Shipping Container Counting Approach Using Unmanned Aerial Vehicle (UAV) and ArcGIS

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ABSTRACT

In Malaysia, the existing of counting approach on the shipping container at depot is carried out by manual based system. This has made the efficiency of the method to be questioned which can be solved through automation. Under previous studies, Unmanned Aerial Vehicle (UAV) is demonstrated for automatic counting of cars and trees. Therefore, the possibility for shipping container counting is highly required in which promotes low-cost alternative and automated-pilot for data collection. Based on this study, the aerial images captured using UAV is combined with geographical information processing software, ArcGIS, towards automated approach for container counting. The overlapping aerial images are post-processed using photogrammetric technique to produce Digital Surface Model (DSM) that represents the ground and above surface feature's elevations. Then, the constructed DSM is filtered to develop Digital Terrain Model (DTM) where it represents the ground surface's elevation only. Then, container's candidates are isolated using subtraction of the DTM from DSM to generate normalized DSM (nDSM) which represents the heights of container's stacks. From the standard size and height of one container from ISO, the number of containers is extracted. The ModelBuilder tool available in ArcGIS is customized for automated geographical information processing. From results, the proposed approach contributed to 100% of counting accuracy.

Keywords: *Unmanned Aerial Vehicle, Counting, Shipping Container, ArcGIS, ModelBuilder*

INTRODUCTION

Malaysia's primary container ports, Port Klang is ranked as the 12th largest and busiest port terminal in World Container League year 2015 due to the massive growth in shipping container handling each year (StarBiz, 2017). From the report by Port Klang Authority's Official Portal (2018), the increasing numbers of container is about 11% with total of 13.17 million Twenty-foot Equivalent Units (TEUs) registered in year 2016 compared to 11.89 million TEUs in 2015 (Port Klang Authority, 2018 & StarBiz, 2017). In order to stay competitive with other countries container ports, Malaysia's port must be improved in term of performance in management system and provide the most economical ways (Nazery, 2012).

At the container terminal in Malaysia, it has been found that the counting approach on the number of shipping container is still incomprehensive and inefficient way which made the current system is labour intensive and impossible for validation especially in the case of a large number of containers. Under previous studies, the delay in customs clearance at Mombasa port is caused by lack in IT integration (Nyema, 2014). Furthermore, the decreasing in production performance in container terminal has been analysed using Stochastic Frontier method and found that it is mostly due to lack in technical efficiency (Liu, 2010). Aside from an analysis that has been carried out using Data Envelopment

Analysis (DEA) in order to analyse the technical inefficiency in Middle Eastern region' container terminal, it can be concluded that the factors involved are implications from operational time, labour, berth occupancy and the operational performance of cranes (Almawsheki & Shah, 2015).

Therefore, the inefficiency of the current counting approach on shipping container is able to be described in terms of time, cost and technical aspects. By improving the aspects, the performance of the container counting method can be improved significantly. The integration of automation is being considered that enable to improve the efficiency of the overall system's performance in container terminal operations (Sadeghian *et al.,* 2014). The examples are seen from previous research made related to container terminal that include automation of gates, quay cranes and yards (Martín-Soberón et al., 2014). Researchers have demonstrated an automated approach of counting based on Unmanned Aerial Vehicle (UAV); the automatic counting approach of car (Moranduzzo & Melgani, 2014) and palm trees (Bazi *et al.,* 2014). Both concepts have shown promising results based on the combination of UAV captured images and geomatics concept. Due to this, the intent of this research is to study the possibility and capability of UAV and geomatics concept for the counting application on the shipping container.

Nowadays, the application of UAV is considered a low-cost alternative, time-saving and high-flexibility (Anuar *et al.,* 2013 & Khairul, 2015). It can be applied by collecting the data in form of image that contains the shipping container's stacks. Specialized and sophisticated software is used to post-process the images through several phases until the number of containers are extracted accurately. Agisoft Photoscan (Agisoft, 2018a) software is suitable to post-process the images with using photogrammetric technique (Agisoft, 2018b, Saikia *et al*, 2010, Venkatramaiah, 2011 & Natural Resource Canada, 2016) to produce digital elevation models and orthophoto. From study, Agisoft software has demonstrated to be able to produce digital elevation model with expected accuracy within centimetre-level (Tokunaga & Uysal *et al.,* 2015).

