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Research Article

Intelligent Wireless Fire Extinguishing Robot

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Abstract

Increasing human population and technological development has lead to increase in fire accidents and hazards. Adverse conditions and physical limitations of human being make fire extinguishing challenging and demanding task. Fire extinguishing is very risky task and it may involve loss of life. Robotics is the emerging solution to protect the surrounding and human lives. Fire extinguishing robot is a hardware model which can be used for extinguishing the fire during fire accidents. It can reduce the errors and limitations faced by the humans during fire extinguishing task. Our designed robot can search the area, locate the fire and extinguish fire before it rages out of control. Our proposed robot can efficiently extinguish any kind of fire in any geographical location. It is able to navigate the building while actively scanning for the flame. It can send various data from the sensor to the cloud and can be operated wirelessly by any person from anywhere in the world through internet. With the help of Internet of Things, it can send alert and notifications to the user about the status of the fire. The robot which we have proposed in this paper found its application in fire extinguishing operations during fire accidents where the possibility of the servicemen to enter the fire prone area is very less.

Keywords: *Fire fighting robot, Internet of Things, Wireless controlled robot, Microcontroller.*

1. Introduction

A robot is a multifunctional re-programmable device which can be used to perform various challenging tasks. It performs functions normally ascribed to humans in form of a human. Fire extinguishing is a challenging task for human due to physical limitations and adverse conditions during fire accidents. Fire robot can be used for such high risk task of extinguishing fire. Many fire robots have been developed over the past few years but few of them can be controlled wirelessly by human beings. Some of the proposed robots are automated robots that search fire with the help of sensors and extinguish it but searching fire takes long time and robot are not intelligent enough to detect the flames that has more potential to spread fire so that it can be extinguish first before the fire rages out of control (B.Swetha Sampath *et al*, 2011). In some cases due to faulty readings of the sensors, the algorithm used for autonomous fire robot fails and robot fails to perform its task of extinguishing the fire (Kristi Kosasis *et al*, 2010). In this paper we have designed an intelligent fire fighting robot that can be operated wirelessly from anywhere in the world with the help of data received from the sensors. The designed robot sends all the data from the sensors to the cloud where it gets analyzed. The robot is also capable of sending live videos to the cloud so that the user who is operating the robot wirelessly can view the situation inside the room which is caught in fire. The robot designed in this paper eliminates the possibility of the failure of operation of extinguishing fire due to faulty sensor reading by reprogramming it wirelessly according to the environment. The proposed robot has the ability to accurately locate the position of the flames by actively scanning the entire area for flames and obstacles so that the fire which has more potential to spread fire can be detected and extinguished early which would reduce the possibility of fire getting spread to other areas.

2. Overview of Fire Extinguishing Robot

The robot consists of arduino yun and arduino uno microcontroller which acts as the brain of the robot by taking the decisions and giving commands to the output devices. It consists of flame sensor to detect the flame, temperature and humidity sensor to measure the temperature and humidity, ultrasonic sensor to scan for obstacle, servo motors for rotation, web cam for recording videos, H-bridge for driving dc motors, water pump and nozzle for extinguishing the fire. Ultrasonic sensor is mounted over the servo motor to scan the area for objects and obstacles. Web cam would capture video and sends to the arduino yun

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microcontroller where it gets processed. H-bridge is used for the movement of the robot in left, right, backward and forward direction. Nozzle is connected to pump which is connected to small container containing water. The nozzle is mounted over servo motor so that it can spread water over the large area of fire. Fig. 1 shows the overview of the components where the line shows the connection. Fig. 2 shows the design of fire extinguishing robot.

