

**AUTOMATIC BAT COUNTING AND IDENTIFICATION OF BAT SPECIES
USING TERRESTRIAL LASER SCANNING**

SUZANNA BINTI NOOR AZMY

UNIVERSITI TEKNOLOGI MALAYSIA

AUTOMATIC BAT COUNTING AND IDENTIFICATION OF BAT SPECIES
USING TERRESTRIAL LASER SCANNING

SUZANNA BT NOOR AZMY

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DEDICATION

Family that always believe in me

Noor Azmy Bin Zainaabidin

Siti Zurina Binti Mohd Zulkifli

Mohd Sabri Bin Noor Azmy

Suhana Iryani Binti Noor Azmy

Mohamad Syafierul Asyraf Bin Noor Azmy

My Best Buddy

Rizka Akmalia

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ABSTRACT

The current practice in roosting bat population survey and species identification is either based on net capture, visual observation or optical-mechanical count methods. However, these methods are intrusive, tedious, time consuming and at best, only reports an estimation of the roosting population of bats. Here, the present study showed the use of Light Detection and Ranging (LIDAR) concept using terrestrial laser scanner was successful in remotely identifying and determining the exact population of roosting bats in caves. The laser scans accurately captured the three dimensional (3D) features of the roosting bats and their spatial distribution pattern in total darkness. Using LIDAR, the determination number of bats can be conducted, spatially analyze the 3D distribution of bat populations as well as generate a 3D topological structure of the roosting cave. This resulted in a high resolution model of the cave, enabling exact count of visibly differentiated individual bats. This successfully leads to the species identification of the *Hipposideros larvatus* and *Hipposideros armiger* reported in this study. This studies anticipate that the development of the LIDAR into a non-intrusive technique will open up new possibilities in bat roosting studies. This novel method would possibly allow future works accomplishment of researchers to study roosting behavior such as maternity roosting patterns, roost sharing and roost-switching patterns within the topographical context of the speleological (caves, subterranean spaces and caverns) internal surface, thus making rigorous quantitative characterizations of cave roosting behavior possible. The final results of this study would be an automated procedure for bat population count and the function of point cloud data in assisting the species identification.

Keywords: Laser Scanning, Roosting Bats, LIDAR, Automatic Bat Counting, Bat Population.

ABSTRAK

Kaedah praktikal yang biasanya digunakan di dalam kajian bilangan populasi kelawar serta pengenalpastian spesies adalah menerusi penangkapan kelawar menggunakan jaring (*net capture*), pemerhatian visual ataupun pengiraan menggunakan peralatan optikal-mekanikal. Bagaimanapun, kaedah-kaedah ini berbentuk *intrusive*, yang mana ia mengganggu subjek secara fizikal sama ada melalui sentuhan ataupun cahaya. Selain itu, kaedah praktikal sedia ada mempunyai kekangan dari segi masa (memakan masa) dan hanya melaporkan anggaran populasi dan bukannya bilangan tepat individu kelawar di sesuatu tapak kajian. Di dalam kajian ini, konsep *Light Detection and Ranging* (LIDAR) di aplikasikan dengan menggunakan peralatan *Terrestrial Laser Scanner* (TLS) digunakan secara capaian jauh bagi mendapatkan bilangan populasi serta identifikasi spesies kelawar di dalam gua. Pancaran laser akan mengimbas gua secara jitu untuk merakam kedudukan ruang kelawar serta gua dalam bentuk tiga-dimensi (3D) didalam keadaan gelap gelita. Penggunaan LIDAR membolehkan bilangan individu kelawar ditentukan di samping menganalisis taburan kelawar secara spatial dan juga menghasilkan struktur tiga dimensi topologi gua. Hasil pengimbasan ini menghasilkan model gua dengan resolusi tinggi yang membolehkan kelawar dikira dan jumlah populasi kelawar di dalam gua dapat dipetakan. Melalui kaedah ini, dua (2) spesies kelawar dapat dikenalpasti iaitu *Hipposideros larvatus* dan *Hipposideros armiger*. Kajian ini dijangka dapat membuktikan bahawa penggunaan LIDAR akan membuka ruang baru dalam kajian berkaitan kelawar. Hasil dari kajian ini berupa satu prosedur untuk mendapatkan bilangan populasi kelawar secara automatik dan membuktikan bahawa kegunaan data *point cloud* dapat membantu pengenalpastian spesies kelawar.

