UAV And Lidar : The Next Big Thing In Survey And Mapping

UAV dan LiDAR : Mendepani Peluang dan Cabaran Terkini dalam Ukur dan Pemetaan

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Abstract

Surveying is known as one of the earliest profession in the history of mankind. The basis of such claim was due to the fact from the historical evidence found in places like Greek, Egypt, Stonehenge and Mesopotamia in a form of equipment, documents and ancient drawings. This evidence dated way back to early human civilization. It is believed that the civilized community back then, they also had to earn a living to make ends meet just like we are doing in present time. The majority of the working class people, they plant corps and with the profit they made from their agricultural activity, they had to pay tax according to the land area that they occupied or alotted. In conjunction to that, the function of surveying during those days was very straight forward which is to calculate the area for the purpose of tax collection by the respective authority. This was the breakthrough in the science and knowledge of surveying. Thus the scientific effort to accurately determine the area of a plot of a land and to map its features onto a paper are part of what land surveying was all about. Moving forward in present time, despite the dynamics of the technology, still the fundamental of surveying and the motivation of producing plans and maps remain unchanged. The elements that have grown rapidly from the past to present are certainly in areas concerning the tools, gadgets, software and the application used in getting the surveying job done. Hence, this study would discuss and further explore the potential and the challenges of using this cutting edge technologies known as Unmanned Aerial Vehicle (UAV) and Light Detection and Ranging (LiDAR) because, in general, both are considered as the next big thing in survey and mapping.

Keywords : UAV, LiDAR, Total Station, Global Navigation Satellite System (GNSS), Cadastral Survey, Topographic Survey

Abstrak

Kerja ukur dikenali sebagai salah satu profesion yang terawal dalam sejarah ketamadunan manusia. Asas kepada fakta ini adalah berdasarkan kepada penemuan bukti yang terdapat di tempat-tempat peninggalan sejarah seperti Yunani, Mesir Stonehenge dan Mesopotamia dalam bentuk peralatan, dokumen dan gambar kuno yang menunjukkan aktiviti ukur telah bermula sejak awal peradaban manusia. Adalah difahamkan bahawa, sebagai masyarakat yang telah bertamadun pada masa itu, mereka juga harus bekerja untuk memenuhi keperluan asas hidup mereka. Sebilangan besar dari golongan orang kebanyakkan, mereka bercucuk tanam dan dengan hasil dari usaha penanaman tersebut, digunakan untuk membayar cukai mengikut keluasan tanah yang mereka usahakan. Fungsi kerja ukur pada ketika itu adalah mudah, iaitu untuk mengira kawasan bagi tujuan kutipan cukai oleh pihak berkuasa. Maka di situlah sains dan pengetahuan mengenai kerja ukur mula berkembang. Usaha secara pengiraan saintifik untuk menentukan keluasan sebidang tanah dengan tepat dan memetakan butirannya ke atas kertas adalah sebahagian daripada matlamat kerja ukur tanah. Melangkah ke abad ini, walaupun dengan kepesatan kemajuan teknologi terkini, asas terhadap kerja ukur iaitu bagi menghasilkan pelan dan peta tetap tidak pernah berubah. Aspek yang berkembang pesat dari masa lalu hingga sekarang tentunya adalah dari segi kecanggihan peralatan, perisian dan aplikasi yang digunakan bagi memudahkan aktiviti pekerjaan ukur. Oleh itu, artikel ini akan membincangkan dan akan mengupas potensi serta cabaran dalam menggunakan teknologi yang canggih ini, iaitu Unmanned Aerial Vehicle (UAV) dan Light Detection and Ranging (LiDAR) kerana, secara umumnya, kedua-duanya adalah sangat berpotensi digunakan dalam aktiviti ukur dan dan pemetaan.

