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Towards Reducing the Damage of Fire Through Firefighting Autonomous Robot

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Abstract- In most of the offices in Pakistan, the water spray is usually used as a fire extinguisher agent to control moderate fire. This traditional practice smothers the fire at the cost of damage in terms of electronics equipment and documents located in the vicinity of the fire. To reduce the damage rate, an autonomous firefighting robot is developed that first detects fire with the help of flame sensors, then automatically reach to the fire place and extinguishes the fire through releasing the cloud of carbon dioxide gas. Moreover, it is capable of sending notification through Short Message Service (SMS) to the concerned person or rescue departments. A series of tests have been performed on implemented robot and the results show that it functions well as intended.

Keywords-Short Message Service, Robot, Firefighting, Flame Sensor, GSM

I. INTRODUCTION

A robot is a machine designed to execute various tasks in an automatic way with speed and accuracy [1]. Robots can be categories in numerous types based on the jobs they perform. They can be guided by external gadget or the control might be inserted inside them. In these days, robots are programmed to efficiently perform complicated and dangerous tasks in various domains, such as industrial, medical, civil, electrical etc. They perform these tasks with the help of sensors and modules which are connected by various micro controllers through wires and jumpers [2]. Robotics gained the popularity due to the advancement of various technologies such as artificial intelligence, computing, sensors, nanotechnologies and etc. [3].

Fire has numerous positive attributes including energy, heat, cleansing, etc. but it is extremely dangerous when it becomes out of control [4]. It is common observation that a house, office, factory, commercial areas etc. can easily catch fire from short circuit, the misuse of instruments and appliances, heating equipment and smoking. Fire can cause heavy damage and loss of human life and property. It is sometimes impossible for the fire fighters to access the site of fire because of explosive material, smoke and high temperature. To cope up this situation, robots can play a vital role for fire extinguishing. The robots have the abilities to operate in that environment in which human cannot work.

In literature, several firefighting robots are developed. Firefighting robots are designed keeping certain tasks in mind such as locating, analyzing and controlling fires, conducting search and rescue and monitoring dangerous variables [4]. These robots mostly rely on Ultra Violet (UV) or Infrared (IR) sensors. Anna Konnda [5,6] is a very interesting robot concept developed by the SINTEF Group. It is a water-powered hydraulic robot snake. It is driven by twenty custom-built water hydraulic cylinders. The snake measures 3 meters long and weighs 75 Kgs. Numerous micro-processors are used to control this robot. The main controller may be connected to a Personal Computer (PC) through Bluetooth. The Firemote [7] is a firefighting robot designed by Ryland Research Limited. Its weight is around 450 Kgs. This robot is a remote controlled (up to 300 meters); it can endure high temperatures as well as extinguish fire using either foam or water. These robots extinguish the fire but the use of water as fire extinguishing agent may damage the electronic equipment and important documents. Secondly, these robots have much weight that a single person can't be able to move it alone. Mobile firefighting robots are mostly in the form of remote controlled vehicles attached with fire control tools like water or foam hoses [4]. These robots have the ability to move into unsafe areas for human-beings with the help of visual camera, an array of sensors, IR and other technology that provide information for the navigation to a remote operator. Fire Ox [4] is semi-autonomous firefighting vehicle that carries its own water tank. It can be controlled from up to 200 miles away. The Tactical Hazardous Operations Robot (THOR) is semi-autonomous that operates by the remote operator. Thermite Robot [4] is a remote-control vehicle. It carries a hose and has the ability of pumping 500 gallons of water per minute. In such kind of robots,

operator is mandatory and fire may cause hug amount of loss before rescue operation starts. In some cases, a black line path is assigned, so by following those path robots extinguish fire. Also, robots are designed as tank robot with flame, ultrasonic, thermal array, and compass sensor [7]. Its simulation area is designed in miniature, its miniature equipped with furniture, sound damper and uneven floor. But the use of various sensors makes the design complicated; there will be a possibility of messing up of the output.

In [8], a design of robot that is capable of detection and suppressing fires to minimize human life risk is presented. The robot is designed with the help of flame sensors, ultrasonic sensors and Arduino IDE. The robot has the capability to detect flames in indoor environment and maneuvering towards the flame to extinguish it with the help of carbon dioxide. A hardware based automatic fire extinguisher robot is proposed in [9]. The robot had the temperature sensing capability that helped to detect the fire and to move the robot toward the fire. In this work thermocouple is used to detect the fire and to measure its intensity. Moreover, calcium silicate protection shield is used to avoid self-destruction of robot. Another implementation of designing of fire fighter robot system based on web server is presented in [10]. It comprised of two DC motors for motion. The robot used three sensors including temperature sensor to monitor the temperature, IR sensor to detect the obstacle and smoke sensor to detect the fire. Android phone is also mounted on robot that continuously captured the images with the help of mobile phone camera and transmitted the snapshots to the web server so the user is able to view the current scenario of area where that robot is working, from anywhere through the web server. The robot detected the fire and moved toward it and tried to extinguish the fire with the help of water spray.

