LANDSLIDE MOVEMENT DETECTION USING UNMANNED AERIAL VEHICLE (UAV) PHOTOGRAMMETRY

HELMI BIN ABD KADIR

UNIVERSITI TEKNOLOGI MALAYSIA

ACKNOWLEDGEMENT

"With the Name of Allah, the Most Gracious and Merciful Creator"

Alhamdulillah, first of all I am grateful of Allah for the guidance and blessing that help me in completing this master project. I would like to extend sincere appreciation and heartfelt gratitude to my supervisor, Assoc. Prof. Dr. Zulkepli Majid for assist, guidance and advice to finish this thesis.

In addition, I would also like to thank all the lecturers and technical staff especially to Mr. Mohd Faizi Mohd Salleh, for helping me with data collection and processing. I would like to thank my friend Muhammad Pauzi Mat Zam, Mr. A'amir Hashim, Mr. Hanipah (GNG Group) and Ms. Nursyahira Ahmad Fuad for helping me directly or indirectly for the discussion. Next, a deep gratitude to my beloved family especially to my wife Mrs. Marlia Marzuki, my loving children, and all my friends for giving me supports and help in my study.

Very special thanks to *Bahagian Biasiswa, Kementerian Pengajian Tinggi* for sponsoring the tuition fee for this Master's program. I am very grateful for the much needed scholarship.

Thank you and may Allah give the best in return.

ABSTRACT

Nowadays, Unmanned Aerial Vehicle (UAV) technology is increasingly widespread in monitoring and tracking landslides. This technology can also produce high-resolution digital surface model (DSM), digital elevation model (DEM) and orthophoto which can help researchers in detecting land surface change, especially in small areas. In this study, the research methodology was designed by comparing two observation data with different flight altitudes of 50 and 60 meters. The main purpose of this study was to assess the accuracy of the registration method between Match Bounding-box Centers (MBBC) and Iterative Closet Point (ICP). For the first observation data, the data was retrieved in July 2018 while for the second observation data in November 2018. During the data collection process, DJI Phantom 4 with high-resolution camera was used to take images according to predetermined flight planning. Registration process and georeferencing have been implemented using Pix4D software while point cloud comparison has been implemented using CloudCompare software. The Global Navigation Satellite System (GNSS) observation methodology has been implemented for the preparation of ground control points (GCPs) and check points (CPs). Image quality has been proven by comparing check points with GNSS observation method. Based on the results obtained, the RMSE for both observation data ranges from 0.017 meters to 0.040 meters. The results of the registration method show that ICP registration method is better than MBBC registration method in detecting land movement. In fact, flight altitude also plays an important role in assessing accuracy of point cloud. In overall, UAV platform and ICP method is the best option to detect landslide movement in short time and save cost.

