Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF IOT-BASED TIPPING BUCKET RAIN GAUGE USING ARDUINO FOR RAIN TYPE DISCRIMINATION

TAN CHIN KWANG

Bachelor of Electronics Engineering Technology with Honours

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A project report submitted
in partial fulfillment of the requirements for the degree of
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI KEJUTERAAN ELEKTRIK DAN ELEKTRONIK

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Supervisor Name : DR. NOR AZLAN BIN MOHD ARIS

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DEDICATION

This thesis is dedicated to my parents and family member who give me many kinds of support and encouragement during completing this project. I also would like to dedicate my friends and supervisor that always possibly help me when I have trouble with this project

ABSTRACT

A rain gauge is a common instrument used to measure the amount of liquid that has been collected within a period of time by meteorologists or hydrologists. There are many different types of rain gauges and the most common measuring instrument is tipping bucket. Tipping bucket rain gauge (TBRG) is a rain measuring instrument which functions automatically and can detect the type of rain (light, medium, heavy and violent). Modern tipping bucket rain gauge involves the electronic circuit to record or transmit to a remote collection station. Therefore, Internet of Thing (IoT) can be applied in TBRG and subsequently result in a more systematic and automatic way. A new IoT device with connecting Tipping Bucket Rain Gauge is designed and integrated with Lora antenna to achieve the transmitter area over 10 km. Besides that, the arduino system will connect to the server and user can obtain the data easily by using a phone. For the tipping bucket rain gauge development, a different material in the form of 3D printed materialis used to reduce the overall development cost. The output will be shown in the LCD display and the phone app. The graphical representation of the data is shown in the app, and can be exported to Excel to carry out the calibration error for the rainfall measurement and is useful for further processing.

ABSTRAK

Alat pengukur hujan adalah alat yang biasa digunakan untuk mengukur jumlah cecair yang telah dikumpulkan dalam jangka waktu tertentu oleh pakar meteorologi atau hidrologi. Terdapat banyak jenis alat pengukur hujan dan alat pengukur yang paling biasa adalah tolok hujan timbal balik (“tipping bucket”). Tolok hujan “tipping bucket” (TBRG) adalah alat pengukur hujan yang berfungsi secara automatik dan dapat mengesan jenis hujan (ringan, sederhana, dan lebat). Alat pengukur moden ini melibatkan litar elektronik untuk merakam atau menghantar ke stesen pengumpulan yang jauh. Oleh itu, Internet of Thing (IoT) boleh digunakan dalam TBRG dan seterusnya menghasilkan cara yang lebih sistematik dan automatik. Peranti IoT baharu dengan yang disambungkan dengan TBRG disepadukan dengan antena Lora untuk mencapai jarak kawasan pemancar yang melebihi 10 km. Selain itu, sistem arduino akan disambung ke pelayan di mana pengguna boleh mendapatkan data dengan mudah dengan menggunakan telefon. Untuk pembangunan tolok hujan “tipping bucket”, bahan yang dicetak daripada mesin pencetak 3D digunakan untuk mengurangkan kos pembangunan keseluruhan. Keluaran akan ditunjukkan dalam paparan LCD dan aplikasi telefon. Graf data ditunjukkan dalam aplikasi, dan juga eksport ke Excel untuk melakukan ralat penentukuran untuk pengukuran hujan. Dan juga berguna untuk pemprosesan selanjutnya.

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LIST OF SYMBOLS

σ	-	Standard Deviation of estimation
%	-	Percentange
℃	-	Temperature
μ	-	Average error of estimation
mm	-	Milimetre
hr	-	Hour
mm^2	-	Surface area in milimeter

LIST OF ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
IoT	-	Internet of Thing
TBRs	-	Tipping Bucket Rain Gauge
RG	-	Rain Gauge
SMS	-	Short Message Service
GSM	-	Global System Mobile
ARG	-	Automatic Rain Gauge
GPRS	-	General Packer Radio Service
SQL	-	Structured Query Language
ABS	-	Automatic Rain Gauge
LCD	-	Liquid Crystal Display

