INTEGRATION OF POINTS CLOUD DATA FROM AIRBORNE AND TERRESTRIAL LASER SCANNER.

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ABSTRACT

The purpose of this study is trying to solve the shortage of the data due to the limitations of the laser scanner instrument in data collection. The data integration between ALS with TLS are able to provide complete data for used by other applications such as 3D model of building, 3D model of forestry mapping, documentation of historical building, forensic and many more. The scope of this study focusing on the scanning the UTM Eco-Home building using ALS and TLS. The UTM Eco-Home building was chosen because it has a unique design and structure that can be test the capabilities of the laser scanner instruments. The ALS used to scan the roof top of the building and the TLS used to scan the façade of the building. The laser scanner instruments are used in data collection are to ensure that is no part of the building are missed to scan. After completing scanning the UTM Eco-Home building process, the dataset used for integration through registration method using man-made. The man-made is chosen because the characteristic of man-made can be seen in both dataset. The level of accuracy is assessed by comparison method with the conventional measurement using total station. The result from the integration is using for many purposes for example 3D city modelling, 3D forestry mapping, 3D topographic mapping, historical documentation and others.

ABSTRAK

Kajian ini dijalankan adalah bertujuan untuk menangani masalah kekurangan data yang diperolehi disebabkan oleh alat laser yang terhad dalam pengumpulan data. Kerja integrasi data dari ALS dan TLS mampu memberikan data yang lengkap untuk digunakan oleh aplikasi yang lain seperti 3D model bangunan, 3D perhutanan, dokumentasi bangunan tinggalan sejarah, forensik dan banyak lagi. Skop kajian ini fokus kepada pengambilan data dari ALS dan TLS terhadap bangunan UTM Eco-Home. Bangunan UTM Eco-Home ini dipilih kerana ia mempunyai rekabentuk dan srtuktur yang unik yang mampu menguji tahap kebolehan alat ALS dan TLS dalam mengimbas permukaan bangunan. ALS digunakan untuk mengimbas bahagian atas bangunan atau atap bangunan manakala TLS digunakan untuk mengimbas bahagian permukaan bangunan. Dua alat digunakan dalam pengumpulan data adalah untuk memastikan tiada bahagian bangunan yang tidak diimbas. Setelah selesai proses pengimbasan bangunan UTM Eco-Home, kedua-dua data diintegrasi dengan menggunakan kaedah registrasi menggunakan ciri-ciri buatan manusia yang dapat dilihat pada kedua-dua data tersebut. Tahap kejituan dinilai dengan membuat perbandingan dengan ukuran bangunan UTM Eco-Home yang diukur secara konvensional menggunakan alat total station. Hasil daripada integrasi ini boleh digunakan untuk pelbagai tujuan contohnya pemodelan 3D bandar, 3D pemetaan perhutanan, 3D pemetaan topografi, dokumentasi sejarah dan lain-lain.

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LIST OF ABBREVIATION

$\Delta\Phi$	-	Transition
Δt	-	Resolution of time measurement
ΔR	-	Range resolution
μd	-	The difference of mean of sample
$\mu 1$	-	The mean of observation from dataset 1
$\mu 2$	-	The mean of observation from dataset 2
3D	-	Three dimensional
AM	-	Amplitude Modulation
ASCII	-	American Standard Code for Information Interchange.
ATV	-	All terrain vehicle
BIM	-	Building Information Modelling.
c	-	Speed of light
c ($\tau 0$), etc	-	Point of samples.
CCD	-	Charge coupled device.

CEES	-	Centre of Electrical Energy System.
Dintegration	-	Dimension from point cloud integration dataset.
Dautocad	-	Dimension from field work survey (AutoCAD).
ETL	-	Extract process, transform and load.
FM	-	Frequency Modulation.
FOV	-	Field of view.
GLONASS	-	Global Navigation Satellite System.
GPS	-	Global Positioning System.
Ho	-	Null hypothesis.
Ha	-	Alternative hypothesis.
HDL	-	High Definition LiDAR.
ID	-	Identification.
IMU	-	Inertial Measuring Unit
ISIIC	-	Institute for Innovative Smart Infrastructure and Construction
KALAM	-	Centre for Built Environment Malay World
LAS	-	LASer.
LiDAR	-	Light Detection and Ranging.
LRF	-	Laser range finder.
m	-	Distance of the surface where pulse were reflected
n	-	Numbers of sampling
NASA	-	National Aeronautics and Space Administration.
Ppm	-	Parts per million.
R	-	Range Distance

RMSE	-	Root Mean Square Error
RGB	-	Red, green and blue
s^2	-	Variance of sample.
t	-	Time interval between sending / receiving the pulse.
TOF	-	Time of flight
UAV	-	Unmanned Aircraft Vehicles
USB	-	Universal Serial Bus
UTM	-	Universiti Teknologi Malaysia
UTM-CRC	-	UTM Construction Research Centre
WLAN	-	Wireless local area network
x, y, z	-	Coordinate value
$\overline{x}$	-	Mean of samples
x_i	-	The element of the sample.
Z_0	-	z score, the function of the observation value (p-hat).