ABSTRAK

Pada masa kini, teknologi penggunaan Pesawat Tanpa Pemandu (UAV) menjadi semakin meluas dalam pemantauan dan mengesan pergerakan tanah runtuh. Teknologi ini juga dapat menghasilkan model permukaan digital resolusi tinggi (*DSM*), model ketinggian digital (*DEM*) dan juga *orthophoto* yang mana boleh membantu penyelidik dalam mengesan perubahan permukaan tanah terutama di kawasan keluasan yang kecil. Di dalam kajian ini, metodologi kajian telah direka dengan membandingkan dua data cerapan dengan ketinggian penerbangan yang berbeza iaitu 50 dan 60 meter. Tujuan utama kajian ini dijalankan adalah untuk menilai ketepatan kaedah pendaftaran diantara *Match Bounding-box Centres (MBBC)* dan *Iterative Closet Point (ICP)*. Bagi data cerapan yang pertama, data telah diambil pada Julai 2018 manakala bagi data cerapan kedua pada November 2018. Semasa proses kutipan data, *DJI Phantom 4* yang dilengkapi dengan kamera beresolusi tinggi telah digunakan untuk mengambil imej mengikut perancangan penerbangan yang telah ditetapkan. Proses pendaftaran dan *georeferencing* telah dilaksanakan dengan menggunakan perisian *Pix4D* manakala perbandingan *point cloud* telah dilaksanakan dengan menggunakan perisian *CloudCompare*. Kaedah cerapan *Global Navigation Satellite System (GNSS)* telah dilaksanakan bagi penyediaan titik-titik kawalan daratan (*GCPs*) dan titik-titik semakan (*CPs*). Kualiti imej telah dibuktikan dengan membandingkan titik-titik semakan dengan kaedah cerapan *GNSS*. Berdasarkan daripada keputusan yang diperolehi, RMSE bagi kedua-dua data cerapan adalah diantara 0.017 meter hingga 0.040 meter. Keputusan bagi kaedah pendaftaran menunjukkan kaedah pendaftaran *ICP* adalah lebih baik daripada kaedah pendaftaran *MBBC* dalam mengesan pergerakan tanah. Malah, ketinggian penerbangan juga memainkan peranan yang penting dalam menilai ketepatan *point cloud.* Keseluruhannya, menunjukkan bahawa *UAV platform* dan kaedah *ICP* adalah pilihan yang terbaik untuk mengesan pergerakan tanah runtuh dalam masa yang singkat dan jimat kos.

TABLE OF CONTENTS

TITLE		PAGE
DECLARATION		**iii**
DEDICATION		**iv**
ACKNOWLEDGEMENT		**v**
ABSTRACT		**vi**
ABSTRAK		**vii**
TABLE OF CONTENTS		**6**
LIST OF TABLES		**9**
LIST OF FIGURES		**11**
LIST OF ABBREVIATIONS		**14**
LIST OF APPENDICES		**15**
CHAPTER 1	**INTRODUCTION**	**1**
1.1	Background	1
1.3	Problem Statment	2
1.4	Aim	3
1.4	Research Objectives	3
1.5	Research Scope	3
1.6	Significance of Study	5
1.7	Outline of The Thesis	5
CHAPTER 2	**LITERATURE REVIEW**	**7**
2.1	Introduction	7
2.2	Introduction to Landslide	7
2.3	Landslide in Malaysia	8
2.4	Unmanned Aerial Vehicle (UAV)	9
2.5	Changed Detection of Point Cloud	11

CHAPTER 3 RESEARCH METHODOLOGY 13

3.1 Introduction 13

3.2 Research Methodology 13

3.3 Preliminary Study 15

3.4 Data Acquisition 15

3.4.1 UAV Image Acquisition 17

3.4.2 GNSS Observation 20

3.5 Data Processing 23

3.5.1 Image Processing Using Pix4Dmapper Software 24

3.5.1.1 Registration and Georeferencing of Multiple 25

3.5.2 Dense Point Cloud Reconstruction 26

3.5.3 Point Cloud Filtering 26

3.5.3.1 MicroStation Filtering 28

3.5.3.2 Noise Filtering Using CloudCompare Software 29

3.5.4 Point Cloud Processing Using CloudCompare Software 30

3.6 Summary 32

CHAPTER 4 RESULT AND ANALYSIS 33

4.1 Introduction 33

4.2 UAV Image Validation 33

4.2.1 Evaluation of Control Points 33

4.2.2 Accuracy Assessment of Check Points Based on UAV Image Products 36

4.3 Point Cloud Analysis Using CloudCompare Software 42

4.3.1 Result of Point Cloud Registration Using MBBC 45

4.3.2 Result of Point Cloud Registration Using ICP 47

4.3.3 Result of 3D Surface Deviation Analysis 49
4.4 Accuracy Assessment of C2C Distance Between MBBC and ICP Registration Method 53

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS 57
5.1 Introduction 57
5.2 Conclusion 57
5.3 Recommendations 58

