Development of Electronic Rain Gauge System

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Abstract—**Rainfall measurement system is a useful tool in weather measurement system. In tropical country such as Malaysia, rainfall measurement for agricultural and weather forecasting system is very important. Sampling-related tipping-bucket (TB) rain gauge measurements have significant errors for short time estimation. In this paper, a stable electronic rain gauge system with comprehensive data manipulation is designed and developed. This project used two major systems (a) tipping bucket with potentiometer and (b) capacitive sensor. Data is recorded and analyzed before the output is displayed. The system measures rainfalls accurately, saves the data reading and shows specific calculated for display.**

Index Terms—**rain gauge, tipping bucket, electronics rain gauge**

I. Introduction

Weather instrument device have been long used by man to manipulate the surrounding nature to our needs and benefits. In the long days, people use weather instrument device as a means to improve agricultural technology to provide adequate food and clothing. As technologies advanced and enhance throughout the years, so does the mechanism of weather instrument devices. And said improvement includes rain gauge system.

From the first traditional rain gauge that was said to be developing in the year 1418, up until electronic rain gauge, the technology in this field has been vastly improvised. Though discovered in the 1418, the usage of rain gauge system was not popularly used until 1441 in Korea where farmers used it to measure rainfall and potential harvest. The typical tipping bucket rain gauge was created circa 1662 by Christopher Wren and it receives wide accepted by European countries. The study of weather instrument devices and designing a prototype on the matter has been done from ages ago. Many international institutions, bodies of government and non-government based have dedicated their resources in said field. Rain gauge system was one of the devices that are proven to be beneficial especially for the biotechnology industry [1]. In the past, the technology of rain gauge system is very narrow and limited. The efficiency of a rain gauge system was mainly determined by two related factors, which is the position of the rain gauge sites and also reliable observer of the system. In short, the system is completely un-automated and it is highly dependent to the user constant involvement for accurate reading. As were suggested by Bleasdale [2].

The typically erratic development of rain-gauge networks in the past was very largely determined by two factors, namely the need to find conventionally satisfactory rain-gauge sites, and the need to obtain the services of good observers. Great positioning to place the rain gauge system was very essential as it enables more stable and accurate reading. A decent site of rainfall measurement would prevent the occurrence of systematic error due to strong wind or rainfall obstruction from surrounding area. The necessity of the constant observation of a system is a limitation of the system itself. Bleasdale [2] emphasized that recording rain gauge at present are not readily available, and fully automated instrument that can function and to be left unattended for a period of time without frequent servicing is needed. The research done by Bleasdale targeted United Kingdom as the subject of the research primarily Britain and Wales [3]. Scientific studies regarding hydrological cycle uses precipitation (rainfall and snowfall) measurement as a basic input for all practical practice. Disturbance of nature, high variability in time and space, and also sensitivity to environmental conditions such as wind, precipitation is extremely difficult to measure accurately [4]-[6].

In this work, Electronic Rain gauge and conventional rain gauge is developed and performance analysis is also done.

II. Overview of Rain Gauges

Currently graduated cylinders, weighing gauge, tipping bucket are examples of more commonly used device for rain measurement system [6]. A standard rain gauge, includes a funnel that flows water into graduated cylinder [7]. Measurement is taken as the cylinder enables reading of water collected. One of the weaknesses of the system is that it can easily be overflow after some period. This overflow of the gauge would be a serious obsolete in data measurement [7].

The construction of conventional rain gauge is simple and can be easily built. The reading has to be taken regularly and the gauge is to be emptied frequently [8]. So this non-automated system needs constant observation.

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Measurement of precipitate can be done by measuring either height or volume of the precipitate [9]. The rain gauge system which uses height measurement usually uses mm unit and not volumetric unit of ml. This is because by measuring height, it is easier to compare as the increase of a certain mm is the same either it is on a cup of coffee or a pond at a lake. As shown in Fig. 1, rainfall can be measured by simply measuring height ‘h’ of collected water in a vessel of uniform cross section.

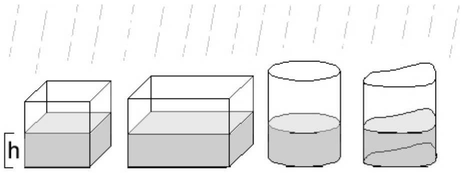

Figure 1. Water container of different shapes and sizes.

