

EFFECT OF LIGHTING DIFFERENCE IN RECONSTRUCTION OF THREE
DIMENSIONAL DENSE MODEL USING CLOSE RANGE PHOTOGRAMMETRY

RAIMI BIN MOHAMED FADZEL

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Science (Geomatic Engineering)

Faculty of Geoinformation and Real Estate
Universiti Teknologi Malaysia

JUNE 2015

In the name of God, most Gracious, most Compassionate

I dedicate my project report work to Allah swt, my family and friends. A special feeling of gratitude to my loving parents, Mohamed Fadzal Bin Bien whose words of encouragement and push for tenacity ring in my ears, and Masanah Sa Binti Abdullah my beloved mother always be my side throughout the process and your love. My Brothers, Zulhanan Bin Mohamed Fadzal, Mohd Hadari Bin Mohd Fadzal, my sister, Sakinah Binti Mohamed Fadzal and lastly my youngest brother Muhammad Khairul Ezy Bin Mohamed Fadzal.

I also, dedicate this project report to my friends who have give lots of ideas and excellent opinion along the process. I will always appreciate all they have done and helping me to achieve the project objectives. And also I appreciate to everyone who was lent your hands until the project report is completed.

ACKNOWLEDGEMENT

I am deeply grateful to my supervisor, Dr Mohd Farid Bin Mohd Arif, for his guidance, patience, and support. I consider myself very fortunate for being able to work with a very encouraging lecturer like him. Without his offering to accomplish this project, I would not be able to complete my study in UTM. I am much obliged to Photogrammetry and Laser Scanning (PLS) group for their help and suggestion made me feel I was not isolated in my project. Last but not least, to all Professor, Associate Professor and Lecturer at Faculty of Geoinformation and Real Estate, thanks a lot for your sharing idea and knowledge in this field.

ABSTRACT

Lighting is one of the main elements in photographic process. Adequate source of lighting is required to give enough illumination to the object. Close Range Photogrammetry (CRP) is one of the technique and it has been used in variety of fields for example forensic, traffic management, archeology, medical, construction and else. These kinds of fields have different condition and environment for instance in term of source of lighting. The lack of illumination on the object can cause many problems, for example the quality of images, the accuracy of the project and more.-Therefore, in this study, consumer grade digital camera is used to capture the image of an object and reconstruct the three dimensional (3D) model, under the different of intensity of light. The images were processed by using PhotoModeler Scanner and irfanView software. This software is help to generate the 3D model and histogram graph for analysis and result. For geometry evaluation, the model comparison is conducted between the model from CRP approach and laser scanning method. Lastly, the models constructed give different result depending on the intensity of light used.

ABSTRAK

Pencahayaan adalah salah satu element di dalam proses fotogrametri. Sumber pencahayaan yang mencukupi diperlukan untuk memberi pencahayaan kepada objek. Fotogrametri Jarak Dekat (CRP) adalah salah satu teknik dan ianya telah digunapakai dalam pelbagai bidang seperti forensik, pengurusan trafik, arkeologi, perubatan, pembinaan dan sebagainya. Bidang ini memiliki pelbagai jenis keadaan dan persekitaran yang berlainan sebagai contoh sumber pencahayaan. Pencahayaan yang tidak mencukupi boleh menyebabkan pelbagai masalah seperti kualiti gambar, ketepatan projek dan banyak lagi. Oleh itu, di dalam tesis ini, camera jenis pengguna akan digunakan untuk mengambil gambar objek dan membina model tiga dimensi di bawah cahaya yang berbeza. Gambar yang ditangkap telah diproses dengan menggunakan perisian PhotoModeler Scanner dan IrfanView. Perisian ini membantu dalam menghasilkan model 3D dan graf histogram untuk dianalisa dan keputusan. Bagi penilaian geometri, perbezaan antara model telah dilakukan antara model daripada teknik CRP dan imbasan laser teknik. Akhir sekali, model yang dihasilkan memberi keputusan yang berbeza bergantung kepada pencahayaan yang telah digunakan.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF ABBREVIATIONS	xii
	LIST OF SYMBOLS	xiv
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Problem Background	3
	1.3 Problem Statements	4
	1.4 Objectives of Study	5
	1.5 Scope of Study	6
	1.6 A Brief Note on the Methodology	7
	1.7 Significant of Study	9
	1.8 Thesis Outline	9