Kata kunci: Imbasan Laser, Kelawar, Kajian Populasi, Pengiraan Automatik

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LIST OF ABBREVIATIONS

2D	Two dimensional
3D	Three dimensional
ALSM	Airborne Laser Swath Mapping
ASCII	American Standard Code for Information Interchange
DBSCAN	Density-Based Spatial Clustering Of Applications With Noise
DEM	Digital Elevation Model
EMF	Electromagnetic field
khz	Kilohertz
LIDAR	Light Detection and Ranging
mm	Millimetre
mW	Miliwatt
NEXRAD	Next-Generation Radar
nm	Nanometer
NOAA	National Oceanic and Atmospheric Administration
py	Python file
RGB	Red Green Blue
TLS	Terrestrial Laser Scanner / Scanning
TOF	Time of Flight
WNS	White Nose Syndrom

LIST OF SYMBOLS

λ	wavelength
v	value of speed of light
t	and the measured time interval
$\Delta\varphi$	measured phase difference
R	laser range
$\Delta\lambda$	modulated wavelength
\pm	more or less
I	intensity
ρ	reflectance of material
cos	cosine
α	incidence angle
r^2	distance/ mean of range
η_{sys}	system transmission factor
C	unknown factor

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The core business in biodiversity is the ecology and the evolution of species. This research will deal with the evolution element which caters the study of the origin of the diversity and the ecology which study about the biological organism with its environment. The main biological features in this study are bat, or scientifically known as *Chiroptera*. Bat are the only mammals that have ability to fly that constitutes of more than 1,111 species all over the world (Kingston et al, 2009). According to Kingston, 2009, the population of bat worldwide are declining over time and eight species has been found extinct. Thus, a frequent monitoring of population size is required to track species declination and to prevent the extinction of the bats.

Bat has been a reclusive animal, human never realizes the important role plays by the bats in balancing the environment and symbiosis equilibrium. Human ignorance and fear towards bat indirectly affecting their population. In certain areas in the Asia region, bat is consumed as exotic food pervasively without any controls and awareness. Bat is known for its function as pollinators, organic fertilizer as well as insect population controller as it consumes on insect as one of the components in preserving the equilibrium of natural symbiosis (Kunz, 2011). Bats are beneficial to the environment as it serves as the pollinator and spread the plant seeds. There are some species of the plant that partly and fully dependant on the bats as pollinator.

According to Kingston et al., 2009, in Malaysia at least 31 plant species rely on bats for pollination including favourites such as durian, petai, mango, banana, guava, jackfruit and papaya. In the same paper, Kingston et al., (2009) reported, in the mid-80's the sales of durian were valued as much as US\$ 120 million and the petai trades in Klang Valley approximately estimated to reach US\$ 2.8 million annually.

Besides that, bats also important to the agricultural economy since it helps to eat pest insect in a significant amount. According to study by Boyles et al., 2011, it is estimated that single individual of little brown bats, *Eptesicus fuscus* can consume from 4g to 8g of insects each night during the active season. The declination in numbers of bat definitely will disrupt the agricultural profits due to destroyed plants eaten by the pest.

The population declination is one of the inspirations of the idea of this research. As reported by many bat researchers such as Lane et al., (2006) and Kingston et al., (2009), there is a need for a method to allow the quantification of bat population count in fast, automated yet accurate results. This method allows the bat population survey to be conducted more frequently for cataloguing and observation to detect the species declination. From the annual catalogue, some action can be taken in order to prevent the extinction of bats in the future.

