PERFORMANCE ANALYSIS OF REAL-TIME LIGHTNING
REMOTE SENSING

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

2022

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Performance Analysis of Real-Time Lightning Remote Sensing

Sesi Pengajian : 2021/2022

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DEDICATION

I humbly dedicated this thesis to be submitted in partial fulfilment for the degree of Bachelor of Electronic Engineering with Honours. The project aims is to classify the type of lightning. Hence, the content of this study is to classify lightning from the lightning dataset in real-time with high accuracy.

This thesis is dedicated to my supervisor, PM DR. MOHD RIDUAN BIN AHMAD for his continued support and counsel during the time I developed the system. The dedication also to my parents, who have never failed to give me financial support, and moral support which has made possible the success of this project.

ABSTRACT

Lightning happens when electrostatic discharges occur between positive and negative charges between cloud to cloud or cloud to ground. Every different type of lightning has its different appetence and waveforms. This lightning remote sensing system is an early detection and warning alarm which can give advanced notice of lightning. The project's objective is to design a Performance Analysis of Real-Time Lightning Remote Sensing and increase the system accuracy for lightning classification. The system uses Picoscope 2204A to send digitized lightning signals to the MATLAB software. The digitized signal is processed in MATLAB and saves the lightning data. The project's expected outcome is to identify the type of lightning with high accuracy.

ABSTRAK

Kilat berlaku apabila nyahcas elektrostatik berlaku di antara cas positif dan negatif di antara awan ke awan atau awan ke tanah. Setiap jenis kilat mempunyai ciri dan bentuk gelombang yang berbeza. Sistem penderiaan jauh kilat ini adalah pengesanan awal dan penggera amaran yang boleh memberikan notis kilat lebih awal. Objektif projek adalah untuk mereka bentuk Analisis Prestasi Kilat dalam Masa Nyata dan untuk meningkatkan ketepatan sistem untuk pengelasan kilat. Sistem ini menggunakan Picoscope 2204A untuk menghantar isyarat kilat digital kepada perisian MATLAB. Isyarat digital sedang diproses dalam MATLAB dan menyimpan data kilat. Hasil jangkaan projek ini adalah untuk mengenal pasti jenis kilat dengan ketepatan yang tinggi.

ACKNOWLEDGEMENT

Alhamdulillah, most precious thanks to ALLAH S.W.T, who will give me the opportunity to complete my thesis. All praise to Allah.

Firstly, my most sincere gratitude to my supervisor Prof. Madya Dr Mohd Riduan Bin Ahmad, for his kindness and patience during this year of this project and for who made this work possible. His guidance, understanding and advice carried me through all the stages of writing my project.

My deepest thanks and appreciation to my beloved father and late mother, Abd Latiff Bin Md Salleh and Rahmah Bt Badri and my family for their continuous support, encouragement, and prayer from the beginning until the end. Your prayer for me was what sustained me this far.

Finally, thanks to my friends in UTeM and everyone who have been contributed by supporting my work and helping me during the journey till it is fully completed which makes the journey of this project even more cheerful.

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LIST OF SYMBOLS AND ABBREVIATIONS

CG	:	Cloud to Ground
NCG	:	Negative Cloud to Ground
PCG	:	Positive Cloud to Ground
IC	:	Intracloud
NIC	:	Negative Intracloud
PIC	:	Positive Intracloud
CA	:	Cloud to Air
CC	:	Cloud to Cloud
NBE	:	Narrow Bipolar Events
NON	:	Unknown
V	:	Voltage
KM	:	Kilometer
ETS	:	Equivalent-time sampling
GUI	:	Graphical User Interface
TD	:	Thunderstorms Days
ns	:	Nanosecond
ps	:	Picosecond

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CHAPTER 1

INTRODUCTION

1.1 Background

Lightning is one of the most frequently occurring geophysical phenomena[1]. Lightning is an electrical discharge resulting from imbalances between storm clouds and the ground or within the clouds themselves[2]. It is also a significant weather hazard that occurs at an average rate of 50 to 100 discharges per second worldwide[3]. As a result of its negative impact on human safety, equipment failures, and danger, lightning strikes are a significant concern for humanity. Numerous lives are lost annually due to lightning-related incidents around the world. In fact, lightning-related deaths and property damage are more common in countries with more thunderstorm days, such as Malaysia[4]. Lightning is also a sudden electrostatic discharge during an electrical storm. When it strikes an object on the ground, it temporarily allows charged regions in the atmosphere to equalize themselves. 90% - 95% of lightning strikes on the ground are negative-charged, which is a stepped leader. When the charge differences between the large region of negative charge at the centre of a thunderstorm and the small region of positive charge at the base of the storm increase, the leader develops. The minimal amount of positive charge at the cloud's base near the developing conductive channel is insufficient to balance the negative charge that has accumulated along the channel's path in the atmosphere. Thus, the negatively charged channel emerges from the cloud's base and continues to move toward the ground[5].

There are various types of lightning flashes, including cloud-to-ground (CG), cloud-to-cloud (GC), cloud flashes, anvil crawlers, and ribbon. The cloud-to-ground (CG) type of lightning occurs the most frequently. The other type of lightning flashes occurs infrequently. Positive cloud to ground (+CG) and negative cloud to ground (-CG) are the two categories of cloud to ground (CG). Cloud flashes are also classified as narrow bipolar even (NBE) and intra-cloud flashes (IC).