Kata kunci: UAV, LiDAR, Total Station, Sistem Penentududukan Sejagat (Global Navigation Satellite System), Ukur Kadaster, Ukur Topografi

Introduction

In general, there are several discipline in survey and mapping. Amongst them are Cadastral Survey, Mining Survey, Engineering Survey, Topographic Survey and Hydrographic Survey. Each discipline mentioned has its own method of data collecting, data processing, data analysing and data presentations. Basically, the effort of the data collected will be used as the basis in producing the relevant plans and maps according to the type of surveyed done. survey and mapping are now a huge industry. Both have evolved from using very basic equipment such as chain, measuring tapes and theodolites to Total Station (TST) and Global Navigation Satellite System (GNSS). To carryout survey especially topographic survey and cadastral survey using these conventional equipment may still be relevant. The time taken to complete the survey may vary according to the area being surveyed, the larger the area the more time it will take to complete the survey.

The surveying task is very much subjected to the weather condition and very depending on the workforce and labour. These issues were considered as among the setbacks before but with the development of the recent technologies such as UAV and LiDAR in surveying and mapping, we are now seeing many options and alternatives offered besides using the conventional way of doing survey and mapping. What makes UAV so different from the conventional equipment of doing survey is that operating UAV for survey and mapping doesn't require as many people as operating conventional survey equipment. UAV is an autonomous flying vehicle which does not require a pilot on board and suitable for surveying small area by capturing data through the RGB (Red, Green,Blue) camera mounted on the UAV. The photo captured will undergo specific process through photogrammetry technique. Whereas LiDAR is fundamentally a distance technology. From an airplane, helicopter or UAV, LiDAR systems send light to the ground. This pulse hits the ground and returns to the sensor. Then, it measures how long it takes for the light to return back to the sensor. By recording the return time, this is how LiDAR measures distance. In fact, this is also how LiDAR got its name – Light Detection and Ranging. The big question now revolves around whether this UAV and LiDAR are able to replace certain segment in survey and mapping functions.

Methodology

Taking into the consideration of the wide range in Surveying and Mapping, this paper will be focusing on 2 surveying discipline, namely topographic survey and cadastral survey. In essence, carrying-out topographic survey and cadastral survey are to produce maps or plans. The most important and critical information on a map or a plan is the scale. Topographic maps as shown in Figure 1 are usually known having relatively small scale (ranging from 1 : 10,000 to 1: 50,000) compared to cadastral plan where the scale are relatively bigger (ranging from 1 : 250 to 1 : 500). To put things into perspective how to relate the scale factor between topographic map and a cadastral map are by looking on the general character.

For topographic map of Peninsular Malaysia, Kuala Lumpur and other cities in Malaysia are being represented just by a single dot. Each dot for each city. Where as in cadastral plan (in cadastral, the terms used is plan rather than map) is a very focused plan of a small area showing details such as the boundary line of the surveyed land parcel, the lot number and the bearings and distance of the boundary lines.

The purpose of topographic survey is to gather survey data or also known as geospatial data that comprise the natural and man-made features of land, as well as its elevations. From this information, a three dimensional map can be produced. For cadastral survey, the main purpose is purely for the issuance of the land title. This is done by accurately planting the boundary monument on each corner of the land parcel after being determined of its distance and the horizontal angle or bearings. The drawings of the boundaries for that particular land parcel later being transferred onto a plan for verification and used for land title registration.

The most common equipment and widely used in topographic and cadastral survey are Total Station (TST) and Global Navigational Satellite System (GNSS). TST can be considered as a modern surveying equipment compared to the more previous equipment in surveying such as theodolite, chain and measuring tape. While a theodolite is an instrument which is used primarily to measure angles, both horizontal and vertical, TST is an electronic theodolite (transit) integrated with an electronic distance measurement (EDM) to read slope distances from the instrument to a particular point, and an on-board computer to collect data and perform advanced coordinate based calculations.

The scope of discussion in this paper will be in the context of looking and weighing the factor such as, the duration of the surveying being done, the estimation of cost, labour and the quality of the end result of the product. In this manner, the main product of the surveying works are map and plan.