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In recent years, laser scanner technology widely used in field of measurement because of the easily and quickly data collection and provide an accurate of points cloud data. The laser scanning is non-contact technology to capture the physical object digitally using laser light line and the object of surface generate the points cloud data (Fröhlich & Mettenleiter, 2004). That means, the exact size and shape is able to capture accurately then can generated in the form of points cloud allows to be processed in a computer in three dimensional (3D) model. The abilities to measure accurately, 3D laser scanner technology was selected for use in this study because 3D laser scanner can scanning the surface including complex surface provide timely and accurate points cloud. Laser scanning have many types of method in collecting data and in this study will cover on Airborne Laser Scanner and Terrestrial Laser Scanner.

Airborne Laser Scanner is an active remote sensing technology that capable to collect the data for a wide area (Shan & Toth, 2008). Airborne Laser Scanner technology develop rapidly in recent years because its use so widespread in various fields. This makes the Airborne Laser Scanner applied with difference heights are introduced to achieve the maximum use of Airborne Laser Scanner technology. Airborne Laser Scanner technology is widely used in agriculture, city planning, 3D city models and many others (Mohammed, 2015).

Terrestrial Laser Scanner is a new technology used for measurement on field that allows data obtained quickly and generated in a form of points cloud (Staiger, 2003). The points cloud data provided the information such as x, y, z coordinate of the surface from the ground accurately, reflectance value and color of the surface after processing the points cloud using the specific software. The Terrestrial Laser Scanner have different type of resolution on collecting point cloud data such as low, medium and high where every type of resolution collecting points cloud data have a different dense of point clouds. High resolution with more density give more information of the object and vice versa.

Due to the accuracy of laser scanning technology, facilitate data collection and time consuming, the data from Airborne Laser Scanner and Terrestrial Laser Scanner are used in this study to integrate the points cloud of the unique design of Universiti Teknologi Malaysia (UTM) Eco-Home building. Both data from Airborne Laser Scanner and Terrestrial Laser Scanner are required to ensure that no surface is left to scan from façade of the building up to the top surface or rooftop of the building. This study exploring on how the Airborne Laser Scanner and Terrestrial Laser Scanner data integrated and finally checking the accuracy assessment.

1.2 Problem Statement

The urban areas has a unique and high trend building in this era because this type of areas usually have a high population density and if possible, the land use of this areas will be maximized. In modelling the high and unique building like this, it would be incomplete if the data collection process is done at the bottom or the top of the building only due to the limitation of the scanning instrument capability from Airborne Laser Scanner and Terrestrial Laser Scanner. The integration the two data from the Airborne Laser Scanner and Terrestrial Laser Scanner makes the whole building be covered from the building facade up to the rooftop and which can solve the problem.

The integration process either Aerial Photo with Terrestrial Laser Scanner or Airborne Laser Scanner with Terrestrial Laser Scanner are not new but massively applied in other fields such as forestry. The reason of forestry tend to use the integration data because the study of the forestry need to use data from the ground up to the top for the purpose of modelling the tree, from the base of the tree up to the canopy and suitable for mapping the large areas of the forest (Kankare *et al.*, 2015; Jones *et al.,* 2016). For 3D modelling of the building, completeness of data from building facade to the rooftop next to the interior of the building is emphasized because from the 3D model of the building will be apply for other uses such as as-built, building information modeling (BIM), documentation of historical building (Kedzierski *et al.*, 2015) 3D city modelling and others.

Modelling the object in 3D, scanning process from various perspectives have to be done to avoid missing important part especially for the as-built documentation work involving historical or under construction building (Arayici Y, 2007). Ensuring the all parts of the building scanned perfectly, Airborne Laser Scanner and Terrestrial Laser Scanner alone is not sufficient. The Terrestrial Laser Scanner technology is used to scan the building facade and the top structure above can be equipped with Airborne Laser

Scanner and the integration from both of these data can be done for the purpose of 3D modelling (Kedzierski *et al.*, 2015).