A study conducted by Lane et al., (2006), shows that bats in Singapore and South East Asia faces a serious declination in species richness due to the deforestation and urbanization. Another factor of threats that increase the declination of bat species are the human hunting, White Nose Syndrome (WNS), wind turbine, radio waves, and lighting. White Nose Syndrome caused by fungus (*Geomyces destructans*) which infects the bat's skin while they are hibernating, and the fungus is found reacting by triggering the fatal alteration in behaviour and physiology of bats such as premature depleting of energy reserves. Since February 2006, when WNS was first observed on bats in upstate New York, *G. destructans* has spread west of the Appalachian Mountains and into Canada. To date, over one million bats have probably died, and winter colony declines in the most affected region exceed 70% (Boyles, et al., 2011). Another factor that massively kills the migratory bats are the

wind turbines which can be found numerously across country. In Mid-Atlantic Highland alone, 33000 to 111000 individuals of tree-dwelling bats are recorded killed because of wind turbines. According to studies of Nicholls and Racey, (2009), it is shown that activities on habitat that exposed to the electromagnetic radiation is significantly reduced. Bat activity was significantly reduced in habitats exposed to an EMF (electromagnetic field) strength of greater than 2 v/m when compared to matched sites registering EMF levels of zero (Nicholls and Racey, 2009). The study suggests that the electromagnetic signal within a certain pulse able to induce the aversive response in foraging bats. However, it is largely predicted that the reduction of bat activities in the electromagnetic area may due to thermal induction and an increase risk of hyperthermia than the direct impact of radio waves.

From this motivation, it is important to have a systematic population monitoring methods to allow the species and population recording in a way to preserve and conserve the bat population in Malaysia. Population survey using terrestrial laser scanning method offers a non-intrusive solution to populate the number of roosting bats in the cave without disturbing its ecology or emotion stability by introducing unnecessary light or noise during the data collection.

Another reason to conduct this study is the approach of current practice in roosting bat population survey. It is either based on visual observation or optical-mechanical methods such as acoustic bat detector, infrared cameras, thermal images and radar systems. Historically, censuring bats in caves involves direct roost count for single individuals or clusters with less than 30 individuals; while larger clusters are estimated by multiplying the number of bats in the illuminated area by the total area needed to cover the entire cluster. Traditional methods also include emergence counts, dispersal counts and disturbance count during daylight or crepuscular conditions (dusk and dawn), often with a bat detector for species confirmation. Thermal imagers have been shown to be successful but there are shortcomings in other automated methodologies of bat surveying. Therefore, there is currently no method to accurately and effectively survey, map and identify bats in a non-intrusive manner in caves. With this motivation, we decided to conduct research and development that aim to propose a new non-intrusive method for chiropteran surveys

which utilizes laser scanning technology and GIS principles in analysing the distribution pattern and population size of chiropteran. The focus of research is on the novelty of the method of the survey itself, as well as how the data yield that would be of great benefit to biologist in this area. This thesis will briefly discuss the current practice in chiropteran survey and the comparison with the proposed new method compared to other existing methods.

The major concern of this study is to obtain the population size of the cave bat colony as well as improving the method of bat population survey from a tedious manual count to the non-intrusive, fast yet accurate method using terrestrial laser scanning method. This study will utilize point cloud data produced by the terrestrial laser scanning survey for feature extraction that will yield a highly-dense three-dimensional point cloud data as a product which expands the manipulative ability and the accuracy for comprehensive analysis and modelling. The classification of point cloud data will differentiate the cave rugged shape and the bat individuals. With a detailed survey of laser scanning, it is possible to yield the elaborate shape of each bat to determine its species without direct contact with the subject.

1.2 Problem Statement

The main purpose to conduct this study is to propose an alternative method to speed up the process of obtaining bat population size and assist the species identification process from point cloud data that collected using terrestrial laser scanning technique. The method of conventional and practical data collection used at this time is very tedious, time consuming and tend to involve the contact of human with bats. Furthermore, the population number obtained from conventional method is an estimated or projected value instead of giving a whole value. We proposed a method with property of non-intrusive, full coverage of data collection and less time spend on field but with a reliable quality of data. In order to track and prevent species extinction, at least an annual population survey need to be conducted. The proposed method fulfils the needs, where the data can be collected within half day

and further processing can be done in the lab. The conventional method and the limitation are explained in detail in the literature review section in Chapter 2.

1.3 Aim of the study

This study aims to achieve automatic calculation of bat population numbers and human assisted species identification from the output of utilization of Terrestrial Laser Scanning (TLS) technique as a new approach in the bat survey data collection.