Background Study

Through the years of understanding, experiencing and observing fellow surveyors and practitioners in the surveying field, carrying out topographic survey and cadastral survey be it with theodolite, TST or GNSS do have its own strengths and weaknesses. Elements such as the cost incurred of using the equipment, the availability of workforce in carrying–out surveying task are definitely on the advantages side. The downside however is the time taken to complete the survey for that particular area. Huge area requires more time to complete the survey be it topographic or cadastral. Other factors that also affect the duration of carrying out survey are the density, the natural features and the terrain of the area being surveyed. In this regards, prior making statement and to further justify whether if UAV and LiDAR really are "The New Big Thing in Survey and Mapping", it is by right, that the current equipment being used in Survey and Mapping be also discussed.

Topographic Survey Using Total Station

Basically, the main objective of topographic survey is to produce topographic map. The equipment widely used in topographic survey is using Total Station (TST) as shown in Figure 2, an instrument that integrates electronic and optical function for high accuracy of distance, horizontal and slope angle measurement.

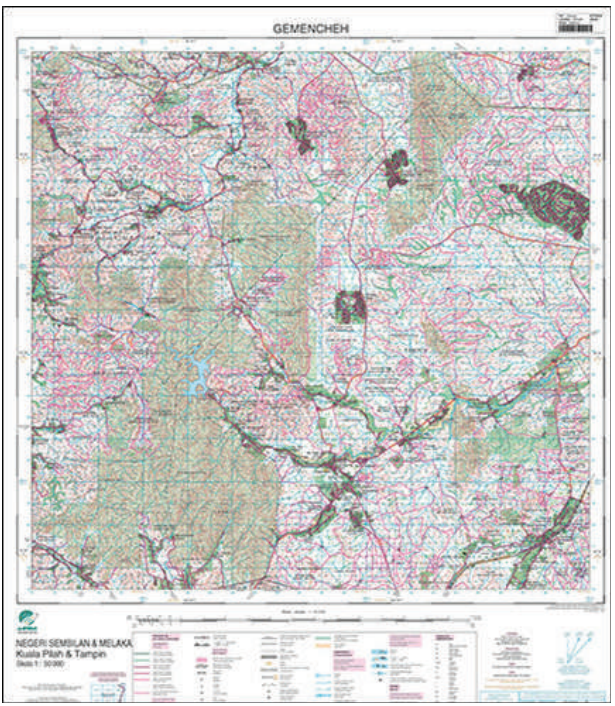


Figure 1: Topographic map of Gemencheh, Negeri Sembilan, one example of end product of topographic survey

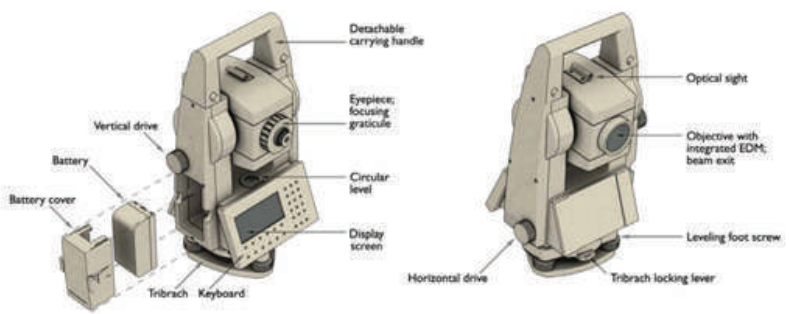


Figure 2: Total Station

The norm in carrying out topographic survey using TST can be seen in the Table 1 and 2 shown below. This norm is being used in the Land Surveying Unit, Public Works Department (Jabatan Kerja Raya – JKR) as the guidelines in monitoring their Surveying fieldworkers on their work progress done in relation to topographic survey. Table 1, showing the norms for area that is clear from any obstacle and with less clearance works needed. Table 2, showing the norms for area that is with obstacle and with many extra clearing groundwork's needed due to the nature of its physical terrain. To give the perspective of the difference between the both, try imagining surveying a plot of land where it is clear as a soccer field and has clear view on all corners of the survey area compared to an area that is filled with trees, bushes, uneven topographic surface where clearance work need to be done prior making any observation through the TST.

The concept of using TST in topographic survey is through establishing the perimeter by traversing the area of interest and getting all the features by calculating the bearing and distance of the features so that all the data collected are able to be correctly scaled and transferred to other medium, that will later be known as a map or a plan.

