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IoT-Based Rainfall Monitoring System to Detect Rainy Flood for Coastal Areas of Bangladesh

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Abstract

Flood disasters in Bangladesh's coastal regions have been a major source of worry due to their damaging effects on both the natural world and people. For this natural disaster to be tracked and efficiently controlled, rainfall measurement must be precise and trustworthy. The rain gauge, which has acquired global acceptability, is the most commonly used instrument for measuring rainfall. This study presents the design and experimental evaluation of a cloud-based sensor-based rain gauge for the real determination of total rainfall and rate. An ultrasonic sensor is connected to a round water container, a round rainwater acquisition, a Bluetooth module, and a data processing unit for data collecting and processing in the proposed recommendation sensor-based rain gauge. Improved rainfall evaluation and detection methods have been created using cutting-edge sensor data processing techniques. Throughout a local rainfall event, the performance of the electronic sensor-based rain gauge is assessed and contrasted with that of a hand-made rain gauge. The experimental results show that the suggested system offers an accurate reading of rainfall quantity and rate per unit of time and area, real-time rainfall monitoring, and reliable and consistent analysis. The created method is made to maintain rainy floods in Bangladesh's coastal regions by storing rainfall data. The system is anticipated to help the region establish an efficient rainy flood monitoring system. Overall, the suggested digital sensor-based rain gauge offers a useful and trustworthy instrument for managing and monitoring rainfall in Bangladesh's coastal regions in real-time.

Keywords: IoT, Rainfall, wireless sensor, real-time data analysis.

Highlights

- Innovative IoT-based rain gauge in terms of accurate flood prediction.
- An interconnected system for analyzing rainfall data in real-time.
- Cost-effective solution for precise rainfall monitoring.

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1 Introduction

The prevalence of heavy rainfall (HRF) and its associated floods have had a major impact on human society in terms of property damage and human loss [1]. Although HRF levels are possible, some areas are more sensitive or at risk than other areas [2]. Bangladesh is largely a low-lying plain country situated on deltas of huge rivers coming as from the Himalayas, seems to have a sub-tropical humid climate, and is regarded as one of the world's highest rainfall areas [3], which may be responsible for the country's transition to an agrarian economy. Precipitation, particularly rainfall, has a major impact on the agricultural industry; the amount of rainfall is critical to the health of live plants and crops. Bangladesh's country's economy and economic progress are inextricably intertwined with the rain-fed agriculture system. Understanding the physical cause and unpredictability of precipitation, particularly severe rainfall, is so critical. Precipitation observations can have a big influence on meteorology, hydrology, agriculture, water resources management, flood prediction, and energy generation. The earliest instrument used to assess precipitation was the rain gauge, which worked by scaling rainfall intensity by duration [1]. These sensors, however, cannot monitor the real-time features of rain, which are critical for calibrating forecast navigation systems used to provide very precise precipitation estimates. Rainfall measurement using satellite downlink attenuation by measuring signal attenuation can be affected by thunderstorms and other environmental factors. Furthermore, rain accumulations generated by satellite signal degradation are specific to the effective rain height chosen. For the last two decades, visual monitoring methods have been devised for use in hydrometers. In 2010, it already had developed particle size velocity dissemination (PARSIVEL) [4]. This approach has been expanded to generate a two-dimensional video distribution (2DVD) that may be used to calculate the general rainfall behavior and volume. The volume and velocity of raindrops were directly estimated using two high-speed orthogonal cameras in 2DVD; however, the exorbitant complexity and price of these devices restrict their utility inside. The High-Speed Image Velocimetry System for Rainfall Measurement measures rainfall with pictures. The images are taken between a camera and an LED backlight source. The size of raindrops may have errors due to the relative distance from the camera which may bring errors in volume calculation. The above-mentioned approaches have inherent limitations in terms of measurement accuracy and resilience in field operations. In this study, a digital sensor-based rain gauge is constructed and tested to estimate the volume and rate of rain in live time during a monsoon season for wet flood management and surveillance through IoT. The information is useful for environmental research and weather prediction. In [5] DGNSS investigations can capture the full landslip movement, from commencement to continuing movement, in great detail. The possible landslip direction is calculated using the directivity from Horizontal to Vertical Spectral Ratio (HVSR) analysis of seismic data collected by three- axis accelerometers. In [6] The results revealed that the transfer functions performed better after recalibrating parameters using local datasets. The root-mean-square error (RMSE) and mean bias were reduced by an average of 34% and 42%.

