International Journal of Civil Engineering and Geo-Environmental

BUILDING INVENTORY FOR SEISMIC RISK ASSESSMENT USING UNMANNED AERIAL VEHICLE

M. N. A. Alel[1]*, E. T. Mohamad[1], R. A. Abdullah[1], M. M. A. Rahman[1], M. A. A. Kadir[2], M. Z. Ramli [2]

[1] Department of Geotechnics and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia
[2] Department of Structures and Materials, Faculty of Civil Engineering, Universiti Teknologi Malaysia

A R T I C L E   I N F O

A B S T R A C T

Keywords:

Unmanned Aerial Vehicles
Rapid Visual Screening
Seismic Risk Assessment

The concept of applying Unmanned Aerial Vehicles (UAV) with proper cameras in acquiring imagery data had been implied for many research and industry purposes in the recent years. This paper shows that the concept of using UAV and camera as a method of data collection of building inventory for seismic risk assessment. It is a part of the method of Rapid Visual Screening (RVS) survey in order to obtain the building inventory that includes the dimensions of building. The UAV used for this project is a high technology hexacopter that flies autonomously in order to obtain a constant data. The camera in the other hand is a high resolution digital compact camera with a Global Positioning System (GPS) built-in the camera for a more precise and accurate data collection of aerial images. The images then will be properly altered which the data acquisition will be used for analysis in a computer software. The case study for this research are buildings in the area of Universiti Teknologi Malaysia (UTM), Johor. The flexibility, safety, eases of operation, and relatively low-cost of ownership and operation make possible of UAV and digital compact camera to be implemented in data collection of building inventory for seismic risk assessment.

1. Introduction

The technology of Unmanned Aerial Vehicles (UAV) was first attempt in 1910's where scientists during the era build this remote-controlled aerial vehicle in order to make them applicable to the World War. Since then, the technology of UAV had been widely improved and modified to be used widely for civil applications.

The latest UAV now were equipped with remote sensing instrumentation offering new kind of way in operating the vehicle while airborne (Adams et al., 2011). Ingenious computer chips that were install into the device makes it easier to be controlled for hovering, landing and flying. The systems now also are equipped with GPS controller that are linked to the satellites which will help the device to be more precise during airborne and also computer software that offer flight planning for the UAV which in the other hand came with an autonomous flight where the vehicle moves itself in according to the path routed by user. These technologies make it easier and reliable to perform the imagery collection.

In aerial photography in order to achieve a high performance of photogrammetry it is important that the data to have the smallest value of ground resolutions (cm/pixels) for the analysis application by using computer software to give a more reliable result. With the high market and new productions of reliable compact cameras that gives great photo quality, it is more applicable to use a small yet affordable high

_____
*Corresponding author. Tel:607-5531533; Fax: 607-5566157
*Email address: alel@utm.my

resolution compact digital camera in obtaining the aerial photos. These cameras are way lesser weight than the ancient digital camera which it helps in having a more reasonable operation. The camera itself has a built-in GPS which gives coordination and altitude data. These data will be useful later for the analysis level.

Although there are other methods of obtaining aerial photos for photogrammetry analysis such are by using satellites or large format aerial camera or commonly known as metric camera but consideration needs to be taken in applying these methods where it is a high cost and least appropriable to be applied in this particular research area (Ahmad, 2011). In the other hand, these methods of obtaining aerial photographs are not time consuming. For that reason, the method of applying close-range photogrammetry with the help of UAV is most suitable method as it is more cost effective and appropriate in this study. Besides, the application of close-range photogrammetry also had been proven to be effective in producing excellent result which had been used widely previously for various applications from archaeology, monitoring issues, disaster evaluation, etc. (Stylianidis et al., 2003).

2. Earthquake Engineering

The South Peninsular Malaysia is located close to the Sumatran faults at which the faults are caused by the tectonic movements of the earth crust. This tectonic movement generate a very high annual rate of earthquake which the tremor effects the South Peninsular Malaysia where the distance between South Peninsular Malaysia is roughly around 300km to the Sumatera Island (Peterson et al., 2004). Buildings in Peninsular Malaysia that are foundationally base to soft soil often will felt the tremor due to large earthquake from the Sumatra. The seismic waves, generated from an earthquake in Sumatra travel long distance before they reach the South Peninsular Malaysia bedrock. The high frequency earthquake waves damped out rapidly in the propagation while the low frequency waves are more robust to energy dissipation and as result they travel long distance (Balendra, 2008).

