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Wireless Operating Robot for Disaster Management

R.K. Jha, S. Kumar & K. Madhav
Shri Mata Vaishno Devi University
Katra, J&K 182320
Jharakesh.45@gmail.com, 2011eec31@smvdu.ac.in, 2011eec68@smvdu.ac.in

ABSTRACT

When a natural disaster like an earthquake hits a populated area or an accident like gas leakage takes place in a building, rescue teams have to get a quick overview of the situation in order to identify possible locations of victims, which need to be rescued, and dangerous locations, which need to be secured. In order to provide the rescue facility, advanced robots embedded with lots of sensors and functions are centre of attraction of people and researchers all around the world. The paper is written on the application of the Wireless Sensor Network for disaster management. The module made for wireless sensor network consists of a fixed node with the rescue team and a moving node with the robot. The robot module works as, searching for living human beings, and collects data from the air quality control module, localizes it with respect to the fixed nodes and sends the data. Thus Robot-supported systems accelerate search operations. The team of rescue members can wirelessly receive the data in real time. It provides a range up to 100 meters when operated at full power.

Keywords- Disaster Management, Robot, Environment Monitoring System, Wireless Sensor Network, Wi-Fi IP Camera, Bluetooth, Household security, Android application development.

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1. INTRODUCTION

Over the last few years, advanced robots embedded with lots of sensors and functions are centre of attraction and attention of researchers all around the world. This paper describes the application and functionality of a Robot that can be used in case of disaster management to rescue human life. The robot is designed in such a way that it can be used by any organisation for various purpose. This robot works as, searching for living human beings and collects data from the atmosphere. The team of rescue members can wirelessly receive the data in real time and perform their job accordingly. By the help of this robot rescue team can get information that the area is safe or not before entering to that particular location.

The robot is equipped with LPG gas module, Temperature and humidity sensor light sensor, Magnetic field sensor, Metal detector. It has a live camera that is equipped with two way audio communication, Day and Night vision. Camera provides live streaming without any delay over wireless link at 2.4 GHz ISM band. Robot is having a latest 18650 Battery which can provide power for three hours at single charge.

Various Applications of the Robot includes:

- Smoke sensing
- LPG leakage detection
- Temperature and Humidity measurement
- Metal detection
- Magnetic field detection
- Provides two way Audio link with operator
- Provides live video streaming
- Provides night vision up to 30 meters range
- It can move on stairs and also rotate 360° without any displacement
- It can carry weight up to 5 kg.

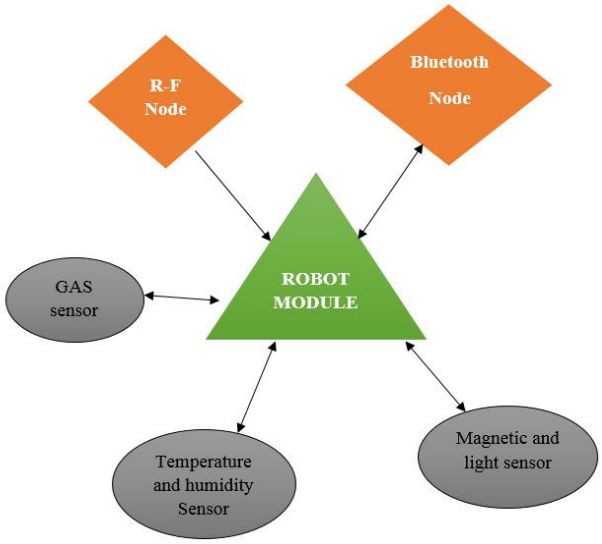

Figure 1: General Architecture of Robot and Wireless Network

The Robot is equipped with both RF module as well as Bluetooth module. Radio link is used where long distance communication is required. It provides a range up to 100 meters when operated at full power. Bluetooth Module provides full duplex mode of communication but it provides range up to 20 meters. The Robot can be operated through any android device. Android device establishes connection with robot through Bluetooth. All the readings from different sensors are displayed on android device. The general architecture of robot with different wireless network is mentioned in Figure 1.