2	LITERATURE REVIEW	11
	2.1 Introduction	11
	2.2 Photogrammetry	12
	2.2.1 Technique and Instrument used in Photogrammetry	12
	2.2.1.1 Camera	13
	2.2.1.2 Photo Control	16
	2.2.1.3 Processing Software	17
	2.2.1.4 Photogrammetry Technique	19
	2.2.2 Digital Close Range Photogrammetry	21
	2.2.3 Laser Scanning	22
	2.3 Radiometric Factors	23
	2.3.1 Resolution	24
	2.3.2 Noise	24
	2.4 Geometric Factors	27
	3.4.1 Camera Calibration	27
	2.5 3D model evaluation	28
	2.6 Lighting	30
	2.7 Summary	32
3	METHODOLOGY OF RESEARCH	33
	3.1 Introduction	33
	3.1 Research Workflow	34
	3.2 Project Planning	35
	3.2.1 Area, Software and Instrumentation	36
	3.2.1.1 Area of Study	36
	3.2.1.2 Processing Software	38
	3.2.1.3 Instrumentation	39
	a) Camera	39
	b) Laser Scanner	43
	3.2 Procedure of Data Collection	45

3.2.1	Camera Calibration	46
3.2.2	Technique	48
3.3	Data Processing	48
3.3.1	3D Model and Image Analyzing	50
3.4	Data Analysis and Finding	50
3.5	Summary	51
4	RESULT AND ANALYSIS	53
4.1	Introduction	53
4.2	Camera Calibration	54
4.3	Three Dimensional (3D) Generation	56
4.3.1	Number of Images against Number of 3D points	57
4.3.1.1	Outdoor Scenario	57
4.3.1.2	Indoor Scenarios	59
4.3.2	3D models result	60
4.3.2.1	Outdoor Scenarios	60
4.3.2.2	Indoor Scenarios	63
4.4	Luminosity Analysis	64
4.4.1	Outdoor Scenarios	66
4.4.2	Indoor Scenarios	69
4.5	Image Analysis	71
4.6	Footprint measurement	73
4.7	Summary	75
5	DISCUSSION AND RECOMMENDATION	76
5.1	Introduction	76
5.2	Discussion	77
5.3	Recommendation	78
5.4	Summary	78
	REFERENCES	79

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	System requirement for menci software	18
2.2	System requirement for PhotoModeler software	19
2.3	Classification of laser scanner	23
2.4	Comparison between Laser Scanning and Photogrammetry	29
3.1	Scenario and number of images	37
3.2	SONY Cybershot DSC-F828 full specifications	40
3.3	Non-contact 3D digitizer VIVID 910 full specifications	44
4.1	Camera Calibration Result.	56
4.2	The number of point cloud generated.	57
4.3	The number of point cloud generated for indoor scenarios	59
4.4	Model Comparison	61
4.5	Indoor 3D dense models	63
4.6	The image and luminosity histogram	67
4.7	Indoor result comparison	69
4.8	Footprint measurement comparison	74
4.9	Average and mean footprint measurement	74

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Research Workflow	8
2.1	The camera obscura concept	13
2.2	Hasselblad MKWE	14
2.3	Non metric camera, Sony DSC-F828	16
2.4	RAD Target system	17
2.5	RAD is placed around the object	17
2.6	The example of overlapping cases. (a) No overlap case, (b) Insufficient overlap case and (c) Sufficient overlap case	22
2.7	Resolution against image detail	24
2.8	De-noising process	26
2.9	Comparison between different ISO used. ISO 100 (left), ISO 1600 (middle) and comparison for small section (right)	27
2.10	(a) Single Sheet and (b) multi sheet camera calibration	28
2.11	Electromagnetic Spectrum	31
3.1	The main procedure in this research	34
3.2	Project planning process	35
3.3	Single Sensor imaging: (a) Mosaic-like greyscale CFA image (b) color variant of the CFA image (c) Demosaicked full-color image	41

3.4	The different RGB arrangement for CFA used	42
3.5	VIVID 910 and Triangulation approach	43
3.6	The process of data collection	45
3.7	The camera calibration workflow	47
3.8	Data processing steps	49
3.9	Data analysis and finding process	51
4.1	Analysis and Finding flowchart	53
4.2	Camera orientation and position	55
4.3	Calibration process is running	55
4.4	Number of Image and 3D point for outdoor scenarios	58
4.5	Number of Image and 3D point generated	60
4.6	Create Dense Surface setting (Outdoor)	61
4.7	The RMSE value against the number of images	62
4.8	Create dense surface setting (indoor)	63
4.9	RMSE value against number of images	64
4.10	The brightness histogram	65
4.11	The cloudy image (Left) and the clearly sky image (right)	71
4.12	The Luminosity histogram comparison	72
4.13	Indoor image (left) and outdoor image (right)	72
4.14	The points of measurement	73

