An automatic reading rain gauge and a computerized recording system for measurement of rainfall

M.D.H.J. Senavirathna, K.D.N. Weerasinghe and C.M. Nawaratne
Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya

Abstract
There are few recording type rain gauges used in Sri Lanka to measure rainfall intensity, duration and onset. However it is not affordable due to high initial, installation and maintenance costs. Therefore, Present research is aimed to design, construction and performance testing of a low cost Automatic Computer Recording Rain gauge System (ACRRS), with facilities to change minimum reading and rain capturing funnel diameter. This system stores electronically measured rainfall data in a database and displays rainfall data on computer graph and report forms. The bottom open technique, which opens the bottom of a bucket is a new method used for rain gauges. An electronic sensor circuit is used to measure the rainfall height. There measured rainfall data sends to the computer via RS232 port by converting it into digital bit string. Data conversion and RS232 port communication are done by a Microcontroller based electronic circuit. The performances of the new rain gauge were tested in the laboratory and in the meteorological station at Mapalana. In the laboratory test, a known volume of water is added at a given intensity, in to the rainfall receiving funnel. Field validation of the rain gauge is conducted in the Meteorological station comparing it with Tipping Bucket and Standard rain gauges. It was detected that the error percentages of Laboratory test and Field test data for new rain gauge are less than 5%. Therefore it can be concluded that the new rain gauge measures rainfall accurately.

Keywords: Rainfall, Rain gauge, Computer, Electronic

Introduction

Rainfall measurement is an important meteorological observation which is used in almost all the spheres including agriculture. The accurate and reliable rainfall data in an accepted format is needed for proper assessment and prediction of rainfall. At present, several types of rain gauges are available for the measurement of rainfall. Rainfall is usually measured in a volume or a weight basis and interpreted it as a height. Available Rain gauges may be recording type or non recording type. Recording types record the rainfall automatically in a given sequence but in non recording types measure the rainfall manually at a given time interval. This interval may be 24hours, 12hours or any other time period.

Due to the rapid development of Information technology fast and easy computerized raingauge systems are available. These systems measure rainfall with the use of Tipping Buckets. There are some identified problems associated with these systems as long as the Tipping Bucket is used. In Sri Lanka, higher installation and maintenance costs are the limitations in installing these systems.

The general difficulties associated with Tipping Bucket rain gauge are,

- Minimum reading of the tipping bucket rain gauge is a fixed value and which could not be changed by the user.
- The precision of Tipping bucket rain gauges has its limitations due to alternate tipping of two buckets.

- The receiving edge as well as the tipping buckets should be leveled precisely to achieve its proper functioning
- Diameter of the receiving funnel cannot be changed to meet different requirements.
- High price of computerized automatic rain gauge systems.

Thus the primary objective of the present research was to develop an automated computerized rain gauge system with easy calibration, installation, data storing, data reporting and data displaying capabilities, while having the capability to change the funnel diameter to switch the user requirements.

Materials and methods

Rain gauge design and construction

The proposed rain gauge system consists of four major parts.

- Rainfall capturing and measuring part – capturing and measuring rainfall
- Sensing and control unit – Sensing the water level and controlling the rain measuring system.
- Pulse to Bits conversion unit – Conversion of the signals coming from the Sensing and Control unit in to bit string and sending to the computer.
- Computer driven software application – Reception, storage, display and reporting of data.

The rainfall capturing and measuring unit captures rainfall with the use of a rainfall capturing funnel and measure using a measuring bucket in user defined minimum reading with the help of an electronic water sensor.