1.3 Objective

This study is motivated to achieve the completeness of data collection due to limitation of capability from the instruments, Terrestrial Laser Scanner and Airborne Laser Scanner are using to scan the comprehensive area. The concerned of this study is about the Airborne Laser Scanner and Terrestrial Laser Scanner points cloud data of UTM Eco-Home building to :

i. Integrate the points cloud data from Airborne Laser Scanner and Terrestrial Laser Scanner in appropriate software according to the suitable method.

ii. Determine the accuracy of the integration of points cloud data from Airborne Laser Scanner and Terrestrial Laser Scanner.

1.4 Study Questions

In fulfilling the objective requirements of this study, several questions need to be answered :

i. How to manage the scanning process efficiently using Airborne Laser Scanner and Terrestrial Laser Scanner equipment.

ii. How to integrate the Airborne Laser Scanner data with Terrestrial Laser Scanner data.

iii. How to determine the accuracy assessment to make sure the integration data can be used for other application.

1.5 Scope of Study

This study is conducted in Universiti Teknologi Malaysia (UTM) Eco-Home building near the Equine Centre, Universiti Teknologi Malaysia, Skudai Johor since the UTM Eco-Home building has an unique design including the rooftop, show in figure 1.1. The UTM Eco-Home has been designed and built by a team of researchers and students of Universiti Teknologi Malaysia (UTM) led by Prof. Dr. Muhd Zaimi Abd Majdi and the research group involved from the Institute for Innovative Smart Infrastructure and Construction (ISIIC), UTM Construction Research Centre (UTM-CRC), Centre for Built Environment Malay World (KALAM) and Centre of Electrical Energy System (CEES).

UTM Eco-Home building was built using interlocking blocks and reinforced concrete. However, part of building structure was built using the research product such as Innovative Modular Pad Footing System and Eco-Crete. In addition, UTM Eco-Home building also uses Fast Track Wall System to reduce the construction time 50 percent and 10 to 15 percent of construction costs. Figure 1.1 below shows the UTM Eco-Home building (www.news.utm.my, 2016).

Figure 1.1 : The UTM Eco-Home building.

Sources : (www.news.utm.my)

The instrument used in data collection process to scan the top of the building is Aerial LiDAR AL3-32 by Phoenix Aerial System, is a multi-platform high definition LiDAR mapping system, show in Figure 1.2. This tool is supported by various satellite constellations such as GPS, GLONASS, Galileo and others, and use the VELODYNE HDL-32 high definition LiDAR sensors that provide 700,000 scan points per second

(www.phoenix-aerial.com/, 2016). The Aerial LiDAR AL3-32 is used together with the appropriate platform called remote control helicopter, show in Figure 1.3. Besides that, the Terrestrial Laser Scanner is the other important instrument used in data collection process. Leica ScanStation C10 with high accuracy-long range scanning (hds.leica-geosystems.com, 2016) is choose to scan the facade of the UTM Eco-Home building, show in Figure 1.4.

Figure 1.2 : Aerial LiDAR AL3-32

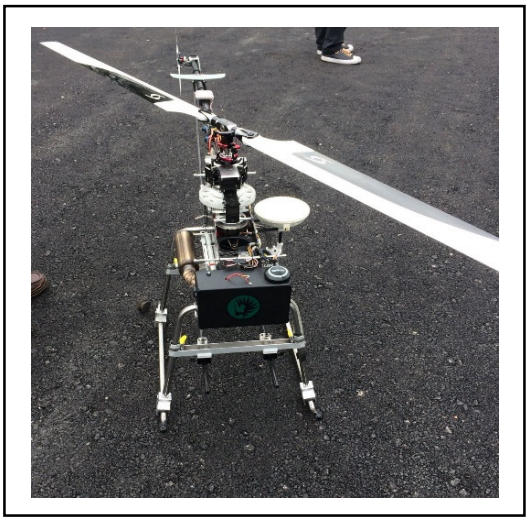

Figure 1.3 : Remote Control Helicopter

Figure 1.4 : Leica ScanStation C10.
Sources : hds.leica-geosystems.com.

The following phase after collecting data is processing stage. The Airborne Laser Scanner data was processed using Quick Terrain Modeler V8.0 software to prepare the data in LASer (LAS) format as a secondary data in this study. The LAS format enable users to process and analyze a compact dense of Airborne Laser Scanner data accurately in accordance with the study. While for Terrestrial Laser Scanner data, the software used for processing is Cyclone 7.3 software. The software provide the facilities to user to interpret the data from Leica ScanStation C10 laser scanner such as as-built and topographic survey (hds.leica-geosystems.com).