LIST OF ABBREVIATIONS

CRP	Close Range Photogrammetry
CCD	Charge coupled device
CMOS	Complementary metal oxide semiconductor
RAD	Ringed Automatically Detection
UAV	Unmanned Aerial Vehicle
DSM	Dense Surface Model
DSLR	Digital Single Lens Reflex
SNR	Signal and Noise Ratio
ISO	International Standard Organization
CFA	Color Filter Array
CFM	Color Filter Mosaic
RGBE	Red, Green, Blue and Emerald
EMCCD	Electron Multiplied Charge Coupled Device
ICCD	Intensified Charge Coupled Device
PET	Polygonal Editing Tool

LIST OF SYMBOLS

μ - Micro

CHAPTER 1

INTRODUCTION

1.1 Introduction

Photogrammetry is a combination of three Greek's words "*photos*" or "*phot*" which means light, "*gramma*" (letter or something drawn) and "*matrein*" (the noun of measure) (Schenk, 2005). In other words, it is science of measurement and interpretation of surfaces and objects from two or multiple overlapping images and without physical contact with the object. This technique primarily aims to construct three-dimensional (3D) model of an object either in the digital form or graphical form by using specific mathematical algorithm to obtain the information from the photographs (Luhmann *et al*, 2006). Apparently, most of photogrammetry people was choosing digital camera instead of film camera for capturing the image of objects or scenes. This is because the digital camera was equipped with high technology and sensor, which provide advantages in recording high quality of images compare with film-based camera. Techniques in photogrammetry can be grouped into terrestrial photogrammetry and aerial photogrammetry. These techniques can be distinguished by looking at the procedure of data acquisition, processing and objective of task. Moreover, photogrammetry has been

used in variety type of industries for example in archeology which used to modeling the pottery, artifacts of culture heritage, statue and building (Kadobayashi *et al*, 2004). Furthermore, in movie industry, these techniques are quite popular for instance, constructing 3D model of character of animation and real motion picture. Last but not least, this techniques is also used in medical industry, architecture industry and engineering as well (Yilmaz *et al.*, 2008).

The development of science and technology in world of photogrammetry served lots of advantages to the photogrammetry people. The improvement can be seen in form of instrumentation, methodology and processing software and hardware. They have tried to create new approach to resolve the problems faced by photogrammetry people. This phenomenon are due to the demand of high data quality, accuracy and precision and also reduce human interfere during the processing. The quality of data is most critical aspect in surveying and in photogrammetry as well. The data recorded is processed to generate 3D model by using 3D modeling software, and then documentation process for all the information, data and result. In archeology industry, all types of data collected related to the artifact must be put in one document for further analysis and interpretation (Barsanti *et al*, 2014).

Apparently, there are multiple different of techniques and equipments that have been used in the measurement of objects for example 3D laser scanner, theodolite and total station, Close Range Photogrammetry (CRP), Coordinate Measurement Machine (CMM), structure light system and direct method. These techniques and equipments can differentiate in term of cost, size and weight of measurement, the object complexity and processing time (Ordonez *et al*, 2009). Therefore, some company cannot afford great investment on expensive instrument like laser scanner and the weight of the instrument is count in selecting the best techniques and equipment in project as well (portability). Moreover, the technique used is depending on the complexity of object because if the object is simple and less complex, it is better to use CRP method instead of using laser scanning technique. Meanwhile, if accuracy is highly concern in a project then laser scanner is the best equipment to use.

Camera has been used so many years as one of the equipment in recording scenes, surfaces or objects. Before the digital camera has been introduced in public, the photographer were used conventional camera which depends entirely on chemical and mechanical process and do not use electricity to operate. The new technology was totally changed how the visual information is recorded. Nowadays, digital camera is widely used by photogrammetry people. It is consists of build-in computer and records the images in an electronic form or digitally. Moreover, digital camera consists of sensor that converts light into electrical charge. The light is reflected on the surfaces of the objects before reach to the digital camera's sensor (Karim *et al*, 2004). There are multiple types of sensors for example Couple Charge Device (CCD), Complementary Metal Oxide Semiconductor (CMOS) and more. These sensors consist of tiny light-sensitive diode known as photosites. For example, a 2.1 megapixel camera has approximately 2 100 000 photosite on the CCD. In other hand, resolution is the amount of detail that the camera can capture and it is measured in pixel. So, the more pixel camera has, the more detail and clear of image can be. The example of digital cameras available in the market are Sony Alpha 7 II, Ricoh EG-30, Leica x(Type 113), Canon PowerShot SX60 HS, Nikon D750, Panasonic Lumix DMC-LX100, Samsung NX1 and more.

