R-Pi based Real-time Weather Monitoring System

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Abstract - *Weather Monitoring plays a pivotal role in our everyday lives. Manual methods of weather monitoring are cumbersome, time-consuming and are not feasible in remote areas. Using the tenets of R-Pi and embedded system design, a Real-time Weather Monitoring System shall be designed, which will eliminate manual intervention. In this project, there are two sections-hardware and software. In the hardware section, various sensors will be incorporated to measure the intensity and level of rainfall in different regions. These sensors will be interfaced with Arduino which will collect the required data from them, following which it will be transmitted to the Raspberry Pi via a GSM Module. The software section incorporates an FTP Client-Server Interface, wherein the real-time weather-related data will be sent to the FTP Client, which is the Raspberry Pi itself, from Regional Meteorological Centre, Mumbai, India. Both these streams of data, obtained from the hardware and software modules of this project, will then be processed by the Raspberry Pi, and sent to relevant organisations, so that they can take precautionary measures in event of any unforeseen conditions, using bulk messaging servers. Both the hardware and software aspects of this project contribute to developing a potent weather monitoring system.*

Key Words*: *Raspberry Pi, less maintenance, GSM, economic viability, real-time

1. INTRODUCTION

Manual methods of recording weather phenomenon are highly cumbersome and unreliable. Moreover, these cannot be used in remote areas. This project aims to create a R-Pi based system for monitoring weather-related phenomenon and generating real-time updates using embedded system design-based hardware setup and the FTP-based Client interfaced with the server at Regional Meteorological Centre, Mumbai. An amalgamation of sensors incorporating raindrop sensors as well as level sensors will be interfaced with Arduino which will transmit the collected data to the heart of the system, the Raspberry Pi via a GSM Module. The real-time data from the Regional Meteorological Centre will also be sent to the R-Pi which will carry out further processing and send the real-time weather updates using bulk messaging servers.

2. LITERATURE SURVEY

An Automated Rainfall Monitoring System (S.P.K.A Gunawardena, B.M.D Rangana, M.M Siriwardena, Prof Dileeka Dias, Dr Ashok Peries, Department of Electronic and Telecommunication Engineering, University of Moratuwa).[1]

The automated rainfall monitoring system addresses the need for obtaining timely, accurate information which is critical for the agricultural sector, using a widely available communication technology, the cellular network. Rainfall is monitored via rain gauges (remote stations) interfaced to GSM radio module which can send the rainfall information embedded in an SMS (Short message Service) to the central station. The data transfer is initiated either by the remote station or by a request from the central station. There can be a large number of remote stations communicating with the central station. The data received is extracted, sorted and saved in the central database.

The data may thus be made readily available to any interested party via the Internet. By using the existing cellular infrastructure, the rainfall data communication inherits its reliability. The main drawback of the system is its high dependability on the cellular infrastructure.

This concept of a rainfall monitoring system has been further expanded in this project by designing a R-Pi based system for generating real-time weather updates. Another valuable addition is that the data generated from the hardware equipment and that received via the FTP Client Server Interface from the Regional Meteorological Centre, Mumbai shall be compared and matched. In this manner, the potency of the hardware design too shall be verified and the purpose of receiving updates in real-time shall be served. Also, the convenience factor has been taken care of, instead of simply using rain gauges as mentioned in the parent paper, an amalgamation of sensors is added which not only eliminates manual intervention to a great extent but also contributes to precision and reduced maintenance costs.

Research Visit to Regional Meteorological Centre, Mumbai, India: As part of the literature survey, we visited Regional Meteorological Centre, Mumbai to understand in greater detail the functioning of the equipment currently used and how this knowledge could be incorporated in this project. It was found that barring some automation, manual methods of measuring weather-related phenomenon are predominantly being used. The same equipment that was introduced by the British since the inception of the Meteorological Centre is utilised to this day, as a result of which maintenance costs are higher.

Having witnessed these drawbacks in an otherwise efficient system, the idea for a reasonable solution was conceptualised, in the form of this project. The prototype designed using an amalgamation of sensors as well as R-Pi and GSM Module will greatly reduce maintenance costs, eliminating manual intervention at the same time. This prototype can also be expanded to work on a larger scale, commercially.