The available lightning detector can only detect lightning in a general sense and cannot accurately classify the type, location, or properties. The data must undergo post-processing, which could take one to three days before being published on the website. It will take time for the information to be delivered. In addition, the ground-based system has a margin of error that occasionally causes it to underestimate lightning. Consequently, the estimation would result in an incorrect calculation of flash energy, location, and type of lightning. Consequently, the displayed result is inaccurate.

Electromagnetic solid radiation accompanies the lightning process, and the signal frequency bands include shallow frequency (VLF), low frequency (LF), high frequency (HF), and very high frequency (VHF). Principally, lightning is observed by using antennas to receive lightning signals in different frequency bands[6].

Differentiating cloud flashes from cloud ground flashes has been a crucial indicator in lightning research and monitoring. According to incomplete statistics, the direct cause of lightning strikes are cloud-to-ground flashes, which kill or injure over 10,000 people annually. After receiving the lightning signal, the lightning sensor will classify it, determining whether it is a cloud flash or cloud ground flash, and then uploading the classification result to the lightning location calculation server. In general, the signal-to-noise ratio of the waveform and the rise and fall times of the lightning waveform are used to differentiate between cloud flash and cloud ground flash[6]. Due to the complexity and diversity of lightning, the statistical method is only applicable to single-pulse events or a single thunderstorm. In addition, this method's classification effect is not optimal for practical applications. The recognition rate of cloud ground flashes is between 70% and 80 %, the recognition rate of cloud flashes is less than 85%, and it cannot distinguish ionosphere reflection signals effectively[6].

From a lightning location perspective, cloud-to-ground flash is lightning that strikes the ground directly. If the location algorithm can utilize the type of lightning as a general condition, this will significantly improve the lightning's location accuracy. The classification of lightning signals is essential for lightning warning and weather forecasting. Numerous cloud-to-ground flashes indicate the presence of regional thunderstorms. The accurate identification of cloud-to-ground types can enhance the safety of aircraft navigation. In conclusion, we need a more effective method to distinguish lightning signals.

1.2 Problem Statement

Malaysia has one of the nearly highest rates of lightning-related injuries globally. This is because this "Crown of Lightning" storm causes more than 70% of power outages in Malaysia [7]. According to lightning researchers in Malaysia, between 100 and 150 people are killed annually by lightning. Using 125 per year produces an annual death rate of 3.4 per million people. In terms of population size, Malaysia's lightning death and injury rate are ten times that of the United States, which has 300 million people, compared to Malaysia's 27 million[8]. As a result of Malaysia's location on the equator and the amount of sunlight it receives, lightning strikes occur nearly every day, generating high vertical updrafts that produce cold fronts and moist air.

It causes more frequent thunderstorms. The clearing of land and deforestation for development also exacerbate the impact. Malaysia is experiencing between 25 and 4000 thunderstorms. The annual average number of thunderstorm days (TD) in Peninsular Malaysia ranges between 159 and 281[9]. However, reliable statistical data on lightning fatalities in Malaysia is often tricky to accumulate. The problem is:

1) The accuracy of lightning remote sensing is hard to accurately identify the detected occurrence of a lightning strike because the noises may cause the lightning frequencies to be hard to detect and affect the identification of the type of lightning.
2) The accuracy of classifying the lightning is low due to signal processing used on the available lightning remote sensing.
3) Available lightning remote sensing is not in real-time

1.3 Objective

The objectives of the project are as follows:

1) To design and develop a real-time lightning detection system.
2) To evaluate the lightning detection accuracy by proposing three different codes.

1.4 Scope

The PicoScope is used to send digitized signals to the MATLAB program. The MATLAB will then process the Pico Scope's digitalized lightning data. MATLAB will perform signal pre-processing. Then, signal processing is used to analyze the lightning location data in terms of positive cloud to ground, negative cloud to ground, positive intracloud, negative intracloud, latitude, and longitude.

Real-time signal processing in MATLAB constitutes the majority of this project. Once the lightning signal is input into MATLAB, the coding will automatically process it and generate its waveform by comparing and analyzing it with a signal processing method. The location and type of lightning will be identified within seconds, and the MATLAB database will be updated accordingly.

1.5 Thesis structure

The project focuses on the classification of lightning in real-time. The content of this project is categorized into five chapters.

Chapter 1 is an introduction which comprises the background of lightning and an overview of the real-time lightning remote sensing system, the objectives, and the project scope. This chapter also discussed about the problem statements regarding the existing lightning remote sensing and signal processing method.

Chapter 2 is explained about the literature review to which the other research is related. In this chapter, some reviews regarding three common types of lightning flash and the information about signal processing methods of the previous study will be mentioned.

Chapter 3 explains the technical design of the coding and methodology used in recognizing the lightning remote sensing system. This chapter also discusses the activities about the activities of the project, such as working flow, procedure, block diagram, and some methods for the development of the project.

Chapter 4 is discussed based on the result and the overall project. The operation and what happens with real-time lightning remote sensing is discussed. Also, the similarities and differences will be explained by comparing the theory and practice.

Chapter 5 concluded with the whole project. This chapter summarises the overall achievement of this project and discusses some recommendations for