Having to know that Malaysia is now prone to receive seismic waves from the neighbouring region, the country has realized that seismic hazard in the country is real and having a high probability that it will be a threat to the public safety and also causes damage to the properties. Come to fact to know that only less than one percent of buildings in Malaysia are seismic resistant (Sooria et al., 2008). Since then, the government had started to begin study research and assessments on the buildings in Malaysia that are prone to be a seismic risk during a strong earthquake occurrence. There are few

methods on doing assessment of seismic risk that are previously perform which there is involvement in developing macro zonation map for two hazard level using statistic theory of extreme values from Adnan (2012), ground failure assessment, structural dynamic analysis and assessment for system component damage.

In this study, seismic risk assessment is done in a form of performing UAV with a digital compact camera to determine the building inventory of buildings. Unmanned aerial vehicles (UAVs) equipped with remote sensing instrumentation offer numerous opportunities in disaster related situations (Adams et al., 2011). These UAVs previously was used by the military and leisure but now are more towards the application in helping Research & Development (R&D) of studies (Jamaludin, 2009). UAV with a proper camera resolution can be used for the purpose of aerial photography. Demand on performing aerial photography has increased especially after development of design, research and production of UAV platform. Photogrammetry is classified as an art, science and technology process in order to acquire information about features on earth surface (Tahar et al., 2011). To control or piloting the UAV is not an easy task as a proper or professional operator must be needed together to solve any technical problems on UAV during flight operation on field (Sidek, 2008).

3. Rapid Visual Screening (RVS)

As we can say, urban areas in Malaysia such as Kuala Lumpur and Johor Bahru are pact with the rising of tall buildings and structures which are meant for the usage of commercial and industrialized usage. As discussed above, where some areas in the Peninsular of Malaysia are affected with the tremor, there will be a need in having an express evaluation so that it will act as an essential comprehension on buildings that are affected. So it is needed for the local authority or even the private sector to have a rapid assessment in order to observe the building for its safety. The next step that can be taken will be the detailed assessment on the risk that may occur during for the time a tremor hit a certain urban area will not cause into resulting with failure of structures or to be harmful to the population or resident around it.

Rapid Visual Screening is developed as a preliminary step in assessing risk management in order to identify the safety of the buildings whether it is safe to be operate or not (FEMA, 1994). RVS include building inspection interior or exterior where the screener details every data by only with visual inspection which will be filed in a Data Collection Form.

Figure 1: A RVS Data Collection Form

Figure 2: Leica Disto A5.

This activity is done without the need of any calculation but later to be analyzing together with computer software such as GIS as to retain the result. With the result obtained from the analysis, the building can be further observed whether it is needed to have a further evaluation on the seismic vulnerability. Besides that developers also could plan for post-earthquake safety evaluation in order to enhance the capability of the community surround (Sinha et al., 2004). Figure 1 show an example of a RVS Data Collection Form.

4. Data Acquisition, Processing, and Analysis

4.1 Case Study

The case studies for this research study were picked among the buildings in the compound area of Universiti Teknologi Malaysia, Johor. In order to achieve a more effective result, different types of building are chosen in order to have varies result data in making this research study more efficient. Before performing the UAV procedure in data collection, a site investigation is done in order to obtain the actual dimensions of the buildings involved as the case study. The operation of measuring the dimensions was done with a Leica Disto A5 distance measuring tool which has a laser rangefinder tool in order get the dimensions. Figure 2 shows the Leica Disto A5.

After analysing and performing brief study, 3 buildings are chosen as the case study of this study in order to comply with the objectives. The case studies that are chosen are from different dimensions and purposes. The first case study is Case Study 1 as shown in Figure 3 which is a building block M40 of Tun Dr. Ismail College. The building is a two-stories building that are used as an office for the "Pertubuhan Juruukur Diraja Malaysia" for the Johor region.

The following case study is Case Study 2 which is a 7-stories tall building as shown in Figure 4. The building is located at Dato' Onn Jaafar College which it is the student residential apartment College 16 block XC A.

The final case study is Case Study 3 which is shown as Figure 5 which is the staff's houses near the Tun Razak College. Four blocks of houses are captured as the case study. The houses are one-story. Table 1 shows the on-site measured dimensions of the case study buildings.

Table 1: Table shows the dimension of case study buildings.

Dimension	Case Study Buildings		
	1	**2**	**3**
Height (m)	6.196	24.152	3.655
Width (m)	12.15	45.901	8.065
Length (m)	17.501	75.371	12.578

Figure 3: Case Study 1 - Building Block M40

Figure 4: Case Study 2 - Student Residential Apartment

Figure 5: Case Study 3 - Staff's Houses

4.2 Agisoft Lens Calibration

In this research study, the camera used is the Canon SX260 HS which is a compact digital camera and lens calibration software used is the Agisoft Lens which is a powerful and user friendly software.