1.2 Problem Background

Photosite is used to convert light into electrical charge. The light that released or transmitted from the source is reflected by the surfaces before reached to photosite. The accumulated charge is shifted vertically into serial output register and shift it again horizontally to readout each individual pixel. Certain sensors are able to work efficiency in different illumination. Basically, the charge of a pixel is reflex on the amount of light received by a photosite. In other hand, it is important to select the types of lighting to ensure the high quality of images can be produced, because low quality of images can

affect the geometry and radiometric information and also causing some problems during the processing phase (Blizard, 2013). Therefore, he was suggested to provide an adequate of illumination exposed surrounding the object during capturing the images activity, so the high-detail, sharp and flat imagery can be produced.

In addition, one of the steps in 3D model reconstruction process is locating the image target point or reference. The sharp and clear images are help to locate the target point accurately. Therefore, high resolution camera allows sharper and more detail of the images, which improves the resolvability of the target point. Besides, external light source is used to provide enough illumination of the object (Jack, 2003). Indoor and outdoor activities are also can affect the result and images quality because of the different in source of lighting.

Outdoor activity is depends on the sun light. The sunlight might produce shadows and different brightness between the images. The formation of shadows are due to when the sun is not on top of the object and the brightness is different because of the cloud is covering the sky during the capturing image. Meanwhile, indoor activity is using artificial source of lighting for examples bulb, fluorescent and others. The number of bulb and the distance between the object provides difference illumination to the object. It is important to ensure all the images have similar brightness and shadows. Otherwise, overlapping the texture process can generate inconsistent texture on the model (Radoservic, 2010).

1.3 Problem statements

The study and research were carried out and identified some of problems in previous study. The problem statements are:

1. Lighting is one of the factors that affecting the quality of images and it is used in reconstruction 3D dense model. In order to simulate the illumination and brightness at the real cases, the difference of lighting models is used. Then, multiple overlapping images of an irregular artificial object are captured by using consumer grade digital camera at different position. Does 3D dense surface can be established from these images?
2. Quality of images is important in image interpretation and measurement process which to be identified from its form, brightness or color distribution for every image point, values in the form of radiometric information and geometric information (position in image) can be obtained. This requires measurement systems with appropriate geometric and optical quality. So, what are the relationship and effects to the radiometric and geometric information of images and output (model) when differences of lightning are used?
3. New methods and equipments have been introduced with high technology implied to fulfill the demand for high precision and accuracy of the output. For example, laser scanning technique, this technique is provided more accurate result compare with conventional method in reconstruction of 3D model (Kadobayashi *et al.*, 2004). Therefore, which 3D models are more accurate by comparing the 3D model obtained by laser scanning technique?

1.4 Objectives of study

There are three objectives for this study and they are:

1. To reconstruct 3D dense models from difference source of illumination.
2. To study the accuracy of 3D models formed by using difference source of illumination
3. To evaluate the 3D models in term of geometry and radiometry.

1.5 Scope of Study

This study is covered only small irregular artificial object and size which is to simulate the small artifact goods such as poetry, human footprint, tombs and more. The approximate object's dimension used in this study is 27 cm width, 36 cm long and 10 cm height and the size is easy to handle. It is because the object is move from one place to another place. Moreover, to make sure the object use is similar throughout the study, the object was made up from less fragile medium and fix shape such as cement. Cement is one of the suitable medium to create artificial object because, the object would not able to change whatever condition and place.

The process of data collection was planned to do at two different places; indoor and outdoor space at near to Faculty Geoinformation and Real Estate, Universiti Teknologi Malaysia, Skudai Johor Baharu, Malaysia (1°33'37.1"N 103°38'13.5"E). Based on article from Malaysia Meteorological Department website, on the average, Malaysia received about six hours of sunshine per day. Therefore, the light intensity is different at different country and continent based on the latitude and longitude but this is not the only factor that affecting the light intensity (Paul Burgess, 2009). The data collection for outdoor activity is collected within that period of time. Meanwhile, indoor activity is fully dependant on the artificial lighting and it is explained in chapter 3 in this thesis.

So, this study would not touch any big scale of object in reconstructing 3D model. The processing software used is the PhotoModeler Scanner software which less expensive and low system requirement, instead of using expensive sotware such as Softimage Face Robot software, Autodesk Maya, Autocad and other 3D modeling and graphical software. Photomodeler scanner is capable to processing both types of data/techniques; image-based and range-based technique in creating 3D model. In other hand, the expensive software requires high system requirements either in processing and also storage. Lack of experience of using the expensive software is one of the factors of selecting the PhotoModeler scanner.