CHAPTER 1

INTRODUCTION

1.1 Background

Rain gauge is a common instrument used by meteorologists or hydrologists to measure the amount of liquid collected over a period of time. There are many types of rain gauge which are tipping bucket gauges graduated cylinders, simply buried pit collectors and weighing gauges. The common instrument in the rain fall measurement is tipping bucket rain gauge. Therefore, the purpose of this project is to study the tipping bucket rain gauge, since it can be used to estimate the amount of rainfall. In addition it can also be used to estimate the amount of snowfall during snow season. However, tipping bucket rain gauges are expensive compared to others type of conventional rain gauge. This is because it is incorporated with automatic data loggers. Nowadays, Internet of Thing (IoT) become prevalent in this world. The IoT is a system of interconnected computing devices that can transmit data over the network without human-to-human or human-computer interaction. By using IoT, we can collect the data from rain gauges in an easy and systematic way. In order to reduce the cost of the tipping bucket, the project aims to design a new tipping bucket rain gauge by using different elements. Furthermore, it will use IoT system via Arduino to transmit the data such as the type of rain, daily, weekly, monthly and yearly accumulated rainfall to the phone.

1.2 Problem Statement

Tipping bucket rain gauge is recognized as the world standard for measuring rainfall and precipitation in remote and unattended locations. Although tipping bucket rain gauges is not as accurate as standard rain gauge, it is useful to distinguish the type of rain (light, medium, heavy or violent). However, due to mechanical movement, it is much more expensive since it is incorporated with automatic data logger. Besides that, it needs a camera to record the motion. Nowadays, the modern tipping bucket uses electronic components such as reed switch to obtain the data. It becomes easier to get the data and no need to use a camera and human eye to record the tip and hit the calibration/stop screw. However, it cannot be automatically send the data to user. But with the use of Internet of Things (IoT), it can achieve automation without checking the record to get the result. However, the area of the tipping bucket rain gauge will be limited if we use the wire to connect to another device to show the result. In this case, a new IoT device with connecting Tipping Bucket Rain Gauge design integrated with using Lora antenna to achieve the transmitter area which is over 10 km. Besides that, the arduino system will connect to the server and the data can be abstained easily by using a phone. For the tipping bucket rain gauge will use different material to reduce the cost of tipping bucket rain gauge.

1.3 Project Objective

The main aim of this project is to propose a systematic and effective system to measure rainfall which uses a tipping bucket rain gauge by using IoT.

Specifically, the objectives are as follows:

a) To develop a rain gauge system that is able to detect the type of rain.

b) To design a low cost IoT based tipping bucket rain gauge with an ability to transfer data to cloud.

c) To design a display that show the result rainfall measurement on the phone app for easy monitoring.

1.4 Scope of Project

The scopes of this project are as follows:

a) Use Arduino as a microcontroller for programming and creating a systematic and effective system.

b) Coverage for connection of the transmitter and receiver is limited within 10 km.

c) To design the phone application, Blynk app is the best choice to use which has free server and limited open source.

d) Tipping Bucket Rain Gauge will be produced by 3D printer to reduce the cost. However, the disadvantage is heat intolerant during hot day

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this contemporary society, the rain gauge is an important rain measuring instrument to estimate the amount of rainfall. It provides accurate and relevant information about the weather. Besides, it can remind us to bring along an umbrella if the local meteorologist detects it as a rainy or cloudy day. It not only can track weather, but also can be utilised to help farmers plan the best time for planting. The farmers can recognize the weather pattern and start to take precautionary action. This directly can prevent destruction of yield crops by natural disasters. Rain gauge is the easiest tool for everyone to measure precipitation. There are many different types of rain gauges and the most common measuring instrument is tipping bucket. Tipping bucket rain gauge (TBRG) is a rain measuring instrument which functions automatically and can detect the type of rain (light, medium, and heavy). Modern tipping bucket rain gauge involves the electronic circuit to record or transmit to a remote collection station. Therefore, internet of thing (IoT) can be applied in TBRs and subsequently result in a more systematic and automatic way. Internet of Things (IoT) is an advanced and efficient solution for connecting things to the internet. This has become a common phenomenon in this modern age as it is applicable in every industry and even the living environment around us.

