Review on the Innovation of Rain Gauge as Rainfall Measurement Tools

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ABSTRACT: One of the most well-established tools in rainfall measurement is rain gauge, where the accuracy for recording point rainfall is superior compared to the other methods such as weather radar or satellite. This paper aims to review on the different types of rain gauges and their applications. The rain gauges can be classified into three types to distinguish their principle of operation which are conventional, sensor-based, and IoT-based. From the review, it can be assumed that the technology of rain gauge is still improving although it has limited capability specifically for point rainfall measurement only. However, the data from multiple rain gauges or network of rain gauges are helpful to provide validation to the higher spatial resolution tools for improving rainfall estimates.

Keywords: *Rain gauge; rainfall; IoT*

1. INTRODUCTION

The knowledge of rainfall is crucial due to its high spatial and temporal variability. Aside from understanding and predicting the global climate change as well as weather anomalies, it is also required in the field of radiowave propagation, especially in the transmission impairment due to rain. Ground-based equipment (i.e., rain gauge) have been utilized for observing the rainfall, thus enable forecasting and predicting the occurrence of natural disaster.

Rain gauge functionality has been improved throughout its application over a wide range of fields. From a simple measurement of accumulated rainfall on daily basis up to a long-term period, it is also typically used as ground validation data for improving the radar estimate [1]. It is one of the equipment that have been extensively used worldwide and able to measure point rainfall accurately.

This paper aims to review a few types of rain gauge based on its classification, and functionality. A general overview on the rain gauge and its application is presented before a more thorough comparison is carried out to understand the innovations that has been applied towards the rain gauge. Further, opportunity for improvement will be proposed based on the current technology.

2. TYPES OF RAIN GAUGE

There are many types of rain gauge available which has different principle of operations but sharing similar functionality. One of the examples is as mentioned in a comparison of three rain gauges [2] in 1965 where a standard gauge, a shielding gauge, and a tipping bucket rain gauge (TBRG) were used to estimate precipitation amount in inches. Rain gauges are typically cylindrical container with a different size of opening and build. A standard rain gauge consists of removable, funnel-shaped collector attached to a measuring tube. The shield on the shielded type of rain gauge is intended to reduce wind and turbulence effect so that the reading can be more accurate [2].

TBRG on the other hand uses a mechanism to count the number of tips where its resolution is typically ranges between 0.1 mm and 1 mm per tip. Although TBRG in general is not as accurate as standard rain gauge due to error that might occurs since it requires filling up the tipping bucket to count for one tip, it can provide better temporal resolution especially during heavy rain since the bucket will be filled up faster thus enable faster tip count. Niemczynowicz in his paper in 1986 [3] mentioned that the TBRG type of rain gauges has replaced almost every other type of rain gauges because it produces rainfall data in digital form which is suitable for automatic recording.

TBRG can be further divided into a few types based on their different build and origin. For example, in [3] the TBRG used for comparison were LTH (Sweden), RIMCO (Australia), and PLUMATIC (Norway). In one of the recent works, Liao et al. [4] in 2020 provides detail explanation on the types of TBRG available where the author specifically emphasized on the performance and error correction of such gauges with the assist of digital photographic technology. Three TBRG were used in the study was differentiated by the resolution of the tipping bucket (0.2 mm, 0.5 mm, and 1 mm).

3. RAIN GAUGE CLASSIFICATION

In principle, rain gauges can be classified into three main types. First, is the conventional rain gauge which include standard measuring tube rain gauge, weighing rain gauge, and TBRG. The conventional rain gauge is simple to be constructed and has lower development cost, thus allowing large number of installations over a wide area or locations. Standard rain gauge, for example, consists of a measuring tube with scale in millimeter unit that required to be manually read and emptied on daily basis, and have been established for quite a long time. Although the accuracy of such rain gauge is good for recording point rainfall data, it suffers from low temporal

resolution. Second, is sensor-based rain gauge such as acoustic rain gauge (e.g., [5], [6], and [7]), and optical rain gauge (e.g., [8]). The third one is considered as more advance where it incorporates Internet of Things (IoT) technology and is called as IoT rain gauge (e.g., [9]).

Each type differs in terms of its use and components. From the conventional type to automatic type, the applicability of measurement in general, improves. Among the three, the rain gauge that incorporate IoT technology could be considered as the most comprehensive since it typically combines several sensors to operate as an automatic weather station. This capability is made possible due to the processing power of microcontroller such as Raspberry Pi and Arduino that can process multiple input concurrently (e.g., [9] and [10]). Further, it can provide remote observations over a wide coverage area.

4. RAIN GAUGE APPLICATIONS

The most fundamental application of rain gauge is to provide accumulated rainfall such as applied by hydrologist and meteorologist. Such measurements are useful in the field of weather forecasting, health (e.g., waterborne disease [11]), satellite rainfall algorithm [12], and flash flood [13], to name a few. In addition, it is also used by radiowave engineers especially involving prediction model (e.g., [14] and [15]). Sensor-based rain gauge such as acoustic and optical rain gauge improves in terms of temporal resolution compared to the traditional one (e.g., [7]).

TBRG, although not as accurate as standard rain gauge, can be useful to distinguish the type of rain (light, medium or heavy) by differentiating the rate of tip counts. However, this functionality has not been implemented so far, and might be useful because the type of rain is one of the important parameters that can be used as input to the prediction of flash flood. Further, it can also be used to estimate the probability of rain [14] when the data is collected over a long period (one year and above).

5. CONCLUSION

As a conclusion, innovation in terms of components, design, and functionality of rain gauge, enables numerous opportunities for improving the measurement of point rainfall, and at the same time, improving the estimate by higher spatial resolution equipment. With the added capability of microcontroller such as Arduino and Raspberry Pi, it can be further incorporates with advanced functionality to provide a comprehensive rainfall measurement data.

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