Table 1: Normal area

Area (ha)	Duration (days)
1 – 1.9	3
2 – 2.9	5
3 – 4.9	7
5 – 7.9	9
8 – 11.9	11
12 – 15.9	13
16 – 19.9	15
20 – 24.9	17
25 above	19

Table 2: High density/hilly/bushy area

Area (ha)	Duration (days)
1 – 1.9	3
2 – 2.9	5
3 – 4.9	7
5 – 7.9	9
8 – 11.9	11
12 – 15.9	13
16 – 19.9	15
20 – 24.9	17
25 above	19

Cadastral Survey Using Total Station

Malaysian Cadastral system is based on the Torrens System which basically consists of 2 vital components namely; land registration and cadastral survey. (Mohammad Yunus et al., 2013). Carrying out cadastral survey is about making the technical effort to accurately measure the boundary of a plot of land for the purpose of issuing land title. The product of cadastral survey for this particular purpose is a certified plan as shown on Figure 3. Malaysia is fortunate to be acknowledged as being having amongst the best practices in cadastral system in the world (Lim et al., 2018). The leading agency in Cadastral Surveying in the country is non-other than Department of Survey and Mapping or better known as JUPEM.

Since the early 90's, JUPEM has embarked on the modernization of the cadastral survey system in stages in line with the advancement of computer technology. With utilising the modern day surveying equipment such as TST and GNSS, JUPEM on average, via it's Survey District Offices throughout the country are able to produce 0.5 hectare of land parcel surveyed per surveying team per day. The details of the average performance between the surveyed area and the days taken are as Table 3 below.

Table 3 : Average performance of cadastral survey done
by 6 team of Surveyors in Survey Office Pulau Pinang, June 2020

Surveyor	Days	Area (Ha)	Average (Ha) per day
A	3.3	0.4	0.1
B	2.3	3.7	1.6
C	2.8	1.6	0.6
D	2.4	0.1	0.1
E	3.1	0.4	0.1
F	1.8	1.3	0.7
Total	**15.7**	**7.5**	**0.5**

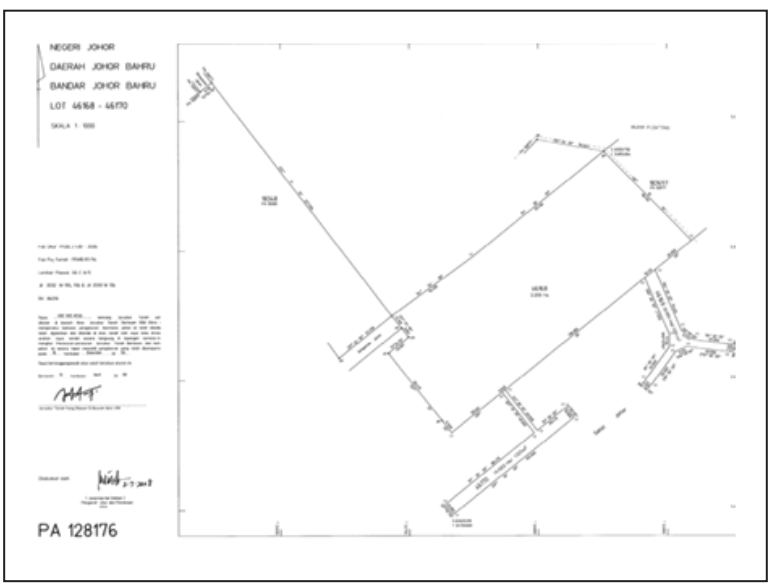


Figure 3: A certified plan for Cadastral as the product of cadastral surveyed done

Topographic Survey Using UAV

UAV by definition is an unmanned aircraft which operates remotely controlled, semi-autonomously, or autonomously, without a pilot sitting in the vehicle (EisenbeiB, 2009). In the recent years, UAVs were most often associated with the military due to its cost and the availability of the positioning satellite system for civilian. But as the cost of the technology are now becoming cheaper and the availability of the positioning system has been open to civilian use, we are now seeing wider functions of UAV or also known as drone as shown as Figure 5 and 6.