1.6 A Brief Note on the Methodology

In surface, this study is aims to manipulate the condition surrounding the object especially the lighting. The differences of illumination either indoor or outdoor would give effect on the reconstruction of 3D model, radiometric information and geometry. Therefore, the irregular artificial object is converted into 3D model by using CRP procedure. Multiple of images are captured surrounding the object at different camera position to ensure 60 % overlapping or more of images can be achieved.

The software used to create 3D dense model is PhotoModeler scanner Software. This software is able to determine root mean square error, total error, residual and precision values of projects. In order to determine the accuracy of the project, laser scanning technique is used and apply on the similar object before 3D model can be obtained. And then, the analysis of the model is made to identify the accuracy of the project. Last but not least, the geometrical assessment is performed by comparing the 3D model from CRP method, laser scanning method and direct method.

In this research, it is begin with project planning where all the information related with project are collected to understanding which suitable instrument, techniques and procedure to be used. Afterthat, all the output from project planning is implemented in data collection activities. Capturing the images of the object using the CRP technique and scanned by laser scanner as well is a part of activities in data collection phase. Since, the camera used in this project is non metric camera, it is compulsory to do camera calibration first in order to identify the camera parameters to be inserted in processing software. These materials or images are processed by using PhotoModeler software in reconstruct the 3D dense model. The measurement, analysis of the model and the error are able to compute by using the software. Lastly, the comparison between all models and the accuracy is performed during the project analysis and finding phase. And also give the solution of problem statements of the study.

