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Microcontroller Based Remote Weather Monitoring System

Emmanuel G. Dada*, Stephen B. Joseph, Digima Mustapha, Birma I. Hena

Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State, Nigeria

Abstract The measurement of temperature, relative humidity and light intensity remotely by using the sensor is not only important in weather monitoring but also crucial for many other applications such as agriculture and industrial processes. This study proposed a remote weather monitoring system that is based on Arduino Uno Microcontroller that have the ability to monitor, measure and display the temperature, relative humidity and light intensity of the atmosphere, using analogue and digital components. The analogue outputs of the sensors are connected to a microcontroller through an ADC for digital signal conversion and data logging. An LCD display is also connected to the microcontroller to display the measurement. For analysis and archiving purposes, the data can be transferred over GSM and receiver section to a mobile phone. The device has many advantages compared to other weather monitoring system in terms of its smaller size, on-device display, low cost and portability. The major strength of our proposed technique is that it does not need computer or internet service for monitoring locations remotely hence making the method to be cost effective. It is obvious that our proposed system is better in terms of expense, compactness, memory size and logging interval-setting ability.

Keywords Weather Monitoring System, Arduino ATmega328 Microcontroller, DHT11, LM35, GSM

1. Introduction

Advancement in science and technology has made it possible to predict the climatic condition for a particular location [1]. A weather station is believed to be a scientific technique that permits measuring the parameters of meteorological conditions centered on the situations of the environment both on the land or on sea for a particular place with certain devices with the intention of comprehending forecasted weather states, and to analyse atmospheric properties [2, 3]. In this new era, weather monitoring is of immense importance and has found application in many fields of human endeavour varying from following the progress of farm ground weather conditions to industrial conditions monitoring [4]. A self-regulating weather surveillance system is a device that is used for measuring and recording weather-related parameters by means of sensing devices devoid of human involvement [5]. The parameters being measured can be to an isolated place by the use of a network connection [6]. Weather monitoring assists in monitoring various factors that contributes to atmospheric conditions of a particular place such as temperature, humidity and light intensity [7]. There is need to keep track of the weather situations so as to sustain bumper harvests of farm produce and to guarantee environmental safety in industries [8]. Indigenous weather measurements are very critical to a large and varied range of vocations, from gardeners to fireman. It offers continuous monitoring of climatic conditions for various types of applications [9]. Weather monitoring system can be classified as using wired communication or wireless communication [6]. For the wireless communication, the network will be easily accessible and user friendly and there will not be need for the user to be physically present at the site to keep track of the climatic condition [10]. Wireless communication is a wide-ranging term that combines every techniques and practices of connection and communication between two or more devices by a wireless signal through wireless communication mechanisms and apparatuses. The Communication is set and the information is disseminated through electromagnetic waves such as radio frequencies, infrared or satellite. The distances concerned may just be a few meters as in television remote control or long such as in radio communications. GSM technology is the most economical and the most handy technology now being used for wireless communication [11]. The wireless weather monitoring system fundamentally needs a small number of elementary modules such as GSM module, display module, sensors and microcontroller module [12]. Monitoring weather conditions is important not only as an environmental baseline, but to maintain quality working conditions, studies and recreational safety. When the principles of wireless monitoring are applied to weather, the result will be increase in accuracy.

Remote monitoring of environmental parameters is important in various applications, agricultural and industrial processes [11]. In earlier periods, weather monitoring systems were commonly centered on mechanical or electromechanical devices which are disadvantaged by the downsides such as inflexibility, necessary human interference, associated parallax errors and robustness. The aim of this research work is to design and implement a simple and low cost weather monitoring system using LM35, LCD and ATmega328P microcontroller unit to monitor weather conditions of the desired location and transmit it to a cell phone at distant location through SMS. The following objectives were achieved: Analog data from LM35 was fetched and fed to one of the ADC channel of Microcontroller. Display the temperature, relative humidity and light intensity on LCD screen which is pre-processed and calculated by ATmega32. Send the measured temperature, relative humidity and light intensity to user with the help of GSM module (SIM 800) Via SMS. The proposed system will only measure temperature, relative humidity and light intensity respectively and is developed for small area.

