Unmanned Aerial Vehicle (UAV) and ArcGIS for Shipping Container Counting

Afiq Abdullah[1], Jasmee Jaafar[2], Khairul Nizam Tahar[3], Wan Mazlina Wan Mohamed[4]

[1,4]*Malaysian Institute of Transport (MITRANS), UniversitiTeknologi MARA, 40450 Shah Alam, Selangor, Malaysia.*
[2,3]*Centre of Studies for Surveying Science & Geomatics, Faculty of Architecture, Planning & Surveying UniversitiTeknologi MARA, 40450 Shah Alam, Selangor, Malaysia.*
[1]afiqabdullah14@gmail.com
[2]jasmee@salam.uitm.edu.my
[3]khairul0127@salam.uitm.edu.my
[4]wmazlina@salam.uitm.edu.my

***Abstract*— The current approach in counting shipping containers at port terminal in Malaysia is done manually. This process will incur cost, time and labour intensive. Furthermore, this technical issue has led to delay in container operation. This has made the operational efficiency factor to be questioned. Therefore, promoting an automated approached seems appealing. Previous studies demonstrate the capability of Unmanned Aerial Vehicle (UAV) images for automatic counting of cars and trees. In this study, combinations of aerial images captured using UAV and geo-processing software, ArcGIS, are promoted towards automated approach for counting shipping containers. The overlapping UAV aerial images are post-processed using photogrammetric technique to create Digital Surface Model (DSM) which represents the ground and above surface feature's elevations. Then, the constructed DSM is filtered to produce the Digital Terrain Model (DTM) that represents the ground surface only. The container's candidates will then be isolated by subtracting the DTM from DSM to generate normalized DSM (nDSM) that represents heights of container's stacks. Knowing the standard size and height of one container, the number of container can be extracted. The ModelBuilder tool provided under ArcGIS made automated geo-processing able to be customized. This paper will discuss the steps taken in the automated process and the benefits towards operational efficiency at container terminals.**

***Keywords*—** *Container terminal, operational efficiency, UAV, shipping container, ArcGIS, ModelBuilder, counting*

1. Introduction

Container terminal or depot is the place where the shipping container is being kept for storage, damage inspection and fixing. Currently, the existing approach of shipping container counting is done manually and the process is time consuming as well labor intensive. Validation process seems impossible when the number of containers is large. Furthermore, during operation, manual counting will involve human interventions and this will affect safety issues especially at busy terminals.

It is reported that the efficiency of container terminal relates to technical efficiency [1]. On the other hand, study found that one of the most important factor is the need of integrated IT to speed up Customs clearance [2].

Operational efficiency is directly related to the increasing of shipping containers need to be handled. In Malaysia, Port Klang experiencing growth of 10.8% Twenty-foot Equivalent Units (TEUs) of containers to be handled in year 2016 with total 13.17 million TEUs compared to only 11.89 million TEUs in year 2015 [3]. In Figure 1 [4], the growth of TEUs per year keeps increasing. Without consideration of the operational efficiency improvement, the increasing of TEUs per year will become a huge problem for Malaysia ports in the future especially to maintain its competitive environment.

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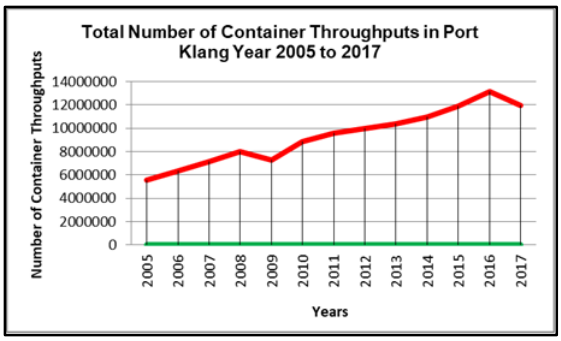

Figure 1. Total number of container throughputs in Port Klang from year 2005 to 2017[4]

Furthermore, the negative impact on the performance of logistics in Malaysia is due to delay factor in cargo business. This results in declined of transshipment activities from 10% to 15% over the years [5].

Another research has been conducted to show that the automation in logistics will promote an improvement at container terminals [6]. It is also proven that automation will be able to saves energy, improve security, provide better planning, reducing operational time as well reducing operational cost [7]. These include, automation gates, automated of yards and also automation of quay cranes at container terminal [8].

In this study an automated approach towards shipping containers counting is proposed. Integration between UAV datasets (Aerial Images) and ArcGIS software as a mean of processing will be introduced.

2. Method

In this approach (Figure 2), there are two main phases involved. The first phase relates to the automated data collection stage with automated post-processing. The second phase involved processing using the ArcGIS ModelBuilder tool application to extract the number of containers.