Figure 5: Drone- DJI Phantom 4 Pro

This range of civilian roles includes rescue, surveillance, traffic monitoring, weather monitoring and firefighting, to personal drones, business drone-based photography, as well as videography, agriculture and last but not least in survey and mapping. As highlighted earlier in this paper, UAV in topographic surveying will be the main discussion.

Topographic mapping using UAV requires the technical process of photogrammetry as shown on Figure 7. Photogrammetry is the science of making measurements from photographs. In photogrammetry, a UAV captures a large number of high-resolution photos over an area. These images overlap such that the same point on the ground is visible in multiple photos and from different vantage points. This process with the assistance of photogrammetry softwares will generate an orthophoto. An orthophoto is a corrected version of the aerial photograph that has been rectified and is as good as a map in terms of the scale and the map projection. Meaning to say, for an orthophoto scale 1:10,000, 1cm on the orthophoto is equivalent to 100 m on the ground.

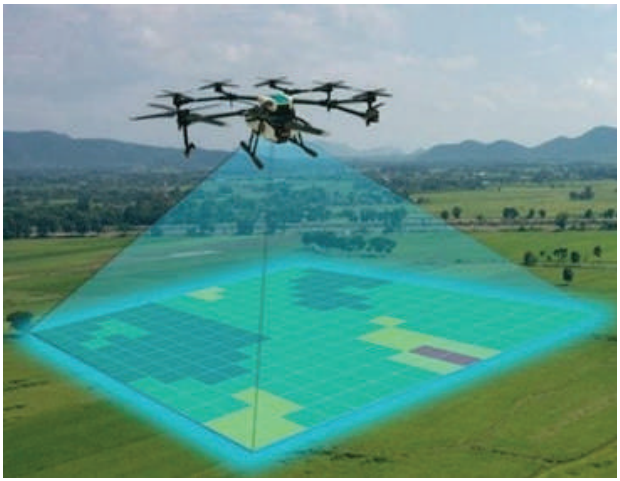


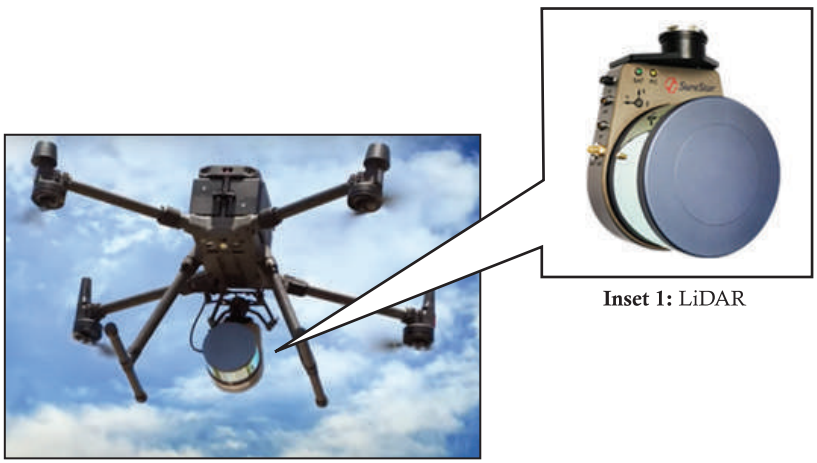
Figure 6: UAV- Capturing photograph of topographic data of on an area

Figure 7: Photogrametric process of Aerial Protograph

The cost of a typical UAV platform for Survey and Mapping purposes depends on the on-board instrumentation, payload, flight autonomy, type of platform and degree of automation needed for its specific applications. Low-cost solutions are not usually able to perform autonomous flights, but they always require human assistance in the take-off and landing phases.

Topographic Survey Using UAV LiDAR

Alongside photogrammetry, airborne LiDAR is an established method for measuring and modelling the Earth's surface. However, improvements in size, weight and power requirements mean that LiDAR is now increasingly capable of being operated from UAV, or better known as UAV LiDAR as shown on Figure 8.