To operate robot through radio link, a separate remote is used. It has two different RF module clocked at 315MHz and 433 MHz The two different frequency are used to avoid the chances of inter channel interference. The interfacing of the different sensors is done through Arduino UNO board since Arduino is an open source microcontroller so modification of robot is very easy through any computer. The following sections describe the related work, Process Flow Chart, Mechanical architecture design, Hardware architecture of the robot, hardware architecture of the receiver and transmitter, navigation algorithm, Sensor interfacing algorithms, Android Application for Robot control, summary and finally the conclusion.

2. RELATED WORK

The paper by Raghad Dardar [1] discuss a low cost and low power consumption robot used for guiding rescue teams when disasters happens using wireless sensor network. The papers published by Albert W. Y. Ko and Henry Y. K. Lau [2] and [3] discuss various things about rescue mechanisms including camera mounted probes, search dogs, and audio devices. The paper [4] by Trupti B. Bhondve proposes a monitoring system using sensors unit and camera module to record, analyze conditions of human body and transmit data. The paper [5] by Tsuyoshi Suzuki, Ryuji Sugizaki describes an autonomous deployment and restoration of a Wireless Sensor Network (WSN) using mobile robots. Paper [6] by Kamol Chuengsatiansup explained about a team of search robots for rescue missions.

Each robot contain various sensors including digital compass, laser range finder, a thermopile array, Carbon Dioxide sensor, tilt sensor and microphone. This module can also be operated in teleoperated and autonomous mode. The paper [7] by D.Kurabayashi describes a survey of studies on collective intelligence of autonomous robotic agents, especially emergent functionality in a swarm. Paper by Kuntze, Helge-Bjoern [8] discuss about the objectives and first research results of the ongoing joint research project SENEKA. The paper [9] by M. Tornow addresses a gesture and hand posture based HMI-system. The paper [10] by D.I Gertman discusses about increasing the range of higher level robot behaviors such as autonomous navigation and mapping and reports on experiments underway intelligence residing on the robot to enhance emergency response.

3. PROCESS FLOW CHART

We have followed the following Flow chart for the implementation of Robot which begins from the architecture designing and ends by the final implementation**.** The top to down approach for process to implement robot for disaster management is mentioned in Figure 2.

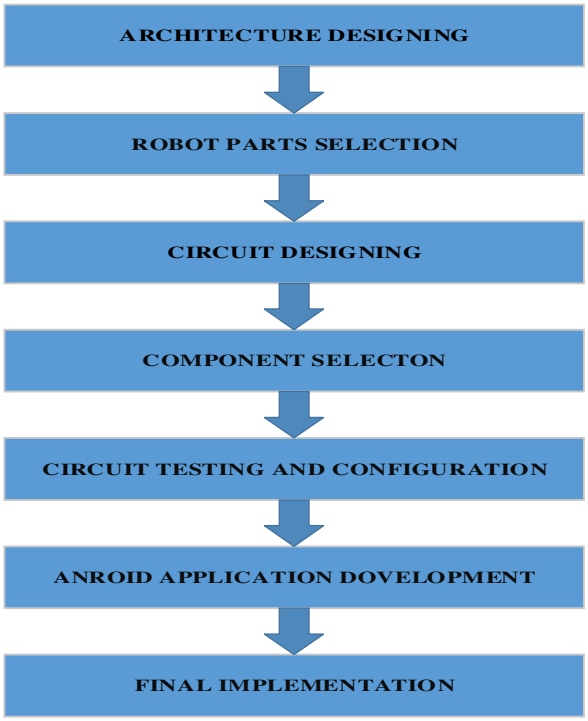

Figure 2: Process Flow Chart

4. ARCHITECTURE DESIGN

The Architecture design includes Mechanical design as well as Hardware design.

4.1 Mechanical Architecture Design

Mechanical architecture is one of the most important part since it provides necessary strength to robot and play crucial role for its proper movement. The Architecture is designed in such a way so that the robot can rotate 360 degree without having any displacement and it can also move on stairs. From our Research we have concluded the perfect length × width × height for body of such a robot would be 18″ × 12″ × 3″.