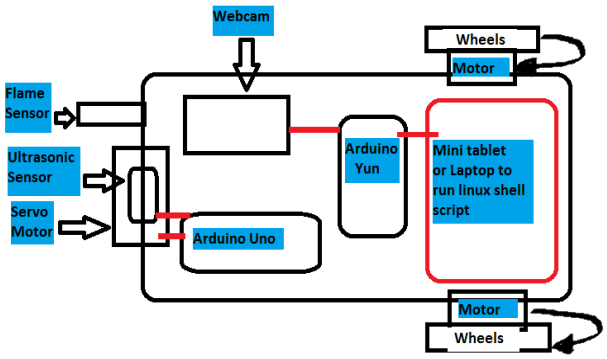

Fig.1 Components of designed robot (Top View)

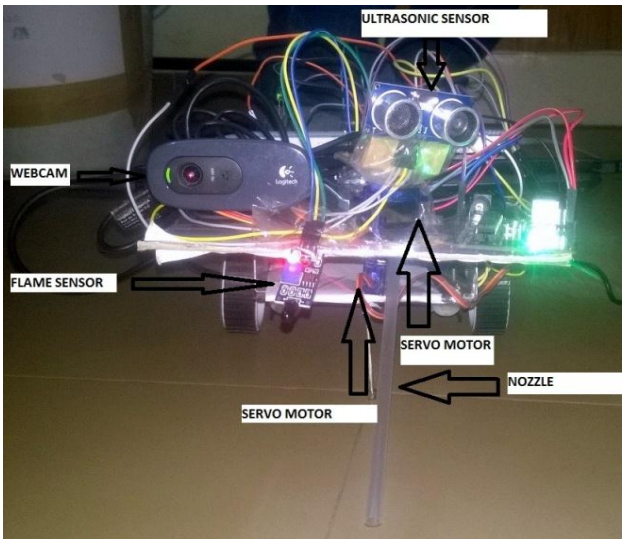

Fig.2 Design of fire extinguishing robot

2.1 Control Board

Processing power is provided by the arduino uno and arduino yun microcontroller. Arduino Yun microcontroller has Atmega32U4 and Atheros AR9331 processor whereas arduino uno is based on Atmega328P (C.Rajan *et al*, 2015). The Atheros processor supports Linux distribution based on OpenWrt. It has 14 digital input/output pins, 6 analog pins, 16MHz crystal oscillator, ICSP header, USB port and WIFI support. The bridge supports the communication between the atmega32U4 and Atheros processor. This processor has the ability to run scripts, communicate with network interfaces and the peripherals.

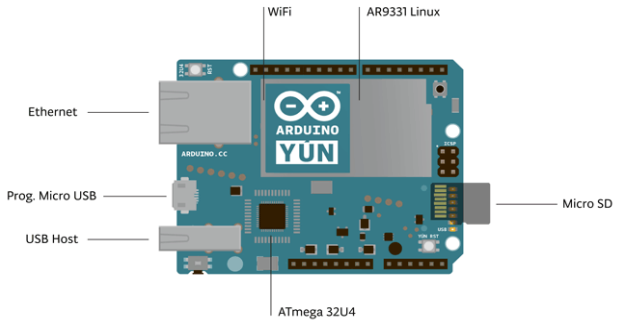

Fig.3 Arduino Yun microcontroller

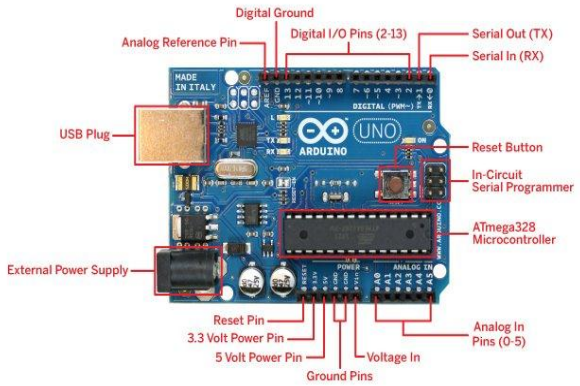

Fig.4 Arduino Uno microcontroller

2.2 Sensors

Flame sensor is used for short range fire detection. The accuracy of flame sensor is up to 3 feet. It detect flame or wavelength of light source within 760-1100nm.

