Advanced Techniques in As-Built Survey by using UAV Technology

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Abstract. As-built surveys are needed to record variations from original Engineering plans to what is actually built and the final set of drawings produced at the completion of a construction project. As-built surveys are required by many agencies to prove the location of a structure at a point in time. These are especially important for maintenance and future development of the site. To handle this task conventionally, total station was used, but it is more costly, time consuming and more skilled surveyors are required to conduct a total station survey. Purpose of this study is to investigate the Unmanned Aerial Vehicles (UAV) system for comparison of the proposed drawing of UTHM Pagoh Campus with the as-built orthomosaic images and to carry out the mapping based on imaged by UAV. Therefore, a method of mapping by UAV, the application of camera-equipped for visually monitoring construction and operation of buildings was used to collect all the information directly on the site which is on the study area. It is also to carry out the mapping based on imaged by UAV. The data collections show that method to earn all information required for this study is by using UAV equipment, Pix4D and Global Mapper software to generate the images. The result of the study is proved that the ability of the UAV in production of as-built survey mapping is can be achieved and it also ease the as-built survey work due to saving time and skilled surveyors are not required. Thus, UAV is very suitable for engineering work purposes

1. Introduction
In this technology advanced era, many new technologies that have been developed to ease the work of surveyor in geomatics field. The most accurate traditional method of doing an “as-built” survey is by using a Total Station, but it is more costly, time consuming and required the surveyor's skill to handle the total station survey. Currently, Unmanned Aerial Vehicles (UAV) is increasingly used for different applications such as mobile surveillance, environmental monitoring and as-built surveys in the construction field. The UAV is light, small size, easy to controlled, it spend less time and less energy to fly across a wide area or long distance.[1] This UAV technology allows each project to retrieve data at an appropriate accuracy level, using relative accuracy for information gathering or absolute accuracy for design engineering and construction phases. Accuracy in an aerial mapping project is essential to get professional results. In elements of accuracy for UAV technology, as camera resolution has improved, so has the ability to digitize the world in greater accuracy than ever before [2]. A
previous work by [3] found that the application of UAV is able to become an alternative in creating an orthophoto map due to more economical and less time consuming.

In this study, the proposed research had covered effective strategies to make as-built surveys by using UAV. This study is focusing more on the comparison of an as-built survey with the image mosaic of UTHM Pagoh Campus based on UAV. Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh Campus was the proposed site of this project and a comparison was made based on the proposed drawing and the actual development on the site. This study is very crucial to bring the advantages of UAV system for as-built survey field. Thus, this study can help to reduce the manpower, time and cost for the management of the site. It’s also improved the quality and quantity on the data acquisition by using UAV system. This UAV technology is unique in that inspections and surveys can be accomplished in record time, while the data retrieved is at premium quality. To put it another way, a most common use for UAV, is in measuring locations where vehicles and personnel cannot otherwise access. Surveying roadways, flooded areas or congested city landscapes are perfect assignments for UAV technology. The technology offers a cost-effective alternative to surveying hazardous sites, in a matter of hours compared to days or weeks. Therefore, UAV is very important in helping to conduct as-built survey. In addition, the equipment and software that will be used for this study are based on technology and hence, by using this alternative way, not only removing the time consuming, it could reduce the cost of the as-built survey work.

2. Literature review

UAV system and reviews the main civilian applications of UAV. There is plenty of definition of the unmanned aerial vehicle (UAV) in the literature. The UAV is an aircraft with no pilot on board. It can be remote controlled aircraft or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems. There are many different classifications of UAV based on different aspects, some classified UAV according to its function, some UAV were classified based on their size, and some were classified according to their flights altitude, endurance limit, etc [4].

| Category          | Max. Flight Altitude (m) | Missions                                             | Systems                  |
|-------------------|--------------------------|------------------------------------------------------|--------------------------|
| Micro/ Mini UAV   | 150-300                  | Surveying inside building, agriculture, pollution   | Black Widow, Microstar,  |
|                   |                          | measurements                                        | Microbat, Fancopter      |
| Tactical UAV      | 3,000-8,000              | Mine detection, search and rescue, weapons delivery, | Phantom, Copter 4,      |
|                   |                          | communications relay                                 | Mikado, Robocopter 300  |
| Strategic UAV     | 15,000-20,000            | Communications relay, boost phase interrupt launch   | Global Hawk, Raptor,    |
|                   |                          | vehicle, airport security                            | Condor, Helios, Predator-IT |
| Special Task UAV  | 20,000-30,000            | Anti-radar, anti-ship, anti-aircraft, anti-infrastructure, | Mali, Harpy, Lark,     |
|                   |                          | aerial and naval description                         | Marula, Pegasus,        |
|                   |                          |                                                      | Flyrt                    |

2.1. DJI Phantom 3 Advanced

DJI Phantom 3 Advanced is a quadcopter manufactured by Chinese producer of flying and camera stabilization systems DJI. Phantom is a small quadcopter that weights 1.3 kg with battery and
propellers included. It has a 12.4 megapixel camera with 94° field of view lens. UAV’s main characteristic is its permanent integration with the camera. These devices are considered as low-cost and low-power sensors and that is why they are commonly used in cheaper equipment like commercial drones [5].