We have selected Aluminium sheet to make its base body. Aluminium sheet is preferred because it is very light in weight and very strong. The actual view of base body is mentioned in Figure 3.

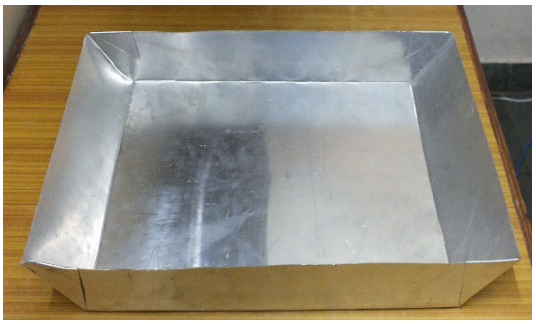

Figure 3: Base body of the Robot

After designing the Main body, we have designed the hands of the robot with the help of wood. To make robot move on stairs it is calculated that the perfect length × width × height of hand should be of 5.4″ × 1.3″ × 0.5″. Actual view of the arm of the robot is shown in Figure 4.

Figure 4: Arm of the Robot

Four wheels of Diameter 7 cm and width 4 cm are chosen to provide better grip to robot.

4.2. Hardware Architecture Design

This section will describe the hardware architecture of the robot that will be used by rescue team during disasters.

4.21 Platform

The robot is based on a motor driver IC board mounted to a robotic tank platform, in order to enable it to travel on rough surface and on stairs. The platform consists of six geared DC motors whose gears can be changed to control its power and speed according to the requirement. The motor driving circuit can get input either directly from RF signal decoder or through micro-controller board while operating over blue tooth link.

4.2.2 Humidity And Temperature Sensor

Humidity and Temperature Sensor DHT11 includes a resistive-type humidity measurement component and an NTC temperature measurement component. It is connected to a high performance 8-bit microcontroller in order to offer excellent quality as well as fast response. Each DHT11 sensor features extremely accurate calibration of humidity calibration chamber. The calibration coefficients stored in the OTP program memory, internal sensors detect signals in the process. The single-wire serial interface system is integrated to become quick and easy.

4.2.3 LPG and Smoke Sensor

LPG and Smoke Sensor MQ5 is highly sensitive towards methane, propane and butane. It consists of SnO_2. When SnO_2 is heated, O_2 gas absorbed at the surface and it forms a barrier at the surface. When density is varied at the surface, the gas is sensed.

4.2.4 Magnetic Field Sensor

It contains a vacuum tube having two metal plates. Whenever the vacuum tube connecting the two metal plates is passed through a magnetic disturbance, the two plates gets connected. As a result of this connection the current starts to flow and hence the magnetic field is detected.

4.2.5 Wireless Camera

Wireless camera used in this Robot is basically an Internet protocol camera, or IP camera, which is a type of digital video camera commonly employed for surveillance. It can send and receive data via computer network and the Internet. The camera has Day and Night Vision and it can detect motion in 30 meter range. It consists of two separate motors which enables it to give a planar vision of 360° and upward vision of 270°. Motor movement of camera can be controlled wirelessly by Operator. It is also equipped with two way audio communication module.

4.2.6 Light Sensor

LDR (Light Dependent Resistor) is used here to sense the intensity of light. The resistance of a photoresistor decreases with increasing incident light intensity.

5. TRANSMITTER AND RECEIVER ARCHITECTURE

Transmitter: Transmitter circuit of robot is basically remote of the robot which is operated by the user. The RF remote of robot contains two RF transmitters which transmit signal using two antennas. It has two HT12E IC which encode signal according to the address generated by DP switches. In this circuit one of the HT12E IC is use to encode data generated by touch sensitive key. These four touch sensitive keys are used to control the movement of robot. The other HT12E IC is used to encode the data generated by push keys. These keys are used to control the lights and arms of the robot. The detailed circuit diagram of transmitter is shown in Figure 5.