The Digital Elevation Models to be produced are Digital Surface Model (DSM) and Digital Terrain Model (DTM). The DSM is a model that comprises of ground elevation as well the above-ground feature's elevation such as building and trees (Gomarasca, 2009). As for the DTM, it only represents the ground elevation (Gomarasca, 2009). Aside from that, another product developed through the photogrammetric technique is the orthophoto, which represents RGB image with corrected for its scale and orientation (Barazzetti et al., 2014 & Paine & Kiser, 2012, Greer, 1994).

Additionally, ArcGIS (Esri, 2018) is used where it is a geographical information software that specialized in geographical information processing. In ArcGIS, a tool called ModelBuilder (Esri, 2017) is used to be customized for generating the number of containers automatically as possible. With using ArcGIS, the DTM subtracted from the DSM to generate the normalized DSM (nDSM) (Abdelguerfi, 2012), which represents the isolated container's candidates from ground surface. This is used together with orthophoto to be geographically processed until the number of containers are extracted accurately.

In this study, combinations of UAV and ArcGIS are applied to propose a new approach of accurate shipping container counting.

RESEARCH BACKGROUND

Currently, the counting approach on the shipping container in Malaysia is carried out by manual based system (Hashim, 2017). From this study, it has been found that situation of the depot is making the current approach to be considered labour intensive and absurd, primarily for the case that involved a large number of shipping containers. For example, the large size of the terminal, many unreachable spaces between the rows of container stacks, heavy machineries continuously operate in and out, have made the factors of operational efficiency to be questioned. Referring to the report that has been generated from Port Klang Authority's Official Portal (2018), there are increasing growth of Twenty-foot Equivalent Units (TEUs) in Port Klang from year 2005 to 2017 as shown in Figure 1.

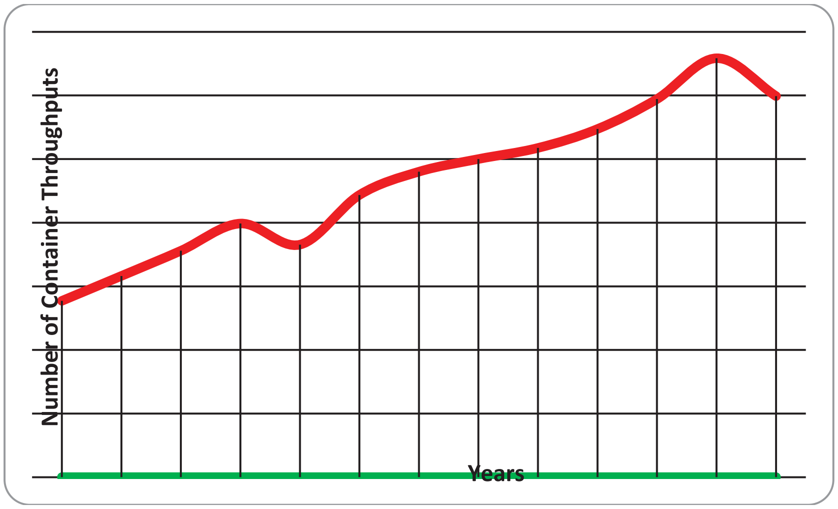

Figure 1: Number of Container Throughputs in Port Klang Year 2005 to 2017.
Source: (Port Klang Authority, 2018)

Jeevan et al., (2015) has mentioned that from his findings, dry ports or depots are container terminal that developed to accommodate high volume of containers without the needs of unnecessary investment towards seaport's enlargement. However, an economical and efficient approach are required to support the huge number of containers to be handled by seaports as well coping with the strategy of improving the operational efficiency of container management at depots. Therefore, Malaysia's container ports management performances must be gradually improved to continuously provide the most economical system in order to retain clients, attracting new users, attracting new investments and maintaining overall competitiveness (Nazery, 2012).

From the issues, in maintaining the overall competitiveness between ports, a new approach for the shipping container counting is proposed using combination of Unmanned Aerial Vehicle (UAV) photogrammetric technique and geographical information processing. This leads with objective to produce the model of container from the approach and finally assessing the accuracy obtained. This study will promote an integration of automation into the existing approach.

METHODOLOGY

The methodology of this study is described on Figure 2, where it comprises of 3 main phases. Phase 1 for studying the factor of inefficiencies in the current container counting approach practices in Malaysia; Phase 2 to deploy the UAV in order to collect the images data and post-process to produce Digital Terrain Model (DTM), Digital Surface Model (DSM), Orthophoto; and Phase 3 is to geographically process the inputs as to generate the number of container and then finally to assess the accuracy.