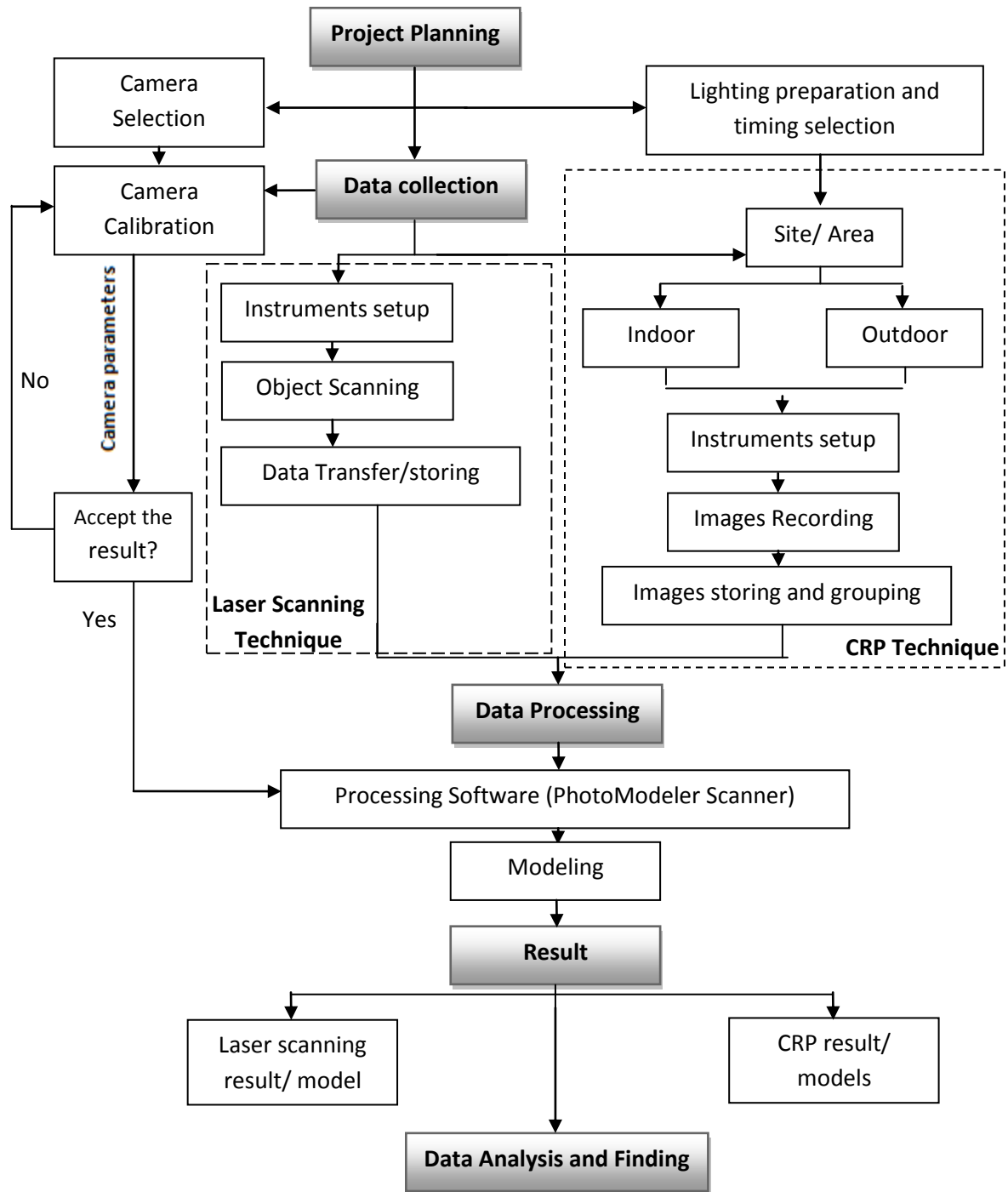


Figure 1.1: Research Methodology Workflow

1.7 Significant of Study

This research is trying to investigate the effect of lighting towards the radiometric information and geometric of 3D model by using CRP technique. Since, the photogrammetry has been used in multiple types of industries, so the environment might be different from one another. What I mean, the brightness and illumination of site area where the image-based photogrammetric technique is applied. Moreover, this research is trying to give idea on lighting selection and suitable period where the sun light position and then it may reduce the shadow and brightness to get the good quality of images.

A part from that, this study is applied laser scanning technique and creates the 3D model. Most of researcher did mention the advantages of laser scanning technique in creating 3D model. Therefore, in this study, this technique is set as a benchmark of the result obtained from CRP method to see which models created is most accurate, and then identify which lighting model gives better result/illumination to the object.

Last but not least, the images captured with different of lights produce different of intensity value on the images. Therefore, by using luminosity histogram analysis illustrated the relation between intensity value and images of different exposure. Moreover, another aspect is evaluated such as luminosity histogram, the image analysis and the relationship between the number of image and point cloud generated.

1.8 Thesis Outline

This thesis consists of five chapters. Chapter 1 explains the introduction of this study, background of problems, problems statements, objective and scope of the study, brief note on the methodology and significant of the study.

REFERENCES

a **Journal**

- Abd. Manan Samad, Norazlini Hassan Sauri, Muhd Asyraf Hamdani et al (2012). *Kellie's Castle Facade Recording Using Digital Close-range Photogrammetry*. IEEE 8th International Colloquium on Signal Processing and its Applications.
- Anthony P Lyons, T. Akal and E. Pouliquen (1998). *Measurement of seafloor Roughness with Close Range Digital Photogrammetry*. OCEANS '98 Conference Proceeding (volume 1).
- Armin Grun, Fabio Remondino and Li Zhang (2004). *Photogrammetric Reconstruction Of The Great Buddha Of Bamiyan, Afghanistan*. The Photogrammetric Record 19(107): 177–199
- Benjamin Ummenhofer and Thomas Brox. *Pattern Recognition: Dense 3D Reconstruction with Hand-Held Camera*. Springer Berlin Heidelberg. pp 103-112; 2012
- C.Mythili and V. Kavitha (2011). *Efficient Technique for Color Image Noise Reduction*. The Research Bulletin of Jordan ACM, Vol 11(111)
- Celestino Ordonez, Belen Riveiro, Pedro Arias and Julia Armesto (2009) *Application of Close Range Photogrammetry to Deck Measurement in Recreational Ships*. SENSOR ISSN 1424- 8220
- Cengishan Ipuker(2010). *The Reason of Changing The Name to "Geomatics"*. FIG Congress 2010 Facing the Challenges – Building the Capacity Sydney, Australia, 11-16 April 2010
- Daniel Huber, Burcu Akinci, Pingbo Tang et al., (2010). *Using Laser Scanners for Modeling and Analysis in Architecture, Engineering, and Construction*. 2010 44th Annual Conference on Information Sciences and Systems (CISS), IEEE,1–6