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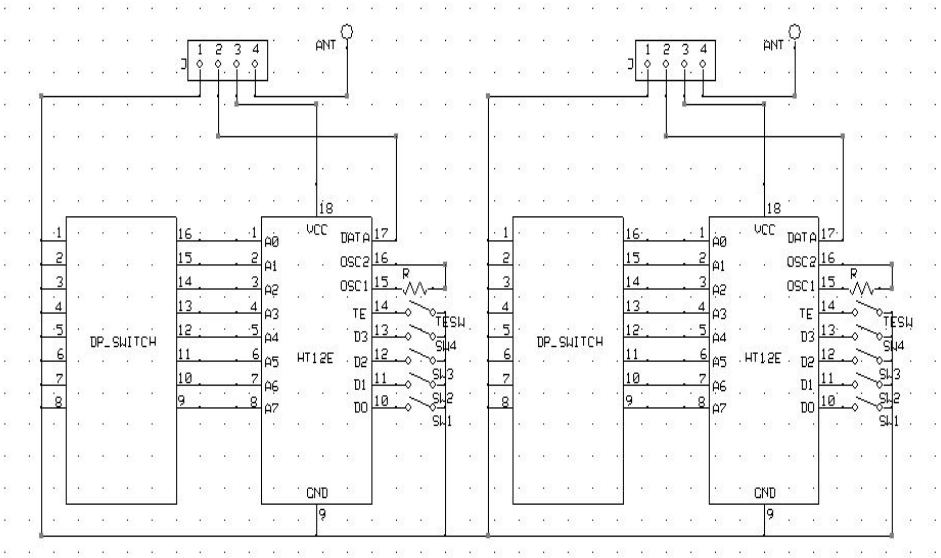

Figure 5: Transmitter Circuit Diagram

The user can also use any android based device as Remote to control the robot. In this case robot will be operated using Bluetooth link.

Receiver: Receiver circuit contains two RF receivers which receives signal from RF transmitter. The received signal is then given to the signal Decoder IC HT12D. The Decoder ICs decode the signal according to the 8 bit address generated by DP switches.

The output of the decoder IC is then given to the Motor Driver Circuit. This circuit has a voltage regulator (LM7805) to provide proper voltage to RF module and Decoder IC. The circuit has two pins to which two antennas are connected which increases the signal strength and provide long range. The detailed circuit diagram of receiver is shown in Figure 6.

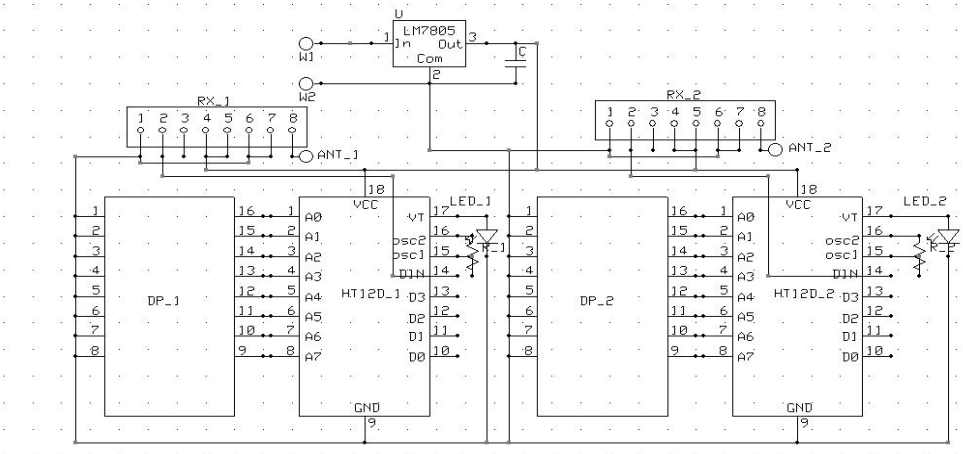

Figure 6: Receiver Circuit Diagram

Arduino Uno will be working as receiver when Android device is being used as transmitter. A Bluetooth module HC-06 is interfaced with Arduino board to provide Bluetooth connectivity.