An Arduino system based firefighting robot application is proposed in [11]. The proposed robot was capable to scan the flame and autonomously navigated through a modeled floor plan and extinguished the fire. In [12], a firefighting robot that scanned the fire flame and autonomously navigated through a modeled floor plan is suggested. The presented robot system can be used as a path guider in normal situation as well. A prototype for an autonomous firefighting robot that have the capability to locate and extinguish the fire in a given environment is also proposed in [13]. The robot navigated the arena and avoided any obstacles it faced in its excursion. The robot consisted of infrared and ultrasonic sensors for navigation, flame sensor for fire detection and a fan for fire extinguishing. It also provided a live feed and map representation that allowed the human to visualize the fire extinguishing process. A design of fully autonomous fire fighting robot having the ability to detect fire candle, navigate through a maze of white fluorescence lines on blue arena and extinguished the candle is discussed in [14]. The blue arena is particularly designed for line-tracking based maze navigation. In [15], proposed a robot that had the ability to search an area and located the fire, then extinguish it before it rage out of control. A robot that had the ability to detect and extinguish automatically is presented in [16]. In order to detect the fire, temperature and gas sensors were used in robot. In this design, water spray is used to extinguish the fire and movement of robot is controlled with the help of gears motor and motor driver.

In can be concluded that most of the existing firefighting robots are either semi-autonomous or are based on complex design. Some of the existing robots are heavy weight and most of them use water as fire extinguishing agent. So, there is a need to develop a simple and light weight firefighting autonomous robot that uses extinguishing agent other than water. The development of such robot not only extinguishes the fire but also decrease the damage rate that occur due to water spares and manual extinguish methods.

In this paper fully automated firefighting autonomous robot is proposed which deal with the fire problems in household, laboratories, small scale industries etc. The robot first detects the fire with the help of flame sensors, then automatically reaches to the fire place and extinguishes the fire through releasing the cloud of carbon dioxide gas. Moreover, it has also an ability to inform the owner and relevant rescue authorizes/ departments about the fire through Short Message Service (SMS).

The rest of the paper is organized as follows. The proposed robot is given in Section II. Section III describes the functionality of the proposed solution. Section IV describes the experimental analysis. Finally, the conclusion is drawn in Section V.

II. Proposed System

A. Hardware Description

The proposed system consists of following hardware modules:

1) Arduino UNO

Arduino UNO is a microcontroller board developed by Arduino.cc which is an open-source platform. It is based on the AVR Microchip ATmega328P micro-controller [17, 18]. It consists of several digital and analog input/output pins that can be interfaced to various expansion boards (shields) and circuits [19]. Integrated Development Environment (IDE) is the software used for Arduino devices. It is free to use and require some basic skills to learn it. It provides the support to control and sense the external electronic devices in real world [20, 21]. In this work, Arduino UNO Rev3 [22] is used. It is programmed using C language.

2) Flame Sensor
The Infrared IR flame sensor is used to locate the fire or other mild assets that are in the range of wavelength from 760nm to 1100nm [23, 24]. The module comprises of an IR sensor, potentiometer, OP-Amp circuitry and a led indicator. When a flame could be detected, the module will activate its red led. This module is sensitive to flame but it could additionally locate everyday mild. The detection factor is 60 tiers. The sensitivity of this sensor is adjustable and it additionally has a solid overall performance.

3) DC Motor Driver
A motor controller is a device that acts as an intermediary among robotics microcontroller, batteries and automobiles [25]. In this robot L298N model [26] of DC motor driver is used. It is an H-bridged motor driver module which can move left and right wheels of the robot separately that help it to move in left or right directions. The main purpose of using DC motor in this work is to drive/move the robot to exact location of flam.

4) Servo Motor
The main function of servo motor is to press the carbon dioxide spray cane. It is also known as cam motor. It has the voltage of 6V and enough power for press the extinguisher can. Servo motor has three pins included power and input [27]. In this work, 6v Servo motor is used [28].