2 Literature Review

2.1 Precipitation Measurement

Precipitation measurement and categorization have inherent flaws that must be acknowledged before they can be employed in computer models or other analyses [7]. Because of the substantial regional and spatial differences, as well as the many kinds of precipitation, precise measurement is challenging (liquid, solid, mixture). Rain measurement consists of three parts: observation, representation, and solution. Precision precipitation entails using a sensor to monitor the amount of air particle matter supplied to the sensors. The degree to which the detected particles properly represent the quantity of precipitation that reaches the surface is critical for assessing the watershed response. The formula denotes how frequently precipitation is recorded (time - minutes, hours, daily) as well as depth changes (resolution of 0.1 mm, 1.0 mm, etc.) [8]

2.2 Recording Weighing Gauges

Rain meter and shield configurations include the following: (a) conventional gauge; (b) double binary system; (c) Wyoming shield; and (d) pit gauge [9]. The water is sucked from the entrance into a small hole in the gauges, in which it drops between one edge of a small 'bucket,' which fills to a specified volume before being emptied (eg 0.1 mm). Because tips may be simply captured as waves with a data log, this gadget is frequently utilized. However, the gauge must be calibrated since the system overloads during high rainfall intensity as well as the amount of water out of each barrel point is smaller than the volume of a bucket [10]. As a result, long-term precipitation records might be shortened at higher intensities, which are frequently important in basin studies. Under severe rain and snow conditions, it is tough to lean over buckets. Lower readings are caused by evaporating and convection currents when heaters are used to thaw frozen precipitation. Because of water must be gathered in a container before rolling, the precise start and finish timings of the rainfall are uncertain with these instruments.[11]

2.3 Rain Statistic in Bangladesh

Bangladesh floods 26,000 square kilometres (approximately 18% of the country) every year, killing over 5,000 people and causing damage to over 7 million dwellings. In 1998, the flood-affected area accounted for more than 75% of the city's entire land area. This volume represents 95% of the annual flow. Heavy rains are one of the vital causes of flooding in Bangladesh [12]. Rain is among the most significant aspects in Bangladesh since agriculture is the mainstay of the economy. Approximately 80% of Bangladeshis live in rural regions and rely on agriculture, either directly or indirectly. Irregular rainfall and the intense events that accompany it can have a consequences on ecosystems, fertilizer management, farming, food security, water quality and availability of health, and livelihood opportunities for ordinary Bangladeshis [13]. As a result, gaining a better knowledge of rainfall patterns has significant ramifications for Bangladesh's social and economic development. Flood or flashflood planning and controlling is a tough task in densely inhabited and cheap terrain areas like Bangladesh. Due to significant rainfall in those areas and the upper catchment region in India, flashfloods have recently shown their hazardous and deadly effects in the northeastern section of the nation, particularly Sumamganj, Kishoreganj, and Netrokona. Flash flood forecasting in India was impossible due to a lack of rainfall data from the higher catchment area. Rainfall measurement data, like many other environmental information, is especially important during times of actual or projected change. With global warming likely to have an unequal influence on rainfall patterns in both space and time, observational records are critical for discovering, measuring, and interpreting hydrological changes. This is a critical step towards designing more effective protective factors for next flood and drought events.