REFERENCES 60

APPENDICES A – E 63 - 91

LIST OF TABLES

TABLE NO.	TITLE	PAGE
Table 2.1	Classification of landslide types (Source: Varnes, 1978)	8
Table 2.2	The advantages and disadvantages of multi-rotor and fix-wing UAV	10
Table 3.1	The specification of DJI Phantom 4	18
Table 3.2	The example of parameters of flight planning according to 1st epoch and 2nd epoch	19
Table 3.3	Corrected height using MyGeoid	23
Table 3.4	The differences of coordinate at each station between both epochs	23
Table 3.5	Selected parameters for the filtering process using ground routine filter	28
Table 3.6	The chronology of the total points of UAV point cloud data processing tasks	30
Table 4.1	The accuracy of GCPs and Root Mean Square Error (RMSE) in the three coordinate directions (Easting (x), Northing (y) and Height (z)) of registration and georeferencing processed calculated by Pix4D software	34
Table 4.2	Comparison coordinate between UAV image generated by Pix4D software and GNSS method for epoch 1 (50 meter)	39
Table 4.3	Comparison coordinate between UAV image generated by Pix4D software and GNSS method for epoch 2 (50 meter)	39
Table 4.4	Comparison coordinate between UAV image generated by Pix4D software and GNSS method for epoch 1 (60 meter)	40
Table 4.5	Comparison coordinate between UAV image generated by Pix4D software and GNSS method for epoch 2 (60 meter)	40
Table 4.6	The parameters of calculated point clouds for 50 meter altitudes	44
Table 4.7	The parameters of calculated point clouds for 60 meter altitudes	45
Table 4.8	The computed values of distance from C2C distance method for MBBC registration method	50

Table 4.9 The computed values of distance from C2C distance method for ICP registration method 51

Table 5.0 The standard deviation, average and RMSE values between MBBC and ICP methods 55

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
Figure 1.1	The study area is at the residential area KTC Kulim, Kedah	4
Figure 2.1	A simple illustrate of a rotational landslide that has evolved into an earthflow (Varnes, 1978)	7
Figure 2.2	The accuracy of measurement methods in relation to the object area or size	11
Figure 3.1	Research methodology flowchart	14
Figure 3.2	Location of GCPs and CPs	16
Figure 3.3	Camera calibration using DJI Assisstant 2	17
Figure 3.4	The example of observation station establish (GCPs)	20
Figure 3.5	Topcon Hyper V GNSS receiver	21
Figure 3.6	The example of post processed by using Topcon Tools software	21
Figure 3.7	The example of final coordinates after post processing using Topcon Tools software	22
Figure 3.8	The example illustration of RTK observation with GCP03 as a base station for epoch 2	22
Figure 3.9	Three main processing in Pix4Dmapper software	24
Figure 3.10	The 3D point cloud processing steps using Pix4Dmapper software	24
Figure 3.11	An example tie-point processing in Basic GCP/MTP Editor tools	25
Figure 3.12	Before and after registration and georeferencing processing	25
Figure 3.13	An example of dense point cloud reconstructed with camera position	26
Figure 3.14	The 3D cloloured point cloud of 50 meter altitude	27
Figure 3.15	The 3D cloloured point cloud of 60 meter altitude	27
Figure 3.16	Filtered point clouds data	29
Figure 3.17	Before and after of noise filter using CloudCompare software	29

