Abstract—The paper is aimed to design and implement a remote sensing and monitoring system running on mobile robot with the capability of transmitting the data wirelessly to operating station. A simple mobile robot prototype with on-board sensors has been designed and implemented to scan and monitor several variables in the surrounding environment. The system enables the user operating from base station to send commands to the remote station mounted on robot, and receive data about the environmental conditions through Bluetooth protocol communication.

Keywords— Remote Sensing and Monitoring, Wireless sensor networks, Mobile robot, Data Acquisition, MATLAB

I. INTRODUCTION

This paper is aimed at designing and implementing multipurpose sensing robot. Robots are widely used in different applications to sense certain physical quantities. Due to ease of use and access, robots have gained much attention in many applications that involve analysing the physical environment and then reacting according to it. There has been tremendous increase of interest in mobile robots and their applications. Using mobile robots equipped with sensors are widely used, especially in environments where human involvement is limited, impossible or dangerous. These robots can be used to perform tasks that are otherwise hazardous for human to do. Mars Science Laboratory also known as Mars Curiosity Rover provides an example whereby different environmental and soil conditions of Mars are examined remotely by operating it from Earth.

This project employs different sensors to measure environmental condition. Firstly Thermistor is used to measure the temperature of the surroundings. LDR (Light Dependent Resistance) is used to measure the intensity of light in LUX. The robot also houses an accelerometer which measures the position of robot. Ultrasonic sensor detects nearby obstacles so that robot can easily navigate through them. Pressure sensor measures the pressure and hence the altitude at which robot is currently operating. Gas Sensor detects smoke as well as Methane Gas. Hall Effect Sensor measures the magnetic field. All of these environmental conditions are measured by robot and reported back to user. The medium used for transmitting data back to user is Bluetooth.

Wireless Sensor Network (WSN) technology along with mobile robots can be used to detect several environmental conditions [1]. Each mobile robot is considered as individual node in the network which can monitor its local region and communicate through a wireless channel with other nodes to collaboratively produce a high-level representation of the environment's states [2]. Through the application of such network, large areas can be monitored.

This paper presents the project developed at NUST SEECS aimed at designing and implementing reliable, smart and cost effective monitory system mounted on mobile robot. The robot can perform tedious tasks repeatedly in hazardous environment. All of the environmental data is displayed on MATLAB User Interface. Thus the project provides real time data acquisition. The microcontroller used in the project is Arduino MEGA ADK equipped with AVR ATmega2560.

II. MOBILE ROBOT DESIGN

A challenging problem in robotic is the design of an outdoor mobile robot. The simplest types of mobile robots are wheeled robots that comprise one or more driven wheels and may have optional passive or caster wheels and possible steered wheels. The implemented mobile robot is a four wheeled vehicle prototype. Two DC motors are used for driving and steering, the first DC motor is used for driving one of the real wheel while the second DC motor is used for driving second rear wheel. The prototype provides support to batteries, sensors, and all elements related to the proposed design. The microcontroller is powered from the same batteries driving the motors but voltage is regulated by Buck Converter.

![Fig. 1 Wheeled Mobile Robot](image-url)
circuit type (L293D) is needed to drive each DC motor forward and backward, as given in Fig. 2. Four output lines from the microcontroller are connected to the H-bridge to drive the DC motors.

![Fig. 2 L293D Interfacing with Motor](image)

III. SENSORS INTERFACING

Different sensors are interfaced on the robot which indicates different existing environmental conditions.

A. Thermistor

Thermistor is basically a thermal resistor. It measures temperature of the environment on the basis of changes in resistance. It is cost effective and incredibly simply to interface but it has the disadvantage of imprecise reading.

Thermistors can be NTC (negative Temperature coefficient) or PTC (positive temperature coefficient). The thermistor used in this project is NTC 10K. NTC thermistors are made up of semiconductor material whose resistance decreases on increasing the temperature. The relationship between temperature and resistance is given by the Stein-Stein Hart Relationship.

The basic equation of Stein-Stein Hart Relationship is:

$$X = \log\left(\frac{10240000}{V} - 10000\right)$$

Thermistor is interfaced with the microcontroller using the following circuitry [3]:

![Fig. 3 Thermistor with Microcontroller](image)

B. Light Dependent Resistor (LDR)

The Light Dependent Resistor is also known as Photoconductive Cell. The resistance of LDR changes with changes in the intensity of Light. Greater is the intensity of Light incidence on the surface of LDR, lesser will be its resistance and more will be the current passing through it and more will be the voltage across it. The relationship between the intensity of light and the resistance of LDR is given by:

The basic circuitry of interfacing LDR with microcontroller is [4]:

![Fig. 4 LDR with Microcontroller](image)

C. Hall Effect Sensor

The Hall Effect Sensor is a sensor that basically senses the magnetic field around. Example includes the magnetic field produced from a current carrying wire. The sensor operates as an on-off switch. If the north pole of the magnet is close to sensor, it will be on and if South Pole is close to the sensor it will be off. The Hall Effect Sensor used in the project is 86A. The basic circuit for interfacing Hall Effect Sensor with microcontroller is given in the diagram [5].