2. Materials and Methods

Our proposed system consists of different units that make up the system: the power supply unit, microcontroller unit, the temperature/humidity sensing unit. This section outlines the various design stages and some of the techniques employed in each phase while carrying out the research work. The modular approach was used in this work where the entire system was subdivided into simpler functional blocks (stages) for convenience purpose. The entire work was carried out in four stages as listed below:

- Stage one (Hardware component and design)
- Stage two (Software design)
- Stage three (simulation with proteus)
- Stage four (physical construction)

2.1. Hardware Design

The hardware section was also subdivided into simpler modules, the modules included in this study are:

1. The power supply unit
2. The microcontroller unit
3. DHT11- temperature/humidity sensing unit
4. LM35 – Temperature sensor
5. LDR - light intensity sensing unit
6. The display unit
7. The GSM module unit
8. Real Time Clock (DS3231N)
9. Buck converter LM2596

The block diagram of weather monitoring system is illustrated in the figure1 below

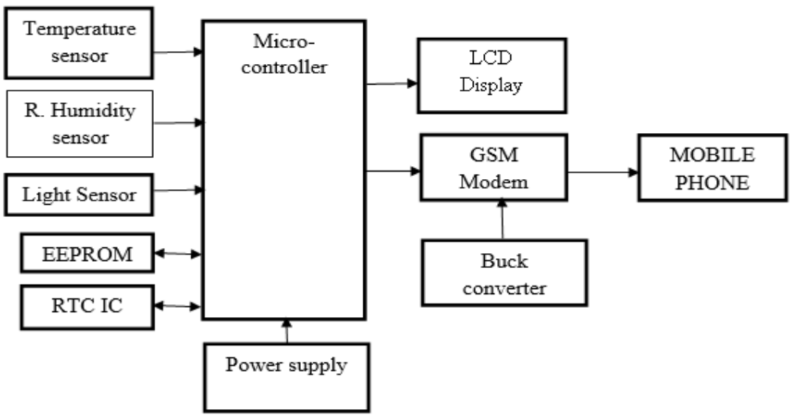

Figure 1: Block Diagram of the Design

2.2. The Power Supply Unit

This study uses D.C voltages at two specified levels: 5V to supply power to the microcontroller and 4.2V to supply power to the GSM module. The power supply unit consists of a step-down transformer, a rectifier circuit (bridge), a filter and a voltage regulator.

2.3. The Microcontroller Unit

The microcontroller used for this study is the ATmega328P mounted on Arduino Uno development board. The Uno is a microcontroller board based on the Atmega328p. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with anAC-to-DC adapter or battery to get started. Arduino is an open-source physical computing platform based on a simple I/O board and a development environment that implements the Processing/Writing language. The board has the following features:

Table 1: Features of Arduino Uno

Microcontroller	**ATmega328P**
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 Ma
DC Current for 3.3V Pin7	50 Ma
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Figure 2: Arduino

2.4. DHT11 - Temperature/Humidity Sensing Unit

This sensor is used to sense humidityand it facilitates the conversion of analog inputs to digital output. We are using digital output pin to connect it directly with the Arduino to Arduino's digital pin (pin 7). There is a step up register in the sensor to control the power. VCC and GND pins are also connected to Arduino. Figure 3 below shows a DHT11 sensor.

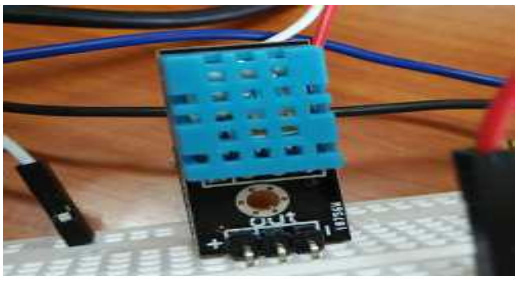

Figure 3: DHT11 Sensor

DHT11 has a full range temperature compensation, low power consumption, long term stability and calibrated digital signal. The DHT sensors are made of two parts, a capacitive humidity sensor and a thermistor. There is also a very basic chip inside that does some analog to digital conversion and spits out a digital signal with the temperature and humidity. A high-performance 8-bit microcontroller is integrated in the sensor with calibration-coefficient saved in OTP memory to provide accurate temperature readings. With the new 3 pin connector that includes several soldering pads and a sturdy casing, plugging in and out the sensor is not going to be a problem anymore. The 3 pin connector is perfect to get it going fast, and extremely easy to use. It is reliable and inexpensive.