Inset 1: LiDAR

Figure 8: UAV with a mounted LiDAR as payload (UAV LiDAR)

What makes LiDAR so effective in topographic mapping is the capability to direct 3D measurements for the target and penetration of the beam through vegetation to collect information from objects and the ground beneath. The light wave front passing through the vegetation produces information on the vegetation as a side product. To yeild such information, certain principles of laser ranging have to be deployed. The traditional way to gain long-range measurements is to shoot powerful laser pulses towards the target and collect the backscattering signal. The signal then is processed to detect object at distinct ranges within the beam illimination area. These system are the current mainstream and use of spectral wavelength to convey the data collection.

Mapping Application Using UAV LiDAR

In a research paper by M.V.Machado et al., 2019, on Evaluation Of Multiple Linear Regression Model To Obtain DBH Of Trees Using Data From A Lightweight Laser Scanning System On-Board a UAV, it was said that vegetation mapping requires information about trees and underlying vegetation to ensure proper management of the urban and forest environments. This information can be obtained using remote sensors. For instance, lightweight systems composed of UAV as a platform, low-cost laser units and the recent miniaturized navigation sensors (positioning and orientation) have become a very feasible and flexible alternative.

The usage of LiDAR was also carried out for Valuing Forest Stand at a Glance With UAV Based LiDAR based on a research paper by Vepakomma and Cormier (2019). In that paper, it was concluded that knowing the value of the forest stand before it is harvested helps in the predictability of the expected wood product basket. The availability of quick turnaround, flexible, low cost, rich and highly accurate scanning through remote sensing technologies like UAV based LiDAR (ULS) offers great potential for automated bucking where each tree can be analyzed at the stump for optimizing its market value. In this sense, UAV LiDAR are more powerful than photogrammetry UAV that is based on RGB Camera because its ability to scan and getting millions of point clouds for 3D data processing. The difference of UAV LiDAR and photogrammetry UAV can be seen in Figure 9.

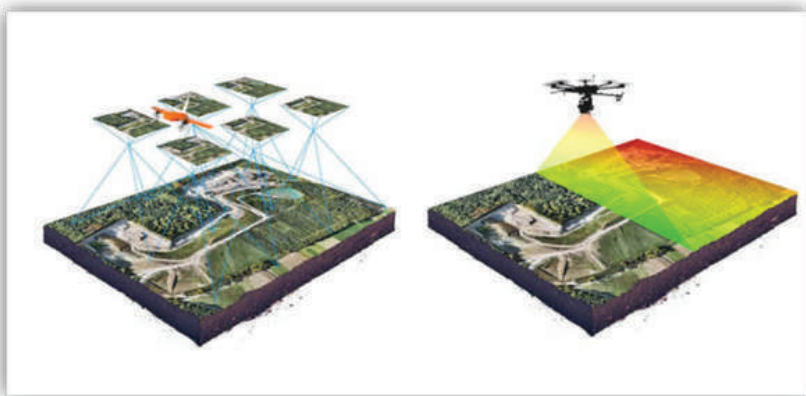


Figure 9: Comparison between Mapping using UAV Photogrammetry and LiDAR

Discussion

The industrial players and communities in the survey and mapping are embracing this the new technology for many reasons. Many research have been done and many more research relating to survey and mapping are taking place because of its potential and capabilities in data capture.

According to the guidelines by the Surveying Unit, Public Works Department of Malaysia (JKR), for area exceeding 25 hectare, 20 days or more needed to complete the surveying and also subject to the level of difficulties of the terrain using a total station for area with high density and hilly features. This would indirectly imply that the estimation duration to carryout topographic survey for INSTUN's area of 80.91 hectare, as shown on Figure 12 would roughly take more or less 64 days for the survey to be completed.