Figure 3.18	MBBC menu	31
Figure 3.19	ICP menu	31
Figure 3.20	The example of result for cloud to cloud distances computation	32
Figure 4.1	The RMSE of epoch 1 and 2 with different altitudes	35
Figure 4.2	The digital orthophoto 50 meter altitude using Pix4D software; a) Epoch 1 and b) Epoch 2	36
Figure 4.3	The digital orthophoto 60 meter altitude using Pix4D software; a) Epoch 1 and b) Epoch 2	37
Figure 4.4	The DEM 50 meter altitude using Pix4D software; a) Epoch 1 and b) Epoch 2	37
Figure 4.5	The DEM 60 meter altitude using Pix4D software; a) Epoch 1 and b) Epoch 2	38
Figure 4.6	An example coordinate value obtain by Global Mapper software	38
Figure 4.7	The differences RMSE coordinate between epoch 1 and epoch 2 for 50 meter altitudes	41
Figure 4.8	The differences RMSE coordinate between epoch 1 and epoch 2 for 60 meter altitudes	42
Figure 4.9	The study area after combination of epoch 1 and epoch 2 with different altitudes (a) 50 meter and (b) 60 meter	43
Figure 4.10	The 4 x 4 transformation matrix as a result from MBBC for epoch 1 and epoch 2 (50 meter)	46
Figure 4.11	The 4 x 4 transformation matrix as a result from MBBC for epoch 1 and epoch 2 (60 meter)	46
Figure 4.12	The result of MBBC – the registered point cloud data for 50 meter	46
Figure 4.13	The result of MBBC – the registered point cloud data for 60 meter	47
Figure 4.14	The 4 x 4 transformation matrix as a result from ICP for epoch 1 and epoch 2 (50 meter)	47
Figure 4.15	The 4 x 4 transformation matrix as a result from ICP for epoch 1 and epoch 2 (60 meter)	48
Figure 4.16	The result for ICP registration method of point cloud data set (50 meter)	48
Figure 4.17	The result for ICP registration method of point cloud dataset (60 meter)	49

Figure 4.18 The C2C result from MBBC registration for 50 meter altitude 50

Figure 4.19 The C2C result from MBBC registration for 60 meter altitude 51

Figure 4.20 The C2C result from ICP registration for 50 meter altitude 52

Figure 4.21 The C2C result from ICP registration for 60 meter altitude 52

Figure 4.22 The comparison analysis between MBBC and ICP registration methods for 50 meter altitudes 53

Figure 4.23 The comparison analysis between MBBC and ICP registration methods for 60 meter altitudes 54

Figure 4.24 The comparison of dataset 50 meter and 60 meter altitude between MBBC and ICP registration methods 55

LIST OF ABBREVIATIONS

3D	-	Three Dimensional
UAV	-	Unmanned Aerial Vehhicle
GPS	-	Global Positioning System
GNSS	-	Global Navigation Satellite System
MBBC	-	Match Bounding-box Centres
ICP	-	Iterative Closet Point
DEM	-	Digital Elevation System
RTK	-	Real Time Kinematic
VTOL	-	Vertical Take-Off and Landing
PSO	-	Particle Swarm Optimization
DEM	-	Digital Elevation Model
GCP	-	Ground Control Point
CP	-	Check Point
C2C	-	Cloud-to-Cloud
m	-	Meter

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix A	Image Processing Step Using Pix4D Software	63
Appendix B	Steps of cropping dataset using Quick Terrain Modeler v8.0.7	77
Appendix C	Steps of Filtering using MicroStation software	79
Appendix D	Noise Filtering using CloudCompare Software (open source)	85
Appendix E	Steps of Registration Method Using CloudCompare Software	87

CHAPTER 1

INTRODUCTION

1.1 Background

Over the last two decades, Malaysia embraces rapid growth in the infrastructure development and building construction. This phenomenon has encouraged development in new areas as well as hillside areas. Consequently, excavation in the hillside areas around the city has resulted in incidences of slopes instability causing numerous landslide tragedies. To keep the landslide prone area from inhabited and to save lives, monitoring of slope has become very important tool as a prevention of the landslide activities. Generally, slope monitoring is carried out before any landslide hazard and risk assessment is performed.

According to Ahmad (2006), the accuracy of measurements, cost and time required to perform these measurements are important considerations when produce landslides mapping. There is no need to achieve sub-centimeter accuracy when monitoring the shallow landslide because the impact is aimed at assessing the overall landslide (Marek, 2015). Due to financial and technical resource constraints, high accuracy measurement requirements cannot be met. Identifying the smallest affected area are important because of small landslides have a high probability to expanding due to heavy rainfall.