5) GSM Module
GSM module is usually used to send or receive messages through any Sim card. It uses the 12V current as a power source. It has RX and TX pins for input from the micro-controller [29]. In this work, SIM900A GSM/GPRS module [30] is used to send notification about fire detection and extinguishing to relevant person or rescue authority.

B. Block Diagram
The block diagram of the proposed robot system is shown in Figure 1.

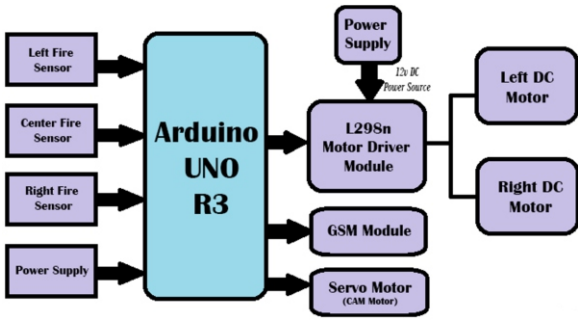

Fig. 1: Block Diagram

1) Schematic Diagram
The schematic diagrams of the proposed firefighting robot using actual modules and paint art are shown in figure 2 and 3, respectively. The block diagrams show all the connections which are made during the development of proposed robot. Black and red color wires show the power connections by battery while all the input/output (D0) wires are connected with Arduino.

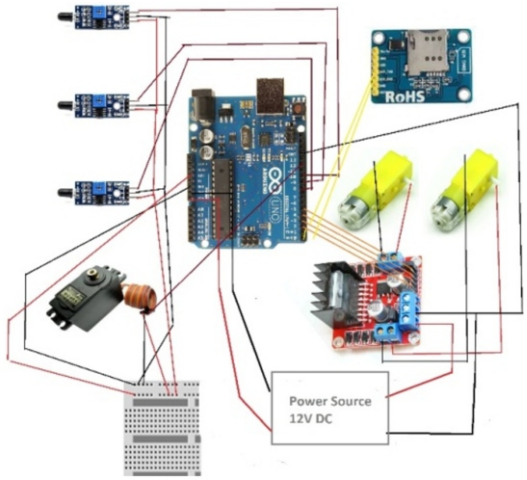

Fig. 2: Schematic Diagram (Actual Modules)

2) Flow Diagram
The flow diagram of the proposed solution is shown in Figure 4.

III. WORKING

The working of the robot is demonstrated below:
Step 1: Initially, robot is in steady state and detecting the fire with the help of flame sensors. Figure 5 shows the steady state of the robot.
Step 2: When the fire is detected by the robot, its red LED turns on as shown in Figure 6.
Step 3: After detecting the fire, automatically SMS is send to the owner whom number is feed in the GSM module. Figure 7 shows the sample SMS.

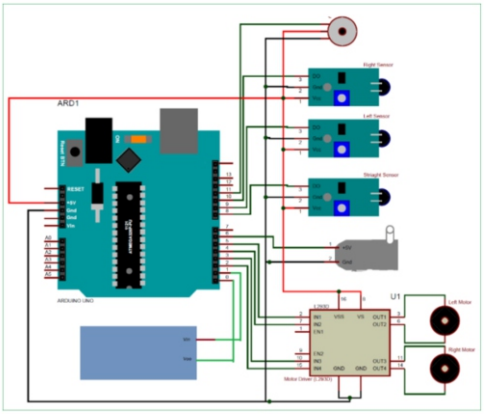

Fig. 3: Schematic Diagram (Paint Art)