The sensor has the following features

1. 3 to 5V power and I/O
2. 2.5mA max current use during conversion (while requesting data)
3. Good for 20-80% humidity readings with 5% accuracy
4. Good for 0-50°C temperature readings ±2°C accuracy
5. No more than 1 Hz sampling rate (once every second)
6. Body size 15.5mm x 12mm x 5.5mm
7. 3 pins with 0.1" spacing

2.5. LM35 – Temperature Sensor

This is a 3-pin temperature sensor IC that measures temperature in degree centigrade and gives output response of 10 mV/°C. Its response is linear and highly suitable for interfacing with the analogue-to-digital converter (ADC) of any micro-controller. For example, if temperature is 25°C, then its output is 250 mV. The sensor operates off 5V DC supply. The output of the temperature sensor is connected to analogue input A5 of the Arduino board The LM 35 temperature sensor is an easy to use, cost-effective sensor with decent accuracy. LM35 is shown in figure 4 below.

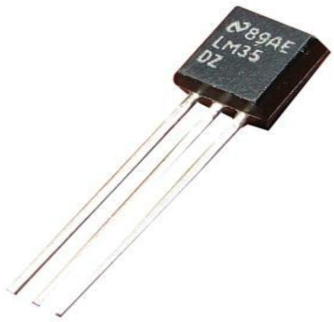

Figure 4: LM35 Sensor

The sensor is essentially a Zener diode whose reverse breakdown voltage is proportional to absolute temperature. LM 35 sensor circuit provides analog input and we connect it with the Arduino analog pin for input (pin 1). Three pins are there for analog input, output and ground.

2.6. LDR – Light Dependent Resistor

An LDR is a component that has a (variable) resistance that changes with the light intensity that falls upon it. This allows them to be used in light sensing circuits. A light-dependent resistor (LDR) is a light-controlled variable resistor. The resistance of this decreases with increasing incident light intensity; in other words, it exhibits photo-conductivity. An LDR can be applied in light-sensitive detector circuits, and light- and dark-activated switching circuits. An LDR is made of a high resistance semiconductor. In the dark, an LDR can have a resistance as high as a few mega ohms (MΩ), while in the light, an LDR can have a resistance as low as a few hundred ohms. If incident light on an LDR exceeds a certain frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electrons (and their whole partners) conduct electricity, thereby lowering resistance. The resistance range and sensitivity of an LDR can substantially differ among dissimilar devices.

2.7. The Display Unit

The proposed system uses a 20 × 4 LCD (liquid crystal display) to display the output to the outside world. It is an electronic display module found in wide variety of applications. A 20 by 4 LCD as shown in figure 5 is preferred over seven segment displays and other multi segment LCDs because they are more economical, easily programmable, has no limitations of displaying special and even custom characters and so on. A 20 by 4 LCD means it can display four lines with maximum of 20 characters per line. In the LCD, each character is displayed in a 5 by 7 pixel matrix. It also has two registers namely: command and data.

Figure 5: A 20 × 4 LCD

2.8. The GSM module Unit

GSM stands for Global system for mobile. It is a device which modulates and demodulates signals as required to meet communication requirements. It modulates an analogue carrier signal to encode digital information, and also demodulates such a carrier signal to decode the transmitted information.A GSM module is a device that modulates and demodulates the GSM signal and in this particular case 2G signals. The modem used in this study is 800L. It is a Tri-band GSM/GPRS modem as it can detect and operate at three frequencies (EGSM 900 MHZ, DCS 1800 MHZ and PCS 1900 MHZ). Default operating frequencies are EGSM 900 MHZ and DCS 1800 MHZ. The figure 6 below shows the SIM800L GSM Module.

