

Intelligent Wireless Fire Extinguishing Robot

AKIB ISLAM¹, P.SATHYA²
School of Electronics Engineering
VIT UNIVERSITY
Vellore, Tamilnadu-632014
INDIA
akib.islam2013@vit.ac.in, p.sathyra@vit.ac.in

Abstract: - Increasing human population and technological advancement has led to increase in the fire accidents. The physical limitation of humans and adverse conditions makes fire extinguishing challenging and demanding task. Extinguishing fire manually by human being is very risky task and it may involve loss of life. Robotics is the emerging solution to protect human lives and their wealth and surroundings. Fire fighting robot is a hardware model which can extinguish fire during fire accidents. It can reduce the errors and limitations faced by the human fire fighters. Robot can search the area, locate the fire and extinguish the fire before it rages out of control. In this paper we have designed a fire extinguishing robot that can extinguish any kind of fire accurately and effectively. It is able to navigate through the building while actively scanning for the flame. It can send various data from the sensors to the cloud and operated wirelessly by any person. With the help of Internet of things and other cloud technologies, it can send various updates to the mobile phone. The robot which we have proposed in this paper finds its application in fire extinguishing operations during fire accidents where the possibility of the service men to enter the fire prone areas is very less. Our designed robot can be controlled wirelessly by any user from anywhere in the world. The medium of interaction between the human and robot is through the Console.

Key-Words: - Fire extinguishing robot, Fire fighting robot, Internet of things, Wireless control robot, Arduino yun microcontroller, Arduino uno microcontroller.

1 Introduction

A robot is a clever re-programmable multifunctional device which can be programmed to perform variety of tasks. It is an automatic device that performs functions normally ascribed to humans or a machine in form of a human. Fire extinguishing is a very difficult task for the human due to physical limitation and adverse conditions during fire accidents. Fire robot can be used for such high risk task of extinguishing fire. Many fire fighting robots have been developed over the past years but few of them can be wirelessly controlled by the human. Some of the proposed robots are automated robot that search fire with the help of sensors and extinguish it but searching fire take long time and the robots are not intelligent enough to detect the most dangerous fire so that it can be extinguished first before the fire rages out of control [1][2]. In some cases due to the faulty reading of the sensors, the algorithm used for autonomous fire fighting robot fails and robot cannot perform its task of extinguishing fire effectively. The problem with some autonomous fire fighting robot is that if the sensors fail to determine the exact position of the

flame then the robot cannot extinguish the fire [3]. 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 videos to the internet so that the user who is operating the robot wirelessly can view the situation inside the room which is caught in fire. This robot eliminates the possibility of the failure of operation of fire fighting robot due to faulty sensor reading and it can accurately locate the position of the flames. The proposed robot has the ability to scan the entire region for obstacles and it can locate the most dangerous fire so that it can be extinguished early which would reduce the possibility of the fire getting spread to other areas.

2 Overview of the Fire fighting Robot

The robot consists of arduino yun and arduino uno microcontroller, flame sensor, temperature and humidity sensor, pair of servo motors, web cam,

ultrasonic sensor, chassis, pair of motors, pair of wheels, H-bridge, water pump and nozzle. Flame sensor would detect the presence of flames and temperature sensor would monitor the temperature. Ultrasonic sensor is mounted over one servo motor to scan the area for objects for obstacles. Webcam would capture the video and send it to arduino yun where it gets processed. H-bridge is used for the movement of robot in left, right, forward and backward direction. Nozzle is connected to the pump which is connected to small container containing water. The nozzle is mounted over servomotor so that it can spread water over large area of fire. Fig 1 shows the overview of the components. Red line in fig 1 shows the connections. Fig 2 shows the design of fire extinguishing robot