1.6 Significant of the Study

The study was conducted after identifying the constraints and problems faced by the user carrying out the work of 3D modelling using point clouds data. Among the problems and constraints facing such as :

i. The limitation of laser scanner instrument in collecting data. Airborne Laser Scanner is lack of capability to collect the data on the building facade and Terrestrial Laser Scanner is lack of capability to collect the data on the top of the building.

ii. The integration data between Airborne Laser Scanner and Terrestrial Laser Scanner can cover the whole surface of UTM Eco-Home building to generate in 3D modelling for other purposes.

iii. Scanning the entire building using Airborne Laser Scanner and Terrestrial Laser Scanner can avoid the important surface not to be scanned.

iv. The integration data between Airborne Laser Scanner and Terrestrial Laser Scanner need to check the accuracy assessment to make sure the integration process acceptable for other application or vice versa.

1.7 Structural of the Study

This study consist five (5) chapters and can be summarized as below :

Chapter 1 : Introduction

Definition and explanation about the introduction of the study including objective of the study, the problem statement causes the issue of the study, the scope, the significant and the outline of the study.

Chapter 2 : Literature Review

Covering on reviews the methodologies on point clouds data of Airborne Laser Scanner and Terrestrial Laser Scanner with the integration process of two different format data. In this chapter also review the suitable software on how to carry out the integration process and check the accuracy assessment of the data. This chapter is also used for guideline for the whole study workflow.

Chapter 3 : Methodologies

In this chapter consist explanation the method of the study on how data collection conducted with Airborne Laser Scanner and Terrestrial Laser Scanner instrument, how the registration process for Airborne Laser Scanner and Terrestrial Laser Scanner data and the accuracy assessment checking comparing with conventional method.

Chapter 4 : Result and Analysis.

The result and analysis obtained from the studies conducted after completing chapter three (3). If there is any problem appear, in this chapter will be discussed further.

Chapter 5 : Conclusion and Recommendation.

From the result and analysis, the conclusion made in this chapter and the recommendation for improvement in future should be state if necessary.

In the early stages, it is important to design the study that follows the course requirement. The design study is to determine the level and duration of the study is completed. Start with identifying the objectives of the study, the problem statement, scope of the study and literature review for references to the study. Next, the study was carried out by methodology which is organize using flowchart to produce the result and analyze the result to determine the accuracy of the study. Table 1.1 below shows the design of the study generally.

Table 1.1 : Study design.

<table>
<tr><td>Introduction</td><td colspan="3">Background, problem statement, objectives, research questions, scope of study, significant and study design.</td></tr>
<tr><td rowspan="6">Literature review</td><td colspan="3">Introduction of Airborne Laser Scanner and Terrestrial Laser Scanner.</td></tr>
<tr><td rowspan="2">Point Clouds</td><td colspan="2">Concept – Represent x, y, z value, intensities, RGB</td></tr>
<tr><td colspan="2">Application – 3D model, 3D mapping, others.</td></tr>
<tr><td rowspan="4">Data integration</td><td rowspan="2">Airborne Laser Scanner and Terrestrial Laser Scanner</td><td>Suitable software uses for Airborne Laser Scanner data and Terrestrial Laser Scanner data.</td></tr>
<tr><td>Common target uses for registration and integration.</td></tr>
<tr><td rowspan="2">Previous works</td><td>Limitation of the Airborne Laser Scanner and Terrestrial Laser Scanner coverage data collection.</td></tr>
<tr><td>Data integration for other application for example forestry.</td></tr>
<tr><td rowspan="4">Methodology</td><td colspan="3">Field work data collection using Airborne Laser Scanner and Terrestrial Laser Scanner instruments.</td></tr>
<tr><td rowspan="2">Processing</td><td colspan="2">Point clouds data integration using suitable software.</td></tr>
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<tr><td colspan="3">Summary</td></tr>
<tr><td rowspan="2">Result and Analysis</td><td colspan="3">Integration of point clouds from Airborne Laser Scanner and Terrestrial Laser Scanner.</td></tr>
<tr><td colspan="3">Accuracy assessment between Airborne Laser Scanner and Terrestrial Laser Scanner data integration with field work dimension survey.</td></tr>
<tr><td>Conclusion and Recommendation</td><td colspan="3">Conclusion of the study and recommendation for improvement.</td></tr>
</table>

1.8 Methodology of the Study

The methodology of the study is an important aspect in implementing this study because in this section determine on how the study was conducted. The methodology of the study is shown in Figure 1.5 below briefly explain the work flow carried out in this study :