- Daniel Carneiro Da Silva (2006). *Non-Metric Digital Camera Images versus High Resolution Satellite Images in Regions with High Cloudiness*. Shaping the Change XXIII FIG Congress Munich, Germany, October 8-13.
- D. Mihajlović, M. Mitrović, Ž. Cvijetinović and M. Vojinović (2008). *Photogrammetry Of Archaeological Site Felix Romuliana At Gamzigrad Using Aerial Digital Camera And Non-Metric Digital Camera*. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B5. Beijing 2008
- Dimitar Jechev (2004). *Close-Range Photogrammetry With Amateur Camera*. Commission V, WG V/4
- E. Sree Devi And B. Anand (2014). *Adaptive Color Filter Array Interpolation Algorithm Based On Hue Transition And Edge Direction*. Journal of Theoretical and Applied Information Technology 31st January 2014. Vol. 59 No.3
- F.A. van den Heuvel and R.J.G.A. Kroon (1992). *Digital Close-Range Photogrammetry Using Artificial Targets*. ISPRS.
- George E. Karrasa and Dionyssia Mavrommati (2001). *Simple Calibration Techniques For Non-Metric Cameras*. CIPA International Symposium, Potsdam, September 18-21, 2001
- Goran Radoservic (2010). *Laser Scanning Versus Photogrammetry Combined with Manual Post-modeling in Stecak Digitization*. Proceedings of CESC 2010: The 14th Central European Seminar on Computer Graphics
- Goran Radosevic (2010). *Laser Scanning Versus Photogrammetry Combined with Manual Post-modeling in Stecak Digitization*. Proceedings of CESC 2010: The 14th Central European Seminar on Computer Graphics
- H.Murat Yilmaz, Murat Yakar And Ferruh Yildiz (2008). *Digital Photogrammetry In Obtaining Of 3d Model Data Of Irregular Small Objects*. ISPRS.
- Habil. András Majoros (2011). *Artificial Lighting Lecture Note*. Budapest University of Technology and Economics Faculty of Architecture Department of Building Energetics and Services
- Heinz Ruther, Julian Smit and Donatius Kamamba (2012). *A Comparison of Close-Range Photogrammetry to Terrestrial Laser Scanning for Heritage Documentation*. South Africa Journal of Geomatic , Vol 1, No 2.

- Huiping, H., Bingfang, W., and Jinlong, F., 2003. Analysis to the Relationship of Classification Accuracy Segmentation Scale Image Resolution, Proceedings of IEEE 2003 International Geoscience and Remote Sensing Symposium,
- Ismail Ma'arof, Siti Zubaidah Bahari, Zulkiflee Abd Latif *et al.*(2013). *Image Based Modeling and Documentation of Malaysian Historical Monuments Using Digital Close-Range Photogrammetry (DCRP)*. IEEE International Conference on Control System, Computing and Engineering
- Jack Leifer (2003). *A Close-Range Photogrammetry Laboratory Activity for Mechanical Engineering Undergraduates*. 33rd ASEE/ IEEE Frontier in Education Conference.
- Jana Visnovcova, Armin Gruen and Li Zhang (2001). *Image-Based Object Reconstruction And Visualization For Inventory Of Cultural Heritage*. <http://www.researchgate.net/>
- Joaquim Salvi, Xavier Armangu and Joan Batlle (2000). *A comparative review of camera calibrating methods with accuracy evaluation*. Pattern Recognition 35 (2002) 1617–1635
- Joyce Farrella, Mike Okinchab, Manu Parmarac, and Brian Wandellac (2010). Using visible SNR (vSNR) to compare the image quality of pixel binning and digital resizing. Proc. SPIE 7537, 75370C.
- Michael Zeman And B. Blakeman (1984). *Terrestrial Photogrammetric Survey of Arltunga Historic Reserve, Northern Territory*. Australian Historical Archaeology, 2
- Mike Craig (2002). *Vertical Aerial Photograph*. In Papp, E. (Editor), 2002, Geophysical and Remote Sensing Methods for Regolith Exploration, CRCLEME open file report 144, pp 1-5.
- Mohd. Faizury Abol Hassan, Ismail Ma'arof and Abd. Manan Samad (2014). *Assessment of Camera Calibration towards Accuracy Requirement*. IEEE 10th International Colloquium on Signal Processing & its Applications (CSPA2014), 7 - 9 Mac. 2014, Kuala Lumpur, Malaysia
- Muhd Safarudin Chek Mat, Jezan Md Diah, Mokhtar Azizi Mohd Din and Abd. Manan Samad., (2014). *Data Acquisition and Representation of Leaves using Digital Close Range Photogrammetry for Species Identification*. IEEE 5th Control and System Graduate Research Colloquium
- Paul Burgess (2009). *Variation In Light Intensity At Different Latitudes And Seasons, Effects Of Cloud Cover, And The Amounts Of Direct And Diffused Light*.

Presentation to Continuous Cover Forestry Group (Ccfg) Scientific Meeting 29 September 2009, Westonbirt Arboretum, Gloucestershire.

