Autonomous Fire Extinguishing Robot (AFER)

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Abstract

Now-a-days fire disasters are very common it will occur at any time and it may lead to loss of money and human lives. This paper proposes the use of robot to extinguish the fire in its beginning stage of a small flame itself by continuously monitoring the area therefore the fire accidents will be reduced. It is also used to help fire fighters in extinguishing fire in narrow areas and also in hazardous situation so it would reduce the risk of fire fighters in the process of saving victims life. This robot is developed to extinguish the fire in its beginning stage itself.

Keywords

Fire extinguisher, Obstacle Avoidance, Fire Detection, Fire Accidents.

Introduction

The fully autonomous fire extinguishing robot (Islam et. al., 2017) is proposed in this paper. Consider server rooms which consists of lots of electric cables and electronic equipment that may cause fire due to short circuit or any accident, if the operator did not mind the accident due to their monotonous work or distraction that might lead to major fire accident (Bollavarapau et. al., 2014). In order to safeguard the workers (Harwayne-Gidansky et. al., 2007) (Xu. H et. al., 2011), the robot can be made to monitor...
by patrolling around the area. If the robot detects a fire (Chang. P et. al., 2006) (Kim. Y.D et. al., 2009) it will stop it from a safe distance and also extinguish the fire and safeguard everyone.

This robot (Pack. D.J et. al., 2004) (Saxena. A et. al., 2020) uses ultrasonic sensor for obstacle avoidance so it could save us from major fire accidents which leads to save lot of important data, lives of human, money and also lots of water or some extinguishing agent. Due to its compact size and portability, it can also be used by fire fighters (Raju. J et.al., 2017) (Maddukuri et. al., 2016) to extinguish the fire in unreachable area by human beings (Chien et. al., 2007).

System Components

These are the main components used in this work.

Arduino Uno

The ARDUINO UNO is an Atmega328p based microcontroller with 14 digital I/O pins, 6 analog input pins, USB port, power port, reset button and an ICSP header. It is the processor that accommodates the programming for the robot to take action according to sensor input.

IR Flame Sensor

The IR Flame Sensor is used to detect flame source or other infrared source which has a wavelength of 760nm to 1100nm. It is best for detecting Hydrocarbon fires. It consists of resistor, capacitor, comparator and potentiometer. Potentiometer is used for adjusting the sensitivity of the sensor.

Ultrasonic Sensor (HC-SR04)

It is an electronic device which has two main components a transmitter and receiver. Transmitter has a piezoelectric crystal which emits ultrasonic sound waves (it travels way more faster than sounds that are audible to humans) and when it falls on an object it will reflect back to the receiver and the reflected waves will be converted into electrical signal (Raju. J et. al., 2017). It has 4 pins namely trigger, Vcc, echo and Gnd. Theoretically it can measure from 2cm to 450cm practically it can measure between the range of 2cm to 80cm.

Servo Motors (SG90)

A lightweight tiny servo motor with very high output power is used in the Fire Extinguishing System. It has a torque of 2.5kg/cm) and can rotate in each direction. The
servo motor in the Fire Extinguishing System is placed in order to spray water axially (0-60 degree).

**Submersible Water Pump**

It is a 3 to 6V pump which is used to pump the water from the can. It has a flow rate of 80-120 litres per hour, operates between the voltage of 3 to 6V and consumption of current is between 130mA to 220mA. The Outlet diameter has the dimension of 7.5mm on the inside and 5mm on the outside.

**DC Motor**

The DC Motor is a 12V 100 rpm motor which is used for the movement of the robot. The Start Torque will be 2.9kg/cm and stall torque will be 11.4kg/cm. The Stall torque is the highest torque that is applied to the shaft and stops the motor from rotating (Saxena. A et. al., 2020). It will run smoothly if the input voltage is between 4-12V.

**L293D Motor Driver**

It is a dual H-bridge integrated motor driver IC that can drive upto 4 motors with maximum voltage of 36V and current of 600mA per motor. This driver is used to control two 12V 100rpm DC motor. It has an onboard heat sink which gives better performance.

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**Figure 1 Circuit diagram of AFER**

http://www.webology.org
Methodology

The Autonomous Fire Extinguishing Robot has three main purposes that is shown in Figure 1.