1.4 Objectives of Study

- i. To show the proof of concept of utilizing point cloud data as alternative of non-intrusive survey for estimating the number of bat roosting in the cave.
- ii. To develop an automated feature extraction of bat from the point cloud data.
- iii. To develop an accurate population estimation of the bat based on the automated feature extraction and clustering of the point cloud data.
- iv. To perform human-assisted species identification of bats based on the collected data.

1.5 Research Question

- i. How to automatically extract the bat individual from the point cloud?
- ii. How to identify the species of the bat roosting in the cave?
- iii. How to validate the correctness of the result of population count using the proposed method?

1.6 Scope of the Study

The research will focus on cave bats that roosting in the cave in the Northern Region of Peninsular Malaysia as shown in Table 1.1. The field of study only covers the population size of roosting bat and the species identification using point cloud data. This study is conducted with few assumptions that is:

- i. The bat is not moving. (roosting position)
- ii. The scan covers the whole study area.

Table 1.1: The study Area

Cave Name	Location	Latitude (N)	Longitude (E)
Gua Asar	Lenggong, Perak	5°10'23.87"	100°59'57.14"
Gua Wang Burma	Padang Besar, Perlis	6°37'41.33"	100°11'13.69"
Gua Kelawar	Sungai Kilim, Langkawi	6°24'6.55"	99°51'32.84"

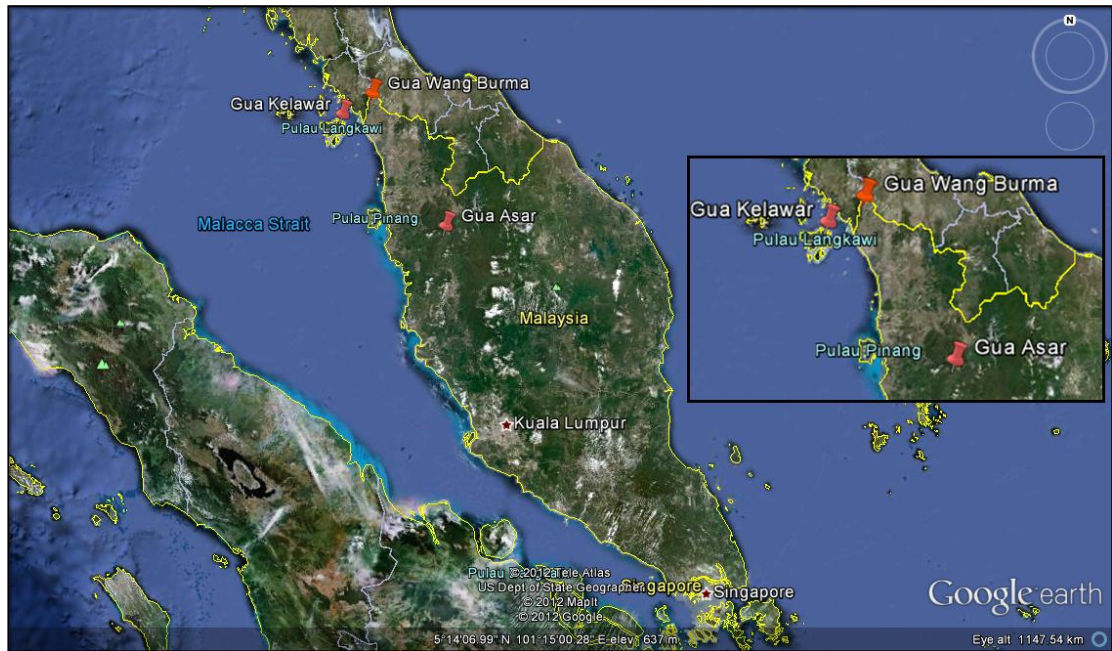


Figure 1.1: The map of study area's location in Peninsular Malaysia

1.7 Expected Results

The results are expected to be in the form of automatic procedure to assist the automatic counting of bats, from the collected point cloud data. From the point cloud data, the species identification will be done semi-automatic on the scanned bat on the point cloud, based on obvious, clear and measurable physical feature that documented as usable for identification.

1.8 Significance of Study

This study will develop a novel method of bat population survey which is scientifically measured accuracy, quick and non-intrusive. With the proof of concept outlined in this research, the bat population catalogue can be compiled annually in order to track the declination of species in order to prevent the extinction.

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