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# Review on Low-Cost Unmanned Aircraft System (UAS) and Digital Image Processing Techniques for Large Scale Oil Palm Tree Health Detection Application

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**ABSTRACT**: Malaysia is the second largest palm oil producer in the world but the production of the palm oil has not been linearly increased as per expected. One of the factors affecting the production of palm oil estate is related to fungal or bacterial infection. Up-to-date, the major disease that infected palm oil tree is *ganoderma boninense* also known as Basal Stem Rot which cause the oil palm tree butt rot. With the primarily aim ofhighlighting significant areas and to identify the application gaps, this paper strikes to collectively address pragmatic yet comprehensive reviews on all unmanned aircraft system (UAS) that could potentially applied in large area oil palm health detection and related digital image processing techniques. Several broad types of on-the market low-cost UAV-based drones were compared, explored and reviewed with respect to type, functionality, speed, dimensions, battery storage and number of rotors. This paper has been structured with first part discussing about the properties and suitability of unmanned aircraft system. In addition, it also provides in-depth review of digital image processing techniques required to kick-start implementation in the health detection of oil palm. Further discussion on suitability of digital image processing techniques in health detection of oil palm were also included. Towards the end, his review paper also summarized on the challenges and opportunities as well as requirement cum cost contradictions for digital image processing on health detection of oil palm plantation.

**KEYWORDS:** Unmanned Aircraft System, Image Processing Techniques, Fungal Infection, Large Area Detection.

## I.INTRODUCTION

Nowadays, product derivatives of palm oil are of high values and tremendously been used in a lot of different products and industries globally ranging from simple item such as processed food to high-end technological required products. The demand and resultant production and consumption of world's oil and fats increased are increasing exponentially with growth rate of exceeding projected growth in the past years. Malaysia has been the second largest palm oil producer in the world [1-3]. Oil palm has the highest average productivity compared to other major crops.Based on the data collected by Malaysian Palm Oil Board in 2015, Sarawak produced 3.7 million tonnes of crude palm oil and in 2016 produced 3.5 million tonnes of crude palm oil [4]. This year, with more trees maturing, state is expected to achieve 3.5 million tonnes and beyond.

However, major oil palm producers are not able to produce sufficient output as per linearizedtheoretical calculated demands. This is mainly due to several factors that are severely affecting the timely growth of young oil palm trees until maturity before output could be extracted for production. The factor that cause the decrease of production oil palm are the environment, labour shortage, land availability and one of the biggest factor is fungal or bacterial infection[5]. Fungi which will rot and eventually kill oil palm trees negatively costing US$500 million a year, in average,for majority of oil palm producer countries in South East Asian countries for example Malaysia, Indonesia and etc[6]. One of the main diseases that affected the health of palm oil tree is *Ganoderma Boninense*. The symptoms of the disease is widely detected by observing the mature leaves wilting and failing through malnutrition over times[3, 7, 8]. This fungi causes the disrupting distribution of water and nutrients in the trees too. Recorded data shows that this fungi infection

caused reduction up to 80% oil palm productivity every years [8].Another disease called *Phytophthora*also reported to cause major decrease of palm throughout the world with symptom of with bud (heart) rot. The symptom observedis also similar to *Ganoderma Boninense* with discoloration of the spear leaf observed physically. In addition, slowly, there is a progressive loss of young leaves resultant in oil palm trees with only a skirt of old leaves and with no young leaves followed by death of the palm [7].
The current mitigation steps carried out by all producers is to manually removing the trees that are infected with the fungi or bacterial infections [6].By removing the infected parts or trees, which is the only effective way to stop disease from spreading to others then the effective loses could be further minimized. This move is also known as “surgery of oil palm tree”. At this hour, all would agreed that a proper management system of healthy detection of oil palm is important as to reduce the production loses. However, the manual visual inspection and monitoring in the early stages of fungi/bacteria detection are challenging and hard to be implemented effectively considering the large scale area to monitor, high man-hour labours, high costs, accessibility issue due to location of plantation often located in the rural and undeveloped area, time consuming and prone-to-high-errors as per human eyes.