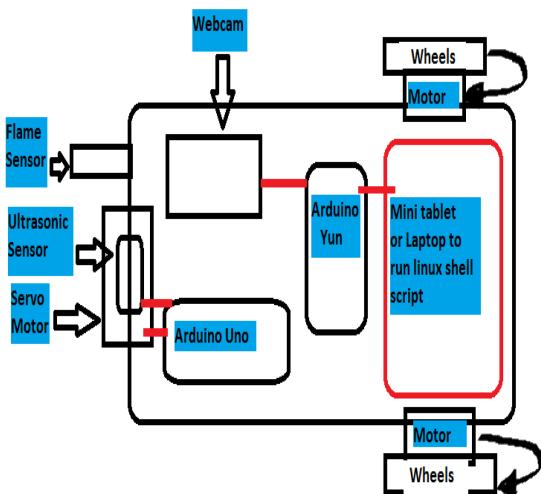


Fig.1. Components of the designed robot (Top view)

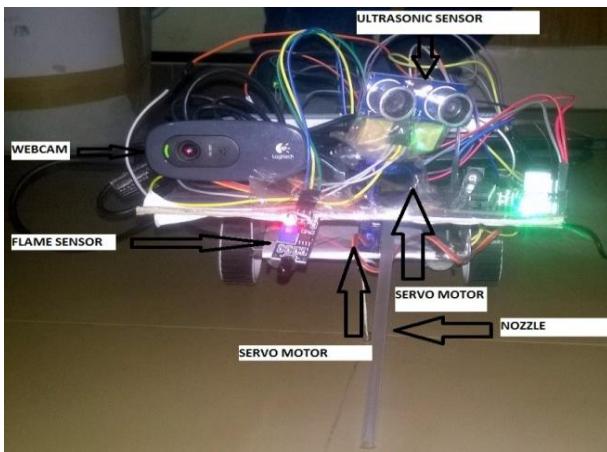


Fig.2. Design of fire extinguishing robot

2.1 Control Board

2.1.1 Arduino Yun

Processing power is provided by the Arduino Yun microcontroller. This microcontroller based on the Atmega32u4 and the Atheros AR9331 [4]. The Atheros processor supports a Linux distribution based on OpenWrt named OpenWrt-Yun. It has 20 digital input/output pins, 16 MHz crystal oscillator, ICSP header, USB-A port, 3 reset buttons, built-in Ethernet and Wi-Fi. The bridge library facilitates communication between the two processors, giving arduino sketches the ability to run shell scripts, communicate with network interfaces and receive information from AR9331 processor. The USB host, network interfaces and SD card are connected to AR9331 and bridge library also enables the arduino to interface with those peripherals.

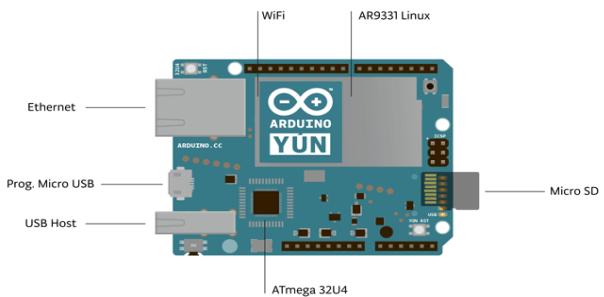


Fig.3. Arduino Yun microcontroller board

2.1.2 Arduino Uno

It is a microcontroller based on Atmega328P. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The Atmega 328 has 32 KB of flash memory for storing the code. It also has 2KB of SRAM and 1KB of EEPROM. The Atmega 328 provides UART TTL serial communication, which is available on digital pins 0 and 1. An Atmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer.

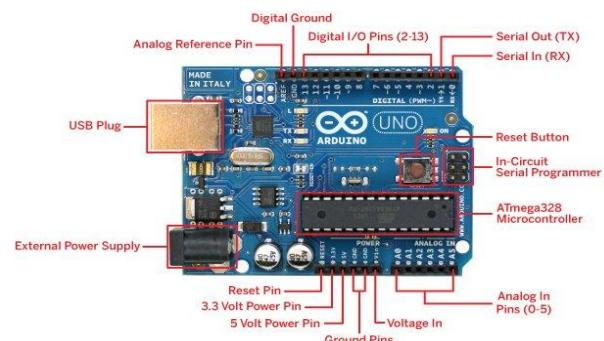


Fig.4. Arduino Uno microcontroller

2.2 Sensors

Flame sensor is used for short range fire detection. The accuracy of flame sensor is up to 3 feet. It can detect flame or wavelength of light source within 760-1100nm. DHT 11 sensor is used to measure the temperature and humidity. DTH 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 [5]. It requires careful timing to grab data. Ultrasonic sensor is used to measure the distance between the robot and the obstacles in front of it. It provides precise, non-contact distance measurements within 3m range. Ultrasonic sensors generate high-frequency sound waves and evaluate 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 [6]. 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 the USB-A port of arduino yun. Logitech C270 webcam has been used in this robot which is compatible with UVC protocol [7].