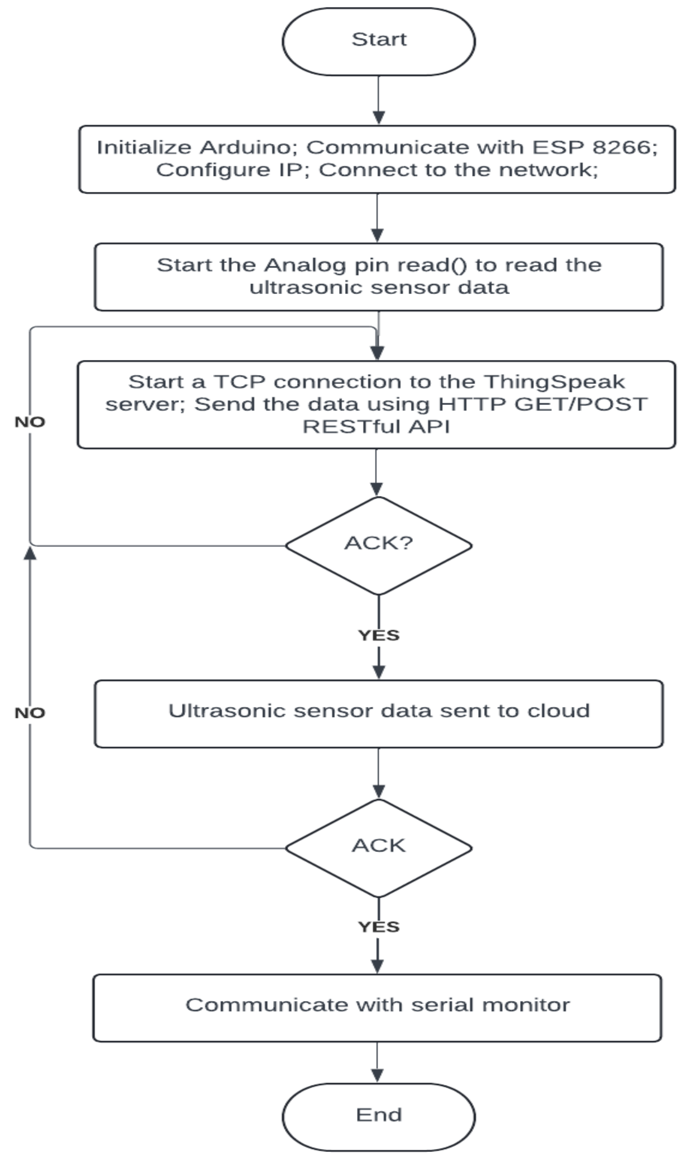

Fig 1. Flowchart of Methodology

3 Methodology

The annual rainfall depth for a particular period, reported in millimetres, is the most frequent rainfall measurement (mm). For example, we could wish to know how much rain fell in one hour, one day, one month, or one year. The proposed methodology is shown in the Figure 1.

We may easily obtain an approximate estimate of monsoon rainfall at home. Simply follow these steps:

- Grab a bottle with clean sides, chop off the top, and place it inverted just on the neck of the bottle to make a funnel.
- Place a measure on the side of the container and fill it with water until the zero point on the ruler is higher than the dips just at the bottom of the bottle. Otherwise, the bumps would distort the measurement.
- Put the precipitation data outside, as far from struc-

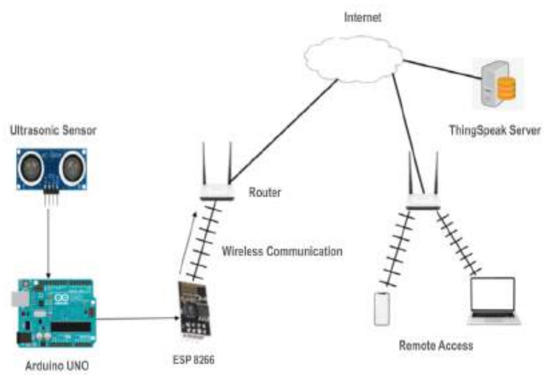

Fig 2. Cloud Communication of the device

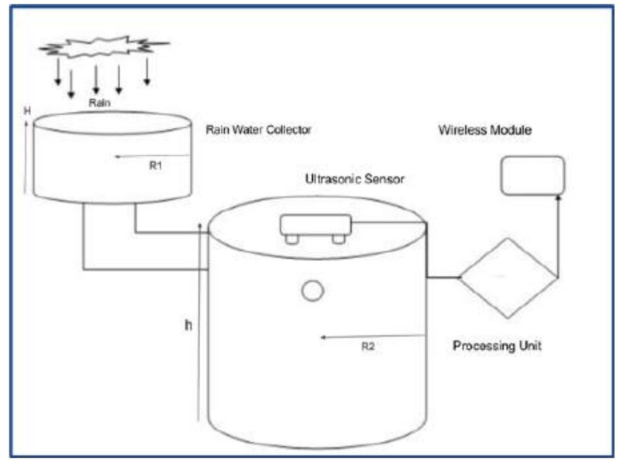

Fig 3. Proposed Sensor Based Device Architecture

tures and trees as feasible.

- To gather data, take regular measurements of the liquid level (for example, each morning at 8.30 am before leaving for school).

If we collect the measurements mostly during summer, part of the water within the container will disappear (up to a few millimetres each day), affecting our readings. We may avoid this by adding a thin coating of grease to the water. Because oil is heavier than water, it will float on top of the water, preventing evaporation. The readings of our rain barrel would tell us the amount of rain that fell over a specific period.
The Methodology is divided into three sections.