Figure 6: GSM Module (SIM800L)

2.9. Real Time Clock (RTC DS3231N)

The DS3231 is a low-cost, extremely accurate I2C real-time clock (RTC) with an integrated temperature compensated crystal oscillator (TCXO) and crystal. The device incorporates a battery input, and maintains accurate timekeeping when main power to the device is interrupted. The integration of the crystal resonator enhances the long-term accuracy of the device as well as reduces the piece-part count in a manufacturing line. The RTC maintains seconds, minutes, hours, day, date, month, and year information. The date at the end of the month is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with an AM/PM indicator. Two programmable time-of-day alarms and a programmable square-wave output are provided. Address and data are transferred serially through an I2C bidirectional bus. The RTC (DS3231N) is represented in the figure 7 below.

Figure 7: RTC (DS3231N)

Figure 8: Buck Converter (LM2596)

2.10. Buck converter LM2596

The LM2596 step-down switching regulator is monolithic integrated circuit ideally suited for easy and convenient design of a step−down switching regulator (buck converter). It is capable of driving a 3.0 A load with excellent line and load regulation. This device is available in adjustable output version and it is internally compensated to minimize the number of external components to simplify the power supply design. Since LM2596 converter is a switch−mode power supply, its efficiency is significantly higher in comparison with popular three−terminal linear regulators, especially with higher input voltages. The LM2596 operates at a switching frequency of 150 kHz thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators. Self protection features include switch cyclebycycle current limit for the output switch, as well as thermal shutdown for complete protection under fault condition. Figure 8 shows the LM2596 buck converter.

The circuit diagram of our proposed weather monitoring system is in figure 9 below.

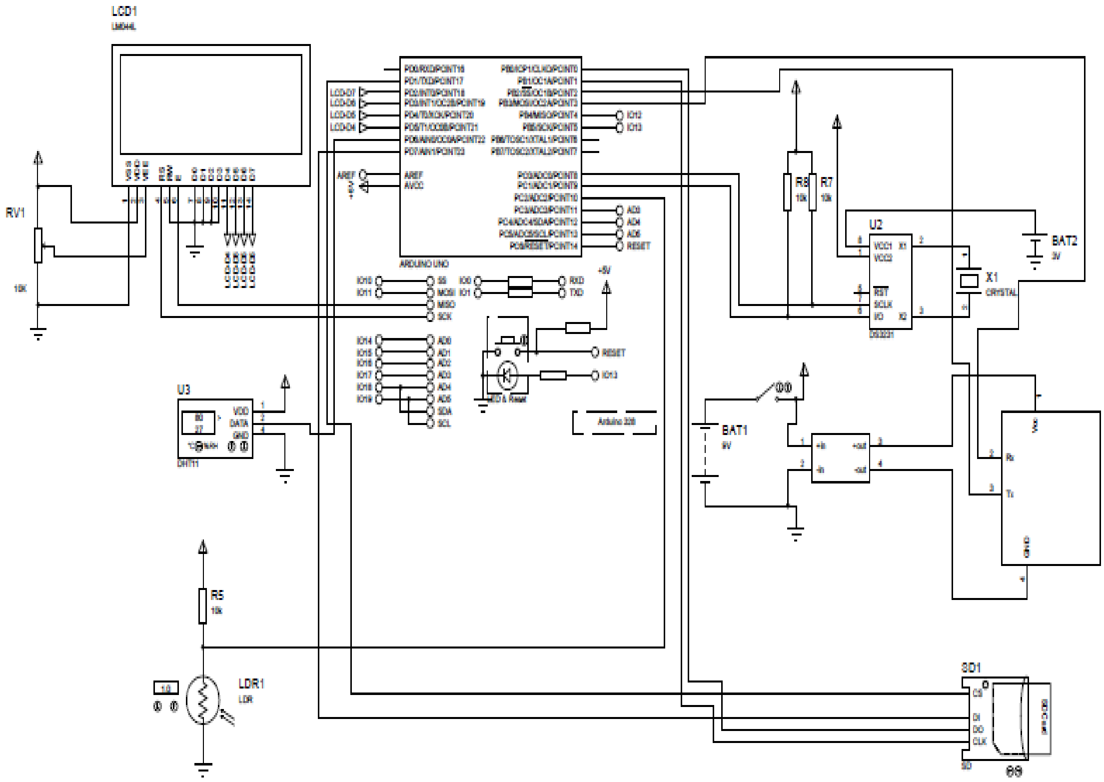

Figure 9: Circuit Diagram of proposed weather monitoring system

2.11. Software Design

The software is designed in other to support the effectiveness of the hardware device. The complex and intricate operating routine of the software is achieved by writing sections as demonstrated in the program flowchart in figure below. Arduino IDE (integrated developer environment) was used throughout the software building stage. The software was written in C language and was developed in sections for easy debugging and then later integrated. The integrated program was built and verified and the hex file was generated which was then loaded into the microcontroller.