3. BLOCK DIAGRAM AND WORKING

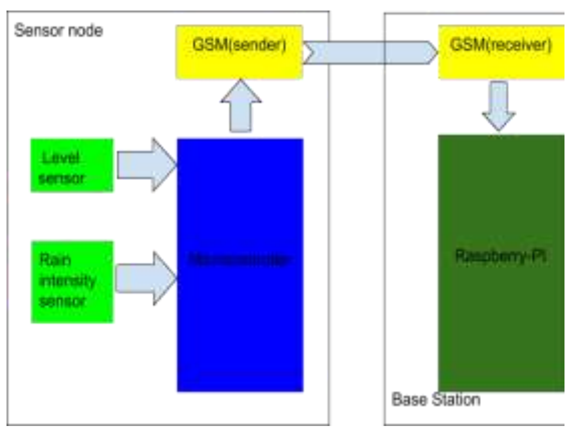

Fig -1: Block Diagram

As shown in the figure above, the data collected from the level sensors and rain intensity sensors is further processed by the microcontroller or Arduino mega, which is further sent to the GSM sender module. At the receiver end, the GSM here accepts the weather updates from the sender GSM and forwards them to the R-Pi, the heart of the system, which will transmit them to the necessary organisations using bulk messaging servers to ensure safety in event of unforeseen circumstances. The real-time data sent by Regional Meteorological Centre, Mumbai via the FTP Client-Server interface (software) shall also be fed into the Raspberry-Pi. The data obtained from the hardware setup shall be compared and matched with that received from the software aspect. Role of GSM: For the purpose of sending the weather updates to the subscriber, the GSM (Global System for Mobile Communications) module is used. It is also used to receive the same at the Receiver end, that is, the Raspberry Pi module. For the sending aspect, AT (Attention) commands are passed to the GSM Module. The AT +CMGF=1 command is used for Text Mode, which commences the serial communication via Arduino. This is followed by AT+CMGS='Required Phone no.' The text message is then sent. To terminate Ctrl+Z followed by special character tilde or ASCII character of 26 is used.

At the receiving end as well, AT (attention) commands are used. In order to set the text precision for GSM, the command AT+CNMI=2,2,0,0,0 is incorporated. The value of character is then taken from serial monitor data in sensor, thus, weather updates will be sent through GSM in this manner.

4. COMPONENTS USED

RAIN GAUGE:

Rain gauge is a meteorological instrument for determining the depth of precipitation (usually in mm) that occurs over a unit area (usually one meter squared) and thus measuring rainfall amount. One millimeter of measured precipitation is the equivalent of one litre of rainfall per meter squared. It is usually measured in millimeters.

Fig-2: Rain Gauge

RAIN DROP SENSOR:

The rain sensor module is an easy tool for rain detection. It can be used as a switch when raindrop falls through the raining board and also for measuring rainfall intensity. The module features, a rain board and the control board that is separate for more convenience, power indicator LED and an adjustable sensitivity though a potentiometer. The analog output is used in detection of drops in the amount of rainfall.

Fig-3: Rain intensity Sensor

Specifications:

- Area: 5cm x 4cm nickel plate on side.
- Anti-oxidation, anti-conductivity, with long use time.
- Comparator output signal clean waveform is good, driving ability, over 15mA;
- Potentiometer adjusts the sensitivity;
- Working voltage 5V;
- Output format: Digital switching output (0 and 1) and analog voltage output AO;
- With bolt holes for easy installation;
- Small board PCB size: 3.2cm x 1.4cm;
- Uses a wide voltage LM393 comparator.

Pin Configuration:

1. VCC: 5V DC
2. GND: ground
3. DO: high/low output
4. AO: analog output

ULTRASONIC SENSOR:

Ultrasonic transducers or ultrasonic sensors are a type of acoustic sensor divided into three broad categories: transmitters, receivers and transceivers. Tr ansmitters convert electrical signals into ultrasound, receivers convert ultrasound into electrical signals, and transceivers can both transmit and receive ultrasound. In a similar way to radar and sonar, ultrasonic transducers are used in systems which evaluate targets by interpreting the reflected signals.

Fig-4: Ultrasonic Sensor

CONTROLLER:

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory andinput/output (I/O) peripherals on a single chip. Sometimes referred to as an embedded controller or microcontroller unit (MCU), microcontrollers are found in vehicles, robots, office

Fig-5: Controller

Raspberry Pi

The Raspberry Pi 3 Model B is the latest product in the Raspberry Pi3 range, boasting a 64-Bit quad core processor running at 1.4GHz, dual band 2.4GHz / 5.0GHz wireless, Bluetooth 4.2/BLE, faster Ethernet and PoE capability via a separate PoE HAT. The dual band wireless comes with modular compliance certification allowing the board to be designed into end product without the need for further wireless compliance testing, improving both cost and time to market.