- In the first section, the sensor value is read from the analogue pin of the microprocessor.
- In the second section, the amount of rainfall is estimated using the sensor data based on the specifications provided by the sensor fabrication company.
- In the third section, the estimated amount of rainfall is sent to the cloud database server (ThingSpeak server) using the Wifi module. The communication between the server and the Wi-Fi module takes place using the TCP/IP protocol suite and is shown in the Figure 2
- Sensor based devised architecture is shown in the fig: 3

Table 1. Collected data from artificial rain

Observation No.	T(sec)	h(mm)
1	150	5
2	100	3
3	150	7
4	150	11
5	150	9
6	200	15
7	180	12

4 Proposed Algorithm Design

4.1 Rainfall Estimation

The radius of the water collector is R1 and the radius of the water pot is R2. Then the cross-sectional area of collector $A1 = \pi \cdot R_1^2$ and the cross-sectional area of water pot $A2 = \pi \cdot R_2^2$. The height of the water measured by the sensor is h.The height of water that would be for the collector is H. Then,

$$\pi \cdot R_1^2 \cdot H = \pi \cdot R_2^2 \cdot h$$
$$H = \left(\frac{R_2}{R_1}\right)^2 \cdot h \quad (1)$$

The height of water for the collector can be measured using equation 1 and thus the following equation may be used to compute rain per segmentation studies per unit time:

$$RR = \frac{H}{T} \quad (2)$$

Table 2. Data analysis using proposed algorithm

h(mm)	R1(mm)	R2(mm)	$(R2/R1)^2$	H(mm)	T(sec)	RR(mm s-1))
5	5	7.5	2.25	11.25	150	0.0750
3	5	7.5	2.25	6.75	100	0.0675
7	5	7.5	2.25	15.75	150	0.1050
11	5	7.5	2.25	24.75	150	0.1650
9	5	7.5	2.25	20.25	150	0.1350
15	5	7.5	2.25	33.75	200	0.1687
12	5	7.5	2.25	27	180	0.1500

Where T is the duration of rain at any instance of time. The values of H have some noise because the upper surface of water in the water pot is not stable during rainfall.

4.2 Noise Reduction

The noise of water height H can be reduced by averaging some consecutive values of H. The value of H is calculated from sensor data after every one-second interval. The average of three consecutive values of H gives better noise reduction.

$$H = \frac{H_{i-1} + H_i + H_{i+1}}{3} \tag{3}$$

5 Performance Analysis

First, data are collected for some observations as mentioned in Table 1.

These collected data are analyzed to estimate the amount of rainfall according to the algorithm. The estimated amount of rainfall is the result of the proposed algorithm. The result of the analysis is shown in the following table 2: The results presented in the table are not for real rainfall data. Artificial rainfall data are collected using the designed prototype and the result is calculated using the proposed algorithm. There is a problem with the sensor data because of ultrasonic sensor produces a small noise when measuring the height of the water. Calculating some consecutive heights of rainfall within a small period of time and averaging them may reduce the error generated due to noise. In Equation (3) an approach is presented to reduce this noise. Here three consecutive calculations are considered within 30ms to reduce error generated due to sensor noise.

The noise of water height H can be reduced by averaging some consecutive values of H. The value of H is calculated from sensor data after every one-second interval. The average of three consecutive values of H gives better noise reduction. Several methods of rainfall estimation have already been discussed in the literature review chapter in detail. One of them is the traditional rain gauge method. This measurement is done in conventional gauges with their rims mounted at a specified interval above the surface of the ground, although it is considered that they measure the rain that really falls on the ground. However, the amount of rain that falls on the ground is almost always larger than the amount reported by a conventional gauge. As a result, there is a regular inaccuracy in a typical rainfall measurement; an error that may have a significant impact on any estimations based on these observations. In our proposed system, we can set the radius of the collector much larger which would reduce this hidden error. Passive microwave readings from orbit have a good possibility of estimating worldwide precipitation. Passive microwave observations overseas are simply attenuation measures that may be extremely closely connected to rain rate regardless of distribution specifics. The dispersion of microwave energy by hydrometeors, particularly in the ice stage, can be utilized to estimate rainfall over land. The specifics of the seasonal rainfall are particularly essential in scattering, making it more difficult to obtain a high degree of precision. When compared to passive microwave measurement, the suggested system is simple enough and will give better accuracy than the passive microwave approach.

6 Conclusion

Estimating rainfall is crucial because it affects climatic and geographic aspects. This study discusses a new method for estimating rainfall using digital sensor data and an algorithm that employs IoT assistance for storing and monitoring the data of precipitation. This procedure is superior to certain others since it is easier and less expensive. The strategy covered in this essay solves certain issues that other approaches have. This study has some features as follows: *Simpler Implementation, Increased Accuracy, Increased Efficiency, Continuous Estimation, Very Low Power Consumption, Cost Efficient.*

7 Limitation & Future Scopes

We have successfully estimated the amount of rainfall events at Dumki, Patuakhali using our proposed system. The proposed system requires manual setup at a geographic location. Our future plans can be summarized in the following points:

- Generating a rainfall prediction algorithm analyzing data for better management of rainy floods.
- Implementing a machine learning algorithm to predict the probability of rainfall and its amount in advance using various climatological and geographical data.
- Improving the performance of IoT support system to enhance the prediction of rain fall in costal areas.

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