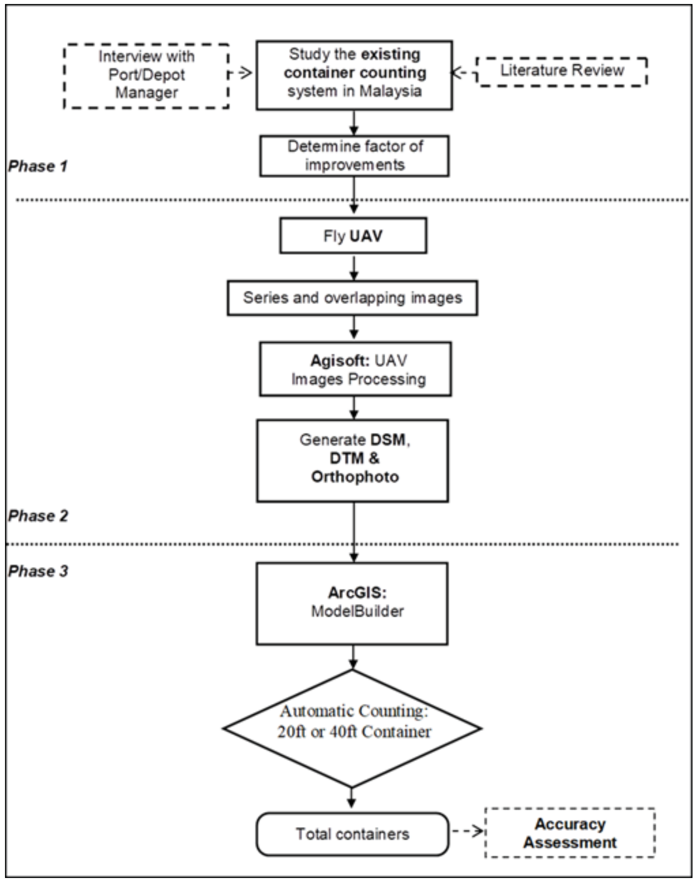

Figure 2: General Methodology flowchart

Phase 1 Preliminary Study and Problem Identification

The study of the inefficiency factors of the current practices of shipping container counting in Malaysia are done by interview session and reviewing with the container terminal operation manager and previous studies respectively. It has been found that the aspects of technical (Liu, 2010 & Almawsheki & Shah, 2015), safety (Sunaryo & Hamka, 2012), cost (Nazery, 2012), time (Nyema, 2014) and sustainability (Kang & Kim, 2017) are required and to be considered for proposing the future counting approach.

Phase 2 Data Collection and Images Processing

The Phantom 4 Pro is being used that fitted with high resolution digital camera and integrated with GPS on board, so that the image is geographically tagged. The study begins with the configuration of flight planning parameters with using smartphone apps before the deployment of the UAV in order to ensure that the flight mission of the UAV is always according with the requirements of the work. This includes locating and defining the size of the covered area, the starting point and end point, the flight path, the flight altitude from the hovering ground and the percentages of overlap images.

The study area of the shipping container depot is located at Port Klang, Selangor with about 13 acres in size. For the creation and generation of the three-dimensional data, the aerial images are captured in series and overlapped based on photogrammetric technique (Natural Resource Canada, 2016; Venkatramaiah, 2011 & Saikia et al, 2010). This is shown in the Figure 3.