![Figure 1. DJI Phantom 3 Advanced][5]

2.2. Pix4D Mapper
There are many different types of photogrammetry software on the market. The ones that appear to be popular with some UAV operators are Pix4Dmapper, Dronedeploy and Agisoft Photoscan require all images to be uploaded to the software company’s server for the processing which we considered to be inappropriate for sensitive accident site imagery. With the company-owned app DJI GO, the UAV can be controlled manually [6]. An input of a fixed flight path, which the UAV should follow, is not possible before the start of the flight. The software starts by identifying key points in a series of overlapping images. A key point is a point of interest, like the corner of a vehicle that Pix4D can identify in multiple images.

Knowing the camera position as shown in Figure 2, orientation and camera properties like focal length, it then projects a line from the camera through a key point. It then repeats this for the next image, resulting in a triangulated position of that key point in 3D space, which is used to create a point in the 3D point cloud. Ideally you want to take sufficient overlapping images so that a single key point can be identified in 4 or 5 different images [7].

![Figure 2. Orientation and camera properties][3]

2.3. Global Mapper
Global Mapper is the go-to application for filtering point cloud data to create accurate, bare-earth Digital Terrain Models (DTM). These DTM allow the criteria to generate customized contour lines that can be exported in shape file or virtually any other vector format. Global Mapper’s powerful cut and fill analysis capability and volumetric calculation tools are used to precisely measure volumes, providing Drone Mapper’s clients in a variety of industries with site-specific intelligence that is essential for efficient project management as highlighted in [8].

2.4. As-Built survey
Most, if not all, construction contracts require the contractor to produce as-built drawings. However, slight information is found in industry literature about as-built and the as-built survey process. In addition, the work scope often changes over the course of the construction project. Beyond executing the change in the field, changes need to be documented to show what was actually constructed. Hence, the owner usually requires a final record to show all changes or, more specifically, any change that modifies the tangible portions of the completed work. The end product of this effort is what the industry terms as-built drawings, or more simply, “as built” [9].

3. Methodology
The method of the study starts with the site preparation and planning that include site review of UTHM Pagoh Campus and training sessions of UAV as in Figure 3.

Site review acknowledges the situations and positions of each buildings on the campus. Training Session divided into two (2) stages which were before and during the flight. Before flights are the planning and preparation which acquire with the planning area of flight and training session under supervision. This is involved with the flight direction that is planned to start from the Share Facilities parking and proceed to the main gate of UTHM Pagoh Campus as shown in Figure 4. While during flights are the images collecting that obtained the capturing images of UAV and checking for any defective of the pictures. The smartphone or any devices such as tab must be connected to the controller of UAV before activating the DJI Go or Pix4DCapture as Figure 5.

Site preparation and planning
i) Site review
ii) Training session

Data collection

Images processing
i) Pix4D

Analysis of data

Conclusion and recommendations

Figure 3. The Methodology Flow Chart

Figure 4. UAV flight direction from the Share Facilities parking to the main gate of UTHM Pagoh Campus

Figure 5. The controller is ensured to be connected with the smartphone and the UAV.
During the process of collecting images as shown in Figure 6, the flight of UAV must be under the observations of the pilot and the pilot must aware of any flight failure. This is also to facilitate communication for keeping a safe distance from the wall structure of building even though with anti-collision. The weather must be suitable for the flight of UAV to be fly and the most suitable time preferred to be is in the morning with adequate exposure.

Figure 6. The positions of the pilot while fly the UAV.

3.1. Images processing

Images processing was comprised of Pix4Dmapper and Global Mapper software. The stages of the image processing of Pix4Dmapper is:

1) Images from UAV are downloading to the Pix4dMapper software. Transfer all the images that have been taken from the UAV flight from study area by using the USB cable to Windows XP computer that is obtained at Geomatic Laboratory UTHM Pagoh Campus.
2) The images need to be run in three (3) stages of processes which is Initial Processing, Point Cloud and DSM, lastly Orthomosaic and Index.
3) Next, proceed the images processing by clicking on the processing tabs and click tick on the initial processing which is the first process and unclicks the second and third processing as shown in Figure 7. Let the images being sort out and the time necessary to finish the first process are about 40 minutes.
4) Unclick the initial processing and click on the start button to lead the images processing as shown in Figure 8.