Recently advances in digital mapping, navigation systems and software development have made it possible to reconstruct 3D surfaces accurately without using a data acquisition system that is expensive grade mapping. Additionally, advances in mobile mapping systems, such as Unmanned Aerial Vehicle (UAV), have made precise and accurate three dimensional (3D) surface reconstructions for anytime and when needed. When small target areas need to be checked, UAV is a better and cheaper option than other platforms because of its highly mobile UAVs

and dynamic acquisition platform. UAVs have more potential to fly at low altitudes and slow speeds and also to reach areas that are cannot accessible from the ground or by aircraft transported. This system reduces the many limitations and increasing the effectiveness of the landslide mapping.

1.2 Problem Statement

In this era of technology, there are a few methods to produce the landslide mapping such as total station, LiDAR (Light Detection and Ranging), remote sensing, GPS (Global Positioning System) and aerial photogrammetry. However there are several advantages to these methods. The main problem lies in the ability to process clear images of the study area in a smaller time frame.

In Malaysia, the extraction of aerial photogrammetry is widely used to map and monitor the landslide area. This technique is considered to be the easiest and most reliable way to obtain the required area data today. While it is a reliable technique, the process may take a lot of time and cost to take very high with a specific area especially for small coverage areas. To reduce cost and time, alternative techniques need to be met by using UAV as a platform.

Therefore, UAV has become as an ideal tool to serve such a purpose since it offers very high resolution of spatial sampling in 3D measurement. In addition, without contact with the landslide area make it as a helpful observation in landslide assessment.

1.3 Aim

The aim of this study was to assess the efficiency of point cloud registration methods by using Match Bounding-box Centres (MBBC) and Iterative Closet Point (ICP). Thus, to generate three-dimensional (3D) deviation analysis using UAV images.

1.4 Research Objectives

The research objectives are as follows:

(a) To produce digital orthophoto, digital elevation model (DEM) and 3D coloured point cloud from UAV photogrammetry images with different altitudes.

(b) To determine the accuracy of check points using UAV photogrammetric images.

(c) To perform point cloud deviation analysis using MBBC and ICP methods for landslide monitoring task.

1.5 Research Scope

The scope of this study is divided into a several aspects. The aspects included the location of study area, hardware and software, and the technique or methods are used. In the implementation of this study, planning and determination processes are very important. Good procedures will create a good result. Among the steps of work implementation are as follows:

(a) The study area has been conducted at the residential area KTC Kulim, Kulim Hi-Tech Park, Kulim, Kedah (**Figure 1.1**).

(b) The digital images are captured by high resolution digital camera attached at the UAV (DJI Phantom 4).

(c) The ground control points (GCPs) will be established by Global Navigation Satellite System (GNSS) observation. The rapid static and real-time kinematic (RTK) are used.

(d) The software such as Pix4D and CloudCompare were used to process the UAV images and point clouds data respectively of the study area.

(e) The MBBC and ICP methods were used to detect the movement landslide surface.