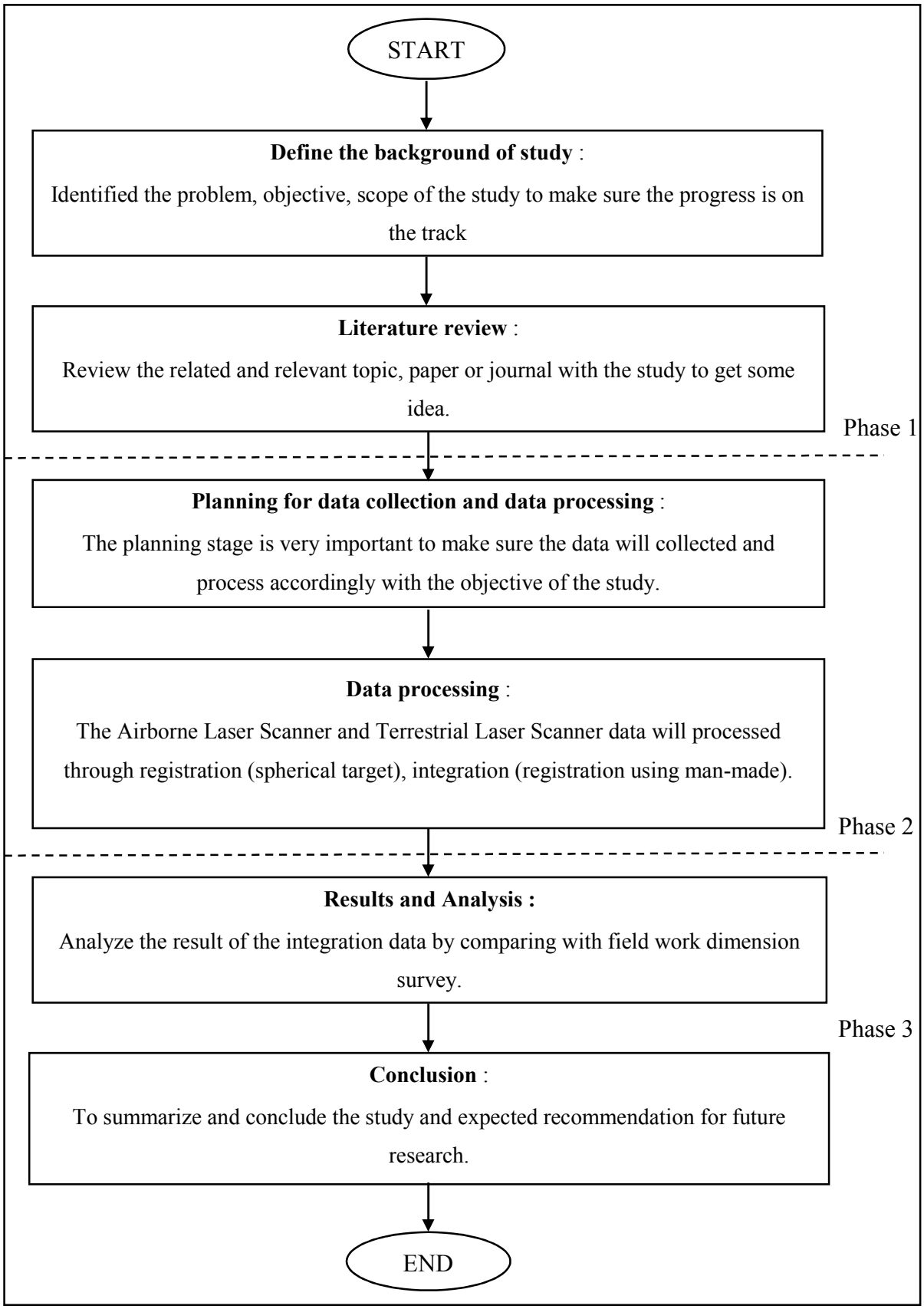

Figure 1.5 : The summary of methodology of the study.

1.9 Summary

The overall of the chapter 1, it can be summarize that the process of identifying the purpose of the study was doing in this chapter. From this chapter 1, the result can be expected from identify the work flow of methodology and analysis can be determine the accuracy of the study.

This chapter 1 plays an important role throughout the course of this study. It used as a benchmark for the next process until the result produce with analysis. After successfully producing the result and analyze it properly, chapter 1 again referred to determine whether the whole process of this study are followed the objectives as state in this chapter.

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