**Our Contributions**: This paper proposes and aims at reviewing a fast, accurate, wide-coverage and non-destructive method for detection of infected oil palm tree. A low-cost UAV-based drone is proposed for the detection of the early sign of this disease in oil palm plantation. This paper provides pragmatic yet comprehensive reviews on all unmanned aircraft system (UAS) that could potentially applied in oil palm health detection. In addition, it also provides in-depth review of digital image processing techniques required to kick-start implementationin the health detection of oil palm.

## II.THE DEVELOPMENT OF UNMANNED AIRCRAFT SYSTEM (UAS)

Unmanned Aircraft System (UAS) refers to an aircraft/flying entity without a human pilot on board and it is controlled from an operator on the ground [9, 10]. It also known as drone or remotely-piloted aircraft system. UAS components built-up consists of air traffic control (ATC) communication equipment, health monitoring, Inter alia, remote pilot station, remotely termination system, launch and recovery elements and also remotely piloted aircraft. The first Unmanned Aircraft Vehicle (UAV) was manufactured by the Americans Lawrence and Sperry in 1916. The main contribution of their work was addition of newly developed gyroscope to stabilize the body, in order to manufacture an auto pilot which known as the beginning of “altitude control” and the device flew a distance that exceeded 30 miles in distance [10-12]. Historically, UAVs were developed aiming at facilitation wars but not recorded to be used in World War I or World War II as per reported by The Historical Perspective of UAS was studied by Civil UAV Assessment Team. However, the authorsreported intense developmentduring the Cold War (1947 – 1991 where the biggest portion of works spurred interest among the scientific community in utilizing UAV for information gathering/surveying/mapping purposes and science missions in which pilotless aircraft provided higher advantages and less human casualties or risk mitigation. Further across the globe, at the end of the Vietnam War, two UAV aircrafts were permitted to fly with surveillance missions over North Vietnam. They are the “Lightning Bug UAV” and “SR-71”, a high-altitude, manned reconnaissance aircraft. After the post-war where peace deals and treaty were signed and honoured, beginning of early 1970s, the development of UAVis heading to smaller size and important features were introduced and installed such as communication devices, picture capturing and recording devices either in static mode or in real time recording[13, 14].

The early development of Unmanned Aircraft System (UAS) was studied by Adam C. Watts et. al[15]. In his work, the authors mentioned about early works by NASA on UAS for high altitude atmospheric sampling during the “Mini-Sniffer” program of the 1970s – 1980s. Back in the 1990s, NASA’s Environmental research Aircraft and Sensor Technology (ERAST) program marked the first major steps towards building up the convention and capacities for work of UAS supporting logical research. Inspired by NASA efforts and improvements in miniaturization, the late 1990s saw numerous efforts among smaller organizations to develop or modify UAS tailored to their own research needs. Figure 1 shows the timeline of development unmanned aircraft system (not meant for warfares) from the past to present

The classification of unmanned aircraft System was studied by Pasquale Daponte et. al[16]. In this work, the author had classified UAS Platform into MAV (Micro or NAV), Vertial Take-Off and landing (VTOL), LASE (Low altitude, short-endurance) and etc. Most VTOL UAV history dated to be in early 1960s and the work progressed slowly through the period of 1970s and 1980s as technological limitations hampered the ability of engineers to realize the design goals for these vehicles. In agriculture application, UAVs were used for monitoring biomasses, crop growth and food quality, precision farming. Where-else, the use of unmanned aerial systems for the mapping of legacy uranium mines was demonstrated by P.G. Martin et. al [17]. In his work, the author used AARM-X8 multi-rotor aerial vehicle as an integrated mapping platform with a small volume [100mm3] un-collimated CZT coplanar-grid Kromek GR1 detector.

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The flight time for this work was 30 minutes. The overall flight time to gather the approximate 300m x 400m area was 5 hours. The results showed that small unmanned aerial system can be used to create high resolution radiation maps in the real- world environment.

