THE APPLICATION OF TERRESTRIAL LASER SCANNING AND WEB-BASED GEOGRAPHICAL INFORMATION SYSTEM FOR INDOOR ASSET MANAGEMENT

LEE SZUE YANN

UNIVERSITI TEKNOLOGI MALAYSIA

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DEDICATION

This thesis is special dedicated to my beloved family members, especially my parents, Lee Kam Chooi and Kok Weng Ho, who have supported me all the way since the beginning of my studies. You have been a source of encouragement and inspiration to me throughout my life especially for the myriad of ways.

I lovingly dedicate this thesis to my dearest Wong Chin Liang, who has been a great source of motivation and supported me each step of the way.

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ABSTRACT

In this era of information technology, majority of organizations have started using information system to record and store information for the existing assets for more effective asset management. However, there are some organizations are still practicing the manual filing system to keep the records. Geographic Information System had been introduced to the asset management. Recently, the Geographical Information System based on three-dimensional technology and internet environment are one of the emerging issues in Geographical Information System field. Thus, this research attempts to improve the weaknesses of the current asset management practice by developing a web-based asset information management system with map visualization and spatial information. Leica ScanStation C10 was used to capture three-dimensional indoor asset models to support the spatial data and store the attribute data of assets into a Geographical Information System database. Several software are used in this study which included Autodesk Revit Architecture, Trimble SketchUp, XAMPP, phpMyAdmin, Netbeans IDE and VRML viewer. The asset management system enables users to manage asset information and database. An added-value designed in the system has enabled spatially query regarding asset information and retrieve asset location through three-dimensional model. This system was designed and developed based on the user requirements. The system performance had been tested by end-users and experts in related field. The results of user testing had proved the developed system is helpful for managing indoor assets. The computerized asset management system enables asset records store in an organized database system. Lastly, new feature of integrating map and three-dimensional viewing in the asset management system can benefits in analysis with Geographic Information System concept such as doing location query, zoom-in and zoom-out, as well as visualize asset location from three-dimension map.

ABSTRAK

Dalam era teknologi maklumat ini, kebanyakan organisasi menggunakan sistem maklumat untuk merekod dan menyimpan maklumat bagi aset yang sedia ada bagi pengurusan aset yang berkesan. Namun, terdapat juga organisasi masih mengamalkan pendekatan manual untuk menyimpan rekod dalam fail. Sistem Maklumat Geografi telah diperkenalkan untuk pengurusan aset. Baru-baru ini, Sistem Maklumat Geografi berasaskan teknologi tiga-dimensi dan internet merupakan salah satu kemuculan isu dalam bidang Sistem Maklumat Geografi. Oleh itu, kajian ini bertujuan memperbaiki kelemahan amalan pegurusan aset semasa dengan membangunkan satu sistem pengurusan maklumat aset berasaskan web yang mempunyai peta visualisasi dan maklumat ruangan. *Leica ScanStation C10* telah digunakan untuk menangkap aset dalaman model tiga dimensi untuk menyokong data ruangan dan menyimpan data atribut aset di dalam pangkalan data Sistem Maklumat Geografi. Beberapa perisian yang digunakan dalam kajian ini termasuk *Autodesk Revit Architecture*, *Trimble SketchUp*, *XAMPP*, *phpMyAdmin*, *Netbeans IDE*, dan pemapar VRML. Sistem pengurusan aset ini memudahkan pengguna untuk menguruskan maklumat dan pangkalan data aset. Rekaan bentuk yang bertambah-nilai dalam sistem ini mempunyai fungsi yang membolehkan pertanyaan ruangan ke atas maklumat aset dan mendapatkan lokasi aset melalui model tiga dimensi. Sistem ini direka dan dibangun berdasarkan keperluan pengguna. Prestasi sistem ini telah diuji oleh pengguna akhir dan pakar-pakar dalam bidang berkaitan. Keputusan daripada ujian pengguna telah membukti sistem yang dibangunkan adalah membantu untuk mengurus aset dalaman. Sistem pengurusan aset yang berkomputer membolehkan rekod aset disimpan dalam sistem pangkalan data yang teratur. Akhirnya, fungsi baru yang menginterasi peta dan visualisasi tiga dimensi dalam sistem pengurusan aset boleh memanfaatkan analisis berdsasar konsep Sistem Maklumat Geografi seperti pencarian lokasi, pembesaran dan pengecilan dan melihat lokasi aset dari peta tiga-dimensi.