2.11.1. Simulations with proteus

After a successful completion of stages one and two, the design was virtually implemented using proteus vsm software to detect likely logical errors in the program and improper operations in the hardware design. During and after simulations on proteus, faults were detected and adjustments were made appropriately. Figure 10 depicts the design simulation using proteus Vsm.

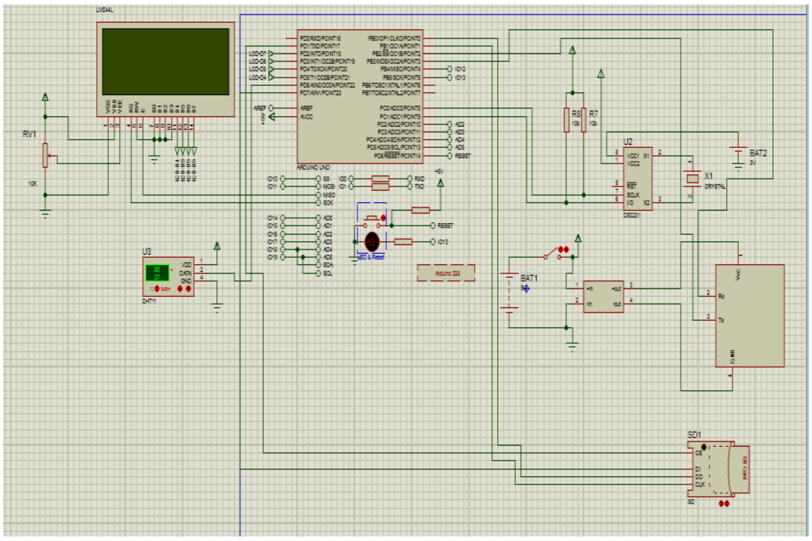

Figure 10: Design Simulation with Proteus Vsm

2.12. Construction

This stage was further subdivided into three;

1. Bread boarding
2. Vero boarding
3. Casing

2.12.1. Bread Boarding

All hardware components were physically assembled on a breadboard as shown in figure 11 below. This is necessary in other to further detect possible hardware design errors which might not be discovered with proteus simulation. Components were tested and adjustments were made as necessary and the design was successfully implemented.

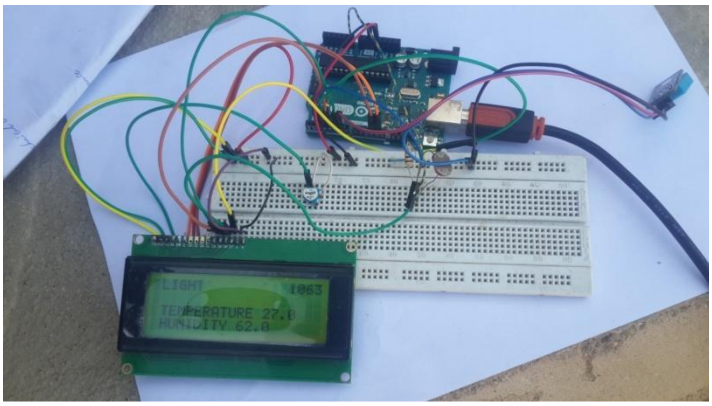

Figure11: Proto Board Implementation

2.12.2. Vero Boarding

The design on the proto board was carefully transferred unto a Vero board. All components were carefully and appropriately soldered and tested.

2.12.3 Casing

The complete soldered project was properly packaged in a thermoplastic casing in other to prevent it from physical damage and other environmental hazards.

3. Result

This section deals with the descriptions of tests performed on the various sections of the overall system and their corresponding results. To verify the correct functionality of the system, each component had to be tested individually. In achieving the effective testing of the component, the breadboard and digital multi-meter were used. Testing was performed on each of the components and section that made up the circuit so as to ensure proper and satisfactory operation of the system. The results obtained were sectioned into four to tally with the objectives. The first objective which is to convert analog data obtained from sensors and fed to one of the ADC channel of Microcontroller has been achieved. The second objective which entails wireless monitoring of the weather system in an enclosure has also been achieved through sensing and display of real time environmental temperature, relative humidity and light intensity on LCD screen as shown in figure 12 below.

