Usage of Micro UAV for Forensic Photogrammetry

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Abstract

In recent years, Micro Unmanned Aerial Vehicle (UAV) has been utilized in numerous fields of activities. It is particularly useful in land-use projects where time and cost are critical to its viability. In the field of forensic science, the application of photogrammetry is crucial in the 3-Dimensional (3D) reconstruction of a crime scene where the details in distance, position and perspective are key elements of the model which provide aid to the forensic team or investigators, lawyers and insurance adjusters. Conventionally, the usage of digital camera such as Digital Single-Lens Reflex (DSLR) in forensic photogrammetry pose setbacks as the crime scene has the risk of being tempered whilst images of the site are being captured. By launching Micro UAV at a crime scene, the site is preserved whilst the evidence is being captured. This will ensure the integrity of the evidence is maintained even long after the on-scene investigation has concluded. This data is valuable since it may take months for an investigator to re-examine a scene and find a new piece of important evidence. The methodology of this study is to collect data on a simulated crime scene, particularly in a constraint area using Micro UAV and process the data using photogrammetry software which will produce a 3D model point cloud. The data will then be compared against data produced using Terrestrial Laser Scanner (TLS) as the primary comparison and Vernier Calliper (VC). The result shows that the Root Mean Square Error (RMSE) of Micro UAV against TLS is ±1.698mm. In conclusion, it is feasible to use Micro UAV for forensic photogrammetry in a constrained crime scene and produce a high-accuracy 3D model point cloud.

Keywords: *Crime scene, Close range photogrammetry, Forensic, Micro UAV, 3D model point cloud*

1. Introduction

Pinhole cameras and film were initially used for photogrammetry in forensics. The use of photographs as evidence in the court system has been allowed since the early 1800s. Videotape recorders were released later in the 1950s and may be used as evidence in court. Digital cameras became an essential instrument in forensic photogrammetry when photography transitioned to the digital age. The reproduction of the scene, particularly the location, distance, and perspective of important scene elements, must be produced with high precision in order for the evidence to be accepted in court [1]. As a result, utilising a DSLR for forensic purposes pose several challenges that may compromise the validity of the inquiry, particularly for a small compact scene that is difficult to reach without tampering with the evidence. This study examines the use of Micro UAV in offering a feasible

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and economical approach to obtaining forensic images. The project will also evaluate how well employing Micro UAV works for gathering evidence at crime scenes, especially in restricted areas, in terms of data accuracy and convenience of usage. Compared with Terrestrial Laser Scanning, a novel forensic photogrammetry technique, the usage of Micro UAV is expected to yield 3D model of a crime scene that is at least as good as or better than those produced by Terrestrial Laser Scanning (TLS). The comparison shall also be made with a conventionally used manual tool which is Vernier Calliper (VC) to further assess the accuracy of objects captured by Micro UAV and TLS.

1.2 Photogrammetry

The general idea of photogrammetry is taking photos from a different angle, which the photos later are combined and interpreted using photogrammetry software to produce a 3D model. To put it in geomatic terms, photogrammetry is defined as the science of producing a reliable measurement using 2D photographs to locate features on or above the surface of the earth. Commonly, the output of photogrammetry is to produce 3D graphic representation or model and have the three coordinates on a point which are X, Y and Z [2].

Additionally, photogrammetry is essential to the process of solving crimes since it can be used to precisely measure and record information about a crime scene and ascertain what was physically possible. As crucial evidence to be presented in court, a photogrammetric expert often plays a significant role in supporting the detectives by creating a 3D reconstruction of the crime scene.

Close-range photogrammetry (CRP) has become a powerful tool for engineers and scientists who wish to utilize images to produce accurate 3D measurements of complex objects including 3D reconstruction of a crime scene. CRP is defined as photogrammetric data collection in 2D in which the distance between camera and subject is less than 300 meters. This technique is a non-contact measurement, therefore it needs stereo-pair photographs of an area in order to measure feature point of interest. The technique has recently gained interest since it is simple to use with digital cameras, has significant versatility in terms of measurement precision, and can simply handle composite and immediate data. Usually in close-range photogrammetry, the process includes 3D metric reconstruction, feature extraction, vanishing point computation, camera self-calibration, dimensional analysis and interactive visualisation. This method is suitable in various types of fields such as automobile, archaeology, civil construction, medical and crime investigation [3].