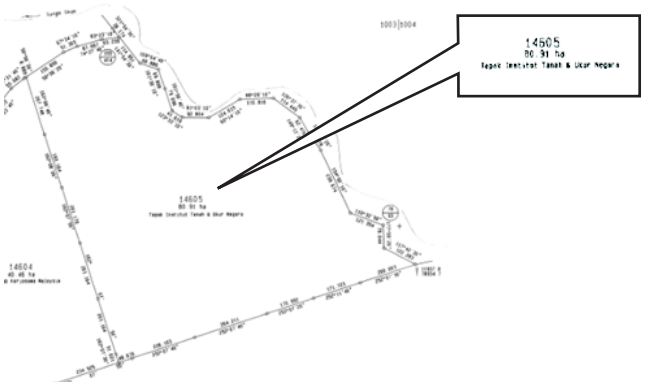


Figure 10: Inset of Certified Plan of INSTUN, showing 80.91 hectare of area

On the other hand, using the UAV to carryout photogrammetric survey for the same INSTUN's area of 80.91 hectare using DJI Phantom 4 Pro would approximately take only 5 days at most, that is 3 hours of flying as per flight planning for topographic data collection, 2 hours of 4 ground control points (GCPs) observation using Real Time Kinematic (RTK) GPS method. Although GCPs are not essential element in UAV mapping, but GCPs will greatly increase the global accuracy of UAV mapping deliverables. The 4 days remaining used in processing the data to generate orthophoto as shown on Figure 13 from aerial photo and finally the digitizing process to produce a topographic map. As to put all parameters that consist of accuracy, cost, labour and duration into perspective on where these surveying equipment stand in terms of its performance in carrying out surveying for the area of interest of 80.92 hectare, the scope of parameters are defined and simplified as Table 4 below.

Table 4 : Parameters of Surveying 80.92 ha of land based on intruments specifications and PWD guidelines on carrying out topographic survey

Equipment	Model	Accuracy (distance measurement)	Cost* (of the equipment)	Labour	Duration (Days)
Total Station	Topcon ES 105 (or any other Total Station with equivalent specification)	2mm	RM 30,000	5 pax	64
UAV	DJI Phantom 4 Pro	50mm	RM 10,000	2 pax	5
LiDAR	Mini Genius LiDAR System (Mounted on DJI Matrice 300)	100mm	RM 250,000	2 pax	5

** Approximated cost are based on the current value from variety of sources and used only for the purpose of making a reasonable parameter on this paper, it should not to be taken beyond this context*

As can be seen on the table, for accuracy, TST top the score with 2mm level of accuracy reading while UAV and LiDAR scored 50mm and 100mm respectively. This is an indication that industrial player will still prefer TST rather than UAV and LiDAR when certain job requires high level of accuracy especially for job such as cadastral survey, engineering survey and geodetic survey. In terms of duration for completion the surveying task both LiDAR and UAV only require 5 days to cover the whole area of interest while TST will be needing more or less 64 days on completing surveying for the same area of interest.

Figure 11: Orthophoto (Aerial Photo taken by UAV) of INSTUN, 80.91 hectare

For most of the applications of UAV LiDAR or camera data, accuracy is the most important requirement. Accuracy can be quantified in absolute and relative accuracy. Absolute accuracy is how accurate the point cloud is in relation to known points in any given coordinate system. Relative accuracy is how accurate the point cloud is relative to itself. For this particular UAV LiDAR, 100mm is the absolute accuracy. It is believed that, while accuracy remains as the priority in surveying and mapping, LiDAR actually came to existence for satisfying the purpose of other mapping applications such as producing an accurate Digital Terrain Model (DTM) and contours as shown on Figure 14. The demand of such deliverables by UAV LiDAR have been greatly increased from time to time, in line with the advancing technology and research in LiDAR.