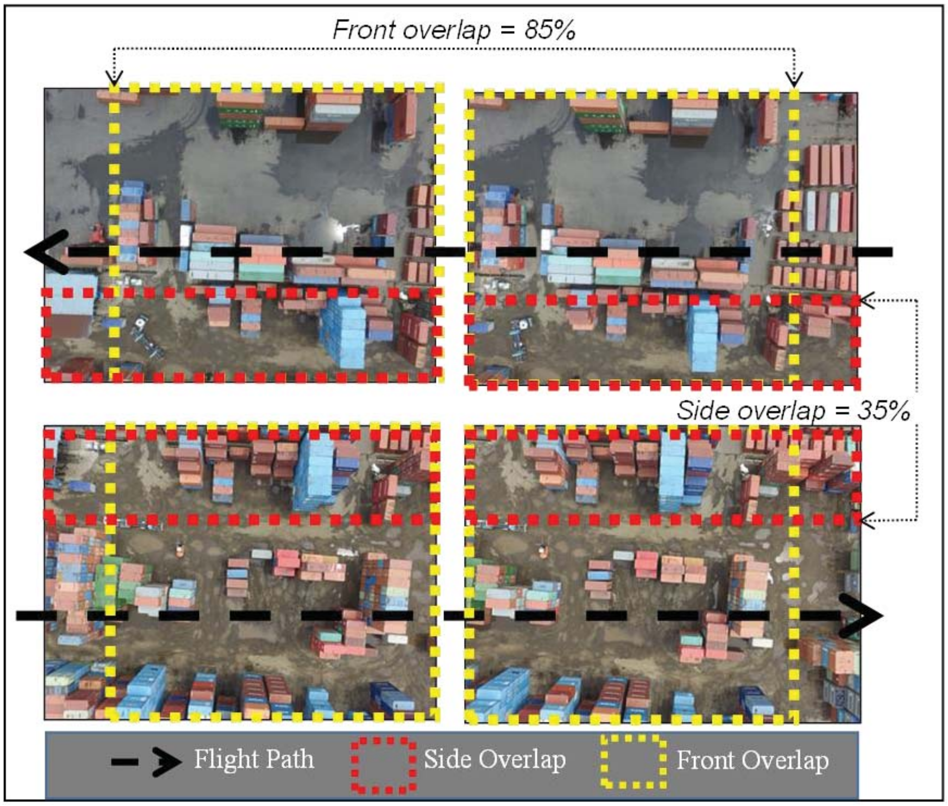

Figure 3: The configuration of overlapped images

Based on Figure 3 above, flight altitude for UAV is set to 70 meters (223 feet) above ground level (AGL), the overlap percentages between consecutive aerial images are set to 85% for frontal overlap and 35% for side lap. High overlap percentages are recommended for UAV photogrammetry based on previous studies where it is to overcome wind effect that could deviate the flight path and orientation of the images, as well to provide a stable imaging towards quality outputs (Raczynski, 2017; Yang, Lin, & Liu, 2016; Wang, 2013 & Xing et al., 2010). The collected images data are then post-processed using specialized photogrammetric technique integrated software, Agisoft Photoscan (Agisoft, 2018a & 2018b) to generate digital elevation models, the DSM and DTM (Gomarasca, 2009). For the next process, the captured images are first added into Agisoft software. Then, the images are aligned based on geographically tagged coordinates X, Y and Z from UAV's GPS.

Simultaneously, it performs image matching based on the overlap percentages between consecutive images. Next, it continued with the creation of dense point clouds from the distribution of coordinates to the unknown points that interpolated from the known coordinates. After that, the step proceeds to build digital elevation models (DEM) and the orthophoto in which the outputs are exported in GeoTIFF format for further uses in ArcGIS software. The relationship between DSM, DTM and orthophoto are described in Figure 4.

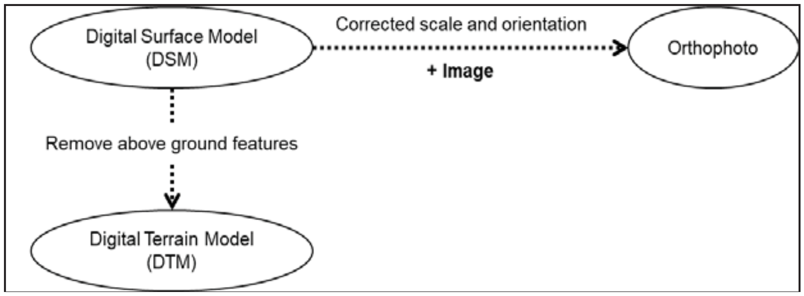

Figure 4: Relationship of DSM to DTM and Orthophoto

In Figure 4, the orthophoto is created based on images and DSM data produced beforehand. As for the DTM, it involves the filtration of above ground features elevations from the DSM. Figure 5, Figure 6 and Figure 7 show the 3D models that have been developed using Agisoft software.