GSM SIM 900:

The SIM900 is a complete Quad-band GSM/GPRS solution in a SMT module which can be embedded in the customer applications. Featuring an industry- standard interface, the SIM900 delivers GSM/GPRS 850/900/1800/1900MHz performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption. With a tiny configuration of 24mm x 24mm x 3 mm.

Fig-7: GSM Module

5. RESULTS AND DISCUSSIONS

The desired result of this project is successful measurement of the required weather-related data and the subsequent generation of real-time updates using GSM. In order to achieve this, some amount of calibration and recalibration has to be performed. This shall ensure that the sensors work as desired. Thus, the sensors are calibrated as follows:

1. Level Sensor: For this, we employ an ultrasonic sensor on top of the capillary tube of the rain gauge. A table is created with fields that include the distance recorded by the ultrasonic sensor i.e. the level in centmetres (cm). (x) and the rainfall (y) which is recorded from the capillary tube.

Table -1:Level vs Rainfall

Level(cm) (x)	Rainfall(y)
0	0
1.26	1
2.35	2
3.66	3
4.61	4
5.36	5
6.31	6
8.71	7
9.81	8
10.81	9
11.21	10

By using the values from the table above, we plot a graph of level versus rainfall:

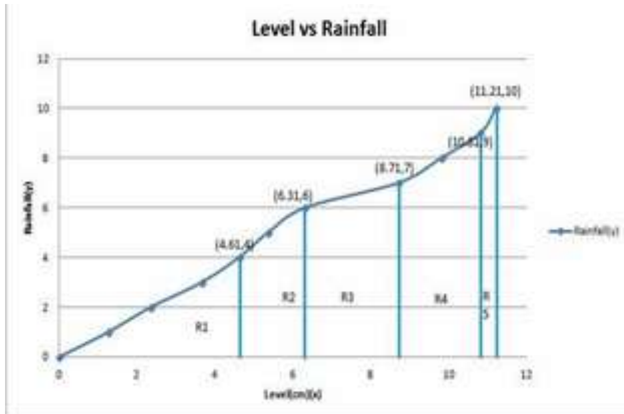

Fig-8: Graph of Level vs Rainfall

As per the above graph, each set of values are split up into different regions, i.e. 0-4 on the y-axis corresponds to the first region, R1; similarly, 5-6 corresponds to R2;7 to R3;8 and 9 to R4; 10 to R5. The equations obtained for each of these regions will be used in the software code for the sensor's calibration. The two-point form of the line equation is used to calculate the equation corresponding to each region.

Region1 (0<=x<=4.61)

(0,0)-(4.61,4)

y=0.867x

Region2 (4.61<=x<=6.31)

(4.61,4)- (6.31,3)

y=1.176x-1.421

Region3 (6.31<=x<=8.71)

(6.31,6)- (8.71,7)

y=0.416x+3.376

Region4(8.71<=x<=10.81)

(8.71,7)- (10.81,9)

y=0.952x-1.291

Region5 (10.81<=x<=11.21)

(10.81,9)- (6.31,3)

y=2.5x-18.025

2. Rain drop Sensor: This sensor is employed to measure the intensity of the rainfall and decide whether it falls under one of the following categories-'No Rain', 'Low Rain', 'Medium Rain' or 'Heavy Rain'. The working of the rain drop sensor is based on Ohm's Law. There is a zigzag metal strip on top of the sensor, the end of the metal strip is connected to a comparator, which compares and amplifies the voltage difference into the TTL logic levels of 0-5 V. When it is unable to detect water drops on the metal strip, the resistance is high and due to the direct proportionality, that exists between resistance and voltage by virtue of Ohm's Law (R=V/I), the voltage is maximum i.e. 5 V. As soon as it detects some water drops, the voltage reduces. However, it is important to note that it will only fluctuate between the logic levels of 0-5 V. The output of the comparator is then given as an analog input to Arduino. Since Arduino has an in-built ADC with 8-bit resolution, Therefore 1024 different analog levels are possible ranging from 0-1023. Thus, this TTL logic level of 0-5 V gets converted into analog levels of 0-1023. Since one sensor cannot cover a large region, so we use an array of such sensors and the individual outputs of these sensors are then averaged

using an averager circuit that consists of an op-amp LF356 and a single averaged analog output, is obtained from this circuit and it is given to the analog pin A0 of Arduino Mega Board.