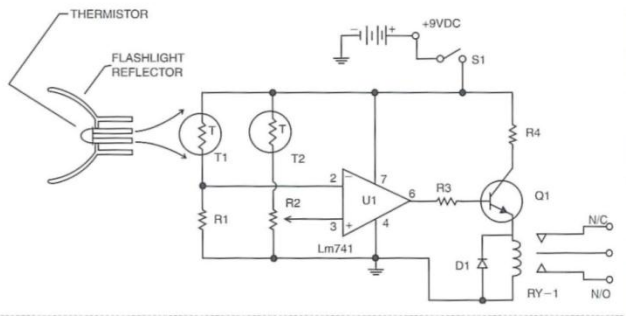

Fig.5 Circuit diagram of flame sensor

DHT 11 sensor uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (Poonam *et al*, 2013). It requires a careful timing to grab data. Ultrasonic sensor is used to measure the distance between the robot and obstacles in front of it. It provides precise, non-contact distance measurements within 3m range. Ultrasonic sensor generates high frequency sound waves and evaluates the echo which is received back by the sensor, measuring the time interval between sending the signal and receiving the echo to determine the distance to an object (A.K. Shrivastava *et al*, 2010).

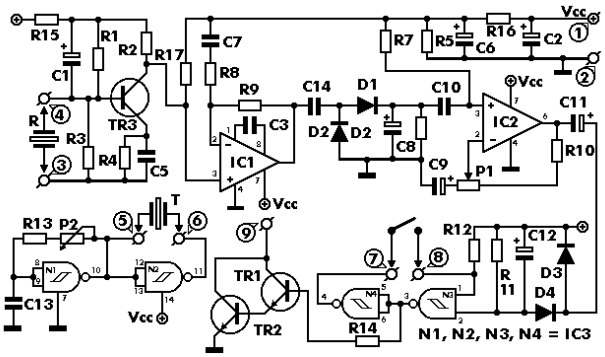

Fig.6 Circuit diagram of Ultrasonic sensor

Ultrasonic sensor is mounted over the servo motor so that it can scan wider area to detect objects or obstacles in front of robot. A servo motor is an actuator that allows precise control of angular or linear position. Webcam is used to record video which is directly connected to USB-A port of arduino yun. Logitech C270 webcam has been used in this robot which is compatible with UVC protocol (Mohammad Syuhaimi Ab-Rahman *et al*, 2013).

2.3 Water Spray System

In this system, a water pump is connected to arduino through relay and water pipe is attached to servo motor. Relay is an electrically operated switch. Relay use an electromagnet to mechanically operate a switch, but other operating principles are also used. Relays are used when it is necessary to control a circuit by low power signal. Water pump is used to extract water from the container and provide it to the nozzle which sprays water to extinguish fire.

Fig.7 Setup of water spray system

Fig.8 Relay Module

2.4 Motor Drive

The two wheels are driven by pair of dc motors which are interfaced to the arduino yun through L-293 dual H-bridge. L293 can drive two dc motors which can be controlled in both clockwise and anticlockwise direction. It has output current of 600mA and peak output current of 1.2A per channel. The in-build diodes protect the circuit from back EMF at the outputs. Supply voltage range from 4.5V to 36V, making 293D a flexible choice for motor drive.