Figure 7. Initial Processing of the images
Figure 8. Point Cloud and DSM, Orthomosaic and Index images processing

Completed with Pix4Dmapper, then proceed to the Global Mapper. This data is compulsory for the analysis purposes to gain the information for the accuracy of the dimensions of the UAV flight images processing with the purpose drawing plan of the UTHM Pagoh Campus. Used the data that obtained from Pix4Dmapper and transfer the file into the Global Mapper tool, it takes photos with overlapping coverage and generates a 3D point cloud output using photogrammetry methods of Structure from Motion (SFM). This technique uses overlapping photographs to derive the three-dimensional structure of the landscape and objects on it, producing a 3D point cloud images as shown in Figure 9.

For UAV-collected data, one of the most powerful and commonly used terrain-based functions is volume calculation. Global Mapper offers a variety of tools for this purpose from simple measuring the components in the UAV flight. As for this study, road, basketball court and certain building were measured to define the comparisons between purposes drawing plan with the actual build on the site. The terrain analysis that will be used are Digital Terrain Model (DTM) and Digital Surface Model (DSM).

4. Results and Discussions

All the images captured from the UAV flight require to process with using the application of Pix4Dmapper to produce the product of photogrammetry orthomosaic images. From the products that has been processed from the application Pix4Dmapper and Global Mapper, information such as the data of the area and the measurement of the component in UTHM Pagoh Campus are obtained.

4.1. Images processing

Getting the photo from the air with using Unmanned Aerial Vehicle (UAV) as the primary medium for this study to produce information of comparisons between the proposed drawing of UTHM Pagoh Campus with the images that obtained from the flight of. Each photo from the air that is produced is having the quality of 12 Megapixel and already adjusted with the flight of UAV with 100m altitudes from the ground with ground control point that is already
allocated to make sure that each of the UAV photo completed with attitude coordinate of longitude and latitude. Each UAV photo needs to be processed by using the application of Pix4Dmapper to produce a complete orthomosaic images that meet the requirements for mapping purposes. Figure 10 shows the result of complete orthomosaic images of UTHM Pagoh Campus with the detail of the images.

Figure 10. Orthomosaic images of UTHM Pagoh Campus

4.2. Proposed drawing of study area
With the aid of AutoCAD in gaining the data about the study area before constructed is intended to obtain the accurate data of dimensions and measurements to be compared with the orthomosaic. The data analysis process in the application of AutoCAD is done with by open up the purpose drawing plan as shown in Figure 11 that is acquired and make an analysis measurement by undertaking the dimensions part.

Figure 11. Proposed drawing of UTHM Pagoh Campus

4.3. Measurement Analysis
Using the data that has been generated from the Pix4Dmapper and transfer to the Global Mapper, the mosaic images will be used to determine the comparisons of measurements between what actually built on site instead what has been proposed before constructed of UTHM Pagoh Campus. The measurement analysis was divided into four parts which were road measurement, basketball court measurement, building measurement and non-existent facilities.
4.3.1. Road measurement. Based on Table 2, it shows that Road 1, locations on Block G are having the most accurate data for road measurement. The differences are ±0.002m between global mapper and as-built. This is proved that data from the UAV images can be used for as-built survey mapping.

| Feature Name | Location | AutoCAD | Global Mapper | As-Built | Differences Global Mapper vs As-Built |
|--------------|----------|---------|---------------|----------|--------------------------------------|
| Road 1       | Block G  | 7.327m  | 6.728m        | 6.730m   | ±0.002m                              |
| Road 2       | Block B  | 7.300m  | 6.665m        | 6.700m   | ±0.035m                              |
| Road 3       | Block A1 | 8.707m  | 8.614m        | 8.650m   | ±0.036m                              |
| Road 4       | Block A1 | 4.000m  | 3.986m        | 3.950m   | ±0.036m                              |
| Road 5       | Block A1 | 4.000m  | 3.954m        | 3.970m   | ±0.016m                              |

4.3.2. Basketball court measurement. Based on Table 4, it can be said that the width of the basketball court, locations on Block B are having the most accurate data for basketball court measurement. The differences are ±0.033m between global mapper and as-built. This is proved that data from the UAV images can be used for as-built survey mapping.