4.2.1 Upload Picture

A complete of 9 pictures which the target is the checkerboard prepared by the software was taken from different sides and angles in order to have different angles of the pinhole-lens. Next step, uploaded pictures must be check thoroughly so that there are no blurry pictures as blurry pictures will not give accurate results. The focal length of the camera is also shown in the data the pictures uploaded.

4.2.2 Calibrate

The next step is to run the calibration and choose the intended calibration parameters that needed to be calibrated. The calibration will not take a lot of time to run. After running the calibration, pictures that have been calibrated can be observed to see the calibrated lines and marks.

4.2.3 Calibration Result

Once calibration had completed, a full report on the calibrated parameters needed are shown in values as shown in Table 2. The values of the calibrated parameters are then to be inserted to the 3D Modelling software for it to calibrate the aerial photographs.

As mention in previous chapter, the computer software that is used for performing the 3D Model Reconstruction is Agisoft Photoscan Professional Edition. The software is used widely for industry and research level for studying data which are from aerial images and 3D modelling images. In this study, 3D modelling construction is not an interest as it is not a needed data for the RVS method. This study is more focused on the aerial model for acquiring the building inventory. The product of this software is the capability of the software to produce orthophoto, DEM, Model and print out details on the result of the stitched photos.

4.3 Analysis Procedure

4.3.1 Photoscan Settings

Before operating the analysis on the software, settings of the software were set to the proper settings in order to achieve a good result of orthophoto and DEM generation. The settings can be adjust at the 'Preferences' tab. The first setting that need to be adjust is the Stereoscopic Mode to be disabled and keep the Compression Level of Project Files to value 6. Writing log to files also must be set in order to achieve the whole project log.

Table 2: Table shows the parameters of case study buildings.

PARAMETERS	VALUE	STD ERROR	PARAMETERS	VALUE	STD ERROR
IMAGE WIDTH	4000	-	Radial K1	-0.03419	0.004515
IMAGE HEIGHT	3000	-	Radial K2	0.132824	0.027271
FOCAL LENGTH (X)	2980.41	2.90262	Radial K3	-0.34641	0.064346
FOCAL LENGTH (Y)	2978.19	2.92512	Radial K4	0.272514	0.0026425
PRINCIPAL POINT (X)	2057.33	1.82547	Tangential P1	-0.00192	0.0001108
PRINCIPAL POINT (Y)	1488.86	1.38183	Tangential P2	0.004103	0.0001499

4.3.2 Adding Photos

Aerial images are taken from UAV and digital camera with proper planning of flight and setting of camera. Data collected are then transferred into Agisoft Photoscan with the 'Add Photos' button in the software. When images are uploaded to the software, camera calibration is done. Images added into the software then must be checked in order to cancel out any images that are blurry and not related to the project.

The advantage of using a GPS built-in digital camera, the aerial images taken from UAV are geo-tagged at which the longitude, latitude and the altitude are included. If not using a GPS built-in camera, the coordinates can be inserted manually with an external file.

4.3.3 Aligning Photos

The next step is to align the photos. This can be done at the 'Workflow' tab and set Align Photo. The accuracy must be set to high in order to have a detail result and pair selection to Ground Control this project involve the aerial imaging. In this stage, the software refines the camera position for every photo and builds the sparse cloud model.

In order to achieve a higher accuracy of photo alignment, photo optimization is done once the photo alignment analysis is done. Photo optimization calculates the internal and external parameter in order to correct any distortion.

4.3.4 Building Geometry

Building geometry is the important part in this software operation for the production 3D Model of the images. Before building geometry, the sparse cloud model must be first analyse into building the dense cloud model where the model must build with high quality. This is important in giving a more proper orthophoto of aerial photos. After setting the bounding box and crop any unwanted cloud, geometry is build.

After completed building the geometry and a 3D model is produced, control points at each aerial photo must be determined. Control points are mark as markers and a total of at least 8 markers must be set. After setting the markers and run the optimization, build the geometry again in order to obtain a more precise 3D Model.

4.3.5 Building Texture

The final step in this software is to build the model into a more interpretable photo. The model is textured in according to the aerial photos in order to build a more accurate orthophoto. Building the texture is done by running it from the 'Workflow' tab button.