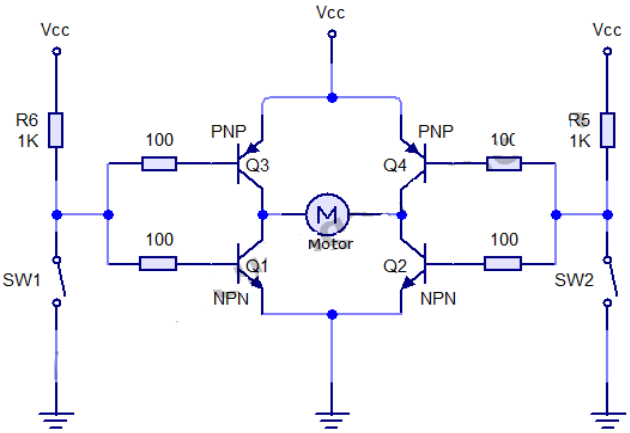

Fig.9 Circuit diagram of L293 H-bridge

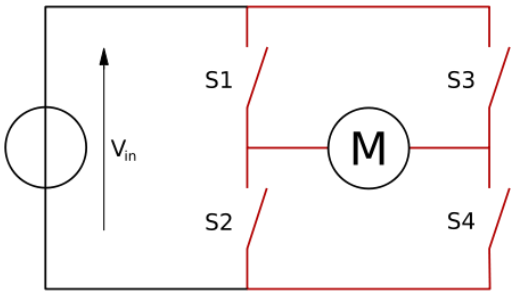

Fig.10 Structure of H-bridge

H-bridge is an electronic circuit that enables voltage to be applied across a load in both directions. The following table summarizes operation, with S1-S4 corresponding to the diagram above.

Table 1 Operation of H-bridge

S1	S2	S3	S4	Result
1	0	0	1	Motor moves Right
0	1	1	0	Motor moves left
0	0	0	0	Motor coasts
0	1	0	1	Motor brakes
1	0	1	0	Motor brakes
1	1	0	0	Short circuit
0	0	1	1	Short circuit
1	1	1	1	Short circuit

2.5 Software Used

2.5.1 Arduino IDE

The open source arduino software is used to write the code for arduino uno and arduino yun microcontroller. The environment is written in java and based on

processing and other open source software. Many libraries can be used for interfacing various sensors with the arduino microcontroller.

2.5.2 Processing

Processing is a flexible software sketchbook for coding within the context of visual arts. With the help of processing environment we can make any visual graphical screen using the data from the sensor (Casey Reas *et al*, 2014). In our robot, processing software is used to create radar like visual graphical screen by mapping the readings from the ultrasonic sensor to the sketch of virtual radar.

2.5.3 Putty

Putty is an open source terminal emulator, serial console and network file transfer application. It supports several networking protocol including SCP, SSH, Telnet etc. Putty software is used by the mini laptop mounted over the robot to program the Atheros AR9331 processor.

2.5.4 Team Viewer

Team viewer is a proprietary computer software package for remote control, desktop sharing and file transfer between computers. Using this software we are able to view the desktop screen of the mini laptop or tablet running processing code and access this virtual radar screen from the host pc.

2.5.5 Temboo Platform

Temboo is a scalable, fault-tolerant environment for running and managing smart code snippets which are called choreos. Choreos can call APIs, simplify the OAuth process, perform encoding, update databases etc. The request from the yun's temboo client causes the choreo specified in the sketch code to be executed on the temboo platform. It assembles the inputs into the format expected by a third-party API, performing the API interaction, handling errors and dispatching filtered results back to the yun using HTTPS. The results are made available to the arduino sketch by way of Process's Stream methods. Temboo serves as a client between Arduino and cloud.