For devices which measure the volume of precipitate, the system usually uses cylindrical container. By simple calculation, ‘h’ can be obtained from said volume as written below and shown in Fig. 2.

$$V = \pi r^2 h$$

$$h = \frac{V}{\pi r^2}$$

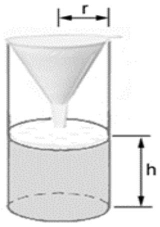

Figure 2. Obtaining height from volumetric formula.

III. Types of Rain Gauge System

A. Tipping Bucket and Weighing Precipitation Gage

Tipping bucket is being used as a rain measurement device from long time ago. It was widely accepted as one of the first systematic device in this field. Not long after, weighing precipitation gage makes it way as people began to consider measuring precipitate other than rainfall in certain country which experiences winter season. Savina, Schappi, Molnar, Burlando and Sevruk [10].

The main advantages of the electronic weighing system are lower evaporation losses and a higher accuracy in assessing the beginning of snowfall events. The tipping-bucket gage measured overall 23.7% less precipitation due to heating related losses, and showed a mean delay of ∼30min in recording the beginning of the events as shown in Fig. 3. The delay can be explained by the time it takes to melt the snow and fill the first tip at the given time sampling resolution (∼20min) and by evaporation losses (∼10min). The delay is important if accurate identification of the beginning of events is required.

In more detail elaboration, measuring snowfall using tipping bucket is highly inefficient because solid particles would have to be melted first before it can flow through tipping bucket gage. Meanwhile it goes through melting process; it is highly possible that some of the precipitate have been evaporated. Thus, inaccurate reading is bound to happen. It can also cause delay in the reading therefore no actual time measurement can be taken. In this particular case, weighing gage would be a better choice as its heat losses is less. The weight of solid particles is included in the reading of the system.

B. Capacitance Sensor Rain Gage

The use of capacitance sensor in rain measurement system includes the use of high pass filter, coaxial capacitance sensor and also a microcontroller. Output display of this mechanism is optional. Either simple LCD screen or even in some cases, SMS module have been used in the past. In a prototype suggested by Worawat, Niwat, Adisorn, Chonlatee and Anonggrit [11] a piece of copper rod is used as the capacitance sensor as displayed in Fig. 4 with front and isometric view. The sensor is designed with the length (L=1000mm), inner radius (R1=5mm), and outer radius (R2=12.5mm).

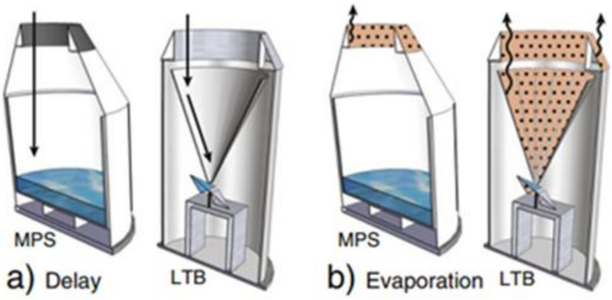

Figure 3. Delay caused by the different precipitation collection paths in the MPS (weighing precipitate gage) and LBT (tipping bucket gages), 3(b): Heated areas (dotted surfaces) from which evaporation may take place are much larger in the LTB.

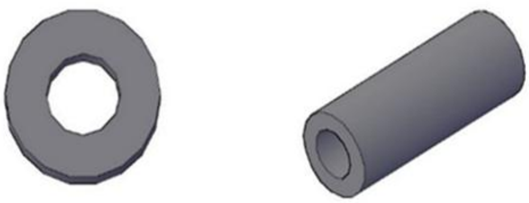

Figure 4. (A) Front view of the sensor (B) Isometric view of the sensor.

The difference of capacitance in presence and absence of water is the main variables in this mechanism. The equations proposed are shown below.

$$C = C_1 + C_2$$

$$C = \frac{2\pi\varepsilon, \varepsilon_0 H}{ln\frac{R_2}{R_1}} + \frac{2\pi\varepsilon_0 (L-H)}{ln\frac{R_2}{R_1}}$$

$$C = \frac{2\pi\varepsilon_0((\varepsilon_r - 1)H + L)}{ln\frac{R_2}{R_1}}$$

The voltage is that a flow out of the capacitance sensor is recorded. Theoretically, the output voltage is linearly proportional to the water level. Worawat [11] have strongly suggested that proportional relationship between water contain and output voltage can be highly beneficial as it can be used by gauge telemetry system. It can measure rain accurately, and it is possible to integrate this system with proper output display module.