Fig.5. Flame sensor



Fig.6. DHT11 sensor



Fig.7. Water spray system setup

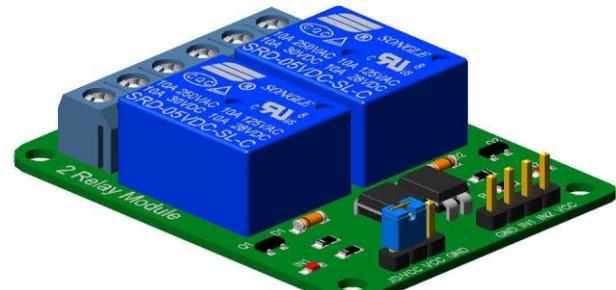


Fig.8. Relay module

2.4 Motor Drive

The two wheels are driven by the pair of dc motors which are interfaced to the arduino yun through L-293D dual H-bridge. L293D 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 [8]. The in-build diodes protect the circuit from back EMF at the outputs. Supply voltage range vary from 4.5V to 36V, making L293D a flexible choice for motor driver.

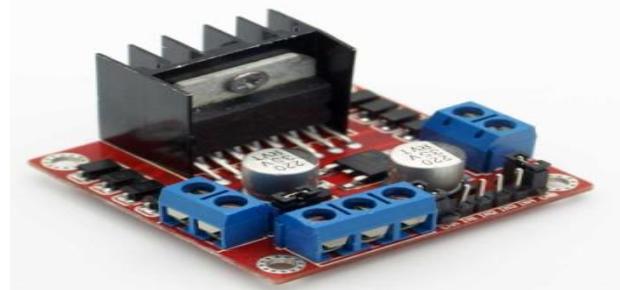


Fig.9. L 298 Dual H-bridge

2.3 Water Spray System

In this system, a water pump is connected to arduino through relay and a 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.

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 the visual arts. With the help of processing software we can make any visual graphical screen using the data from the sensors [9]. In our robot, processing software is used to create the radar like visual graphical screen by mapping the data from the ultrasonic sensor to the sketch of the virtual radar.

2.5.3 Putty

Putty is an open-source terminal emulator, serial console and network file transfer application. It supports several network protocols including SCP, SSH, Telnet, rlogin and raw socket connection. It can also connect to a serial port. Putty software is used by the mini laptop mounted over the robot to programme the Atheros AR9331 processor of the arduino yun. Since webcam connected to the arduino yun via USB A port is controlled by the Atheros AR9331 processor, the command to the webcam is given using putty software.

2.5.4 Team Viewer

Team viewer is a proprietary computer software package for remote control, desktop sharing and file transfer between computers. Team viewer uses RSA private/public key exchange (2048-bit) and AES (256-bit) session encryption. 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 [10].

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. Arduino yun comes preloaded with temboo. 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