1.3 Terrestrial Laser Scanning

Terrestrial Laser Scanning (TLS) is a ground-based imaging technique that efficiently and precisely collects millions of point clouds from the surfaces of objects using infrared laser technology. TLS measures 3D points using an invisible laser, much like a survey total station. The distinction is that TLS can quickly scan the entire scene. 360° horizontally and 310° vertically make up the laser's field of vision. It may be used for a wide range of purposes, including documenting a huge building's façade for pre-fabrication architectural panelling, preserving the circumstances of a crime scene, and recording the flatness of walls [4].

1.4 Structure from Motion

A technique called Structure from Motion (SfM) uses the same feature point to predict 3D models from overlapping 2D photos. Each characteristic that makes up a match between two images is also looked for in other images. A track can be built without a Ground Control Point if certain requirements are met, such as being captured in at least three pictures (GCP). Due to its ability to handle collections of heterogeneous and unordered photos without prior knowledge of the camera characteristics, it has gained popularity in recent years.

SfM is distinct from conventional photogrammetry in three ways. Image matching allows for the automated identification of features in a range of scales, viewing angles, and orientations. It is advantageous while handling a tiny, shaky platform. It is possible to solve the algorithm's equation without knowing the locations of the cameras or the ground control points. Camera calibration can be automatically resolved or improved during the process. So without strict homogeneity in overlapping photos, camera placements, and calibrations, SfM may build photogrammetric models [5]. The application of the SfM technique in close-range photogrammetry and drones has resulted in the creation of low-cost, user-friendly software with great performance and accuracy. The programme can produce dense point clouds, high quality orthophotos, and other photogrammetric outputs like TLS for precise and quick documentation. Create a steady outcome as a consequence, and visualise the data as a 3D model [6].

1.5 Unmanned Aerial Vehicle

Unmanned systems are electromechanical devices that may use their own power to carry out intended missions without the need for a human operator. They have advantages including increased mission safety and reduced operational costs. Through a communication data connection, a base station controls the UAV. Despite the fact that UAVs were originally developed for military applications, their use in geomatics has continued to expand. Additionally, the integration of image sensors and more contemporary positioning tools like GNSS receivers has increased its potential for close-range photogrammetry because it also supports the collection of traditional terrestrial data [7].

According to their weight, UAVs are split into five categories: nano, weighing up to 250 grammes, micro, weighing between 250 grammes and 2 kilogrammes, miniature, weighing between 2 and 25 kilogrammes, medium, weighing between 25 and 150 kilogrammes, and giant, weighing beyond 150 kilogrammes. A number of software packages that incorporate photogrammetric and SfM have been introduced as a result of the popularity of UAVs, which has helped the field of photogrammetry advance. Real-time monitoring, remote sensing, providing wireless coverage, security and surveillance, civil infrastructure, and many more uses for UAVs are among their constantly expanding range of applications. However, the harsh climate can have a significant impact on a UAV, causing it to deviate from its planned course in the case of severe winds, rain, and storms [8].

Figure 1. Example of Micro UAV

1.6 Forensic Photogrammetry

In comparison to the traditional approach, forensic photogrammetry is a sort of close-range photogrammetry that quickly and accurately maps crash and crime scenes. The conventional application of DSLR in forensic photogrammetry is labour-intensive, intrusive, subjective in terms of data collecting, and has very few options for presenting the data to a court [9]. Today, one of the most beneficial and affordable sources of spatial data for photogrammetry is available for forensic use. Due to the environment, it is imperative to take photos of the crime scene as soon as possible to preserve the original features before they are altered, deteriorated, or lost [10].

A 12-megapixel or higher pixel DSLR with a pop-up flash, a hot shoe to attach an external flash, and a memory card are the minimum requirements for the equipment needed to collect evidence from a crime scene [11]. To offer quality that is suitable for photogrammetric purposes, a number of requirements must be applied. Consistency comes first; the photos must be shot using the same camera, same lens length, and same lighting conditions. Angles come in second; different angles will be used to measure the object. The third is reference, which includes a number of nearby items whose measurements can be used as a guide. The fourth need is discernible characteristics; the main topic of the image must be recognisable and clear in at least two or three photos. Last but not least, the major things must be large enough to fill the frame of the picture. The fundamental geometrical concepts that describe the spatial relationships between the evidence in a crime scene include distances (measured on multiple planes), angles (defined on both the horizontal and vertical axes), height differences (distances measured on the vertical axes), surfaces, and volumes [12].