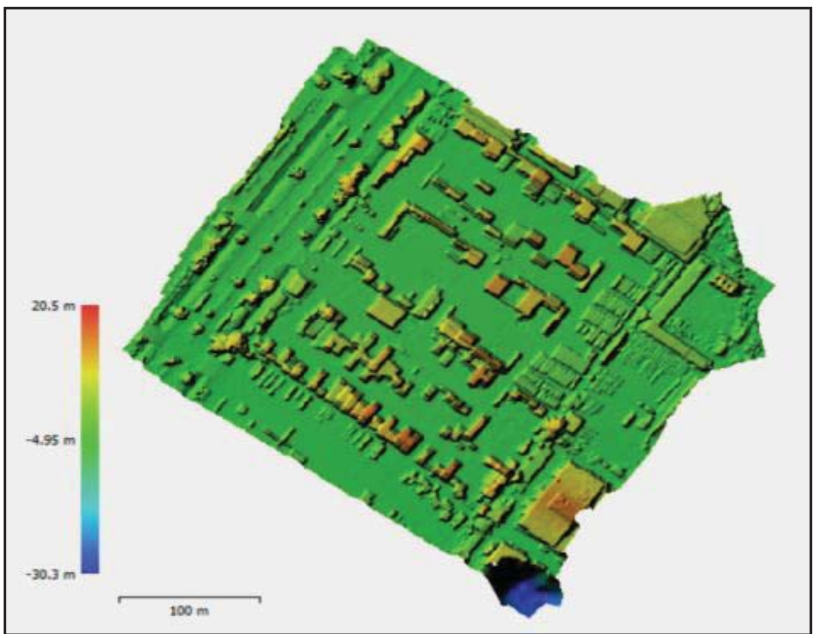

Figure 5: Digital Surface Model of container's stacks

Figure 5 shows the Digital Surface Model (DSM), which is a three-dimensional model that represents the elevation of surface which includes feature (container's stacks) above the surface while Figure 6 represents the Digital Terrain Model (DTM) that was produced from the DSM.

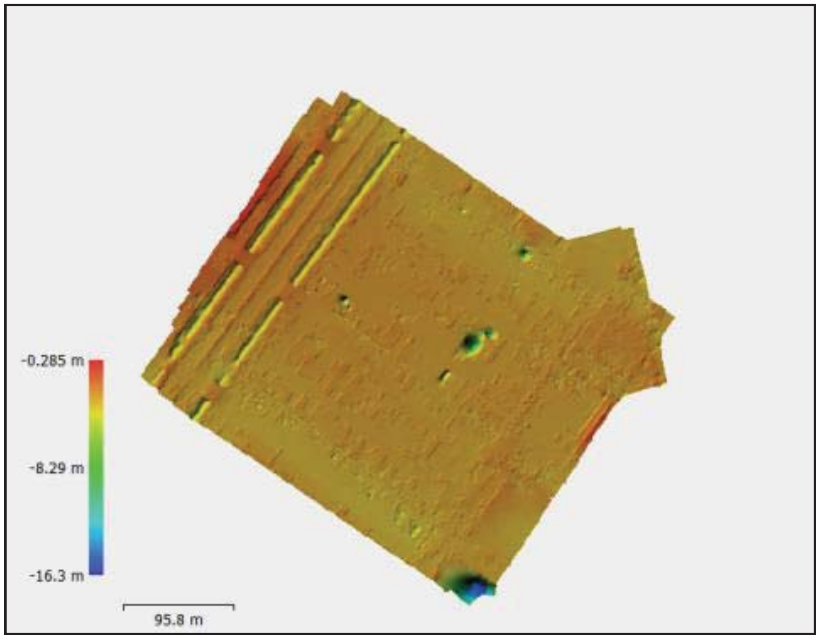

Figure 6: Digital Terrain Model of container's terminal area

Based on Figure 6, the Digital Terrain Model (DTM) produced is also a three-dimensional model but only represents the ground elevation (container's terminal area) where the above surface's feature elevations are removed from the DSM. Figure 7 shows the orthophoto in the area of interest that also developed using Agisoft software.