3. Block Diagram

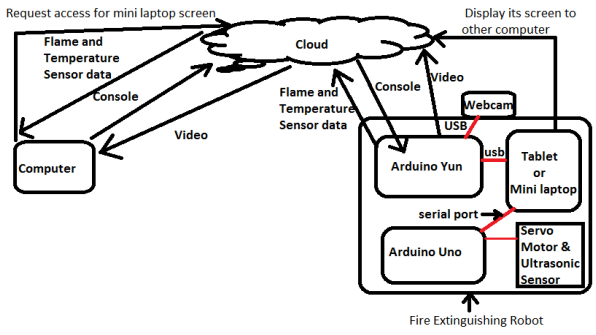

Fig.11 Block diagram of the system

The above figure shows the block diagram of the fire extinguishing robot. The robot consists of two microcontrollers arduino uno and arduino yun. Ultrasonic sensor is mounted over the servo motor which is rotating in both directions. The reading from the ultrasonic sensor is provided to the arduino uno which is connected to mini laptop via USB port. Arduino uno also controls the movement of the servo motor over which the ultrasonic sensor is mounted. The reading of ultrasonic sensor is then mapped in the processing code which is running in the mini laptop to create radar like display. The arduino yun is connected to the DHT 11(temperature and humidity sensor) sensor and webcam. Temperature and humidity reading from the DHT 11 sensor is processed in the arduino yun before sending it to Google spreadsheet hosted on web server or cloud. The temperature and humidity readings logged in the Google spreadsheet is refreshed after every 5 seconds i.e. the new data is logged in the spreadsheet after every 5 seconds. The webcam is connected to arduino yun via USB A port. Arduino yun is also connected to mini laptop where a Linux script is running which give commands to webcam to capture videos and send it to a particular web address. All the data from the sensors is send to cloud where it gets analyzed and the host computer can fetch all the sensors readings to take decision. The host computer can easily access the readings of the DHT 11 sensor logged in the Google spreadsheet by opening the appropriate website. It can also access the video captured by the webcam by entering the same web address which has been used in the Linux script running on the mini laptop mounted over the chassis of the robot. To access the virtual radar display which is running on the screen of the mini laptop, the host computer needs to use software named as teamviewer. The commands from the host computer to the robot are send wirelessly using console. The Console, based on bridge, enables user to send information from computer to Arduino Yun wirelessly. It creates a secure connection between the Yun and the computer via SSH. Using the console we can reprogramme our arduino yun wirelessly if there is any need for modification in the sketch or algorithm.

4. Working of Fire Extinguishing Robot

Once the robot is activated it sends a text message to the concerned user or authority on the fire .The text message is send by the arduino yun with the help of Twilio application using Sendsmschoreo. After getting activated, it makes use of the ultrasonic sensor to accurately detect the distance of the object from the robot. Servo motor starts rotating from 0 degree to 180 degree and vice-versa. Since ultrasonic sensor is mounted over the servo motor which is rotating, it can scan large area. The information from the ultrasonic sensor is send to the arduino uno microcontroller. Processing software has been used to build a radar like screen from the data received from arduino uno. This visual effect would give the user controlling this robot

clear idea about the objects or obstacles in front of the robot. The distance information is mapped on y-axis of the radar and the obstacles are shown as circles.

Fig.12 Virtual Radar Screen

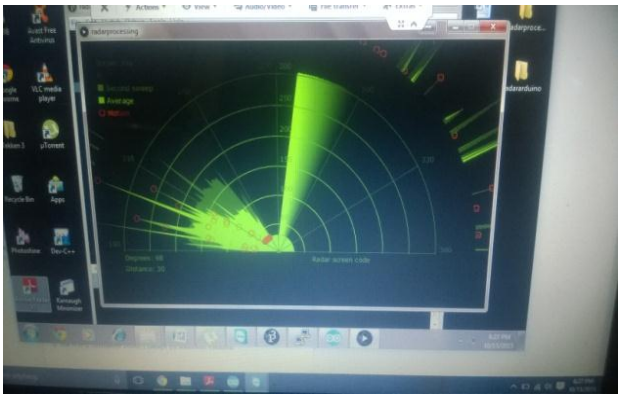

Fig.13 Mapping of ultrasonic sensor values to radar screen via processing environment

Since the arduino uno is connected to the mini laptop or tablet which is running processing software, the host pc cannot directly access this virtual radar. To solve this problem we have used Team viewer software. Arduino yun USB-A port is connected to the webcam which can capture videos. A Linux shell script is running on the arduino yun which controls the webcam. The camera captures the videos and sends it to arduino yun where it gets processed. After processing the video, arduino yun sends the video to the cloud from where the host pc can easily access the videos capture from webcam using web browser like Google chrome , Microsoft edge etc.