6. NAVIGATION ALGORITHM

For the navigation of Robot, four 100 RPM DC Geared Motors are used in which each motor is capable of producing a torque of 2.5 newton meter and for lifting the Robot, two 10 RPM DC Geared Motors are used where each motor is capable of producing a torque of 5 newton meter. This allows the Robot to climb the stairs.

The speed of Robot and the direction of rotation of motors are controlled by using Motor driver IC L293D. This IC is capable to provide 0.6A current per channel (which is the current requirement of motor). It also drives two motors separately in both clock wise and anti-clockwise direction according to the Logic input signal coming from receiver Circuit. The truth Table 1 represents the working of Motor Driver Circuit.

Table 1: Input Logic for Navigation

INPUT A	INPUT B	DESCRIPTION
0	0	Motor Stops
0	1	Motor Runs Clockwise
1	0	Motor Runs Anti-Clockwise
1	1	Motor Stops

IC L293D provides an active high signal at the output pin when it receives an input signal of either 1, 1 or 0, 0 to lock the motor movement and thus breaks are applied. All the details connection is mentioned in Figure 7.

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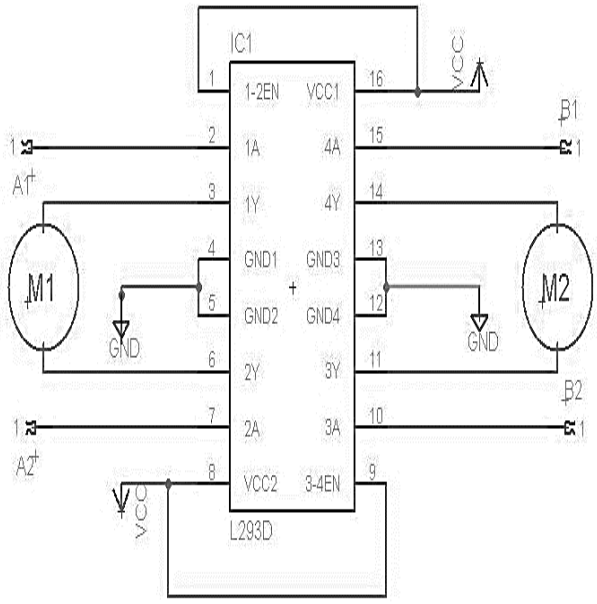

Figure 7: Motor Driver Circuit

7. SENSOR INTERFACING ALGORITHMS

Various sensors are interfaced with the Arduino Board. The idea behind using Arduino is that the systems like Arduino provide sets of digital and analog I/O pins in its IC so that it can be interfaced to different extension sensors and other circuits. The Arduino board have feature like serial communications interfaces, including features like USB for loading programs from personal computers. IC like microcontrollers programming, the Arduino platform provides an integrated development environment (IDE) based on the Processing project, that includes support for C and C++ programming languages also.

7.1 To interface the Temperature and humidity sensor DHT11

DHT11 library for Arduino is used and then proper programming is done to receive its reading and transmit the data to the receiver. The DHT11 is interfaced with Arduino according to the following circuit diagram. The real implementation of interfacing of sensor circuit is mentioned in Figure 8.