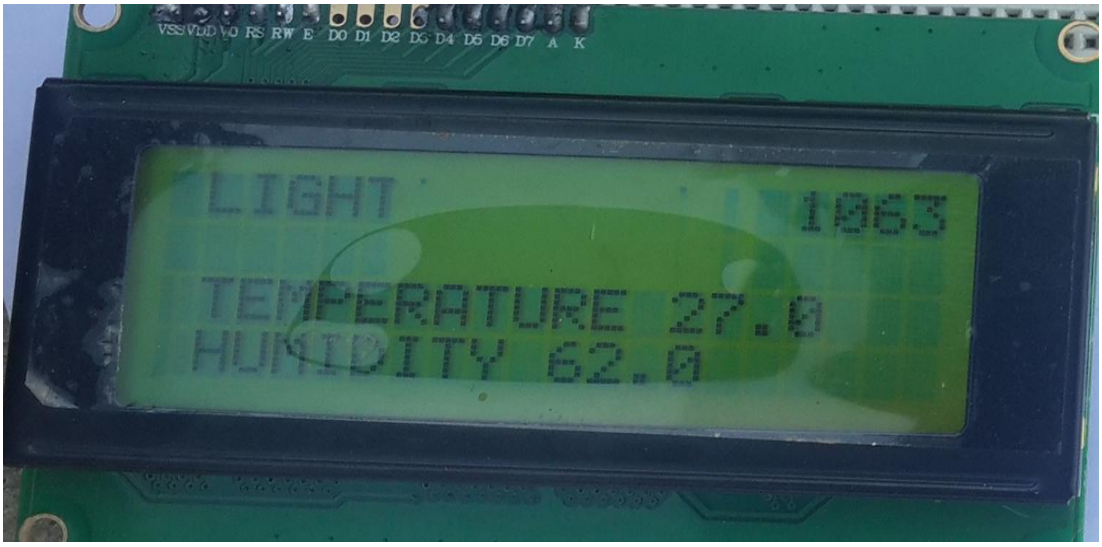

Figure12: Display of real time Light Intensity, Temperature and Humidity

The obtained results which are the measured temperature, relative humidity and light intensity are then sent to the user with the help of GSM module (SIM 800) via SMS. A sample SMS is shown in figure 13 below.

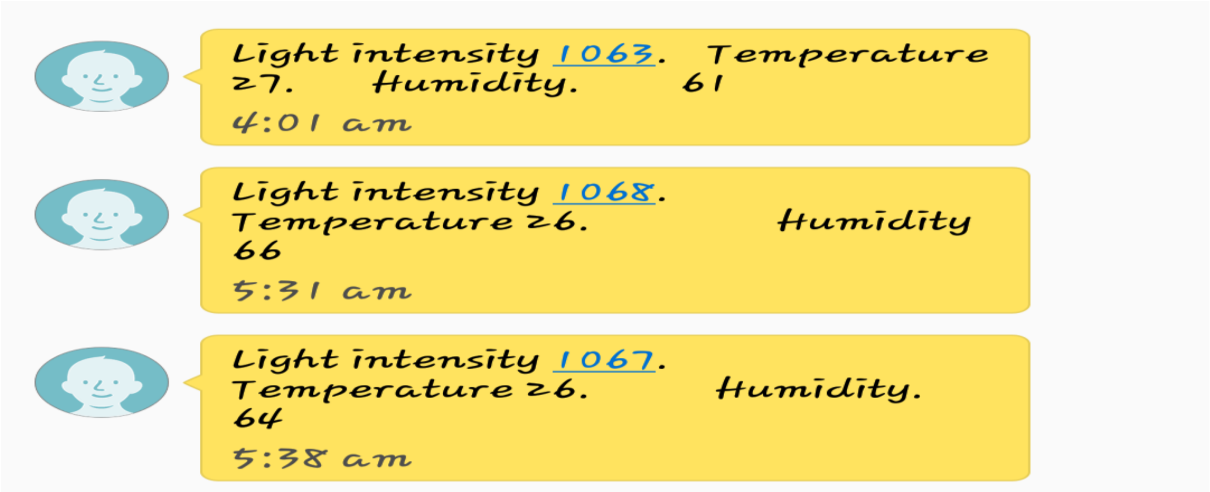

Figure 13: Measured parameters sent through GSM module

After the accuracy of the proposed system has been tested through extensive experiments. The results obtained are summarized in tables 2 – 4 and figures 14 - 16.