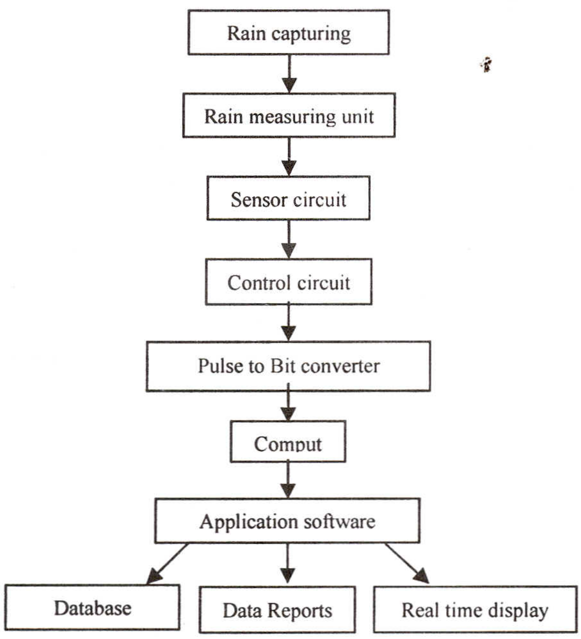

Figure 1 Data flow diagram of the rain gauge system

Sensing and Control unit (S&C unit) senses the water level and controls the rain gauge system. Once the water sensor touches the water surface at the measuring bucket, S&C unit stops the water flow to the measuring bucket by activating an electro magnet operated mechanical arm (water flow control arm). This mechanical arm blocks a metal ball inside a water outlet nozzle to control water flow. The water filed into the measuring bucket is also removed by opening the bottom of the bucket. S&C unit generate an electric pulse which is sent to the Pulse to bit converter at every measurement. Pulse to bit converter, converts electric pulse into a digital bit string (ABCDE) and sends it in to the computer via RS232 port. A computer driven software application captures the bit string and converts it into a predefined (defined by the user) rainfall height to store in a database. An auto updating graph is drawn to indicate the rainfall graphically. The software has other capabilities such as data form generations, Data views, password protection, calibration volume calculations etc. (Figure 1).

The Rain-gauge functional unit (Figure 2) controls the water flow, measure the rain fall and generates electric pulse. The functional part consists of Sensing and control unit, Water flow control arm and rainwater measuring unit. The complete system consists of Rain-gauge, Pulse to bit converter, a computer and the Rain-gauge software.

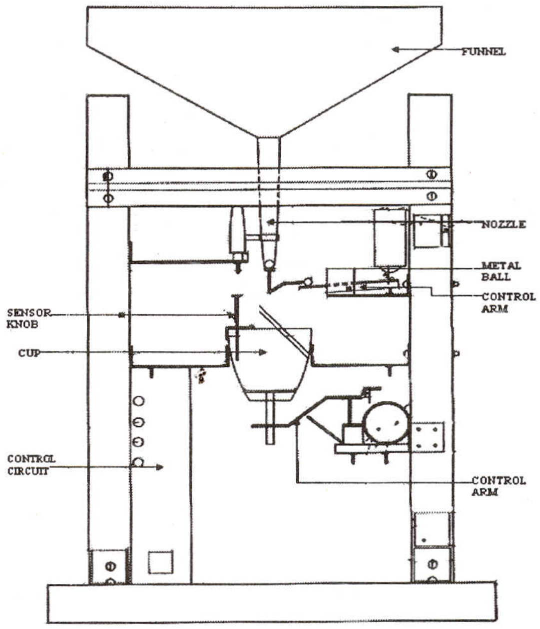

Figure 2 Rain gauge functional unit

Performance testing of proposed rain gauge

Two tests were carried out to test the performance of the new rain gauge.

a. Laboratory test with simulated rainfall intensities

This was done with releasing water in different intensities in to the rain measuring cup with the help of a burette and testing the accuracy of the volume for a given number of tips.

b. Field validation with natural rainfall

Field validations were done in the Meteorological station at Mapalana, by placing it close to the Tipping bucket rain gauge at the same height and same levels with a 20cm diameter capturing funnel. The new rain gauge was calibrated to 0.5mm measuring height to match with the Tipping bucket rain gauge measuring height. The data of the Tipping bucket rain gauge and Standard rain gauge was compared with new Rain gauge data to validate accuracy.

Analysis of the test data

The results obtained from the above tests were statistically analyzed using T test to check whether any significant difference exists between observed and expected values. The correlation between rainfall intensity and error percentage was tested using Pearson's correlation test

Results and discussion

Data obtained from the laboratory test

Table 1 shows the laboratory test data obtained at 0.25mm measuring height for 3 bottom opens of the measuring cup.