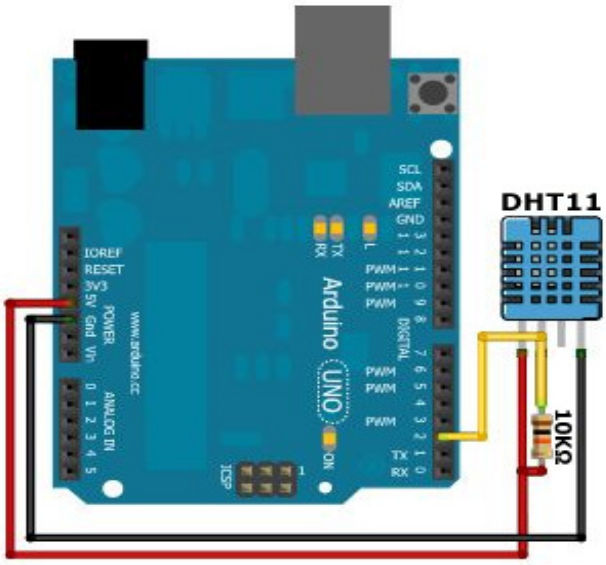

Figure 8: Temperature and Humidity Sensor interfacing

Circuit Diagram
DHT11 Pin 1 (Vss) –> Arduino +5V
DHT11 Pin 2 (Signal) –> Arduino Pin 2
DHT11 Pin 2 (Signal) –> Arduino +5V via Resistor 4.7K
DHT11 Pin 3 –> N/C
DHT11 Pin 4 (GND) –> Arduino Ground

7.2 LPG and Smoke Sensor MQ5 is interfaced with Arduino according to the following circuit diagram.

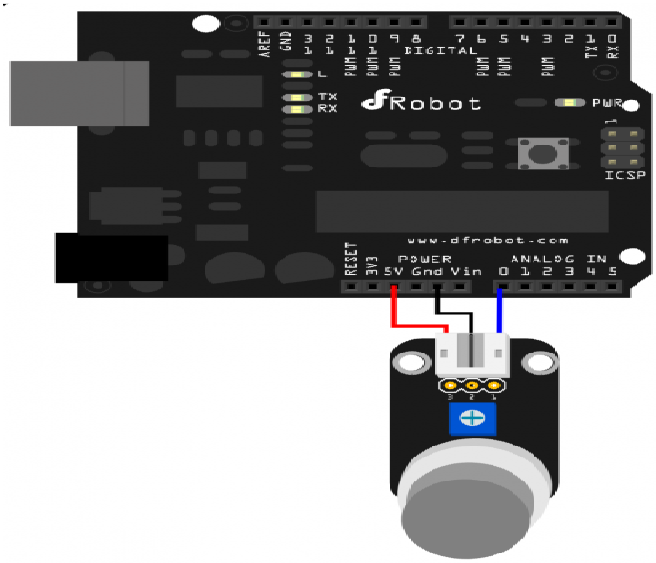

Figure 9: LPG and Smoke Sensor interfacing Circuit Diagram

The detail interface with proper pin connection is given in Figure 9 and the details of Pin 1 to Pin 3 is given below.
MQ5 Pin 1 (OUTPUT) –> Arduino pin A0
MQ5 Pin 2 (GND) –> Arduino Ground
MQ5 Pin 3 (VSS) –> Arduino +5V