| Types of Component | Proposed Drawing (AutoCAD) | Orthomosaic (Global Mapper) | As-Built |
|--------------------|-----------------------------|----------------------------|----------|
| Road 1 (Block G)   | ![Road 1 (Block G)]         | ![Orthomosaic (Global Mapper)] | ![As-Built] |
| Road 2 (Block B turn) | ![Road 2 (Block B turn)] | ![Orthomosaic (Global Mapper)] | ![As-Built] |
| Road 3 (Block A1) | ![Road 3 (Block A1)] | ![Orthomosaic (Global Mapper)] | ![As-Built] |
| Road 4 & 5 (Block A1) | ![Road 4 & 5 (Block A1)] | ![Orthomosaic (Global Mapper)] | ![As-Built] |
Table 4. The measurement data

| Feature Name                  | Location | AutoCAD  | Global Mapper | As-Built | Differences Global Mapper vs As-Built |
|------------------------------|----------|----------|---------------|----------|---------------------------------------|
| Length of the basketball court | Block B  | 34 m     | 36.379 m      | 36.3 m   | ±0.079 m                              |
| Width of the basketball court | Block B  | 19 m     | 21.12 m       | 21.45 m  | ±0.033 m                              |

Table 5. The images of proposed drawing, orthomosaic and as-built

| Types of Component | Purpose Drawing (AutoCAD) | Orthomosaic (Global Mapper) | As-Built |
|-------------------|---------------------------|-----------------------------|----------|
| Length and width of the court (Block B) | ![Image](image1.jpg) | ![Image](image2.jpg) | ![Image](image3.jpg) |

4.3.3. Building measurement. Based on Table 6, it clearly shows that Building 1, locations on PBL are having slightly common data for building measurement. The differences are ±0.050m between global mapper and proposed drawing. It is proved that data from the UAV images can be used for as-built survey mapping.

Table 6. The measurement data

| Feature Name | Location | AutoCAD  | Global Mapper | Differences between AutoCAD and Global Mapper |
|--------------|----------|----------|---------------|-----------------------------------------------|
| Building 1   | PBL      | 36.657m  | 36.707mm      | ±0.050m                                       |

Table 7. The images of proposed drawing, orthomosaic and as-built

| Types of Component | Purpose Drawing Plan (AutoCAD) | Orthomosaic (Global Mapper) |
|-------------------|--------------------------------|------------------------------|
| PBL               | ![Image](image4.jpg)            | ![Image](image5.jpg)         |

4.4. on-existent facilities

After the processing images completed, the comparisons were made with the purpose plan drawing of UTHM Pagoh Campus. There are non-existent facilities that are being caught by the UAV.

Table 8. The images of proposed drawing, orthomosaic and as-built

| Types of Component | Purpose Drawing Plan (AutoCAD) | Orthomosaic (Global Mapper) |
|-------------------|--------------------------------|------------------------------|
| Block B           | ![Image](image6.jpg)            | ![Image](image7.jpg)         |
4.5. UAV characteristics ability in as-built mapping

From the data that have been processed until obtained the measurements’ analysis of UTHM Pagoh Campus with the proposed drawing plan and the as-built orthomosaic images, this is proved that the ability of the UAV in production of as-built survey mapping can be achieved and it also ease the as-built survey work. Table 9 shows the characteristics ability of the UAV that is used to accomplish this study.

| Characteristics | Ability/Capability Limit |
|-----------------|--------------------------|
| i. Flight Duration | 10 until 15 minutes each flight |
| ii. Altitude     | Maximum until 500m from ground level |
| iii. Camera Quality | 12 Megapixel picture as well as 2.7K resolution Video |

Based on this study, the used of UAV are very suitable because of the characteristics ability as state above meets the requirement throughout the processing data at the field. With the use of UAV can reduce the time consumption to gather all the data and required information needed for this study.

5. Conclusion

Based on the analysis of this study, the completion of as-built survey mapping at UTHM Pagoh Campus with using UAV can provide a several results which can be applied for a more detailed study on the ability of the mapping in UTHM Pagoh Campus, especially in as-built survey area. The outputs that resulted from the process analysis such as a file of Pix4Dmapper, orthomosaic images of UTHM Pagoh Campus, complete proposed drawing plan and the details as well as UTHM Pagoh Campus site layout plan elevation that can be accommodated.

From the result of the analysis, it can be applied for different purposes of work and more detailed depending on the job requirements. For instance, the Pix4Dmapper file and the orthomosaic images that resulting from this study can be used to form an actual 3 dimensions images with precise surface rate including the locations of infrastructures or even the gradient on some surfaces. Also, the resulting files from the application of Pix4Dmapper can be used as the propose image to be update on certain area in the Google Earth. If viewed in the Google Earth nearby the UTHM Pagoh Campus, show that there is still no road pavement.

From the analysis of this study, it is proved that the method choose which is UAV for the as-built survey mapping are convenient with the purpose of this study. There are various benefit using this method compared to the existing method. The choosing of UAV methods for mapping devices purpose is a wise selection because it gives benefits to any party. Especially in terms of less manpower needed, a cheaper cost as well as saving more time on the research site. Furthermore, it is suitable for the latest technology needs.

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