IV. Construction of Electronic Rain Gauge

As a startup, the shape of the gauge as displayed in Fig. 5 is chosen to be cylindrical. The opening of the gauge has extra height to prevent rainwater from splashing. Nets are positioned on top of it to block entrance of solid particles. Water enters from an extended funnel, then drops into tipping bucket as displayed in Fig. 6.

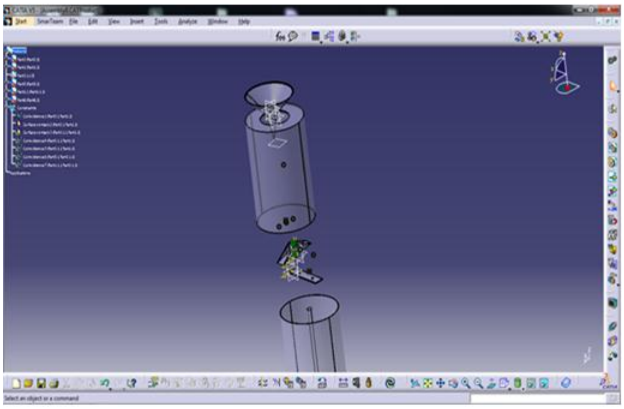

Figure 5. Mechanical drawing of electronic rain gauge prototype

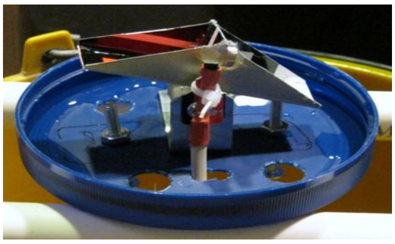

Figure 6. Tipping bucket system with hall effect sensor

This tipping bucket tilts each time a certain amount of water enters. Then, water pours through holes drilled into the capacitance into a cylinder container. The placement of capacitance sensor directly underneath the tipping bucket would also stop water from evaporating into water vapor and thus affecting the reading of our measurement.

A. *Sensors Used in Electric Rain Gauge*

There are many sensors available and applicable to these systems. As there are two ways of measuring rainwater which is through height 'h' and also through volume. So suitable sensors are selected for the rain gauge considering both method of measuring such as potentiometer, Infrared distance sensor.

Potentiometer

Potentiometer sensor is selected to measure volume of water. In conventional design, some rainwater gauge uses Hall Effect sensor that detects magnet presence and therefore would toggle its output.

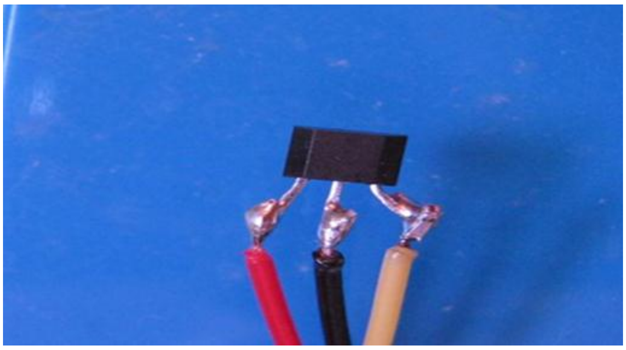

Figure 7. Hall effect sensor connection

Rain hall sensor demonstrated in Fig. 7 is a digital sensor. The disadvantages of using hall effect sensor is that rainwater would have to reach a certain amount of water before the tipping bucket is tilted, which will then activates the hall effect sensor. In other words, its accuracy is very low. In order to improve its accuracy, the tipping bucket would have to be design with the smallest of scale. By replacing the Hall Effect sensors with potentiometer, the problem of accuracy would be improvised. Potentiometer is an analog sensor its output is highly specific scale with the range of 0-1023. Therefore, the mechanical design of the tipping bucket would not have to be small because the water contain measurement does not depends on the tilting of the tipping bucket instead, it reads the value of potentiometer.

Infrared distance sensor

To measure the rainwater through height 'h', another sensor is used in the design of this electronic rain gauge system. The proposed sensor is Infrared distance sensor which is exhibited in Fig. 8. The Sharp IR Range Finder works by the process of triangulation. A pulse of light (wavelength range of 850nm +/-70nm) is emitted and then reflected back (or not reflected at all). When the light returns it comes back at an angle that is dependent on the distance of the reflecting object. Triangulation works by detecting this reflected beam angle - by knowing the angle, distance is then determined.