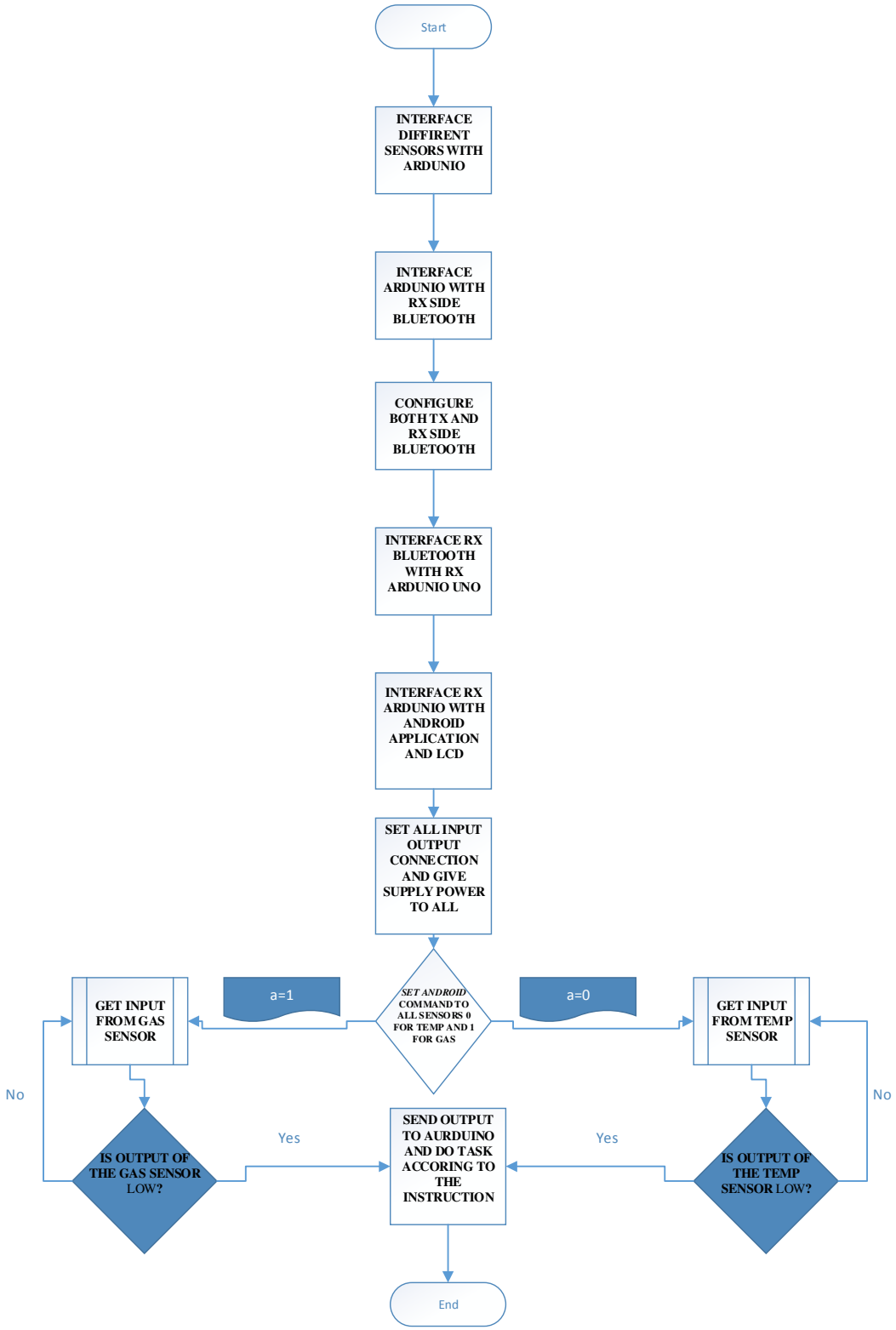

Figure 10: Flow Chart for Sensor Interface

The above flow chart is only for two sensors that is temperature and gas sensors rest of other sensors also works in same type of chart. In Figure 10 all the process sub process and different condition has been mentioned and it will help to deploy real time implementation.

8. ANDROID APPLICATION FOR ROBOT CONTROL

Android Application for this robot is made by using an open-source web application called App Inventor for Android which is maintained by the Massachusetts Institute of Technology (MIT). Android application uses a graphical interface, very similar to Scratch and the Star Logo TNG user interface that allows users to drag-and-drop visual objects to create an application that can run on Android devices. The real interface with Android is given in Figure 11.

Android software like App Inventor includes a designer window in which a program's components for robot movement are specified by using visible components, such as images and buttons, which are placed on a simulated screen area so that buttons can be easily accessed by the operator. The App inventor's blocks editor is used to create the program logic to perform appropriate function every time operator hit a button.

This android application uses the Bluetooth module of the Android device to communicate with the robot. It can transfer data as well receive the data from the robot. It can receive all of the sensors readings and can display them on the device screen. The following screenshot shows the main screen of the android application