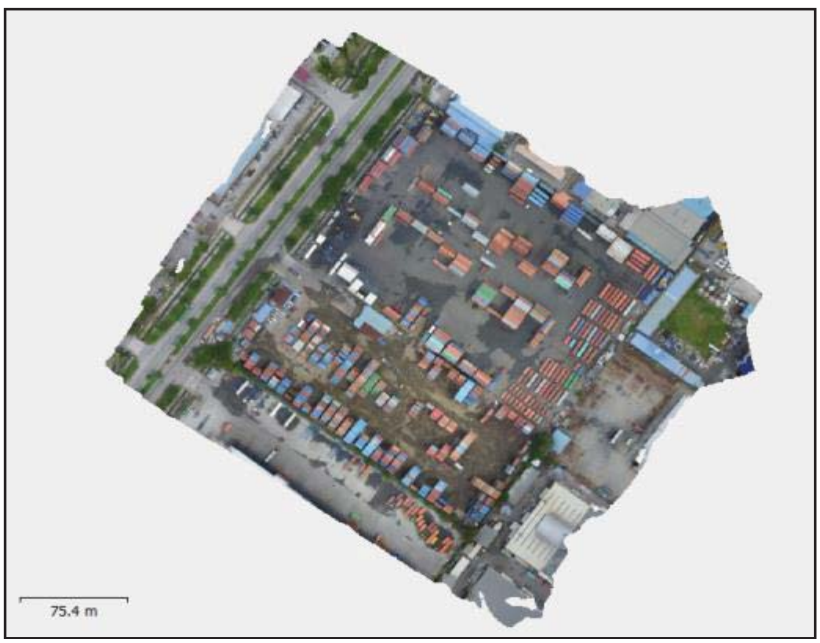

Figure 7: Orthophoto of container's terminal area

In Figure 7, the orthophoto is the RGB image that has been corrected for its scale and orientation (Barazzetti *et al*. 204; Paine & Kiser, 2012 & Greer, 1994) of the depot or container's terminal. These three output models are used as inputs to be geographically processed in ArcGIS (Esri, 2018) software for the next phase.

Phase 3 Geographical Processes and Accuracy Assessment

The geographical processing task involves the filtration process to extract the container stacks then extraction of number of containers which carried out in ArcGIS software. This includes the subtraction of DTM from DSM to produce normalized Digital Surface Model (nDSM) (Abdelguerfi, 2012) which is shown in Figure 8.

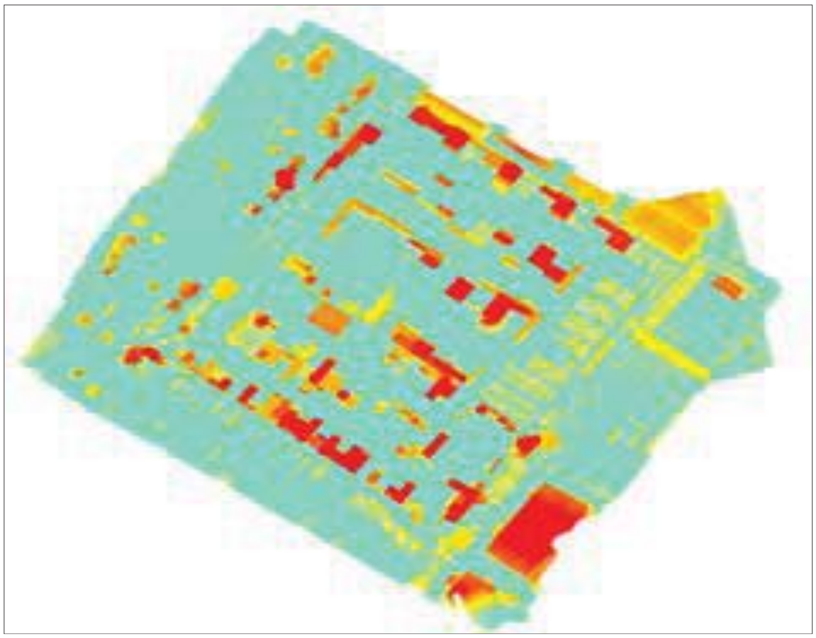

Figure 8: Normalized DSM (nDSM) of Container's Stacks

Based on Figure 8, the nDSM represents only the container's stacks heights with zero (0) value for the ground elevation. The elevation is displayed in color-coded where cyan colour indicates zero (0) value and the yellow to red indicates the container stacks heights from low to high elevation respectively.

Using the nDSM, a few of filtration processes is carried out to remove unwanted entities and to select container stacks candidates for the further assessment. This involves heights classification and conversion of the data into polygon that represents the container stacks model that allows computation to be customized based on equation (1).

$$\frac{\textit{Total Size of Container}}{\textit{Standard Size of Single Container}} \qquad \textit{Number of Container} \qquad (1)$$

Finally, the accuracy of the counting using the system is assessed by comparing with the number verified on-site. Using the International Standard Organization (ISO) 6346:1995 which define the standard size of a container for 20 feet and 40 feet (Lowe, 2006), the number of containers can be counted from the total area and total height modelled. The ModelBuilder tool available in ArcGIS is then customized so that the counting process can be automatically run for another shipping container stacks candidates where it is useful for any repetitive tasks (Hidayat & Andajani, 2018).