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LIST OF ABBREVIATIONS

2D	-	Two dimensional
3D	-	Three dimensional
BIM	-	Building Information Modelling
CAD	-	Computer-aided design
CK	-	Candidate Key
CSS	-	Cascading Style Sheets
DBMS	-	Database Management System
ER	-	Entity-Relationship
FK	-	Foreign Key
GIS	-	Geographic Information System
GPS	-	Global Positioning System
HTML	-	HyperText Markup Language
IDE	-	Integrated Development Environment
IEEE	-	Institute of Electrical and Electronics Engineers
PHP	-	Hypertext Pre-processor
PK	-	Primary Key
RAM	-	Random Access Memory
RFID	-	Radio Frequency Identification
SQL	-	Structured Query Language
TLS	-	Terrestrial Laser Scanning
TOF	-	Time of Flight
URA	-	User Requirement Analysis
URL	-	Uniform Resource Locator
VRML	-	Virtual Reality Markup Language
Wi-Fi	-	Wireless Fidelity

LIST OF SYMBOLS

r	-	Laser beam
x	-	x-axis
y	-	y-axis
z	-	z-axis
φ	-	Horizontal direction
θ	-	Vertical angle

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter gives the general overview of the main topics and highlight the main ideas of this research. Components presented in this chapter including background of study, research problems, research objectives, research questions, scope of study, significance of study and thesis structure.

1.2 Background of Study

In modern society, people are living in an artificial ecosystem where there are vast assemblage of interdependent living and non-living components (Rich and Davis, 2010). Man-made components also known as assets where assets include buildings, tool, piece of equipment, pipe or machinery used in the operation of a utility. Assets can also include mankind such as operator or asset manager.

Assets play an important role in an organization. Moreover, every organizations will strive to improve its operation and management of assets. Information systems are implemented for improving the ways to operate whereas asset management aims to increase productivity, cost efficiency, better asset quality, and better environment performance. However, large number of assets presents some asset management challenges to organizations (Zhang *et al.*, 2009). Tracking and

managing various types of assets are extremely difficult. Real time monitoring, management controlling, and maintenance may be necessary and helpful to ensure a smooth running facility at cost efficient levels, which can lead to increase the sustainability.

Asset management approach is traditionally about manual filing system. The record and information of assets recorded in paper-based form is practiced for the asset management processes till now. The development of information technologies helps people works easier and more systematic in daily activities, especially in the context of management. It offers efficient processing and large amount of information storage for asset management process. A recent developed concept of Geographic Information System (GIS) is an example of innovative solutions and as a tool for management. GIS technology has been introduced few decades ago. It is an information system that is designed to store, manage, manipulate, analyse, and display of spatial information for solving complex planning and management problems (Ramlal, 2005).

To enhance asset management performance, 3D GIS approach is applied for managing and maintaining assets with 3D information models. The 3D GIS approach of asset management relies on accurate locating, mapping, and reporting asset information in a complex 3D context to support the effective asset management (Liu and Yu, 2010). The emerging technologies are utilized to improve the maintenance operation which is considered having higher impacts. In this study, terrestrial laser scanning (TLS) for asset management is a newly emerging application. The laser scanning tool could be used for data collection while GIS approach could provide both data visualization and representations.

There are various types of possible data are suitable to represent 3D GIS data. In this study, the 3D data was acquired from terrestrial laser scanner. According to Ceesay (2014), TLS is suitable for a small area or individual building modelling. TLS technology is an efficient tool, which can acquire high density point data in an accurate and fast way then provide 3D information of real-world objects down to millimetre details (Arayici, 2007). Besides, Arayici (2007) also mentioned that the

laser scanning technology attains advantages over current survey techniques that including EDM, GPS, and photogrammetry; furthermore, its accuracy is ranging from 5mm to 25mm. Considering the remarkable performance of the TLS devices, it can be used as spatial data; emerging GIS approach can improve the asset management.