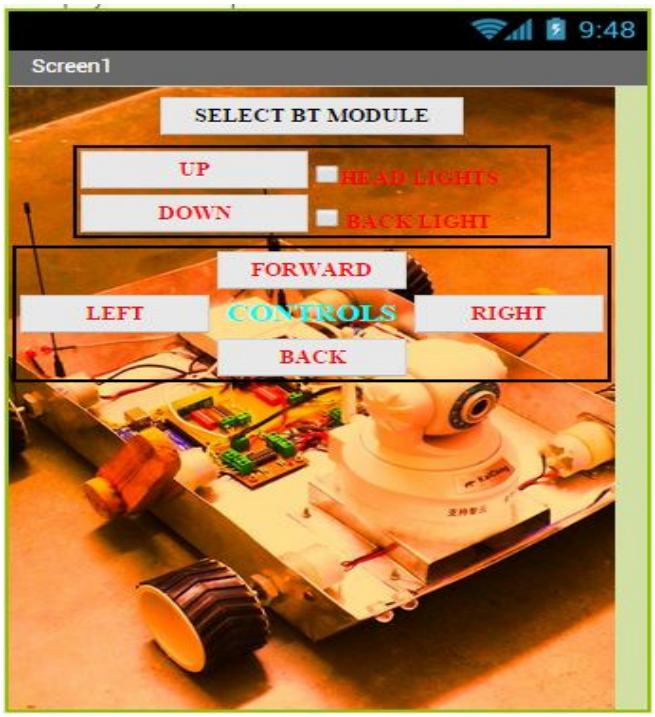

Figure 11: Android Application screenshot

9. FINAL IMPLEMENTATION

In the final implementation the PCB designing and fabrication are done to make the robot fully functional this section includes the PCB fabrication of every circuit and connecting every components and parts of the robot. Figure 12 is remote control for robot and in Figure 13 you can able to visualize real time working model for Wireless Operating Robot for Disaster Management.

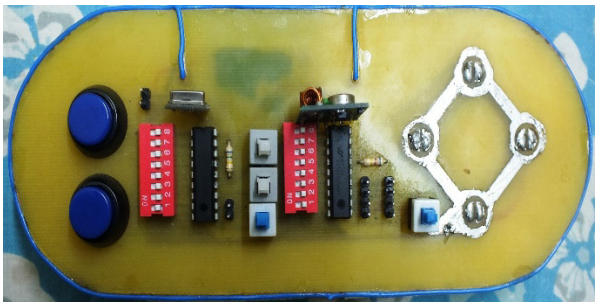

Figure 12: RF remote control for Robot

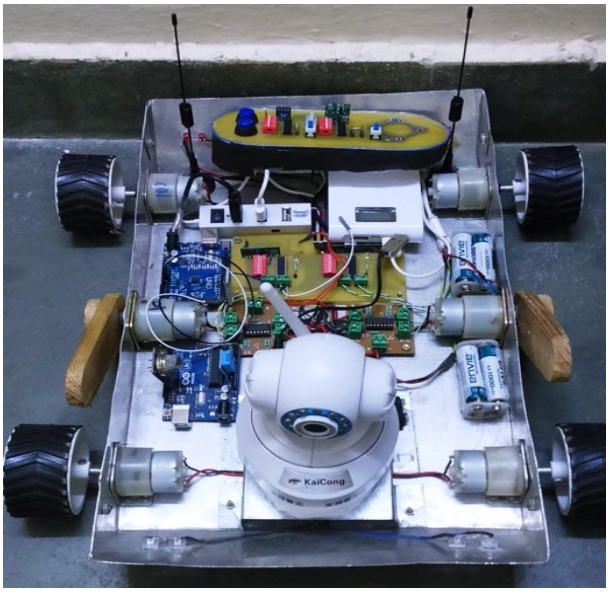

Figure 13: Robot after Implementation

10. CONCLUSION

In this paper we have explained the Hardware architecture, Mechanical architecture, Navigation Algorithm and Sensor interfacing Algorithms, for a robot that can be used for guidance of rescue teams.
The advantage of this design is the wireless camera having both day and night vision and it can be operated through two different network running on two different ISM band since it is equipped with both RF module as well as Bluetooth module. Radio link is used where long distance communication is required. Bluetooth Module provides full duplex mode of communication but it provides range up to 20 meters. One of its best feature is that the Robot can be operated through any android device. So we think that this design is good and effective for rescue teams because it will give an overall picture about the dangerous elements that could exist in the affected area and also the robot will not be that expensive.

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