The geomorphological mapping work of UAS was demonstrated by Chris H. Hugenholtz et. al[18] which similar approach to oil palm health detection. In this work, the author had measure and analyse earth surface morphology and morphodynamics are fundamental tenets of geomorphology. The model had been used in this studies is Hawkeye RQ-84Z Areohawk which have integrated autopilot technology that gives them semi- or fully-autonomous navigation, flight control and image acquisition capabilities. The aircraft was monitored from the ground station that consisted of a laptop running flight control software and an antenna.The fly file was created with third party software and requires information about the total area of the survey, flying height of the UAS, speed that aircraft flew and desired image overlap. There are 99 GPS point were appropriated on flat to gentle slopes in the area. The number of GPS test point can be determined from the following mathematical equation:-

$$n = \left(\frac{Z_{\frac{a}{2}}}{E} * \sigma\right)^2 \qquad (1)$$

where: $Z_{\frac{a}{2}}$ is the critical z-value, $\sigma$is the standard deviation and $E$ is margin of error.

The work was done by M.Perez-Ortiz et. al demonstrated and further convincingly double confirmed the possibility of applying similar approach to oil palm health detection[19]. Although the authors published the work where UAS was applied to detect and map accordingly the weeds in sunflower crops, this similar approach could work perfectly fine in detection of fungi in oil palm as well. The UAS model been used was quadcopter platformwith vertical take-off and landing capability, model *md4-1000*. This study consists of 49 square white frames and every frames was geo-referenced with a GPS coordinate and photographed in order to compare on-ground weed infestation and outputs from image classification. The result from thisstudy further validated some of the main hypothesis in theliterature concerning the flight height and the sensor usage. The earth observations and the role of UAVs had been studied by Civil UAV Assessment Team. In this work, they show the technologies been used with UAVs and technologies required to perform the missions.

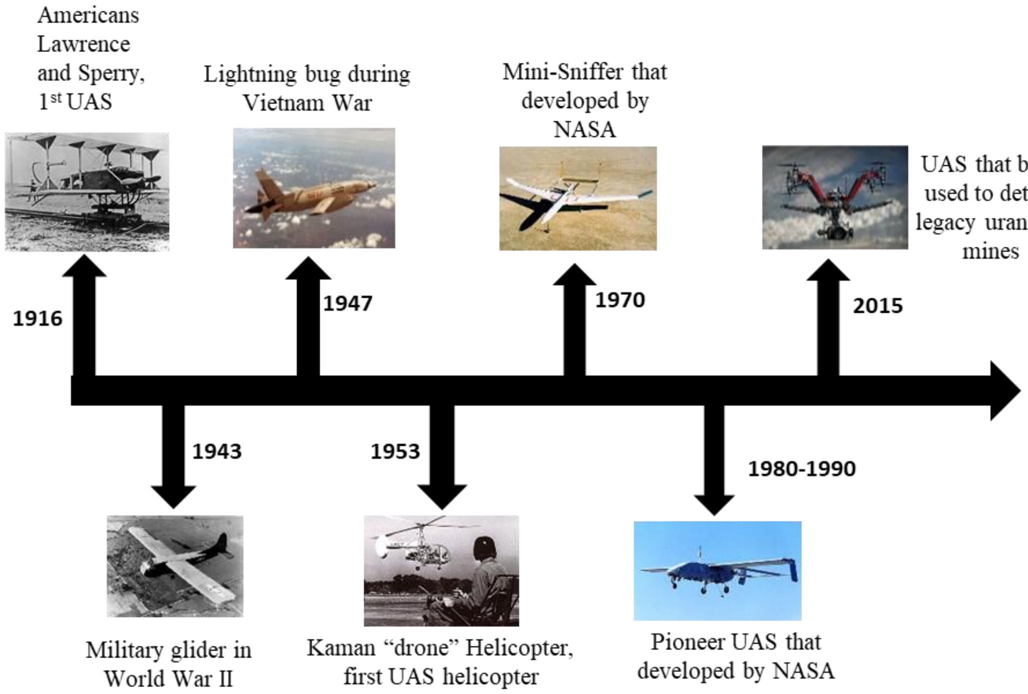


Figure 1: Development Timeline of UAS from the first UAS to present (not for warfare use)[6, 8, 9, 11-20].