Table 1 Laboratory Test at 0.25mm measuring height

Observation	Intensity (mm/min)	Shown (ml)	Expecte d(ml)	Difference (ml)	Error %
1	0.80	47.5	47.1	0.4	0.849
2	0.59	46.8	47.1	0.3	0.637
3	0.62	46.8	47.1	0.3	0.637
4	1.00	47.5	47.1	0.4	0.849
5	0.52	47.5	47.1	0.4	0.849
6	0.42	46.8	47.1	0.3	0.637
7	0.44	46.9	47.1	0.2	0.425
8	0.50	47.2	47.1	0.1	0.212
9	1.41	46.7	47.1	0.4	0.849
10	1.08	47.4	47.1	0.3	0.637

Table 2 shows the laboratory test data obtained at 0.25mm measuring height for 6 bottom opens of the measuring cup.

Data obtained from both 0.25mm and 0.5mm measuring heights were not significantly different from expected values (T test values 0.93 and 0.37 respectively). There is no significant relationship between error percentage and rainfall intensity for this rain gauge for both 0.25mm and 0.5mm measuring heights (Pearson's correlation test values 0.733 and 0.160 respectively)

Table 2 Laboratory Test at 0.5mm measuring height

Observation	Intensity (mm/min)	Shown (ml)	Expecte d(ml)	Difference (ml)	Error %
1	0.85	47.7	47.1	0.6	1.911
2	0.70	47.4	47.1	0.3	0.637
3	0.92	47.5	47.1	0.4	0.849
4	0.81	47.2	47.1	0.1	0.212
5	0.95	47.4	47.1	0.3	0.637
6	0.42	46.9	47.1	0.2	0.425
7	0.45	47	47.1	0.1	0.212
8	1.25	46.8	47.1	0.3	0.637
9	1.34	47.4	47.1	0.3	0.637
10	0.42	46.7	47.1	0.4	0.849

Figure 4 illustrates the error percentage distribution of the rain gauge under 0.25mm and 0.5mm measuring heights.

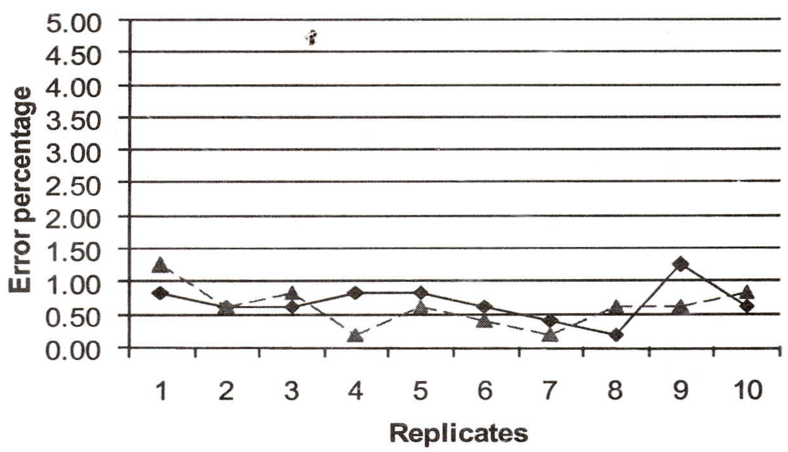

Figure 4 Error percentage distribution of lab tests [0.5mm measuring accuracy (-▲-), 0.25mm measuring accuracy (-◆-)]

Data obtained from the field validation
Table 3 shows the data obtained at 0.5mm measuring height for the field validation of the rain gauge.

Table 3 Standard and new rain gauges data

Date	New rain gauge (mm)	Standard (mm)	Test Error %
6/06/2007	6	6.3	4.76
6/07/2007	3	3.4	11.76
6/08/2007	12.5	13.2	5.3
6/12/2007	30.5	31.5	3.17
6/20/2007	11	11.3	2.65

The field validation has proved that the new rain gauge is capable of measuring rain fall more accurately. The average error percentage of the new rain gauge is less than 5%.

Conclusions and recommendations

User defined rainfall measuring height and rain capturing funnel diameter has improved the user friendliness of the rain gauge. The accuracy of the new rain gauge is at acceptable level and the system can be recommended to apply in any field where accurate and automated rainfall intensity measurement is needed.

Due to technical problems such as power failures, calibration errors and blockages rain gauge may function incorrectly. To overcome power problems rain gauge can be operated with a parallel connected 12V 6A rechargeable battery and the Pulse to Bit converter circuit can be upgraded to hold rainfall data in a memory chip when the computer fails to operate.

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