- Reiko Kadobayashi, Nobuo Kochi and Hitoshi Otani et al.,(2004). *Comparison And Evaluation Of Laser Scanning And Photogrammetry And Their Combined Use For Digital Recording Of Cultural Heritage*.XXth ISPRS Congress Technical Commission V
- Rastislav Lukac and Konstantinos N. Plataniotis (2005). *Color Filter Arrays: Design and Performance Analysis*. IEEE Transactions on Consumer Electronics, Vol. 51, No. 4,
- Rohit Verma and Jahid Ali (2013). *A Comparative Study of Various Types of Image Noise and Efficient Noise Removal Techniques*. International Journal of Advanced Research in Computer Science and Software Engineering Volume 3, Issue 10, October 2013
- Sara Gonizzi Barsanti, Fabio Remondino and Domenico Visintini (2014). *Critical factors and guidelines for 3D surveying and modeling in Cultural Heritage*. International Journal of Heritage in Digital Era, vol 3 number 1.
- Thomas Luhmann, Heidi Hastedt, Werner Tecklenburg (2006). *Modelling Of Chromatic Aberration for High Precision Photogrammetry*. IAPRS Volume xxxvi, Part 5, Dresden 25-27 September 2006
- V. Kaufmann and R. Ladstadter (2008). *Application Of Terrestrial Photogrammetry For Glacier Monitoring In Alpine Environments*. Commission VIII, WG VIII/8
- Vesna Stojaković (2008). *Terrestrial Photogrammetry And Application To Modeling Architectural Objects*. Architecture and Civil Engineering Vol. 6, No 1, 2008, pp. 113 – 125
- William C. Haneberg (2008). *Experience using close range terrestrial digital photogrammetry for 3-D rock slope modeling and discontinuity mapping in the United States*. Springerlink
- Xie Hong-Quan and Jia Hai Hu (2010). *The Development of 3D Laser Scanning Technique in and its Application in Land Reclamation*. ISPRS Journal
- Xiong Hanwei, Xu Jun, Wang Jinming and Huang Puhua (2011). *Camera Calibration Using Multiple Sheets Planar Pattern*. International Conference on Optical Instruments and Technology: Optoelectronic Measurement Technology and Systems, Proc. of SPIE Vol. 8201, 82011S

b) Website Article/ Technical Report/ Paper

Anahid A. Behrouzi, Rui Li (2012). *Instruction Manual: Photogrammetry As A Non-Contact Measurement System In Large Scale Structural Testing*. University of Illinois

Brandon Blizard (2013). *The Art of Photogrammetry: How to take your photo*. Retrieved on 13 December 2014 from www.tested.com/art/makers/460142-art-photogrammetry-how-take-your-photos/

Christoph Greb (2012). *Basic Principles of Luminescence*. Retrieved on 10 December 2014 from <http://www.leicamicrosystems.com/sciencelab/basicprinciplesofluminescence/>

Christopher Crockett (2014). *What is the electromagnetic spectrum?* Retrieved on 10 December 2014 from <http://earthsky.org/space/whatisethelectromagneticspectrum>

Geodetic Sytem Inc (2014). *The Basic of Photogrammetry*. Retrieved on 26 November 2014 from <http://www.geodetic.com/vstars/whatisphotogrammetry.aspx>

Janice VanCleave (2011). *More Incandescence vs. Luminescence*. Retrieved on 10 December 2014 from <http://scienceprojectideasforkids.com/2011/incandescencevsluminescenc/>

Karim Nice and Gerald Jay Gurevich (2004). *How Digital Camera Work*. Retrieved on September 2014, from www.howstuffworks.com

Nasim Mansurov (2009). *Understanding ISO – A Beginner’s Guide*. Retrieved on 12 September 2014 from <https://photographylife.com/whatisisoinphotography>

NASA. *Tour of The Electromagnetic Spectrum*. NASA Headquarters by InDyne, Inc and VI Studios, Inc: Booklet.2010

Neffra A. Matthews (2008). *Aerial and Close-Range Photogrammetric Technology: Providing Resource Documentation, Interpretation and Preservation*. Technical Note 428

Stephen Sagers and Ron Patterson (2010). *History of Photograph*. Cooperative Extension work, Utah State University. (4-H/Photography/2010-01pr)

Toni Schenk (2005). *Introduction to Photogrammetry*. Department of Civil and Environmental Engineering and Geodetic Science. The Ohio State University

Zhengyou Zhang (2000). *A Flexible New Technique for Camera Calibration*. Technical Report MSR-TR-98-71