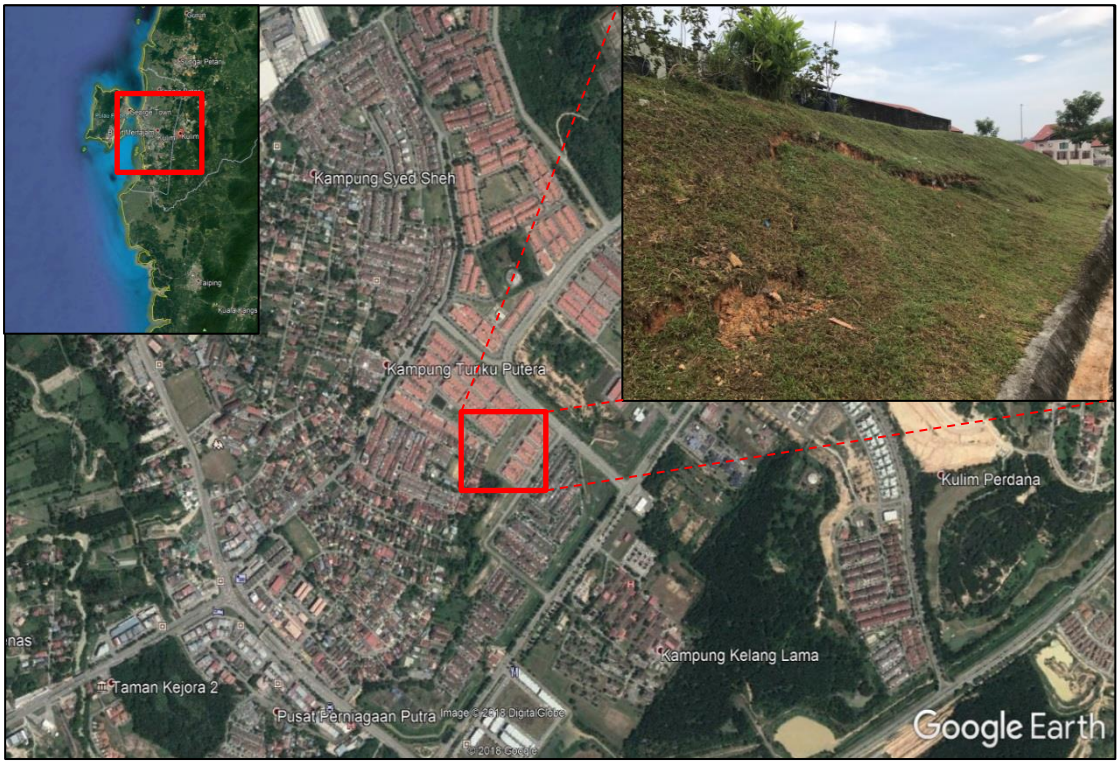

Figure 1.1: The study area is at the residential area KTC Kulim, Kedah

1.6 Significance of Study

Generally, this study can provide benefit to Local Authority of Kulim Hi-Tech, local residents and the faculty. Other benefits of this study that are follows:

(a) Helps researcher or who are experts on disaster management especially on landslide field also knowing about more the potential UAV technology to detect movement surface.
(b) An alternative of low cost technique and tools for landslide monitoring.
(c) For the local residents themselves, their priorities are large-scale education campaign, awareness raising programs and resources in social environmental contexts.

1.7 Outline of The Thesis

This thesis consists of five (5) chapters.

Chapter 1 describes the introduction to the research which includes the background, problem statements, aim, research objectives, and research scopes, significance of study and outline of the thesis.

Chapter 2 covers the literature review which explains the concepts to be applied in this study and the related works based on previous study.

Chapter 3 explains the methodology of this research. This includes the data acquisition, data processing and other important topic related to end production of data.

Chapter 4 discusses the results obtained from this study and some conclusion of the task conducted.

REFERENCES

Ahmad, A. Digital photogrammetry: An experience of processing aerial photograph of UTM acquired using digital camera. In Proceedings of the AsiaGIS, Johor, Malaysia, 3–5 March 2006.

Al-Rawabdeh, A., He, F., Moussa, A., El-Sheimy, N., & Habib, A. (2016). Using an unmanned aerial vehicle-based digital imaging system to derive a 3D point cloud for landslide scarp recognition. *Remote Sensing*, *8*(2), 95.

Besl, P. J., & McKay, N. D. (1992, April). Method for registration of 3-D shapes. In *Sensor Fusion IV: Control Paradigms and Data Structures* (Vol. 1611, pp. 586-607). International Society for Optics and Photonics.

Cruden, D. M. (1991). A simple definition of a landslide. *Bulletin of Engineering Geology and the Environment*, *43*(1), 27-29.

Cho, S., Park, S., Cha, G., & Oh, T. (2018). Development of Image Processing for Crack Detection on Concrete Structures through Terrestrial Laser Scanning Associated with the Octree Structure. *Applied Sciences*, *8*(12), 2373.