Today, internet has become an important resource for obtaining information. Traditional information management systems are all migrating to the World Wide Web (www) for integrating the information and improving facility management (Federal Facilities Council, 2001). A web GIS system is independent from platforms and operating systems. It is designed with tools and features on web pages with emerging of GIS tools. Users can access free GIS applications from web browsers instead of purchasing commercial desktop GIS software packages. Other advantages of web GIS system are all users can access, view, analyze, and share information timely via internet. A management activity with information technology through the connection of network enables users to retrieve related information rapidly in the limited time and space.

1.3 Research Problems

Asset and facilities give institutions excellent physical appearance of the university. The development and growth of university has increased the assets and facilities to improve the students' teaching and learning environment; and to provide the staff a good working atmosphere. However, increasing numbers of assets have reflected the limitations of current asset management system. As reported by Xiao and Sun (2012), assets of higher education institutions has increased the equipments for teaching, research and administrating. The issue of a large number of assets has highlighted the management effectiveness in every sector of management. Although there are various management system in markets, there is no any fixed standard. and thus fails to meet the requirements of each organization. Therefore, a suitable asset management system is needed to improve the asset management level.

Basically, every organization or institution has its own guidelines and practices for asset management. There are different asset management guidelines for every organization; however, the design is based on the asset management lifecycle. In Malaysia, Government Movable Assets Management Procedures has provided a standard asset management regulation for all government agencies in year 2007. This regulation provides a framework and guideline from acquisition phase, operation and maintenance phase to disposal phase. In 2009, an online asset management system or known as *Sistem Pengurusan Aset* (SPA) has been developed and implemented at overall local authorities. This system was planned to be implemented on phases starting from the Headquarters of Ministry to districts and schools management. Yet, some local agencies and universities seem not fully to use information systems at all levels of management. As addressed by Berahim *et al.* (2013), the local government has encountered difficulties in determining quantity and type of assets. This issue is reported in Audit General Report every year.

According to Buang (2011), Audit Report have reported inefficient and ineffective manners in asset management over the years. Besides, Mahadi and Hussin (2007) had pointed out some issues reported in Audit Report, namely, ineffective use of assets procured, improper records of assets and failure of running annual inspection. These issues should be eliminated and improved in a management of assets.

Some organizations often rely on the conventional asset management system which is hard-copy filing system or spreadsheet process system (Panduit Corporation, 2012). The accuracy of data and information can never be guaranteed due to unpredictable human error. Besides this, there is no central database that can provide instant information. Lacking of information and errors within this manual method can render insufficient databases. The current filing management system is less efficient in managing large number of asset records especially when users wish to extract certain information through all the records. This system may cause ineffectiveness to the entire management process (Panduit Corporation, 2012).

Furthermore, information security is always an emphasizing issue to an organization. The hard-copy filing system may cause insecurity or incompleteness of data storage. The asset management processes typically involve general paper works such as invoices, acquisitions and dispositions. The manual spreadsheet and filing system are difficult to keep up-to-date or data lost, especially the process involves more than one person. Under this method, multiple copies of records are made for the related department. It may have different changes applied to each copy by different people and this has added the risks of eventual data loss.

Majority operating in many organizations are paperless in general; people find it more convenient to keep their data in less bulky packages. The computerized asset management systems can eliminate the strenuous paperworks by creating a database system for storing asset information as well as automating the entire management and maintenance procedures. This system also reduces the workload and provides organizations a neat and tidy environment.

Another difficulty of the current management approach is the descriptive information that is separated with spatial location such as map. In some circumstances, map visualization can play an important role in helping users to gain full understanding about a location and environment. Sometimes, staff cannot have full understanding of an asset appearance and its location when they only read from the text information. Moreover, location plans or layout plans of building are usually in 2D computer-aided design (CAD) format. However, administrative staff may not fully understand CAD drawings in planar view. Consequently, this problem has identified the role of showing location plan in 3D visualization which is helpful and understandable.

From the issues above, one of the faculties in Universiti Teknologi Malaysia (UTM) is selected to study its asset management. Faculty of Geoinformation and Real Estate (FGRE) was selected to implement an integrate information management system with map visualization to manage indoor assets. FGRE is located at the centre point in UTM and its location is as shown in Figure 1.1.