RESULTS AND DISCUSSION

Due to the limitations of the system, the different types of 20 feet container and 40 feet container are unable to be counted together. Therefore, the automated counting system is developed into two different types of shipping container counting tools using the ModelBuilder: 20 feet container counting tool and

40 feet container counting tool. Figure 9 and 10 show the 20 feet and 40 feet container stacks modelling based on number of stacks. Figure 11 and 12 show the container stacks outputs for 20 feet and 40 feet container modelling.

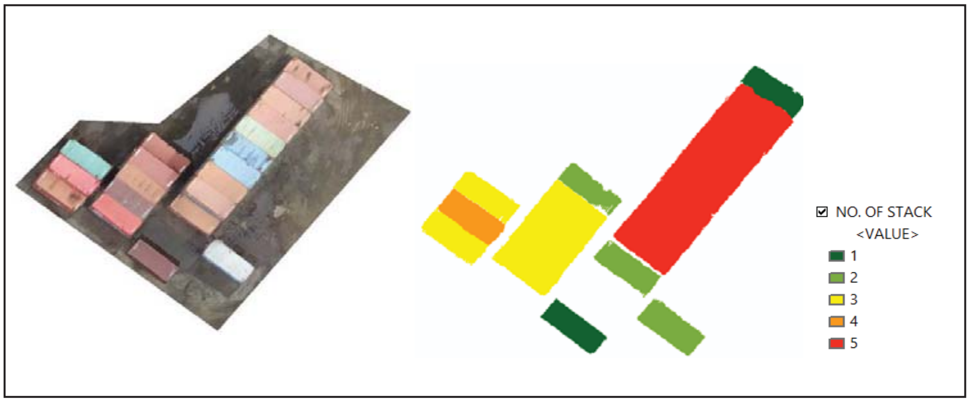

Figure 9: Containers (20 feet) Stack Modelling

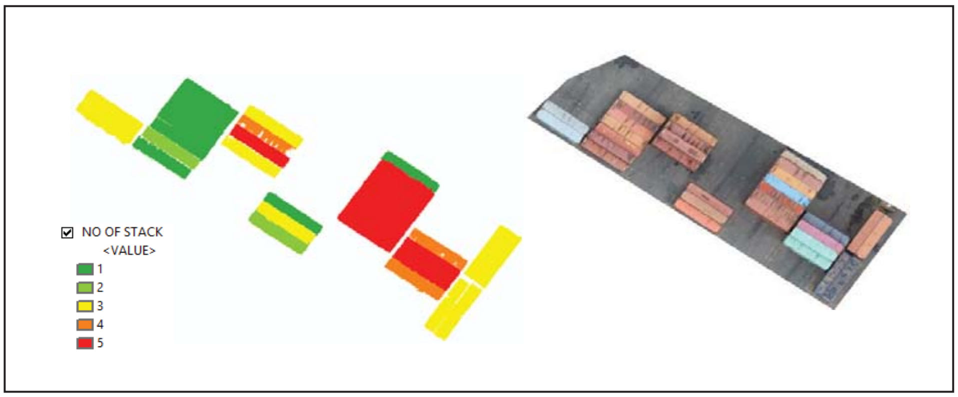

Figure 10: Containers (40 feet) Stack Modelling

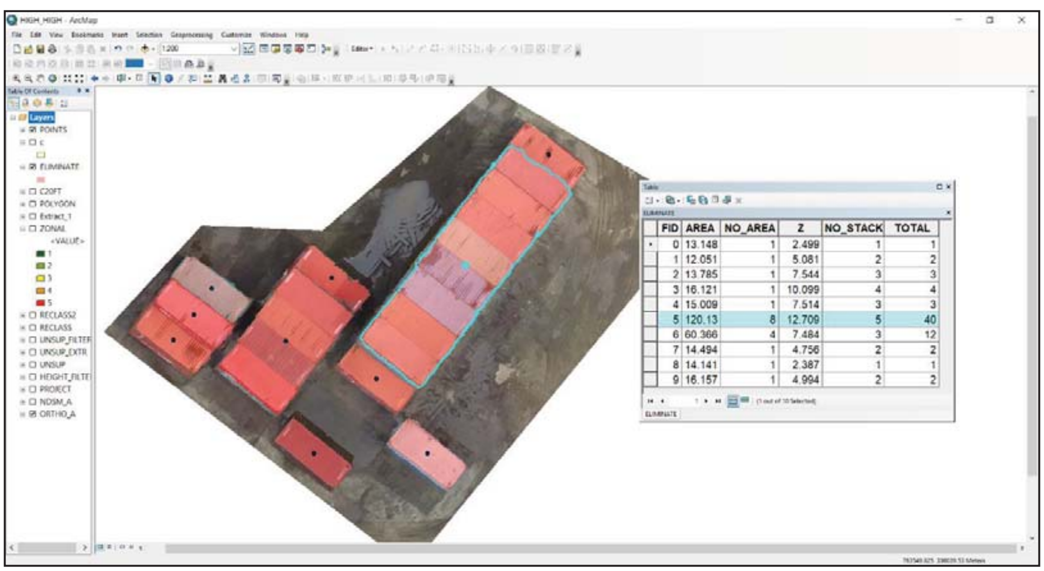

Figure 11: Shipping Container (20 feet) Counting Results

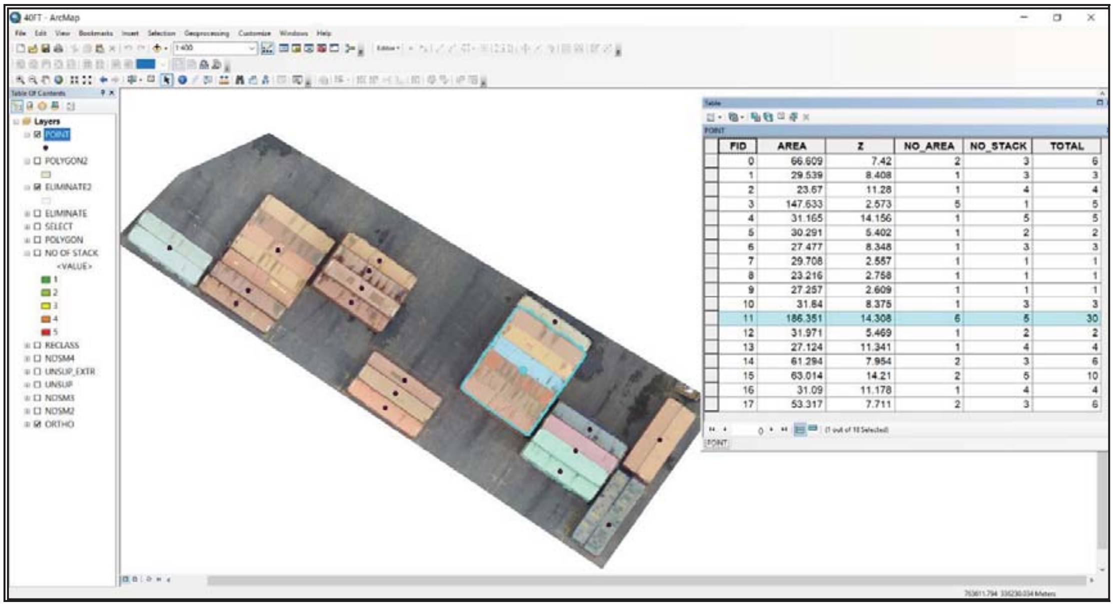

Figure 12: Shipping Container (40 feet) Counting Results

Figure 12 shows the numbers of containers counted are displayed in form of number per area (NO_AREA) and number per stack (NO_STACK) relatively. Additionally, total number of containers is computed based on the multiplication of both number per area and number per stack and displayed (TOTAL). For the counting accuracy assessment, there are 70 containers of 20 feet and 96 containers of 40 feet verified on-site based on manual counting. From the outputs, the accuracy assessment result is tabulated in Table 1.

Table 1: Shipping Containers Counting Accuracy Assessment

Container's Length Type	Total Number Verified On-site (A)	Total Number Counted using Proposed Approach (B)	Counting Accuracy (%) [(A/B) x 100%]
20 feet	70	70	100
40 feet	96	96	100

From Table 1, it is found that the counting accuracy of the system developed achieved 100% for both 20 feet and 40 feet shipping container counting. This is proven by comparing the total number through the on-site verification with the total number counted using the proposed system.

CONCLUSION

The combination of UAV and ArcGIS have made the entire existing shipping container counting task at the depot or container terminal to be automated as well contribute to 100% of counting accuracy. The integration of automation towards the shipping container counting approach will significantly improve the pace of the operation as well mitigating the worker risks in the continually busy environment related to the container's management. Therefore, it supports in increasing the efficiency of the shipping container management.

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