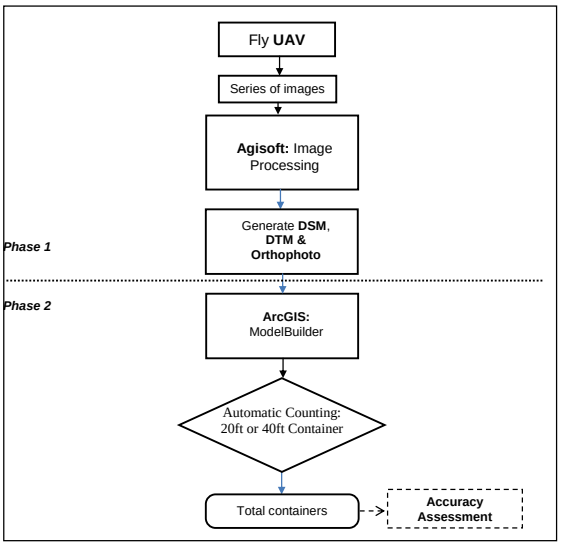

Figure 2. General methodology of shipping container counting

During the first phase, the UAV is fitted with digital camera where it will be deployed to capture images at depot or container terminal. The images will be captured in series with overlapping criteria (60%) [9][10][11].This is to ensure that the three dimensional digital elevation models for the area able to be constructed through the post-processing of the images using photogrammetric technique.

Agisoft Photoscan [12] software is used to create the digital elevation models and orthophoto. Agisoft software is capable to construct digital elevation model with expected centimetre-level accuracy [13]. However, it depends on various factors such as image resolution [14]. In this study, the UAV used for data acquisition is Phantom 4 Pro which able to capture image up to 4K resolution quality.

Digital Surface Model (DSM) which represents ground elevation include features on the surface such as man-made features, Digital Terrain Model (DTM) which only represent the ground elevation and orthophoto will be the main output for the image processing stage. Orthophoto is an image that has been corrected for its scale and orientation [15]. In this study, the DTM is created by filtering the above surface features from the DSM and the orthophoto is an RGB image that is corrected using DSM. This can be described by Figure 3.

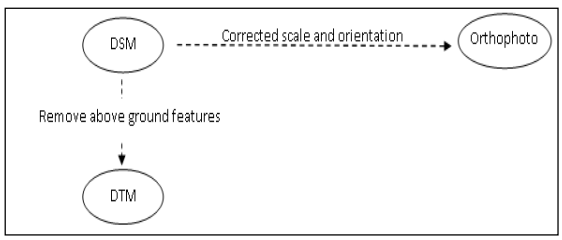

Figure 3. From DSM to DTM and Orthophoto

Figure 4(a), Figure 4(b) and Figure 4(c) show the

DSM, DTM and orthophoto for the study area.

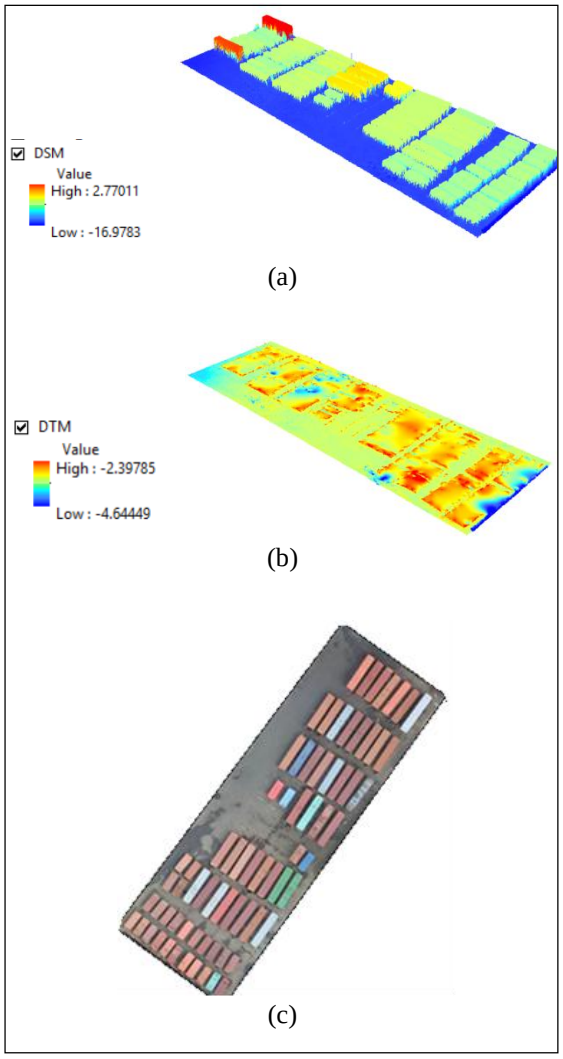

Figure 4. (a) DSM of containers (b) DTM of containers (c) Orthophoto of containers

These three outputs from Figure 4; namely, the DSM, DTM and orthophoto, are then used as inputs into the ArcGIS software for geo-processing in the second phase. Using ArcGIS ModelBuilder tool, a specific models for 20ft container and 40ft container counting are customized separately. The ModelBuilder allows user to customize geo-mathematical model and saved as tool in ArcGIS. In the model, the DTM will be subtracted from the DSM to produce normalized DSM (nDSM) which isolates the container's candidates in various stacks (Figure 5).