Figure 1.1: Location of Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia

1.4 Research Objectives

The study aims to improve the weaknesses of the current asset management practice. To achieve the aim of the study, there are three objectives need to be fulfilled as follows:

i. To develop 3D model of asset using TLS technology
ii. To develop a web-based system for asset management process
iii. To evaluate the functionalities and usability of the developed system

1.5 Research Questions

The following research questions are addressed andshould be answered in order to fulfil the research objectives:

Table 1.1: Research objectives and research questions

	Research objectives	Related research questions
1	To develop 3D model of asset using TLS technology	• How to develop 3D model of assets by using TLS technology? • What kind of data format can be produced for the 3D model of asset?
2	To develop a web-based GIS asset management system in assisting asset management process	• How to develop a web-based asset management system in order to improve the current asset management practice? • How does the developed system can assist the asset management process?
3	To evaluate the functionalities and usability of the developed system	• What kind of functions the developed system performs? • How to evaluate usability of the system?

1.6 Scope of Study

There are four buildings belong to FGRE, namely B08, C02, C03, C04 and C05. Block C05 would be the focus in this research as this building has lecture rooms and research laboratories. The subject of this study is the management of physical indoor assets located in Block C05. Block C05 is a building with height of four levels. Figure 1.2 shows the facade of the building.

Figure 1.2: Block C05 of Faculty of Geoinformation and Real Estate

Assets involved in this research are known as inventory where the asset value costs below RM3,000 (according to UTM regulation). In this study, map visualization with spatial information is intended to be applicable in the faculty asset management system.

There are spatial data and attribute data used in this research. Spatial data are building and indoor map while attribute data are asset information collected from field. The map visualizations used in this research are 2D building floor plan map and 3D room visualization. The 2D floor plan map is obtained using the TLS technology while the 3D room models are used in Virtual Reality Modelling Language (VRML) format, hence it can display the models using web browser VRML viewer. In addition, asset information collected was stored in GIS database.

The system is developed as a web-based system. System interface is important for users to operate the system. Thus, there are few types of software used for the system development in this research. Table 1.2 lists the software used in this research.

Table 1.2: Software used

Software	Purpose / Use
Autodesk Revit Architecture	To construct 3D building and asset models from point clouds
Trimble SketchUp	To export 3D modelsinto VRML format
XAMPP (Apache)	Localhost web server
MySQL Database (phpMyAdmin)	To store asset attribute in database
NetBeans IDE	Source code editor and debugger for application
VRML viewer (browser plug-in)	To view 3D asset models in VRML format

The final stage is to evaluate the ability of the developed asset management system. The evaluation of the developed system is needed to ensure every function can be operated. The developed system will also be tested its ability and benefits in managing assets.

1.7 Significance of Study

The integration of 2D and 3D map visualization in asset management system will help to improve the efficiency and effectiveness for asset management in terms of storing asset information and monitor assets condition. Asset managers will be the most benefited as the system can store information, manage and update the database of assets in the way of easier and more systematic. The system can also present the information about asset locations through 3D visualization.

Furthermore, the system developed as web-based information system with ease-of-use system interface can be easy operated by users through web browser without having knowledge of GIS or other specific skills.

Lastly, this research also shows 3D models generated from point cloud can be used in GIS applications to make the application more interactive with 3D visualization. It is hoped that laser scanning technology would become more widely used as a data collection tool for GIS applications.

1.8 Thesis Structure

The thesis comprises of six chapters and the structure of the thesis is organized in the following way:

Chapter 1 provides an introduction and background information to the research. This chapter has outlined the research problem, research objectives, research questions, scope of study, and significant of study.

Chapter 2 tells the review of relevant literatures. Literature review provides the necessary background about asset management and concept of both integration of GIS and indoor asset management. The literature also reviews the asset management definitions in different contexts, for example, GIS application for asset management, as well as integration of database and 3D model.

Chapter 3explains the methodologies used in this study. It includes the process of data collection during the fieldwork conducted, process of 3D models construction and system development processes. It also explains how GIS can be applied in asset management. The methodology proposed is intended to accomplish research objectives and answer research questions in Chapter 1.

In Chapter 4, the activity sequences of system design and development are described in detail. This chapter begins with analysis of user requirements, and then followed by describing methods of designing the database and system interface.

Chapter 5 presents the results and analysis of this study. Results and analysis from this research are discussed to achieve or fail the objectives of this study.

Chapter 6 provides a conclusion according to research questions. Strengths and limitations of the system are highlighted and future implications are discussed for improvement.

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