Fire Detection

IR flame sensors are used for fire detection. The coverage region of a single sensor will be quite limited so three sensors are used in front of the AFER chassis on the left, right and centre. The sensitivity of the sensor can be adjusted by using the potentiometer in the IR sensor.

The AFER can continuously run around the area so the coverage area will be more.

Obstacle Avoidance

HC-SR04 Ultrasonic sensors are used for obstacle avoidance in this work. The sensor works based on the equation (1),

\[
\text{DISTANCE} = \text{SPEED} \times \text{TIME} \quad (1)
\]

It has a transmitter and a receiver, the piezoelectric crystals in the transmitter transmits an ultrasonic sound wave which travels in air faster than the sound waves that are audible to humans and when it hits an object it will reflect back to the sensor and the reflected waves are received by the receiver. The distance is calculated by using the above equation. Here one can set a distance of 30cm if the sensor detects an object in 30cm it will set as high and the AFER will take an obstacle free path.

Fire Extinguishing

When the AFER goes near the fire the IR sensors will detect the fire and activates both servo and submersible motor pump (Pack. DJ et. al., 2004). Here the stored water is pumped from the can using a mini submersible motor to spray it axially for which a servo motor is used. Water can be used only to extinguish fire that are caused by organic materials like wood, paper etc; CO2 can be used to extinguish fire which is caused by electrical equipment, Foam can be used for organic and flammable liquids, dry powder can be used for any type of fire except cooking oils. Wet chemicals are used to extinguish fire which is caused by cooking oil. Hence it is a prototype, water has been used as an extinguishing agent. The flow of the process is shown in Figure 2.
AFER is a fully autonomous fire extinguishing robot. It will patrol around the area continuously by detecting the obstacles around them using ultrasonic sensor and if it detects fire, in its path then it will extinguish it. The robot has been programmed using Arduino IDE platform. When the robot is switched on, the robot will start to move continuously in a straight path if it has any hindrance before it the ultrasonic sensor will sense it. When the AFER need to move to the right the dc motor present on the right side alone will rotate so that the robot can rotate right side it will rotate until it finds an obstacle free path and when
it finds an obstacle it will start moving straight. Three flame sensors are used for fire detection in the AFER, if the centre detector senses the fire then both the dc motor will stop. Then the AFER and the submersible pump will be actuated to pump the water from the can and the servo motor will also actuated to spray the water axially(0-60 degree), if left IR detects fire then right dc motor will stop and left dc motor alone will rotate, if right IR sensor detects fire then right dc motor will stop and left dc motor alone will rotate when it turn straight to the fire then the submersible pump will be actuated to pump the water from the can and the servo motor also actuated to spray the axially(0-60 degree). The block diagram of the AFER System is shown in Figure 3.

![Figure 3 Block Diagram of AFER System](image)

**Table 1 Readings of AFER System**

<table>
<thead>
<tr>
<th>Right IR sensor</th>
<th>Left IR sensor</th>
<th>Centre IR sensor</th>
<th>Ultrasonic sensor</th>
<th>Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Turn Right</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Turn Left</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Turn on Servo and Submersible motor to extinguish fire</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Right motor alone operates to rotate the robot until. it selects an obstacle free path</td>
</tr>
</tbody>
</table>
Results & Discussion

The Prototype of the AFER System is shown in Figure 4. Since its a prototype it has some limitations like multiple ultrasonic sensor combined with IR sensors or LIDAR sensor that will improve the accuracy and also aids in obstacle avoidance. For fire detection IR sensor is limited to a particular range and it is also sensitive to direct sunlight by combining IR Flame sensor with ultraviolet sensor (orange part of the flame emits IR waves and blue part of the flame emits UV rays) with smoke sensor and temperature sensor fire detection will be more accurate. A low voltage motor is used so the water can be sprayed approximately up-to 40cm which can be much improved by using high voltage motor pumps. The readings of the AFER System for different cases is shown in table 1.

Conclusion

This paper mainly focuses on building a fully autonomous fire extinguishing robot. The final prototype of the robot will successfully patrol around the area without the disturbance of obstacles and detects the fire and extinguishes it. These results will show that the work has been successfully implemented. The AFER System is more efficient in extinguishing the fire. IOT based live streaming camera can also be included to monitor the area and the structure used is more suitable for residential purpose and it can be designed for different terrains.
References