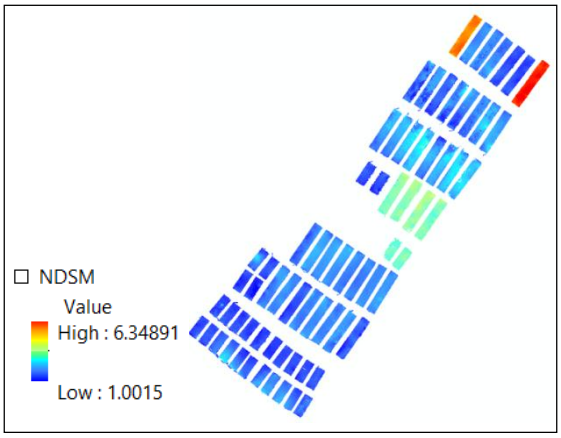

Figure 5. Normalized DSM (nDSM) of container's candidates

Referring to Figure 5, ArcGIS displays the nDSM in color coded form where each represents different elevations. The cyan color on the other hand (Figure 5) represents the ground-elevation with zero value (0).

Additional filtration is needed to clean any unwanted data and leave only the container's candidates to be counted.

The customized ArcGIS ModelBuilder created in this study will then be executed to classify the container's candidates based on height classes.

By using Eq. (1) below, the number of containers are then can finally be extracted.

$$\frac{Total\ size\ of\ container\ stack}{Standard\ size\ of\ 1\ container\ stack} = Number\ of\ containers \quad (1)$$

3. Results and Discussion

Geo-processing tasks carried out by the customized ModelBuilder created for counting the shipping container took less than 3 minutes in average. The number of containers extracted has been compared with the true value obtained by manual counting. It is found that the number extracted using the proposed system is similar to the total number manually counted on-site. Furthermore, based on Figure 6(a) and (b), the proposed system will have an added advantage where it allows further interrogation on the results obtained. It has the capability to segregate containers sizes based on the database build in the automated process.

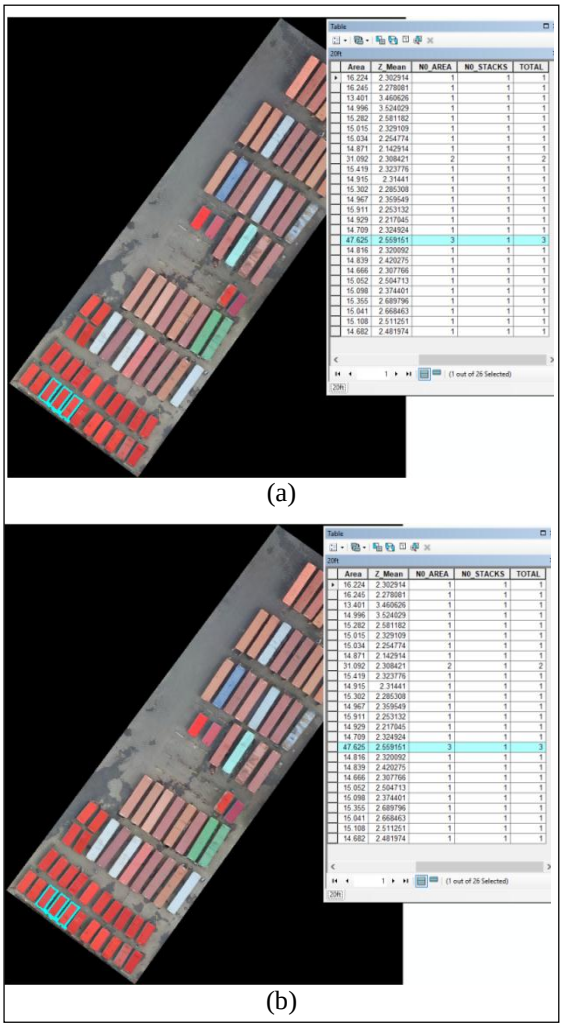

Figure 6. (a) 20ft container counting (b) 40ft container counting

The main advantages of the proposed approached is shown in Table 1.

Table 1. Advantage of the proposed automated approached in shipping container counting

Issue of Current Approach	Factor	Solution	Improves by
Counting is manual and labour intensive for validation	Technical	Automated Data Collection	UAV auto-piloted data collection approach
Time consumes increased as number of container is increasing	Time	Automated Data Processing	Agisoft Batch Processing automated process ArcGIS ModelBuilder tool automated geo-processing
Laborious counting approach required higher cost	Cost	Low-Budget Alternatives	UAV application is cheap
Ongoing container management work at terminal contributes to risk for the worker close to the area	Safety	Indirect approach	UAV provides indirect way of data collection and flexible
Environmental-friendly approach has yet to be found	Sustainability	Battery as power supply	UAV is using battery as power supply, not fuel which will emit harmful gas
Delay issues in cargo business	Instantaneous	Real-time	Application of UAV and ArcGIS for container counting is faster and accurate.

4. Conclusion

In this study the advantage of utilizing UAV images towards automated shipping containers counting is shown. The capability of the automated module generated within ArcGIS software in counting shipping containers is highlighted. The needs of an automated system in counting shipping containers at port terminals will be of high value in port operation. An on-going study based on the knowledge and lessons learn in this study towards an automated shipping containers tagging will be carried out in near future.

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