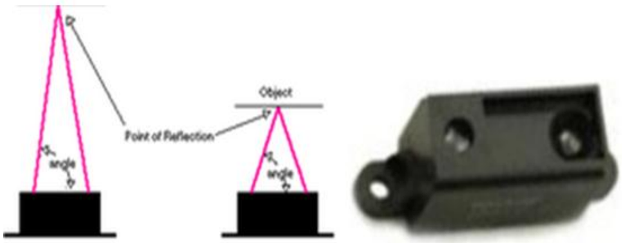

Figure 8. Mechanism of infrared distance sensor

B. *Microprocessor and Other Auxilliary Componenets*

Microprocessor

The microcontroller is one of the most vital parts in our prototype design. Other than measuring the output, the microcontroller is used to be integrated with several other devices to allow data storage, output display and also wireless communication. Each additional component needs to be integrated with microcontroller as it acts as the brain of this system.

Figure 9. Arduino uno

Arduino Uno is used in this program as presented in Fig. 9. The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

Other than microprocessor and sensors, there are many other complementary components which are of high importance to the project prototype.

Arduino shield

Xbee shield as displayed in Fig. 10 is used in this project to be placed on top of the microcontroller so that it is used with the xbee and SD card module. TX and RX pin is readily available to be plug in the available port. This shield is a multi-function senor expansion board that is Arduino compatible. It not only expands the existing interfaces such as data/analog port on the Arduino board, IIC interface, SPI interface, but also the RS485, SD card module interface, Xbee/Bluetooth Bee Bluetooth wireless data transmission interface and APC220/Bluetooh V3 Bluetooth wireless data transmission interface which makes the connection of most sensors to Arduino very easily.

Figure 10. Xbee shield IO expansion shield

SD card breakout board

This SD Card breakout board as shown in Fig. 11 is a simple solution for transferring data to and from a standard SD card. It can be used directly with microcontroller such as PIC and Arduino. It allows adding mass storage and data logging to the project.

Figure 11. SD card breakout board

Xbee wireless module

XBee wireless antenna shown in Fig. 12 has becoming extremely popular among robot builder and embedded wireless communication. It can be used for control and monitoring, data streaming, real time wireless update and also wireless downloader.

Figure 12. XBee 1mW wire antenna - series 1

Xbee data receiver

Xbee dongle as exposed in Fig. 13 is used as the receiver end of the data. The data which came from the sensors processed through the microcontroller and then send to the personal computer. This is where Xbee dongle with an Xbee attach to it receives the data.

Figure 13. XBee dongle data receiver

V. Discussion

With the recorded reading, manipulation of data can be done. Data recorded in the SD card would be connected to the display mechanism. With the proper programming construction, daily, weekly and monthly reading can be calculated. The mean and peak value of rain falls is shown through this output display system. Data retrieved are available for the user's need. Real time reading of rainwater measurement can be seen through the 16x2 LCD screen mounted together with the microcontroller. The experimental analysis shows that indeed potentiometer is perfect to act as a volumetric counter as it is stable and highly sensitive. The capacitive sensor using copper rod provides a reliable height measurement system, and the sensitivity can be controlled as the resistance value inside the circuit is interchangeable. Mechanical parts are also very crucial in this project. By optimizing the design of gauge, we can prevent impurities from entering our system. By adding a little bit of extension in the opening of the system, there would be less water splashes out from the gauge.

VI. CONCLUSION

In the past, the technology of rain gauge system is very narrow and limited. The efficiency of a rain gauge system was mainly determined by two related factors, which are the position of the rain gauge sites and reliable observer of the system. But here the system provide precise data source as volumetric and height measurement of precipitate is taken. The mechanical design with extended opening allows the system to prevent from splashing of rainwater. Nets inside the entrance prevent solid particles from entering our system. The positioning of capacitance sensor system below the tipping bucket provides prevention of rainwater collected from going through the process of condensation, turning into water vapor and goes out from the system. Rubber insulator that covers around the Perspex gauge would also help as it can reduce heat from entering the system. Heat action cause from the sun can interfere with the capacitive sensor as heat effects the resistivity of the capacitor. In summary, the system provides complete rainwater measurement system together with complete data manipulation mechanism. The measurement is highly accurate with two measurement devices, precipitate is safely kept for further research and data of reading is recorded and readily displayed to ease the process of the user. Development of wireless system in rainwater gauge would be recommended for further research. With wireless module, stability of the system would be of the highest priority. Transmission of data through wireless can be easily disrupted and disturbed, therefore development of the system must be comprehensive and can withstand greater obstacle through the path of transmission.

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