From all the studies that we reviewed, we can know that the UAS had been used in many industry and many purpose. Mainly, it start with military and now it develop to other industry such as geomorphology and etc.

## III.PROPERTIES AND TYPES OF UNMANNED AIRCRAFT SYSTEM (UAS)

In this section, UAS models, features and types of Unmanned Aircraft System, UAS were reviewed based on our objective and large scale application area. All papers or materials reviewed are fulfilling the criteria outlined below:

1. Accuracy and Efficient surveillance and mapping missions
2. Day and night operations
3. Multiple altitude operation (high and low)
4. Capability of Real-time operation
5. Physical built-up

The key function of UAS was studied by V.I Kortunov et. al.[21]. In this work, the author studied key functions of manned and unmanned aircraft system are measurement of orientation parameters and speed orientation parameters, estimation of spatial coordinates and speed measures of the aircraft vehicles and also a track angle such as latitude, longitude and altitude, flight and route control, monitoring of on-board equipment status and controlling UAV operator actions. The characteristics of UAS categories was studied by Adam C. Watts et. al.[15] In this work, the author had classified Vertical Take Off and Landing (VTOL) UAS that portability of the platforms for remote area operations without the necessity for runway complexes. Most VTOL UAS can be accomplished with one or two person to operate and make these platforms cost-effective for short-duration observational needs [15]. Camera of the drone also maintain the performance of the drone which it evaluate the quality of the photo been captured. The range of the camera been used by drone in the market are around 2 megapixel to 12 megapixel which can been seen in the table 1 respectively.

Table 1: Features and Models of Unmanned Aircraft

| **Type** | **Fixed wing** | **Multi Rotor** | | | | | |
|---|---|---|---|---|---|---|---|
| **Model** | Hawkeye RQ-84Z AreoHawk | Quadcopter model md4-1000 | Parrot ARDrone 2.0 Quadcopter | DJI Phantom 3 Standard Quadcopter | ELEV-8 Quadcopter | Eagle Pro: 6-Rotor Drone with WiFi Camera | JXD 509W Pioneer UFO drone |
| **Feature** | | | | | | | |
| **Length(m)** | 1.4 | 1.03 | 0.32 | 0.35 | 0.66 | 0.70 | 0.30 |
| **Wind span(m)** | 2.9 | - | - | 2 | - | - | - |
| **Weight (kg)** | >6.2 | 2.65 | 0.8 | 1.216 | 1.13 | 1.2 | 0.780 |
| **Batteries** | Lithium-ion polymer | 13000mAh LiPo battery | 1mA/H LiPo rechargeable battery | 4480 mAh | LiPo Battery 3000 to 4400 mAh | LiPo Battery 750mAH | LiPo Built-in Battery 600mA |
| **Cruise speed (km\h)** | 50-60 | - | 50-60 | 57.6 | 50-60 | 50-60 | 50-60 |
| **Shape of the drone** | Areohawk | Quadcopter | Quadcopter | Quadcopter | Quadcopter | Hexacopter | Quadcopter |
| **Camera** | Olympus PEN Mini E-PM1 | TetraCam mini-MCA-6 | 720p 30fps HD camera | Built-in camera | Not available | WiFi camera | 1080 HD camera |
| **Megapixel** | 12 | 5.2 | - | 12 | - | 0.3 | 0.3 |
| **Lens length** | 14 – 42 mm | - | - | 20 mm | - | - | - |
| **References** | [18] | [19] | [22, 23] | [24, 25] | [26-28] | [29, 30] | [31] |

From table 1 reviewed, Hawkeye RQ-84Z AreoHawk had been used as geomorphological mapping by Chris H. Hugenholtz et al. [18].The length of the aircraft is 1.4 m and the weight is 6.2 kg. The speed of the aircraft can reached to 60 km/h. It can fly up to 2 hours and the limits coverage to approximately 1km. A camera was installed in the aircraft which is Olympus PEN Mini E-PM1 with 12 megapixel and 14 - 42mm lens. Although the fixed wing UAS had the highest specification by compared with multi rotor UAS but the disadvantages for this type of UAS is Hawkeye is not a Vertical Take Off and Landing UAS, it need a runway to take off and landing which difficult for oil palm plantation.From the table 1, Multi rotor UAS is proposed for the Low-cost UAV drone. The advantage for multi rotor UAS is Vertical Take Off and Landing can be accomplished without the necessity for runway complexes. DJI Phantom 3 is The length of the drone is 0.35m with 1.216 kg weight. It installed a 4480 mAh batteries that enable it fly up to approximately 30 minutes. The limit coverage to approximately 3.1km. The speed of the aircraft can reached to 57.6 km/h. A camera was built in with 12 megapixel and 20mm lens [24, 25].