1.7 Previous Research of UAV in Forensic Photogrammetry

The use of UAV photogrammetry in the field of forensic science began to emerge in 2017 when researchers recognized that crime scene investigators often faced difficulties due to the complicated nature of the crime scene, for example the geographical terrain such as cliff edges or remote locations and high-rise buildings [13].

Besides having the capability to map an area expeditiously, UAV can be deployed immediately to a crime scene to provide an overview and extent of the scene, determine entry and exit points to the scene before investigators actually reach the scene. This is especially useful to ensure proper scene management. As UAVs are small and light, close-up photographs are possible without tempering the evidence and scene. Author [14] tested the prospects of aerial 3D modelling in the forensic context using a commercial DJI Phantom 2 drone equipped with GoPro Hero 4 digital camera. The results indicated that drone-based aerial photography is capable of producing high-quality images to build accurate large-scale 3D models of a forensic scene. However, the author noted that less easy-to-spot evidence, such as bloodstains, could only be detected after having been marked with crime scene equipment. The main benefits of UAV photogrammetry are undoubtedly the low costs, flexibility of use and completeness of the model within a very short acquisition and processing time. However, the Author [15] highlighted that the results were less accurate as compared to results of laser scanning, mostly due to the accuracy of GPS survey used to scale and geo-referencing of data. This problem will likely occur in indoor surveys, but the integration of both techniques would overcome the limit.

3. Methodology

The methodology is defined as a systematic way to answer a research question by gathering data according to a certain methodology and offering an interpretation of the learned information.

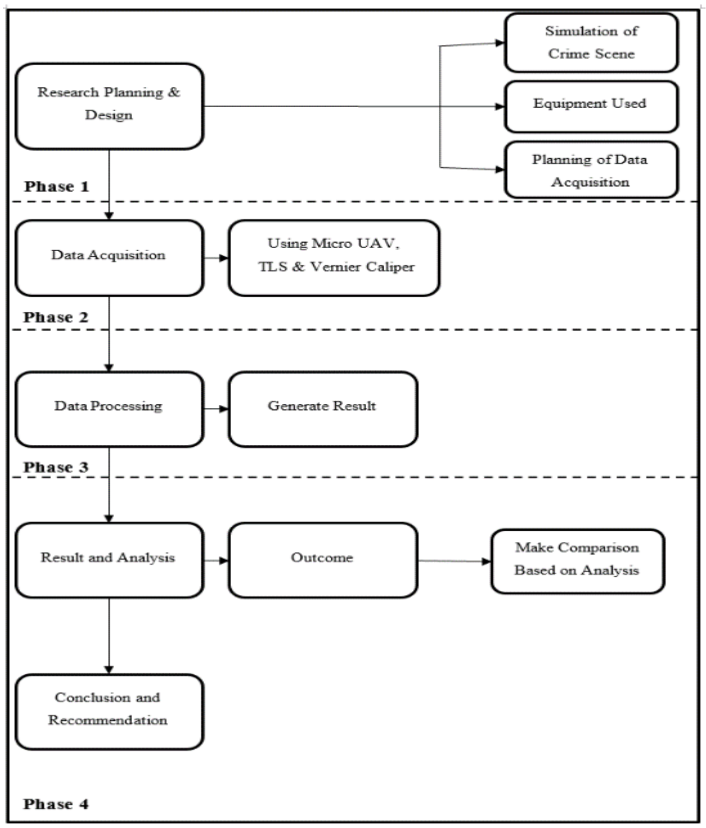


Figure 2. Research Methodology

The overall study procedure will be covered in this chapter, which includes the four phases of research planning and design, data gathering, data processing, and outcomes and analysis as shown in Figure 2.

2.1 Research Planning & Design

This phase is crucial in determining the research type that will produce reliable results that are aligned with the aims and objectives of this study. The study employed a comparative research design, which combines qualitative and quantitative methods. The qualitative methodology offers an understanding of the issue, whilst the quantitative approach offers some conclusive facts about employing Micro UAV and TLS. Setting up a mock crime scene, finding the equipment needed for the data capture, and gathering the data itself are additional important actions that need careful planning.

The simulated crime scene with the advice of an industry expert was set up on UTM campus in an indoor environment. The simulation of a crime scene was set up at Geospatial Information and Imaging Research Group (Gi2RG) which is located in Block C05.