Fig.14 Object seen by the robot

Fig.15 Video streamed on internet by the robot

If the video which is received by the host computer is lagging then it would be a major problem. After series of testing we found that the video which is being received by our host computer does not lag hence, we can get live stream of the video captured by the webcam. The video captured from the webcam will help the user sitting on host pc to view the situation in the room caught in fire and can take decisions accordingly. The arduino yun receives the reading from the DHT 11 and flame sensor. It then maps the analog readings from the flame sensor to the digital reading of 0 and 1. 0 indicates that there is no flame detected by the flame sensor and 1 indicates that flame is detected by the flame sensor. The readings from DHT 11 sensor and the flame sensor are send to the Google spreadsheet hosted in the web server or cloud using Temboo. Arduino Yun uses the AppendRowChoreo provided by Temboo to send data from the sensors to google spreadsheet (Hasnim Harun *et al*, 2015). All the sensors data would be uploaded to the Google spreadsheet after every 5 seconds. The data logged in the spreadsheet can be easily accessed by the host PC using web browser. The data from the temperature and humidity sensor provides crucial information regarding the temperature and humidity of the area to the user controlling the robot. After receiving all the information regarding temperature, humidity, obstacles in front of robot, detection of flames and getting the detailed overview of the fire and the situation with the help of video captured by the webcam, the user sitting on the host computer can finally take decisions on the movement of the robot such that it doesn't collide with any obstacles and it extinguishes fire effectively. After analyzing the sensors data and the fire, the user on the host pc would give command to the robot regarding its movement and operations it needed to be performed .User can wirelessly control the movement of the robot from the host computer using Console Pixel. At the back of the robot there are 3 led which glows according to the direction in which robot is moving. For example if robot is turning right, then the right led would glow and vice-versa. The designed robot responds to the command send through the console window effectively without any delay. Following are the commands used for the movement of robot:

Table 2 Commands for movement of robot

Commands in console window	Actions taken by robot
W	Robot moves forward
B	Robot moves backward
D	Robot turns right
A	Robot turns left
S	Robot stops
P	Servo motor with nozzle start rotating
N	Servo motor with nozzle stop rotating
O	Pump connected to water container gets activated
I	Pump connected to water container gets deactivated

The robot is smart enough to overwrite any commands received from the user which possess threat to its existence or which can do damage to the robot. For example if there is any obstacles detected by ultrasonic sensor in front of robot and the user commands the robot to move forward, then the robot would send warning to the host pc and would not move forward. After receiving inputs from the user via console the robot performs the required operations of extinguishing fire. When it is close to the flame, the flame sensor would show the reading of 1. With the help of video received from the webcam, the user can easily extinguish the fire by typing 'O' and 'P' in the console window. The command 'O' send by the user using console will start the pump connected to the water container mounted below the chassis of the robot and the water starts coming out of the nozzle. When command 'P' is received by the robot from the host pc via console, the servo motor over which nozzle is mounted starts rotating and water is sprinkled in the large region due to 180 degree movement of the servo motor. In this way the robot can navigate in the whole room to locate and extinguish the fire.

