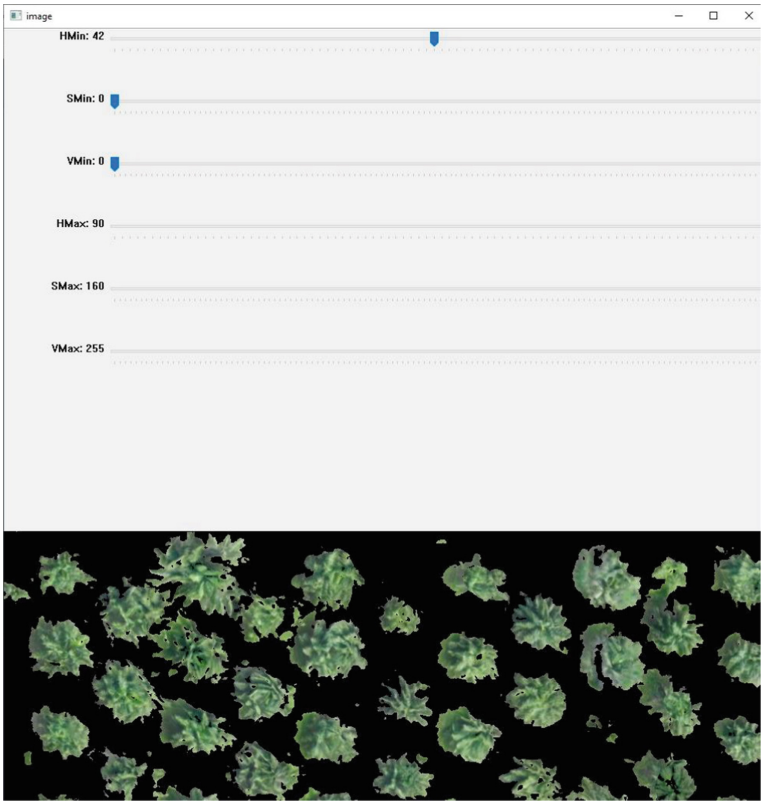


Fig. 9. HSV color filtering.

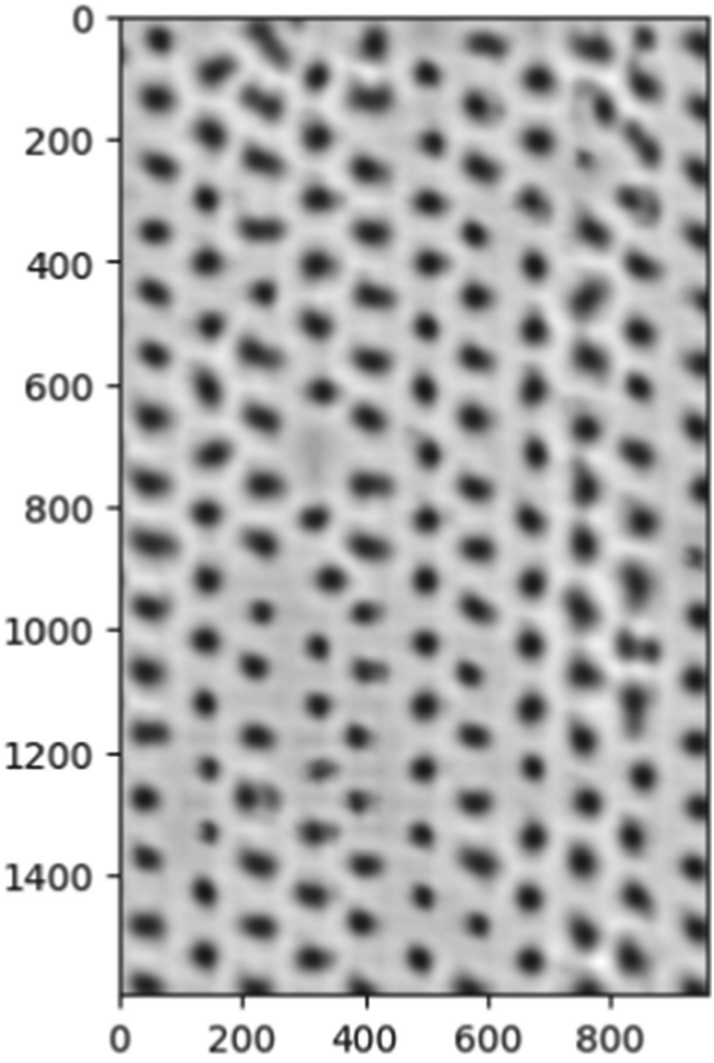


Fig. 10. matchingTemplate()'s output.