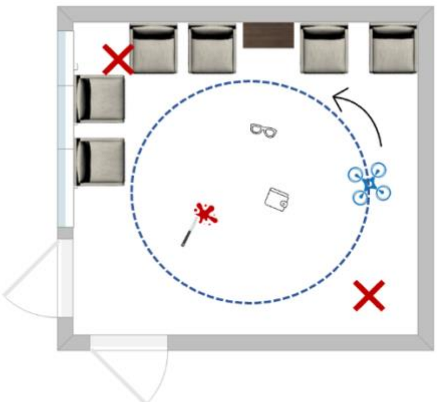
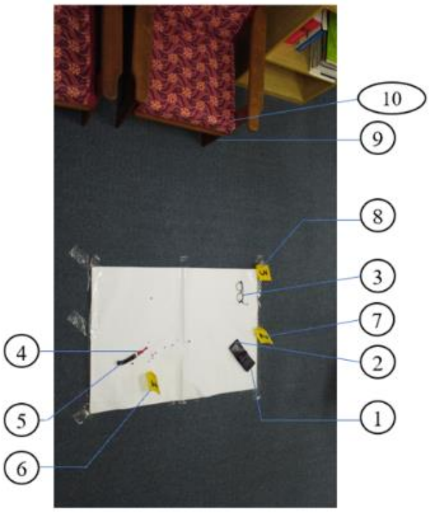


Figure 3. Approximate of overall planning data acquisition

After the crime scene has been set up in a confined space, the deployment of a Micro UAV in the crime scene area starts the process of collecting images. Due to the lack of GPS in a tiny space within a building, deploying autonomous or flight plan operations are not appropriate for this investigation. As a result, a ground pilot will manually operate the Micro UAV.

The Micro UAV was flown in a circular pattern while photographs were captured at various angles to capture the crime scene in its entirety, whilst the location of TLS were marked ‘X’ as seen in figure 3 For this research, artificial targets on the crime scene is used as local reference coordinate system. The objects for accuracy measurement of data extracted from Micro UAV against TLS and VC are shown in figure 4.



No.	Items
1	Wallet
2	Wallet
3	Spectacles
4	Knife Blade
5	Knife Handle
6	Card No.1
7	Card No.2
8	Card No.3
9	Chair
10	Cushion

Figure 4. The distribution of objects for measurement

2.2 Data Acquisition

Data acquisition is the process of using a Micro UAV to capture collections of images from the crime scene and carrying out a laser scan with the TLS deployed at two locations on the crime scene as shown in figure 1.5 below.

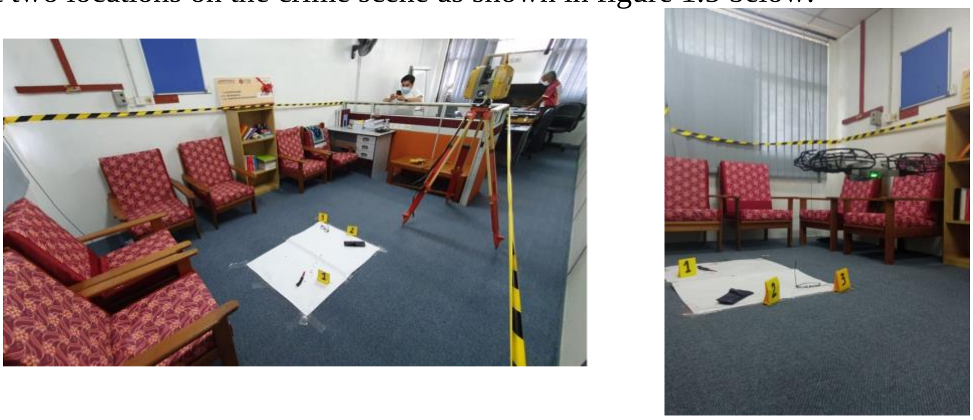


Figure 5. Data Acquisition using TLS and Micro UAV

Following the completion of data gathering utilising TLS and Micro UAV, each object in the crime scene was measured individually using a Vernier Calliper (VC) to determine its length as the conventional method. Comparing these extra measurements is necessary to evaluate the accuracy.

2.3 Data Processing

After gathering information about the crime scene using a Micro UAV, TLS and Vernier Calliper, the inputs were transferred to the lab for data processing. In this study, the structure from motion (SfM) in Agisoft MetaShape Software, will be the foundation upon which the 3D model is formed based on point cloud. The software's primary research related features include Align Photo, Build Dense

Cloud, Build Mesh, Build Texture and Export. The figure 5 below shows every process of Micro UAV photographs in Agisoft Metashape.