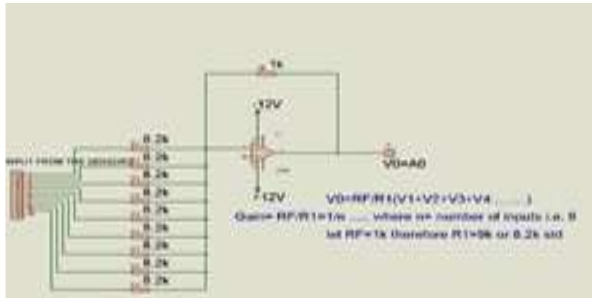

Fig-9: Averager Circuit used in Rain Intensity Sensor

Depending on the analog range of 0-1023, the intensity of the rainfall is determined according to the following table.

Table-2: Category and Intensity

Category	Intensity (Analog value)
No Rain	1015-1023
Low Rain	315-355
Medium Rain	285-314
Heavy Rain	0-284

6. CONCLUSION AND SCOPE

The hardware prototype that was designed and implemented has great commercial and practical scope, such as preventing loss of life in flood-prone areas. The FTP server-client interface enables real-time weather updates to be sent to our client from the Regional Meteorological Centre. Both the hardware and software aspects of this project contribute to developing a potent weather monitoring system. Currently, work is in progress to further enhance its utility by adding more sensors for different quantities, apart from the ones currently in use. For identifying the areas prone to acid rain, a pH sensor shall be interfaced with the existing setup and a cost-effective wind sensor or anemometer is currently being designed to measure the wind speed and direction effectively, at a considerably lower cost than the devices in use at the moment. The design of this project is such that adding new sensors entails no added complexity whatsoever. Moreover, it does not hamper its focal point, which is less maintenance and economic viability. The reduced maintenance costs and economic viability are features that shall help boost the prosperity of the nation and consequently, the world, in the long run. A developing nation like India definitely needs feasible solutions to cut down costs, wherever it may be possible. As it stands, the R-Pi Based Real time Weathering Monitoring System successfully measures weather-related phenomenon, generating real-time alerts, in addition to its advantage of economic viability. Thus, this prototype version can be further marketed commercially, maintaining the very same design, but implemented on a larger scale.

Fig-10: Hardware setup at Sensor Node

Fig-11: Hardware setup at R-Pi or Receiver Side

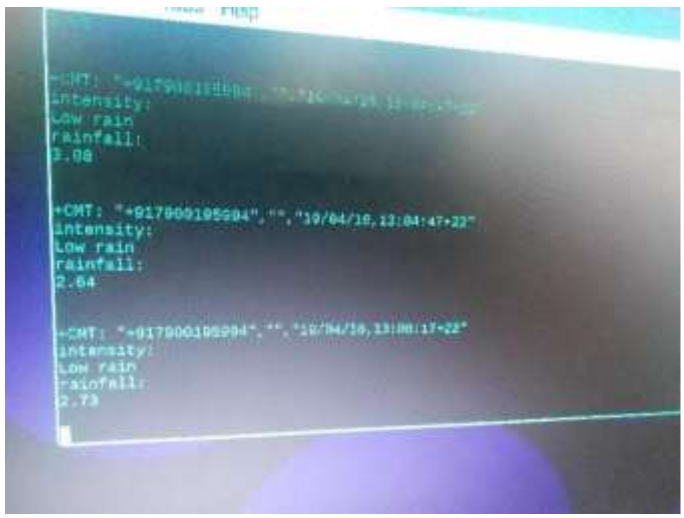

Fig-12: R-Pi Terminal at Receiver node

ACKNOWLEDGEMENTS

We would like to thank our mentor, Dr. Asawari Dudwadkar for her unflinching support and valuable guidance throughout the making of this project. We would also like to thank Mrs. Shubhangi Bhute, Director of Regional Meteorological Centre, Colaba, Mumbai and her staff, for co-operating with us during our research visit to MET Colaba in the initial days of shaping our project. Last but definitely not the least, we are immensely grateful to our college, Vivekanand Education Society's Institute of Technology, for believing in us and providing the necessary support for the execution of this project.

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