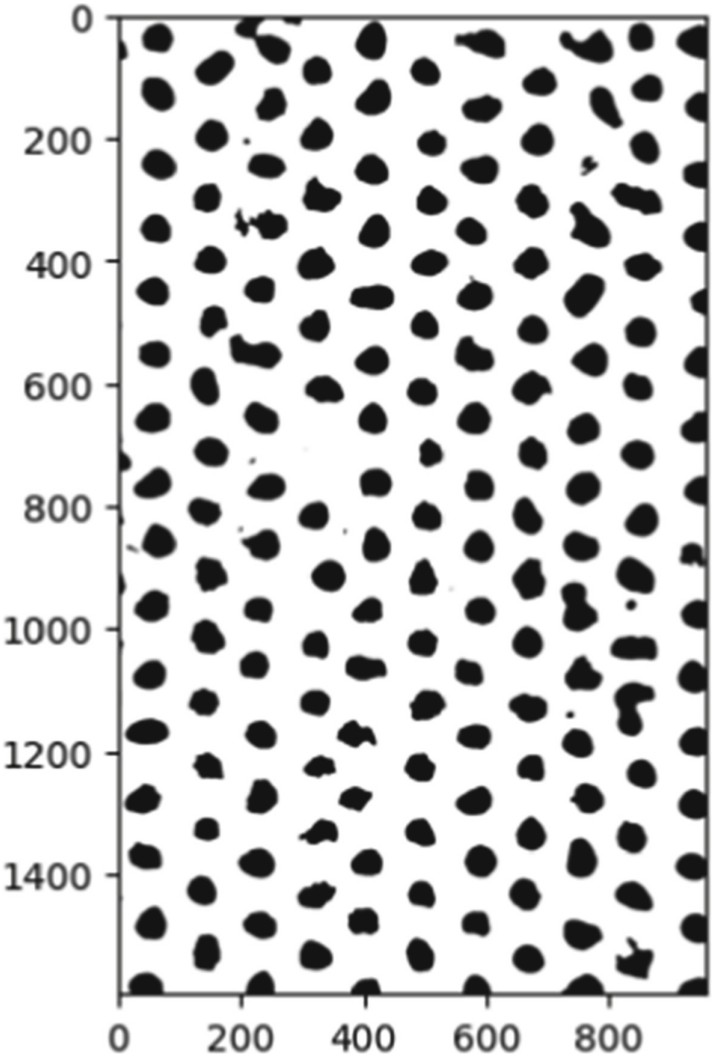


Fig. 11. matchingTemplate()'s binary output.