Cho, S., Park, S., Cha, G., & Oh, T. (2018). Development of Image Processing for Crack Detection on Concrete Structures through Terrestrial Laser Scanning Associated with the Octree Structure. *Applied Sciences*, *8*(12), 2373.

E. Kleber, E. Nissen, J.R. Arrowsmith (2013). Topographic change detection using CloudCompare version 1.0.

Eisenbeiß, H. (2009). *UAV photogrammetry* (Doctoral dissertation, ETH Zurich).

Fuad, N. A., Yusoff, A. R., Ismail, Z., & Majid, Z. (2018). Comparing the Performance of Point Cloud Registration Methods for Landslide Monitoring Using Mobile Laser Scanning Data. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *4249*, 11-21.

Hungr, O., Evans, S. G., & HUTCHINSON, I. (2001). A Review of the Classification of Landslides of the Flow Type. *Environmental & Engineering Geoscience*, *7*(3), 221-238.

Hollaus, M., Wagner, W., Eberhöfer, C., & Karel, W. (2006). Accuracy of large-scale canopy heights derived from LiDAR data under operational constraints in a complex alpine environment. *ISPRS Journal of Photogrammetry and Remote Sensing*, *60*(5), 323-338.

Kim, Min-Koo, Hoon Sohn, and Chih-Chen Chang. "Localization and quantification of concrete spalling defects using terrestrial laser scanning." *Journal of Computing in Civil Engineering* 29, no. 6 (2014): 04014086.

Liu, S., Gao, D., Wang, P., Guo, X., Xu, J., & Liu, D. X. (2018). A Depth-Based Weighted Point Cloud Registration for Indoor Scene. *Sensors*, *18*(11), 3608.

Marek, L., Miřijovský, J., & Tuček, P. (2015). Monitoring of the shallow landslide using UAV photogrammetry and geodetic measurements. In *Engineering Geology for Society and Territory-Volume 2* (pp. 113-116). Springer, Cham.

Nuttens, T., Stal, C., De Backer, H., Schotte, K., Van Bogaert, P., & De Wulf, A. (2014). Methodology for the ovalization monitoring of newly built circular train tunnels based on laser scanning: Liefkenshoek Rail Link (Belgium). *Automation in construction*, *43*, 1-9.

Peppa, M. V., Mills, J. P., Moore, P., Miller, P. E., & Chambers, J. E. (2016). Accuracy assessment of a UAV-based landslide monitoring system. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *41*, 895-902.

Qasim, S., Harahap, I. S. H., Osman, S., & Baharom, S. (2013). Causal factors of Malaysian landslides: A narrative study.

Remondino, F., Spera, M. G., Nocerino, E., Menna, F., & Nex, F. (2014). State of the art in high density image matching. *The Photogrammetric Record*, *29*(146), 144-166.

Rahmana, H. A., & Mapjabilb, J. (2017). Landslides Disaster in Malaysia: an Overview. *Health*, *8*(1), 58-71.

Sprunk, C., Tipaldi, G. D., Cherubini, A., & Burgard, W. (2013, November). Lidar-based teach-and-repeat of mobile robot trajectories. In *Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on* (pp. 3144-3149). IEEE.

Varnes, D. J. (1978). Slope movement types and processes. *Special report*, *176*, 11-33.

Weng, J., Cohen, P., & Herniou, M. (1992). Camera calibration with distortion models and accuracy evaluation. *IEEE Transactions on Pattern Analysis & Machine Intelligence*, (10), 965-980.

Yusoff, A. R., Ariff, M. F. M., Idris, K. M., Majid, Z., & Chong, A. K. (2017). Camera calibration accuracy at different UAV flying heights. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*, 595.

Zhu, Q., Wu, J., Hu, H., Xiao, C., & Chen, W. (2018). LIDAR Point Cloud Registration for Sensing and Reconstruction of Unstructured Terrain. *Applied Sciences*, *8*(11), 2318.