Table 2: Comparison of Temperature measurements

Number of Test	Time	Calibrated Mercury thermometer (°C)	Proposed system (°C)	Difference (°C)
Test 1	4.00am	29.4	29.7	0.3
Test 2	6.00am	29.5	29.6	0.1
Test 3	8.00am	29.3	29.1	0.2
Test 4	10.00am	29.3	29.3	0.0
Test 5	11.00am	29.6	29.6	0.0
Test 6	1.00pm	29.7	29.5	0.2
Test 7	3.00pm	29.7	29.2	0.5
Test 8	5.00pm	29.8	29.7	0.1
Test 9	7.00pm	30.4	29.8	0.6
Test 10	9.00pm	30.5	30.0	0.5

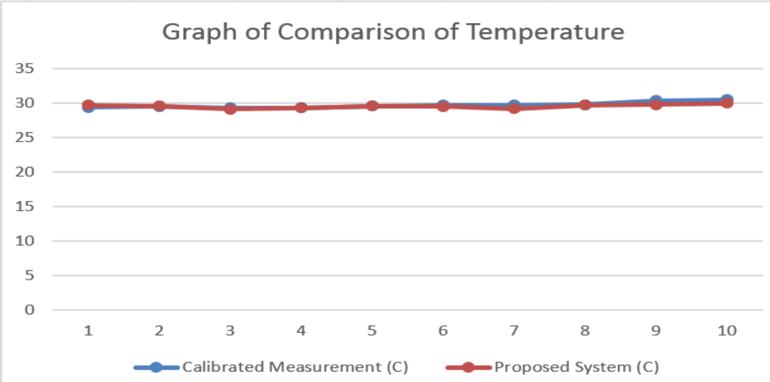

Figure 14: Graph of Comparison of Temperature measurements

Table 3: Comparison of Relative humidity measurements

Number of Test	Time	Calibrated Hygrometer (% Rh)	Proposed system (% Rh)	Difference (% Rh)
Test 1	4.00am	61	63	2
Test 2	6.00am	64	66	2
Test 3	8.00am	65	66	1
Test 4	10.00am	67	67	0
Test 5	11.00am	65	65	0
Test 6	1.00pm	59	59	0
Test 7	3.00pm	60	59	1
Test 8	5.00pm	61	59	2
Test 9	7.00pm	58	58	0
Test 10	9.00pm	59	57	2

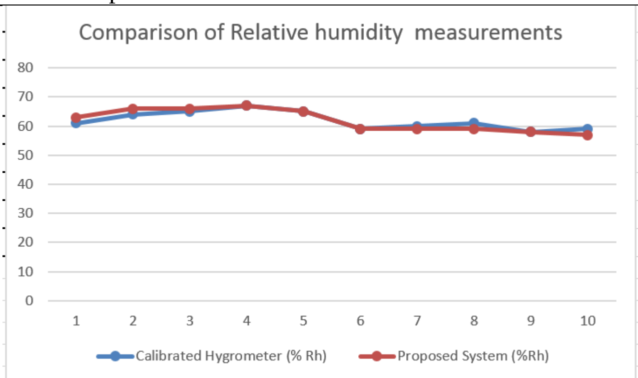

Figure 15: Graph of Comparison of Humidity measurements

Table 4: Comparison of Light Intensity Measurements

Number of Test	Time	Photometer(% lx)	Proposed system (% lx)	Difference (% lx)
Test 1	4.00am	64	63	1
Test 2	6.00am	66	66	0
Test 3	8.00am	65	66	1
Test 4	10.00am	65	67	2
Test 5	11.00am	67	65	2
Test 6	1.00pm	60	59	1
Test 7	3.00pm	59	59	0
Test 8	5.00pm	59	59	0
Test 9	7.00pm	60	58	2
Test 10	9.00pm	59	57	2