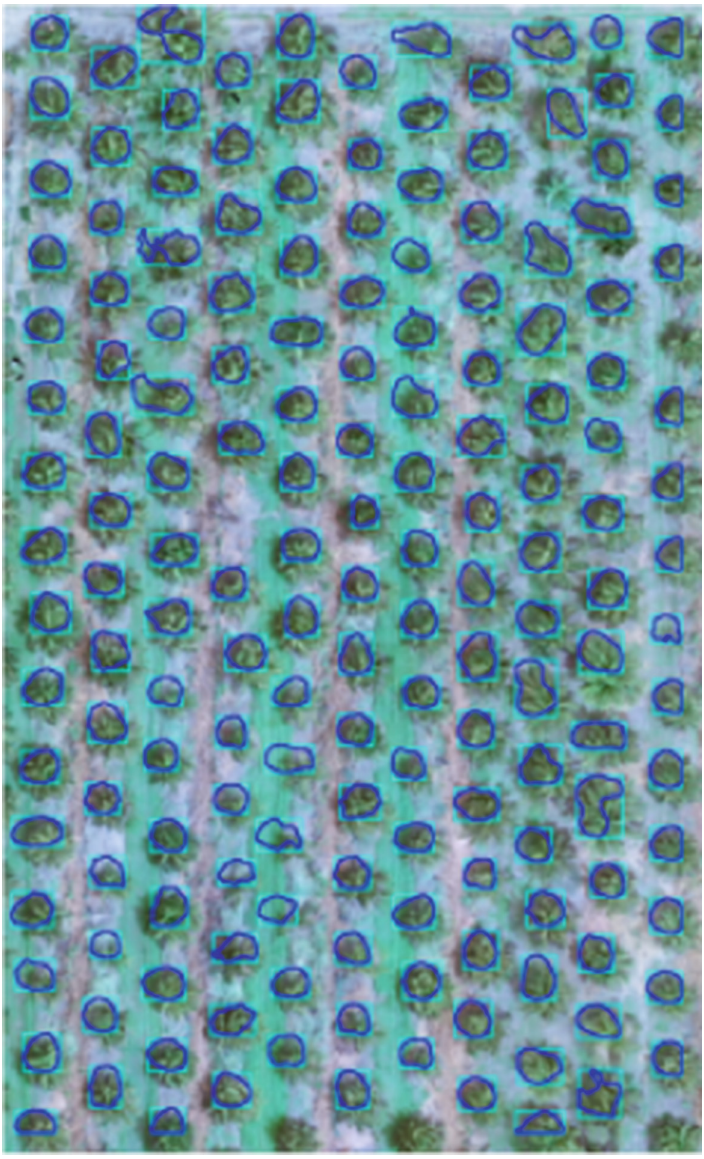


Fig. 12. Counting output.

4 Related Datasets and Discussion

There are not many raw orthophoto datasets available for studying yet. Most of them are the datasets from urban area such as [2] which proposed dataset for car detection. The downloaded photos are preprocessed orthophotos. For [3], the raw images from drone flying are available for Mymar urban

area (https://smithsonian.figshare.com/articles/dataset/Orthomosaic_of_drone_image_in_12_locations_in_Myanmar/12780041) from the survey.

In agriculture area, Vélez et.al. presented a complete dataset for photogrammetric reconstruction over a Pistachio Orchard in Spain. The dataset contains the raw images as well as 3D point clouds and others such as DEM, GCPs etc. Kumar et.al. presented the dataset for detecting maize growth and tassel detection [9,10]. No public dataset avaiable for this work. Simiarly, Monteiro et.al. presented the work for weed segmentation with UAV images[13]. The paper does not provide raw public dataset avaiable

In our case, we intend to provide the case study of processing flows from raw images until preprocessed images and cloud points for further analysis. The 3D point cloud dataset is still small since it takes time to manually annotate from the software. Further automatic annotation is during investigation.

For the tree height estimation, the important part is measuring the tree height in WebODM software, because in choosing a point that we will refer to as a ground point, we want to find the lowest point from the surrounding ground that is uneven in height and has grass that makes the point high. Therefore, we must choose a good angle to view the point to choose. And make sure that the point is not noise.

For the tree counting task, The important part is choosing proper HSV thresholds for color filtering and it's difficult when a canopy of trees were overlapped and includes the shadow from one tree that overlaps another tree, making it look like they are connected to a big tree, this forces us to filter HSV thresholds narrower. We can get rid of shadowing from the start. The improvement will be to fly a drone at 11AM to 1PM. so that the sunlight is at a straight angle which will cause minimum shadows.

5 Data Availability

The dataset can be downloaded at located at https://github.com/MambaClaw/Palm-Tree-Height-Estimation-and-Counting-Tasks.git The first folder is `3D Point Clouds` storing point clouds of each palm tree in a ply file, and the second folder `2D Orthophoto` contains the 2D orthophotos of the palm field. There are two Jupyter notebooks (`.ipynb` extension) containing the sample Jupyter notebook for tree height estimation and tree counting tasks with a regression model. The code for noise removal and computing the bounding box of point clouds using Open3D is also included in the notebook. The template tree is included in the folder. The CSV file for tree height data as well `data_tree.csv`. The installation instruction for the required library is described in README.md. Also, the raw palm images are in folder `Raw`.

6 Conclusion

We proposed the palm tree data drone dataset. We described the protocol steps to construct the data set and tools used to manipulate data. All open-sourced

tools are utilized. WebODM is the starting software to stitch the drone images and then SFM construction. From the derived assets, CloudCompare is utilized to point cloud cutting and noise-cleaning. Next, the 30 palm tree point clouds were extracted and can be further used in the Open3D library for deriving tree properties. We demonstrated two tasks based on our dataset: three height estimation and tree counting. More datasets will be extracted from other types of trees, and other tree properties will be explored from point cloud data.

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