5. Results and Discussion

After completed all the procedure, results from the analysis can be printed out in order to perform a more detailed study and apply the result for objective purposes as shown in Figures 7, 8 and 9. Project must be first save into hard drive in order to observe for future work. Results that can be printed out are Model where the 3D model that is reconstructed can be exported and used. The second result is Orthophoto where the data can be printed out as and JPEG image file or Google KMZ file in which the orthophoto can be mapped into Google Earth Pro. Orthophoto is important as it give the plan image of the buildings. The third result is DEM where the result can be printed in planar view from any direction that is desire. The final result that can be printed is the whole Report which result includes the date of generating the report, Orthophoto, Survey Data, Camera Position and Digital Elevation Model.

Table 4: Dimensions Results

Dimensions	Analysis result
Height (m)	7.188
Width (m)	11.719
Length (m)	16.716

Figure 7: Orthophoto / Plan View

Table 5: Dimensions Results

Dimensions	Analysis Result
Height (m)	36.512
Width (m)	45.275
Length (m)	74.1507

Figure 8: Orthophoto / Plan View

Table 6: Dimensions Results

Dimensions	Analysis result
Height (m)	2.843
Width (m)	8.159
Length (m)	12.880

Figure 9: Orthophoto / Plan View

6. Conclusion

Generally, this study is to develop a solution in RVS method of acquiring the building inventory and the plan of the building in completing the RVS Data Collection Form for the seismic risk assessment by using the application of UAV and digital camera. This is a solution for the conventional way which was done with the sidewalk survey method. Therefore it is important for this study to be done.

Based on the result obtained from performing the method of UAV and the analysis of Agisoft Photoscan in obtaining the building inventory, the conclusions of the study were summarized.

a) The aerial images of buildings can be obtained while flying the UAV.
b) With using Agisoft Photoscan, the orthophoto can be developed.
c) Managed to obtain the dimensions of the case study buildings.

References

Adams, S. M., & Friedland, C. J. (2011). A Survey of Unmanned Aerial Vehicle (UAV) Usage for Imagery Collection in Disaster Research and Management. Paper presented at the Proceedings of the Ninth International Workshop on Remote Sensing for Disaster Response, Stanford, CA, USA.

Adnan, A., Shoushtari, A.V. (2012). Parametric study of seismic hazard assessment of Peninsular Malaysia.

Ahmad, A. (2011). Digital Mapping Using Low Altitude UAV. Pertanika Journal of Science and Technology, 19.

Balendra, T., & Li, Z. (2008). Seismic hazard of Singapore and Malaysia. Electron J Struct Eng (special issue, Earthquake engineering in the low and moderate seismic regions of Southeast Asia and Australia), 57-63. Building Technology, Inc., Silver Spring, MD.

FEMA (1994). A Guidebook to FEMA 154: Rapid Visual Screening of Buildings for Potential Seismic Hazards. A Handbook for Use in the Screening Buildings.Washington, D.C.: ERIC Clearinghouse.

Jamaludin, Z., & Aziz, F. A. (2009). The development of aerial photography application based on aerial image captured from a remote control airplane. International Journal of Management Studies (IJMS), 16(1), 165-184.

Petersen, M. D., Dewey, J., Hartzell, S., Mueller, C., Harmsen, S., Frankel, A., & Rukstales, K. (2004). Probabilistic seismic hazard analysis for Sumatra, Indonesia and across the Southern Malaysian Peninsula. Tectonophysics, 390(1), 141-158.

Sidek, F. K., & Ahmad, A. (2008). Development of mapping procedures using digital imagery derived from unmanned aerial vehicle system.

Sinha, Ravi, and Alok Goyal. (2004) "A national policy for seismic vulnerability assessment of buildings and procedure for rapid visual screening of buildings for potential seismic vulnerability." Report to Disaster Management Division, Ministry of Home Affairs, Government of India, Hindistan.

Sooria, S. Z., Sawada, S., Goto, H. (2008). Proposal for seismic resistant Design in Malaysia: Assessment of possible ground motions in Peninsular Malaysia.

Stylianidis, E., Patias, P., Tsioukas, V., Sechidis, L., & Georgiadis, C. (2003). A Digital Close-range Photogrammetric Technique for Monitoring Slope Displacements. Paper presented at the 11th International Symposium on Deformation Measurements.

Tahar, K. N., Ahmad, A., & Akib, W. A. A. W. M. (2011). Unmanned aerial vehicle technology for low cost landslide mapping. Paper presented at the 11th South East Asian Survey Congress and 13th International Surveyors' Congress, PWTC, Kuala Lumpur.