2.2 Different Type of Rain Gauge

2.2.1 AJoss–Waldvogel disdrometer derived rainfall estimation study by collocated tipping bucket and rapid response rain gauges

This research were done by Tanvir Islam,* Miguel A. Rico-Ramirez, Dawei Han and Prashant K. Srivastava in 2012. They used different type of rain gauges which are one tipping bucket and three rapid response drop counting devices. In the integration period, tipping bucket is more sensitive than the three rapid response rain gauges. [1]

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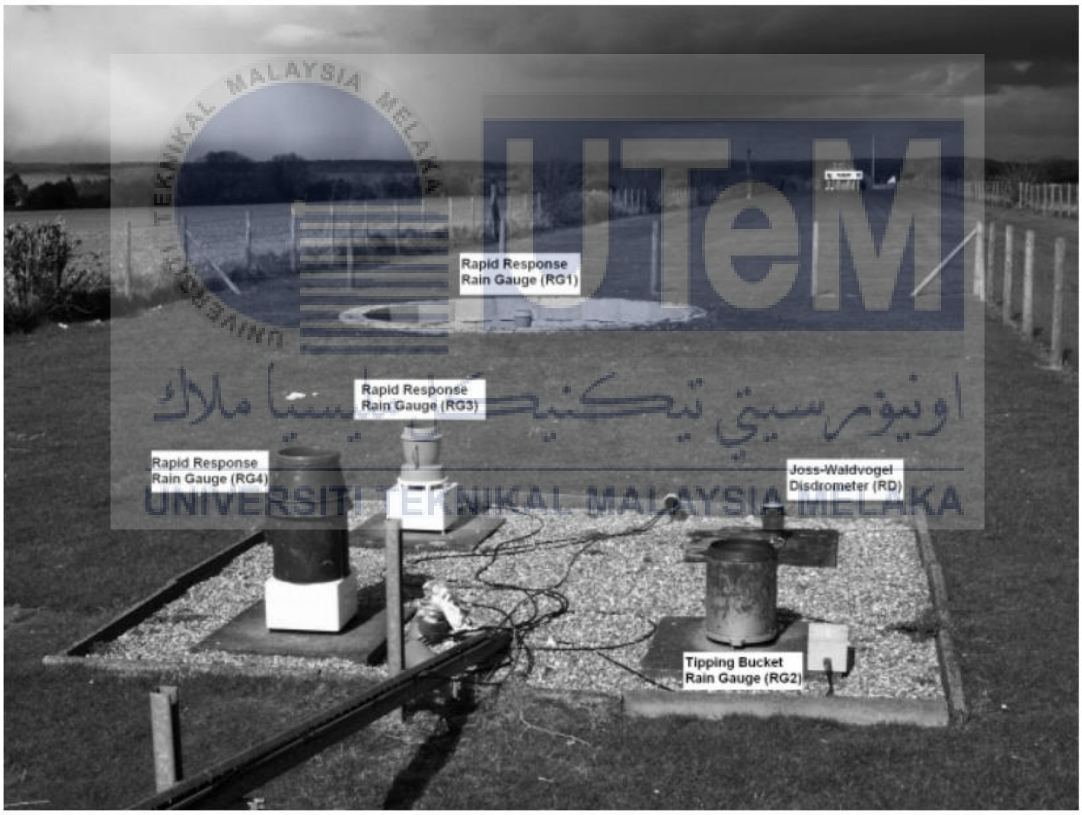

Figure 2-1 Different type of rain gauge testing

Table 2-1 Parameter for the rain gauge

Table I. Statistical performance of the JW disdrometer-derived hourly rain accumulations with respect to the four rain gauges (RG1, RG2, RG3, and RG4). Study period is 2003–2010.

	RG1			RG2			RG3			RG4		
Year	Coefficient of correlation, r	Mean absolute error, *MAE* (mm)	Normalized mean bias (%)	Coefficient of correlation, r	Mean absolute error, *MAE* (mm)	Normalized Mean Bias (%)	Coefficient of correlation, r	Mean absolute error, *MAE* (mm)	Normalized mean bias (%)	Coefficient of correlation, r	Mean absolute error, *MAE* (mm)	Normalized mean bias (%)
2003	0.95	0.24	−29.18	0.89	0.28	−18.65	0.92	0.45	−50.28	0.93	0.33	−45.20
2004	0.95	0.30	−29.87	0.93	0.22	−3.46	0.94	0.27	−30.60	0.95	0.22	−30.61
2005	0.98	0.25	−38.70	0.97	0.16	−1.13	0.97	0.18	−24.44	0.98	0.13	−24.75
2006	0.93	0.26	−18.31	0.99	0.29	19.57	0.99	0.15	−11.26	0.99	0.10	−6.54
2007	0.89	0.28	−26.00	0.94	0.26	19.92	0.98	0.15	−13.49	0.99	0.11	−9.73
2008	0.97	0.32	−34.03	0.97	0.21	10.54	0.97	0.22	−23.32	0.97	0.17	−19.11
2009	0.97	0.35	−43.22	0.97	0.18	−12.95	0.97	0.30	−36.19	0.97	0.24	−32.99
2010	0.98	0.27	−40.07	0.96	0.13	−10.20	0.98	0.25	−35.32	0.98	0.21	−32.71
All	0.93	0.29	−32.65	0.95	0.23	3.02	0.96	0.24	−27.23	0.96	0.18	−23.89