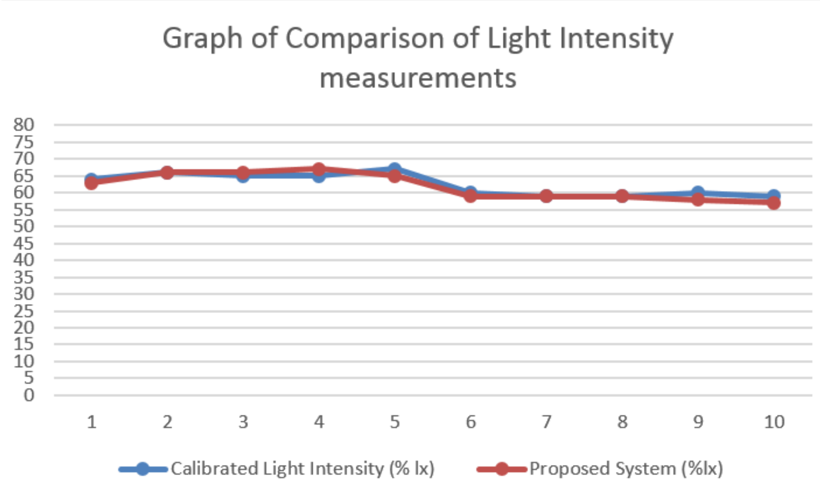

Figure 16: Graph of Comparison of Temperature measurements

4. Discussion

As soon as the constructed model is connected to power, the DHT11 temperature/humidity sensor reads the temperature and humidity of the environment while the LDR sense the light intensity; feed the analog readings to at mega328p microcontroller through its 3rd pin. The microcontroller digitizes the analog readings and display the measured parameters as well send the parameters to the user via GSM module. All readings of temperature, relative humidity together with light intensity are displayed in real time on the LCD. The measurement accuracy of the proposed system was extensively tested through different experiments that were conducted. The system can measure temperature that ranges from 0 ºC to 100 ºC with 0.5 ºC resolution, relative humidity from 35 %RH to 95 %RH with resolution of 1 %RH, and light intensity from 10 %lx to 100 %lx with resolution of 1 %lx. The ultimate accuracy of the weather monitoring system is subject to the accuracy of sensor. The readings from our proposed system are equivalent to the actual measured data using conventional mercury thermometer, calibrated hygrometer and photometer. The results obtained are summarized in tables 2-4, and figures 14-16. It can be deduced from table 2 and figure 14, that the temperature sensor demonstrates a reasonable level of steadiness and accuracy. The average error of 0.6 ºC is observed due to ±0.25 ºC error by the sensor and ±0.125 ºC introduced by Analog Digital Converter. The humidity sensor of our proposed system also displayed very good accuracy as shown in Table 3 and figure 15. An error of 1% is observed mainly due to the magnetization of ferromagnetic property of the humidity sensor. This effect is referred to as hysteresis. This is because the current reading of the humidity sensor depends not only on its current state, but also upon its past history. This is an indication that our proposed system will be very useful in Green house weather monitoring where temperature, light and humidity have very important role to play. The light intensity sensor of our proposed system also shows good accuracy as shown in Table 4 and figure 16.

5. Conclusion

A study on weather monitoring based on Arduino microprocessor with GSM has been done. The proposed system incorporates the uses of sensors and GSM in developing a low-cost, high-accuracy weather monitoring system, using analogue and digital components. The proposed system has been tested through extensive experiments and the results have proven the accuracy and reliability of the proposed system. From the graphs of comparison of temperature, humidity and light intensity it is clear that there is very close conformity between the data collected by our system and one measured by existing calibrated systems, which justifies the measurements made by our system. The proposed system can be helpful in monitoring the temperature, light intensity and relative humidity of industrial, and home processes application that have various parameters. The advantage of this technique is that it does not require the use of computer or internet service for remote monitoring thereby making the approach to be economical. It is thereby evident that the proposed system is of better choice in terms of cost, portability, memory capacity and logging interval-setting capability. In the future, different other sensors as pressure sensors to analyze air quality using gas detectors can also be interfaced with the microcontroller to fetch various information about a location.

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