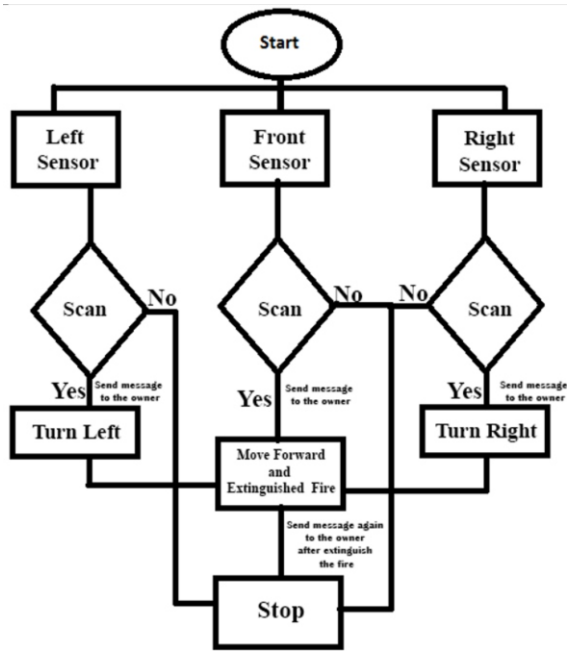

Fig. 4: Flow Diagram

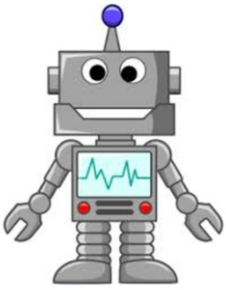

Fig. 5: Steady state of robot

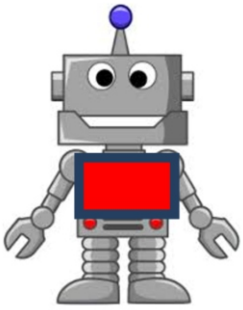

Fig. 6: Fire detected

Step 4: After sending the SMS to concerned person or authority, robot moves towards the fire as shown in Figure 8.

Step 5: When robot reaches close to the fire. It releases the cloud of carbon dioxide gas to extinguish the fire as depicted in Figure 9.

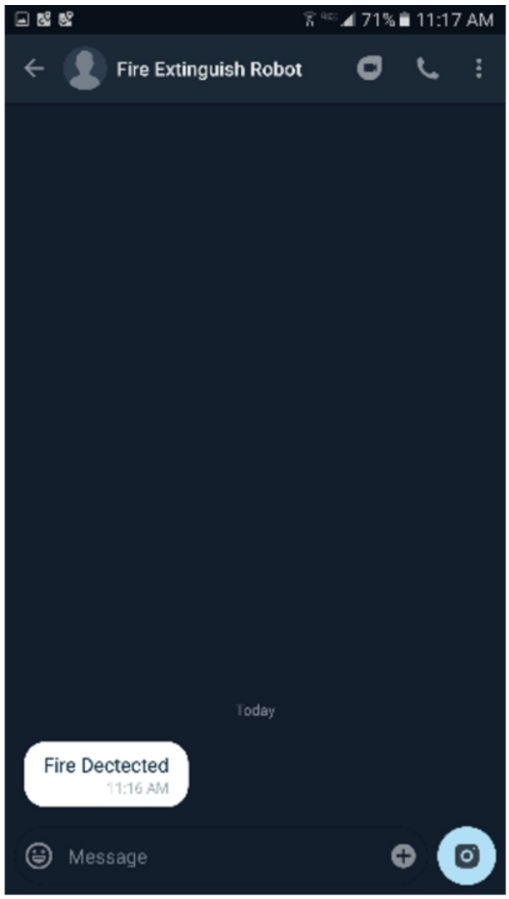

Fig. 7: Fire detected notification

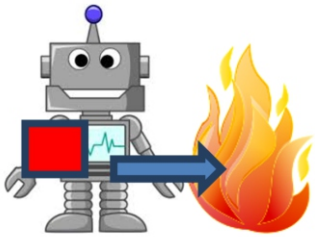

Fig. 8: Proceed toward the fire

Fig. 9: Spray carbon dioxide on fire

Step 6: After successfully extinguishing the fire, robot sends SMS to owner again. The sample SMS is shown in Figure 10.

Fig. 10: Fire extinguished notification

IV. Experimental Analysis

After all the connections and programing of the robot, finally the product is ready for the test. For this purpose, the robot was placed in the room. After the complete fire extinguishing process, it is observed that the robot is able to detect the flame having wavelength from 760nm to 1100nm with the range of 20 cm in all three directions (straight, right, and left) [5]. After fire detection, the robot sends the message to the owner, then approaches to fire position rapidly and try to extinguish the fire with the spray of carbon dioxide. After successfully extinguishing the fire, robot sends SMS to the relevant person.

The prototype of proposed fire extinguishing robot is shown in figure 11.

Fig. 11: Prototype of the proposed robot

V. Conclusion

In this work, firefighting autonomous robot is presented to reduce the loss of human life and property caused by the fire. The robot is capable of detecting the fire in its vicinity with the help of flam sensor and send notification to the concerned person through SMS. After sending SMS, robot moves toward the fire and try to extinguish the fire using carbon dioxide spray. Moreover, after successfully extinguishing the fire it send SMS again to the relevant person. The experimental results show that proposed robot functions well as intended.

In future, this solution can be converted in to a firefighting drone. The use of quad copter mechanism instead of wheel in proposed solution may play a handy role to extinguish the fire on high building with the help of remote control.

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