## IV. DIGITAL IMAGE PROCESSING TECHNIQUES

Digital image processing refers to the process of improving the quality of digitally gained image through certain mode of analysis and manipulation [32-34]. It also included the scope of computer-based digital image processing. The advantages of digital image processing by MATLAB are following (1) High correctness and good reproducibility. Image processed by computer which has higher accuracy, (2) easy to control. The controlling parameters can be set and altered freely by the program and (3) available to have modular or multiplicity approaches. Various processing steps are required to be done digitally before any images could be analysed or use for further derivation; a raw image to processed image. First, the image acquisition step had to be done. Next, the image pre-processing needs to be carried out before being partitioned or segmented through image segmentation step. Only after this step, the images are to be store and used[35, 36]. In the literature, various platforms were reported over the years and few that are widely being implemented are Agisoft Photoscan Professional Edition, Image processing Toolbox – MATLAB, AngioSys 3.0 Image Analysis and etc.The direct intermediate studies was carried out by Dimitris Kaimariss et. al and his group where the comparison of UAV image processing software were being studied extensively [37]. In this study, authors reported results from two types of image processing software which were Agisoft Photoscan and Imagine UAV. The authors summarized that Imagine UAV has bigger advantages as the software provides the flexibility and ability to do measurement on area, volume, and create cross sectional capability. While both software tools are almost equivalent, the accuracies differs and depends on the external orientations of drone images [37].Next, this paper will be reviewing on the techniques that could be applied for large scale oil palm tree health detection in low-cost Unmanned Aircraft System (UAS).

i) Pixel count algorithm

The MATLAB based image processing was widely demonstrated by Dolly Nayak et al.[38]. In this work, the authors demonstrated the image processing through pixel count algorithm as per proposed with intended output to measure the length and width of a betel leaf using MATLAB platform. To accomplish their objectives, hundredsBangla betel leaf with different size had been taken by digital scanner to provide sizeable pools for calibration. The images obtained was in RGB image format and converted using MATLAB to grey scale and finally to the binary image after applying thresholding, noise filtering and segmentation. Pixel counting algorithm was implemented as per mathematical equation outlined below. The authors obtained overall accuracy of 99.4% for length measurement and accuracy of 98.48% for width measurement.

$$Length\ (cm) = \frac{Maximum\ value\ of\ pixel\ sum\ in\ column * 2.54}{Pixel\ per\ inch} \tag{1}$$

$$Width\ (cm) = \frac{Maximum\ value\ of\ pixel\ sum\ in\ row * 2.54}{Pixel\ per\ inch} \tag{2}$$

Another MATLAB image processing was demonstrated by P. Raghu Veera Chowdary et. al. In this work, the author used various type of image processing algorithms for gesture recognition such as pixel count, detection of circles, morphological operations and scanning method [39]. The input image was captured by the camera and inserted to computer in RGB format. The RGB image was converted to Binary image in MATLAB by using function im2bw. The binary image is filtered by using median filter of dimension 3. The conversion of binary image is eroded by using appropriate structural element of dimension 3 to 5.The result for the experiment which showed the robust method which delivers accurate results for 82.47% of images [39]. The result had be done by MATLAB image processing toolbox had more accurate than other image processing software.