![Figure 5: Hall Effect Sensor with Microcontroller](image)

D. Humidity Sensor

The humidity of an environment is sensed by ultra-low cost temperature and humidity sensor, DHT11. It uses a capacitive humidity sensor and a thermistor to measure the surrounding...
air and spits out a digital signal on the data pin. The output is digital. Compared to DHT22 which is also a humidity sensor, DHT11 is less precise, less accurate and works in a smaller range of temperature and humidity but at the same time it is smaller and less expensive [6].

E. Smoke Sensor

The MQ Series of gas sensors use a small heater inside with an electro-chemical sensor. They are sensitive for a range of gasses and are used indoors at room temperature. They can be calibrated more or less but a known concentration of the measure gas or gases is needed for that. The output is an analogue signal and can be read with analogue input of the microcontroller that is Arduino.

The internal circuitry of the sensor is shown in the figure below.

![Fig. 6 MQ Sensor internal Circuit](image)

F. Accelerometer

Accelerometer is basically used to measure the proper acceleration. However it can also be used to measure the coordinates. By measuring the amount of static acceleration due to gravity, we can find out the angle the device is tilted at with respect to earth. [8] In this project, the robot’s position and tilt is being monitored by the accelerometer.

The accelerometer used in this project is ADXL345. It is small, thin, low power, 3-axis MEMS accelerometer with high resolution measurement at up to +/- 16g. The output of accelerometer is digital and is accessible through either a SPI or I2C digital Interface. I2C communication is used in this project.

![Fig. 7 Functional Block Diagram of ADXL 345](image)

G. Pressure Sensor

Pressure was sensed using BMP085 pressure sensor. It consist of Piezoresistive sensor, and analogue to digital convertor with serial I2C communication. It delivers uncompensated values of pressure, temperature and altitude. The microcontroller send the start sequence to start pressure or temperature measurement. After converting time, the result value can be read via the I2C interface. For converting temperature in °C and pressure in hPa the calibration date has to be used.

![Fig. 8. Flow Chart of Pressure Sensor](image)

H. Ultrasonic Sensor

Ultrasonic sensor (type HCSR04) was used for distance measurement and avoid any obstacle in working environment. To use this sensor, a short 10us pulse is applied to sensor input. The sensor will automatically send out 8-cycles burst of ultrasound at 40 kHz and raise its Echo. The internal timer/couter of the microcontroller is used to calculate the range through the time interval between sending trigger signal and receiving echo signal.[9]

IV. WIRELESS COMMUNICATION

The remote station communicates with the operating station wirelessly through Bluetooth Communication. Bluetooth is a wireless technology standard for exchanging data over short distances. The physical range of Bluetooth is usually up to 60 meters. Bluetooth uses short wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz. Bluetooth was standardized as IEEE 802.14.1 but the standard is no longer maintained [].

The module used for Bluetooth communication is HC-06. It uses simple RX-TX communication to interact with the microcontroller. HC-05 which is also a Bluetooth module has an added advantage that it can be used as Master as well as Slave while HC-06 can only be used in Slave Mode. The baud
rate selected for the Bluetooth Communication was 9600 baud per second.

![Diagram of Microcontroller and HC-06 Module](image)

**Fig. 9 HC-06 Module connection with Microcontroller [10]**

V. MATLAB USER INTERFACE

User Interface is extremely important in any project of this kind therefore this project also includes a user friendly interface. Using the GUI, the user can interact with the remote station mounted on the robot. The GUI built on MATLAB includes the basic navigation buttons. Using those navigation buttons, the user can maneuver the robot. Along with it, the GUI enables the user to sense a particular environmental condition such as Temperature or Pressure. The GUI provides the user with an option to connect to the robot through Bluetooth Communication.

By the use of MATLAB, data acquisition is made possible and the data can then be further analyzed or passed through signal conditioning units if required. Through the use of MATLAB, different filters can be applied to data obtained from the sensor so as to increase the accuracy of the results. Through Data Acquisition, Data logging is also possible. The following figure indicates the MATLAB GUI.

![MATLAB GUI](image)

**Fig. 10 MATLAB Graphical User Interface**

VI. ROBOT OPERATION

The operation of the robot involves establishing the connection between the MATLAB GUI and the monitor station mounted on the robot.

![Robot Algorithm Diagram](image)

**Fig. 11 Robot Algorithm**

When the Bluetooth connection is established, the robot is then able to receive direct commands from the user. From the GUI, the user can move the robot in any direction by clicking the button on the interface. In order to acquire any value of the sensor so as to measure the environmental conditions, the user can press the button on the GUI. The received data from the remote monitor station on the robot is displayed on the GUI. In this way the user is made aware of the environmental conditions existing in the inaccessible environment.

VII. RESULTS AND DISCUSSION

The multipurpose sensing robot operated as per expectations. All of the readings that are Temperature, Pressure, Light Intensity, Magnetic Field, Distance from Obstacle, Position of the robot, Altitude of the robot above sea level and humidity were accurate with an error of not more than 5%. The DC motors operated as per the requirement with desired transient and steady state characteristics.

CONCLUSION

This paper describes the prototype project developed at NUST School of Electrical Engineering and Computer Science as part of Semester Project for the course of Instrumentation and Measurements. A reliable, cost effective, smart, energy efficient and effective communication channel between the operating station and remote monitor station mounted on a robot has been designed and implemented. Through data acquisition, the user is informed about different variables of environment that currently exists in certain region.
The designed and implemented robot satisfies all the plans that this project was aimed for.

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REFERENCES