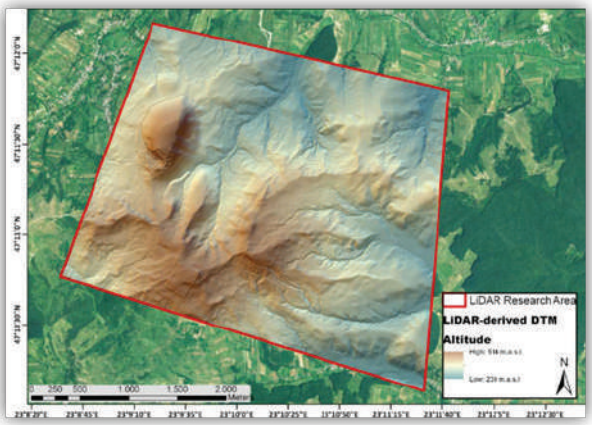


Figure 12: Digital Terrain Model of an area of interest from LiDAR

In cadastral survey, it is well understood, that LiDAR technology may not seems to excite players from this cluster due the high cost and how relatively less accuracy in terms of the LiDAR deliverables. Even in due times, if the level of accuracy may increase significantly, we still have to deal with the restriction in National Land Code (1965) before we could see LiDAR be used widely in Cadastral Survey. Section 396 (b) of the said Act, clearly regulated that, a surveyed land parcel is when boundaries have been determined and have been demarcated on the surface of the land by boundary mark. That being said, planting a boundary marker is still essential for cadastral survey for title issuance. This would requires ground work because photogrammetry UAV or UAV LiDAR alone does not fit the criteria of Section 396 (b) of the National Land Code (1965).

Practicality wise, LiDAR may not seems a big deal in cadastral survey but getting UAV involve in certain segment in cadastral survey might be a different story. Many research have been done with regards to the matter but not to the extend of issuing a land title. One research in line with cadastral survey segment done by Mohammad Yunus et. al. (2016), was about utilising photogrammetry UAV to accurately verify land encroachment case in Cameron Highland, Pahang. The issue was about the land use authorised for agriculture under Temporary Occupancy License (LPS) being commercially abused as shown in Figure 16 and 17.

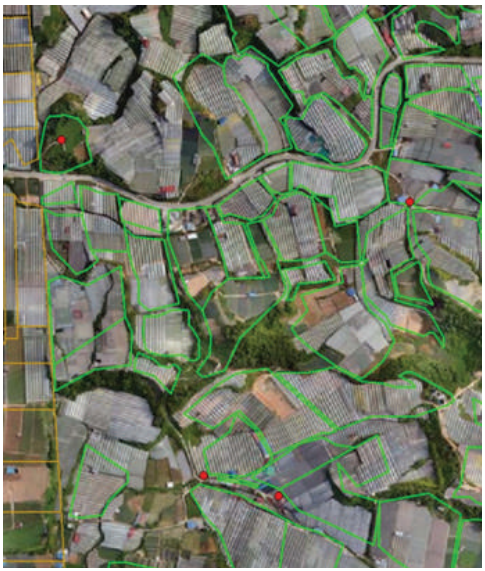


Figure 13: Overlay between Orthophoto and Landuse authorised for agriculture (green line)

Figure 14: Graphical display between Landuse authorised by the Land Office for agriculture (blue line) and the actual land illegally being occupied (green area)

From the case study, the authorities having all the solid graphical evidence from the orthophoto, were able to swiftly bring the case to justice. Should the conventional method of surveying using TST was chosen rather than the UAV, it might take days before the volume of encroachment can be clearly defined.

Conclusion

In comparing these three technologies, what's essential to understand is that the one is not better than the other. Each has their strengths on certain areas and has their limitations on other area. It boils down to understanding the differences in approach and the capabilities as well as limitations of the three technologies. To determine which equipment suit best for surveying task to be carried out be it topographic survey or cadastral survey, decision made should be based on business need, cost and return of investment (ROI).

On one side, we have Total Station, a moderate technology of surveying equipment yet very practical and economic in achieving high accuracy in producing cadastral plans and topographic maps. On the other side we have UAV, very economic yet limited to map small area with very moderate level of accuracy. The latest technology LiDAR maybe with the least score in terms of accuracy and the cost but for application such as producing Digital Elevation Model (DEM) and for mapping for research, LiDAR without a doubt is a brilliant technology that would take mapping to the whole new level.

As to conclude, this paper would suggest that while the use of TST is still very much relevant in survey and mapping activities, this paper also concur with the general views of communities and the main players in surveying and mapping that UAV and LiDAR without a doubt are "The New Big Thing In Survey And Mapping" due for its wide potential and its incredible capabilities in geospatial data collection.

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