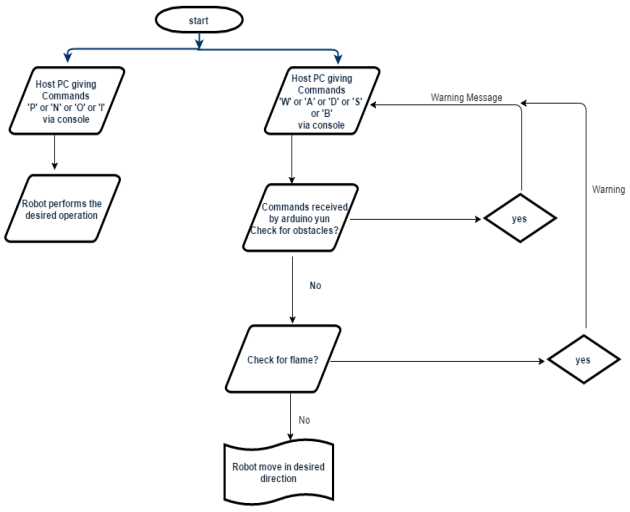

Fig.16 Flowchart of operations performed by the robot

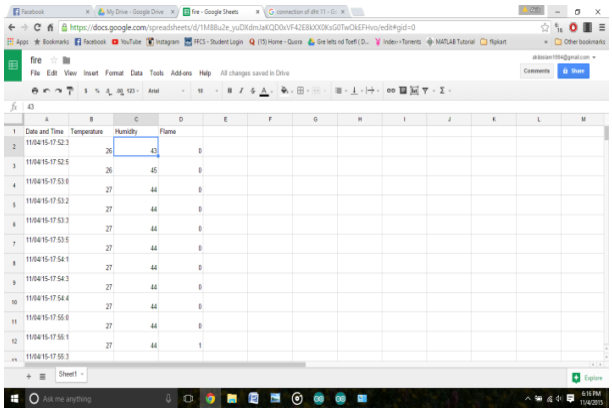

Fig.17 Data from sensors logged in the spreadsheet

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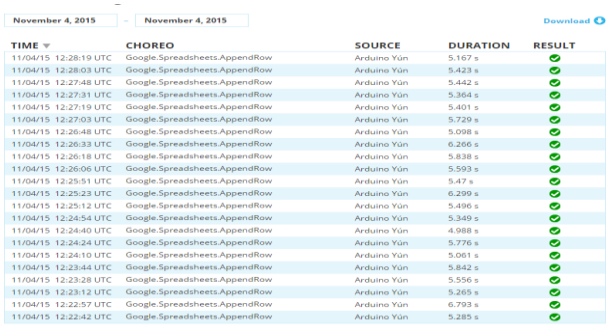
	A	B	C	D	E
1	Date and Time	Temperature	Humidity	Flame	
2	11/04/15-17:52:3	26	43	0	
3	11/04/15-17:52:5	26	45	0	
4	11/04/15-17:53:0	27	44	0	
5	11/04/15-17:53:2	27	44	0	
6	11/04/15-17:53:3	27	44	0	
7	11/04/15-17:53:5	27	44	0	
8	11/04/15-17:54:1	27	44	0	
9	11/04/15-17:54:3	27	44	0	
10	11/04/15-17:54:4	27	44	0	
11	11/04/15-17:55:0	27	44	0	
12	11/04/15-17:55:1	27	44	1	
13	11/04/15-17:55:3				

Sheet1

Fig.18 Zoom version of the data logged in



November 4, 2015 – November 4, 2015 Download

TIME	CHOREO	SOURCE	DURATION	RESULT
11/04/15 12:28:19 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.167 s	
11/04/15 12:28:03 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.423 s	
11/04/15 12:27:48 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.442 s	
11/04/15 12:27:31 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.364 s	
11/04/15 12:27:19 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.401 s	
11/04/15 12:27:03 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.729 s	
11/04/15 12:26:48 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.098 s	
11/04/15 12:26:33 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	6.266 s	
11/04/15 12:26:18 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.838 s	
11/04/15 12:26:06 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.593 s	
11/04/15 12:25:51 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.47 s	
11/04/15 12:25:23 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	6.299 s	
11/04/15 12:25:12 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.496 s	
11/04/15 12:24:54 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.349 s	
11/04/15 12:24:40 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	4.988 s	
11/04/15 12:24:24 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.776 s	
11/04/15 12:24:10 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.061 s	
11/04/15 12:23:44 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.842 s	
11/04/15 12:23:28 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.556 s	
11/04/15 12:23:12 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.265 s	
11/04/15 12:22:57 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	6.793 s	
11/04/15 12:22:42 UTC	Google.Spreadsheets.AppendRow	Arduino Yún	5.285 s	

Fig.19 Temboo confirmation of successful data logging

Conclusions

We have successfully designed the wireless fire extinguishing robot which is capable of taking and analyzing inputs from sensors and responds to the commands send by the user. The robot has capability to detect any kind of obstacles and fire anywhere in the room. The robot can perform its operation under adverse circumstances effectively. In future we want to integrate more sensors with the robot so that more readings can be analyzed by the user so that precise commands can be given to the robot to perform its operation effectively in lesser time and we want to combine laser range finder to get more exact and quickly environment mapping.

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