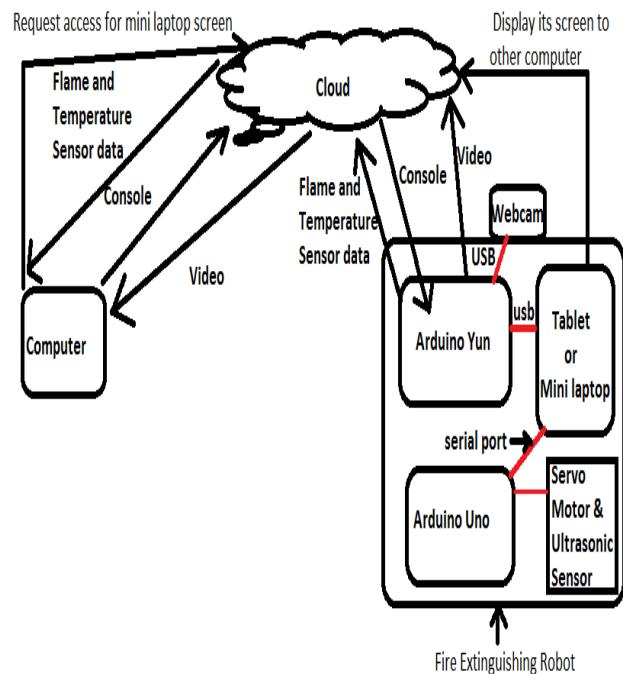


Fig.10. Block diagram of the system

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 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 team viewer. 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 Fighting 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 [11]. 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 red circles.

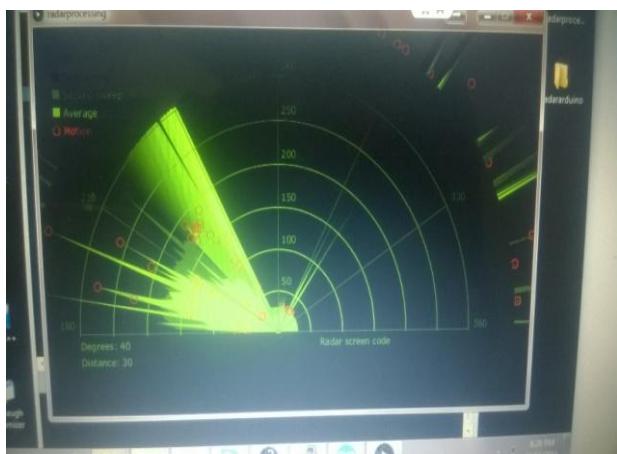


Fig.11. Virtual radar screen

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[13].



Fig.12. Object seen by the robot



Fig.13. Video of the object recorded by the webcam and accessed using web browser by host pc

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 [12] provided by Temboo to send data from the sensors to Google spreadsheet. 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 [14]. 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 1. Commands and action taken by 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.

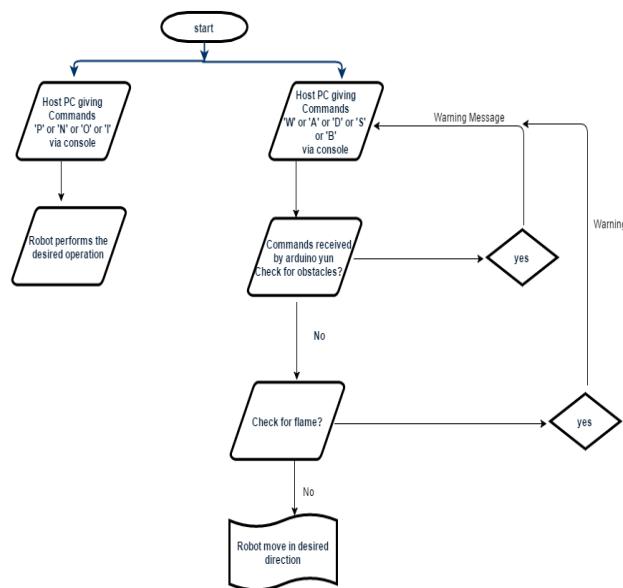


Fig.14. Flow chart of the operations performed by the robot

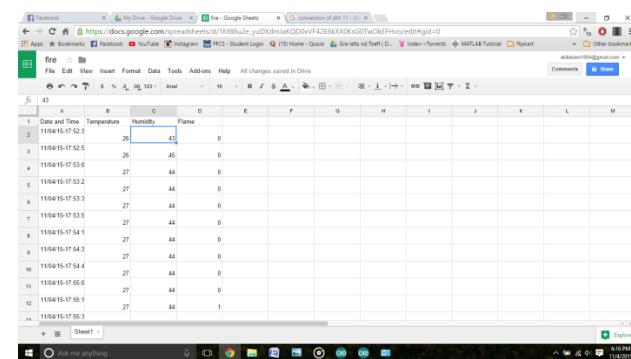


Fig.15. Data from the sensors logged in spreadsheet

	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				

Fig.16. Zoom version of data logged in spreadsheet

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

Fig.17. Temboo conformation of successful data logging

5 Conclusion

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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