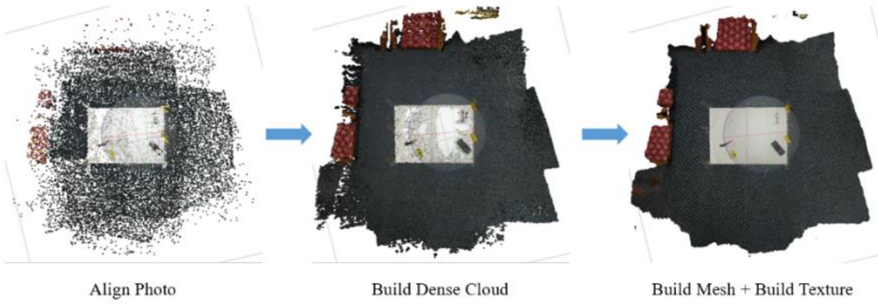


Figure 5. The workflow of processing images from Micro UAV

For the processing of TLS data, it requires only importing data into Agisoft Metashape and Build Dense Cloud. However, the point cloud from TLS requires a cleaning process in order to acquire within the area of interest. Figure 6 shows the output of TLS before data cleaning. After data cleaning, is as in figure 7.

Figure 6. The overall output of TLS

3. Results

The process of images and point clouds were made using Agisoft Metashape until 3D model point cloud and 3D point cloud were produced. For UAV data, the process of aligning photos until texture took around 2 hours whilst TLS data took around 3 hours to produce 3D point cloud. Apart from volume of data, process duration is also dependant on the computing capability.

Figure 7. On the left is the output from Micro UAV (Figure 7A) whilst on right is the output from TLS (Figure 7B)

The 3D model of the crime scene is represented by the point cloud that was created. By adding mesh and texture to the model, the surface of the point cloud model is formed and created more photorealistic in terms of visualisation.

The number of overlapping images for data redundancy is essential to provide high-quality results. Figure 8 shows the result of overlapping images generated by Agisoft Metashape according to color gradient. The black dots are the position of camera captured on the crime scene using Micro UAV.

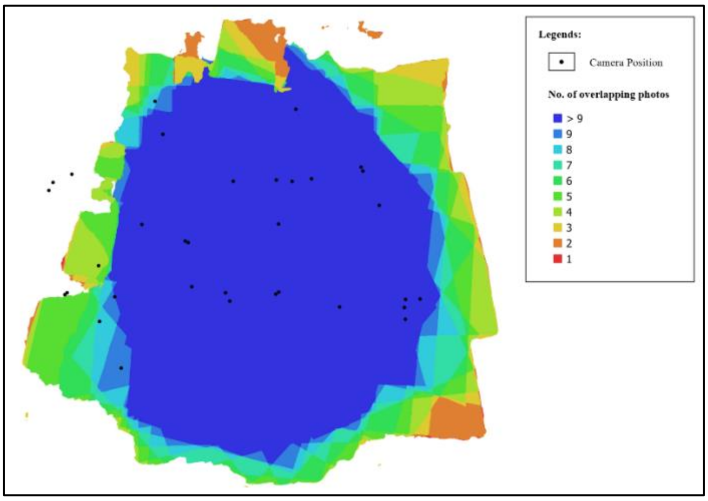


Fig. 8. Overlapping Images

As shown in figure 8, the highest overlapped photos, which are above 9, are illustrated in deep blue color at the centre of the area of interest. As the number of overlap decreases, the color gradient changes from blue, cyan, green, yellow and to the least overlapped images in red. The model in yellowish to reddish colored area appeared to be more distorted as compared to models in the centre of the area of interest.

The measurement from Micro UAV data was extracted using Agisoft Metshape whilst data from TLS was taken from Cloud Compare. Both measurements were compared against the conventional method using Vernier

Calliper. For analysis, the measurement of length of the objects within the crime scene was recorded. Analysis used in this research is Root Mean Square.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(yi - \hat{y}i)^2}{N}} \quad (1)$$

Where,
yi = true value
$\hat{y}i$ = observed value
N = number of observations

Table 1 Difference in length of sample data

No.	Items	Difference in length (mm)	
		TLS-UAV	TLS-VC
1	Wallet	-4.428	-3.559
2	Wallet	-2.230	-3.796
3	Knife blade	-7.752	-8.540
4	Knife handle	1.458	1.413
5	Card No.2	4.250	-0.058
6	Chair	0.693	-0.559
7	Cushion	2.162	2.110
RMSE		1.698	1.423

Table 1. shows the result of analysis using Root Mean Square Error (RMSE) calculation. The measurement error describes the anomalies between the benchmark measurements obtained from the TLS against Micro UAV and Vernier Calliper. The RMSE for TLS and UAV is ±1.698mm, and for TLS and VC is ±1.423mm based on the differences. Statistically, the lower the RMSE value, the better is the given model.