2.3 Different Model of Tipping Bucket Rain Gauge

2.3.1 Research on tipping bucket rain gauge with digital photography technology

This research was presented by Minhan Liu, Jiufu Liao, Aimin Cai, Zhao Huang, Yixin Zhuo, Peng Li, and Xuegang in 2019 that used digital photographic technology to detect tipping bucket rain gauge. Based on these three types of TBRG, the time variation characteristics of bucket rotation were obtained.[2] In this report, it will get a corrected data which improve the existing protocols from two aspects. Second, the measuring error of the two bucket compartments can be computed which leads us to calibrate and adjust.

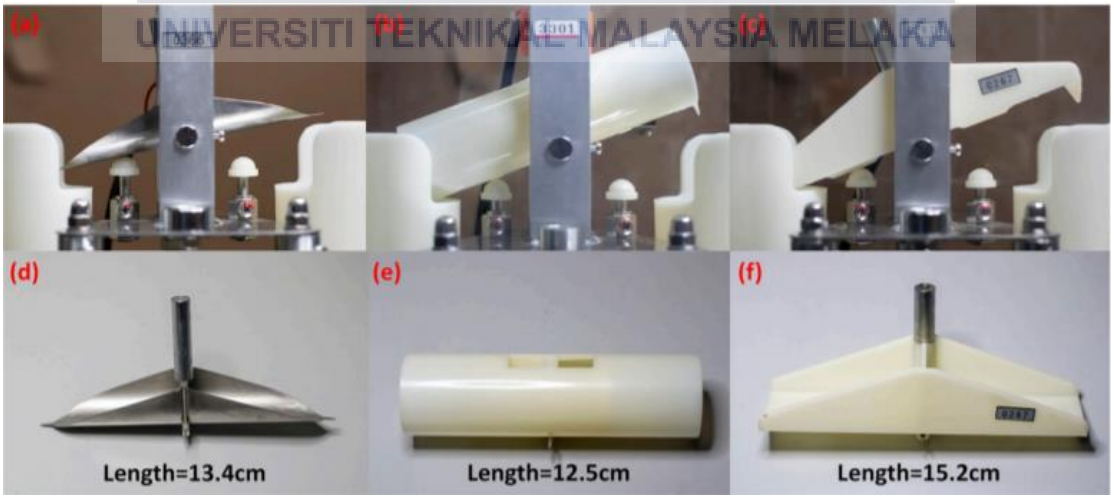

Figure 2-2 Three different model of TBRs

Table 2-2 Result of the T1, T2 and T3

TABLE 2. The result of T_1, T_2, C_V, and undercatch error for the TBRs tested. RI is rainfall intensity.