ii) Feature extraction algorithm

The technique which was tested by Samarawickrama et. al. and demonstrated the high possibility of applying similar approach in oil palm health detection[40]. In this study, feature extraction algorithm in MATLAB had been used for automated surface defect detection system for ceramic tiles. The objective of detection system is aimed at checking or defects such as cracks in the middle of tile, in the edges, in corners and finally color variation defect detection [40]. The reported accuracy rate of the testing sample is 96.36%. On the other hand, another feature extraction algorithm was demonstrated by Pinto et. al. [36]. The author had been using the feature extraction algorithm to classify the crop and plant disease. Statistical texture based features were extracted using Gray level Co-occurance Matrix (GLCM) and the feature set consist of contrast, energy, mean, homogeneity, standard deviation and coarseness are used and classification is done on the basis of these. The author also stated that the accuracy can be increased by using various other enhancement techniques and by increasing the size of the training dataset. 4 machine learning classifier had been investigated in this paper which are K- Nearest Neighbors (KNN), Native Bayes Classifier, Support Vector Machine (SVM) and Multinomial Logistic Regression. Accuracy of the 4 machine learning classifier had been compared with different diseases of the plant. The table 2 showssummary of the 4 machine learning classifiers with respect to accuracy.

Table 2:Summary of accuracy comparison for 4 machine learning classifiers[36, 41]

| Disease | MultiSVM (%) | KNN (%) | Native Bayes (%) | Multinomial Logistic Regression (%) |
|---|---|---|---|---|
| Leaf Spot Disease | 86.95 | 95.65 | 91.3 | 86.95 |
| Rust | 85 | 75 | 65 | 90 |
| Powdering Milder | 96.66 | 86.66 | 100 | 93.33 |
| Healthy leaf | 100 | 100 | 100 | 100 |
| Average | 92.15 | 89.32 | 89.075 | 92.57 |

iii) K- mean Clustering

K- means clustering algorithm is widely used for grouping the pixels in a picture into k-clusters with each cluster having a constraint which classifies pixels into a single cluster [36, 42, 43]. K-means is mainly used for image segmentation.The studies was done by Dhanachandra et. al demonstrated success of the image segmentation using K-means Clustering Algorithm and Subtractive Clustering Algorithm[44]. The author had segmented an image by using k-clustering algorithm, using subtractive cluster to generate the initial and the output image are also tune by varying the hyper sphere cluster radius. Another literature where this algorithm was successfully applied in detection of leaf diseases and classification by means of digital image processing was reported by Prakash et. al.[35]. In this study, K-mean clustering was being applied to detect the plant leaf diseases by MATLAB. The groupfirst used K-Means algorithm for segmentation and later, texture features extracted by Gray – Level Co-Occurrence Matrix (GLCM) feature and Support Vector Machine (SVM) for classification [41]. In the food industry, Nurhayati et. al successfully demonstrated the success of the detection of the beef quality using mobile-based K-Mean Clustering method[45]. In this study, the author had used this algorithm by means of image processing to detect the quality of the beef.

iv) Extended region grow algorithm

Another technique that could be considered in large scale detection is extended region grow algorithm. This was demonstrated by Martin et. al in his work where the group managed well in identification and counting of pests using extended region grow algorithm[46]. In his work, authors used MATLAB image processing toolbox to identify and count the pests by using extended region grow algorithm. The detection mechanism used to detect the insect (pests) in the image is extended region grow algorithm.

## VI. CONCLUSION

As for large scale oil palm tree health detection application, multi rotor UAS is proposed for the Low-cost UAV drone. The advantage for multi rotor UAS is Vertical Take Off and Landing can be accomplished without the necessity for runway complexes. While it is nice to have big size device for large scale geomorphological mapping especially in oil palm plantation, the cost of owning and operative cost would be tremendously high. UAS provides another option for lower owning and operative cost but requires modular mapping for extremely huge scale oil palm plantation.

Otherwise, it is more economical to operate UAS. However, battery storage is an issue that needed to be taken into account during planning and operating stages. In term of image quality, most lenses technology nowadays could provide sufficient enough pixels for image processing especially using mobile phones. From above summarized literature and reviews, we noted that MATLAB image processing toolbox have more function as expected and it processes image efficiently and effectively. MATLAB can processing image by different mathematical algorithm which may show different result. K-mean clustering algorithm is proposed as the starting technique for image segmentation as this algorithm has the ability to classify pixel into a single cluster and grouping the pixel in a picture into clusters and counting.

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