As shown in figure 7, it is observed that there are three items i.e. spectacles, card no.1 and card no.3, that produced large RMSE values which indicate the presence of significant error, hence table 1 has excluded three undetectable items from the RMSE calculation. This result is aligned with Figure 7B where there are gaps in data extracted from TLS as depicted in the picture in the elliptical-shaped void. This may happen due to the limitation of TLS for setting up in close and tight compound or placement of TLS require adjustment. This is aligned to the previous report that indicates the TLS laser field of view is 310° vertically and 360° horizontally as illustrated in Figure 9 below.

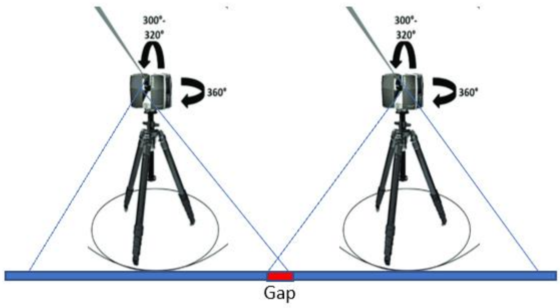


Figure 9. Illustration of the TLS positioning

Overall, based on the data with TLS being the benchmark, Micro UAV provides the acceptable accuracy of ±1.698mm, a difference of only ±0.275mm as compared to Vernier Calliper.

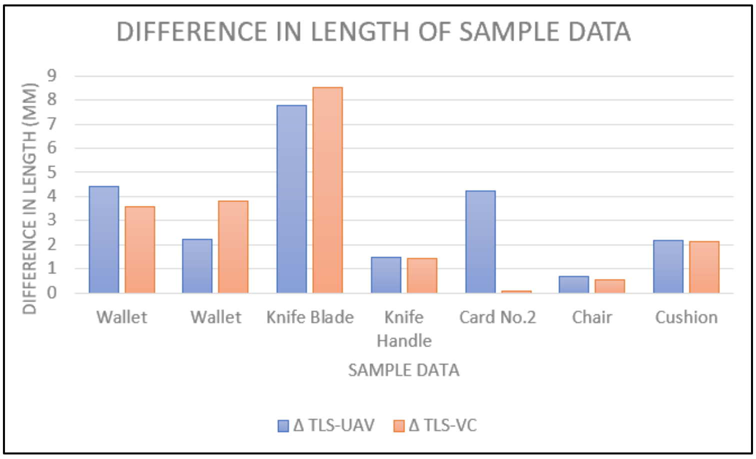


Figure 10. Difference in length of sample data.

4. Conclusions

The primary goal of this study is to evaluate the efficacy and accuracy of using Micro UAV in the field of forensic photogrammetry to capture evidence without tampering the crime scene by producing a 3D model point cloud. The Topcon TLS, GLS2000 serve as the benchmark for this study and are compared against Micro UAV, which is DJI Mini 2 and also against a conventional method of using Vernier Calliper. Although it is known that TLS produces larger amounts of point cloud and covers a larger area as compared to generated point cloud from Micro UAV, the visualization output of TLS in this study is not photogenic in comparison to that of Micro UAV, possibly due to the tight and confined area and placement of the TLS. It is worthwhile to revalidate the study with more objects set up within a confined space with better placement of the TLS.

In terms of efficacy of using Micro UAV in forensic investigation, the study found that the portability, lower cost of investment, ease of use and coupled with acceptable accuracy of the generated 3D model point cloud will be the primary driving factors. However, usage in confined spaces pose challenges due to absence of GPS coordinates but can be overcome with experienced and skilled UAV operator to maneuver the UAV manually.

In conclusion, the creation of a meshed and textured 3D model from the Micro UAV image processing has the ability to provide accurate dimensional measurement with the accuracy of ±1.698mm, which is advantageous for data recording and interpretation for forensic photogrammetry.

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