Type	RI (mm min^{-1})	$T_{1,\min}$ (s)	$T_{1,\max}$ (s)	$\overline{T_1}$ (s)	C_V for T_1 (%)	e_u (%)	$T_{2,\min}$ (s)	$T_{2,\max}$ (s)	$\overline{T_2}$ (s)	C_V for T_2 (%)	$\overline{T_1}/\overline{T_2}$ (%)
JDZ02	0.4	0.21	0.44	0.29	19.11	0.98	0.27	0.5	0.35	16.48	83.44
	1	0.22	0.36	0.27	11.80	2.31	0.27	0.42	0.33	10.65	83.05
	2	0.22	0.36	0.26	12.87	4.47	0.27	0.42	0.32	11.47	82.67
	3	0.22	0.33	0.26	10.89	6.55	0.27	0.39	0.31	10.29	82.67
	4	0.21	0.29	0.25	8.16	8.35	0.26	0.35	0.30	7.85	81.62
JDZ05	0.4	0.25	0.39	0.32	10.09	0.43	0.32	0.45	0.38	8.43	83.95
	1	0.25	0.36	0.29	9.53	0.97	0.31	0.42	0.35	7.96	82.71
	2	0.23	0.33	0.28	9.22	1.85	0.29	0.39	0.34	7.75	81.96
	3	0.23	0.36	0.29	9.59	2.88	0.29	0.42	0.35	7.93	82.74
	4	0.24	0.32	0.28	6.82	3.67	0.3	0.38	0.34	5.66	81.99
JDZ10	1	0.33	0.4	0.36	4.56	0.60	0.39	0.45	0.42	3.51	85.01
	2	0.33	0.37	0.35	3.69	1.17	0.39	0.44	0.41	3.31	84.89
	3	0.31	0.37	0.34	3.87	1.72	0.38	0.43	0.41	3.11	84.39
	4	0.31	0.35	0.33	2.78	2.20	0.38	0.41	0.39	2.10	83.77

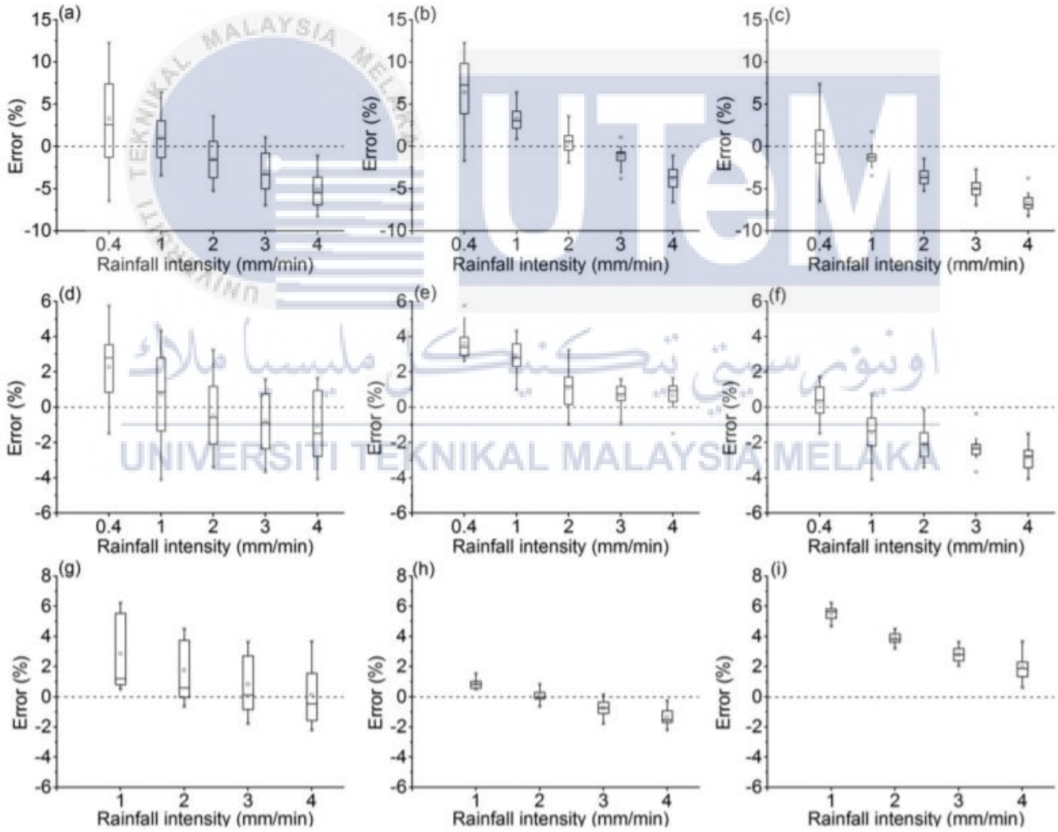

FIG. 9. Gauge errors based on Eq. (7): (a) JDZ02, (b) left bucket of JDZ02, (c) right bucket of JDZ02, (d) JDZ05, (e) left bucket of JDZ05, (f) right bucket of JDZ05, (g) JDZ10, (h) left bucket of JDZ10, and (i) right bucket of JDZ10. In the box, the tiny dot is the mean. The dash lines are the reference line.

Figure 2-3 The result of rainfall intensity