

Design and Construction of a Remote Controlled Fire Extinguishing Robot

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Abstract

From the recent years, robotics has turned out to be an ingredient over which many people had shown their interest and gained popularity due to the advancement of many technologies. Therefore, it has been decided to design something that can make human life easier and comfortable and the interest of review is to make a fire extinguishing robot. Fire detection and extinguishment are perilous jobs that invariably put human lives (especially firefighters) in danger. The proposed fire extinguishing robot is designed for extinguishing fire in a small floor plan of a house, office or shopping mall of specific dimensions with the help of the CO₂ fire extinguisher which can be carried by the robot itself. Controlling of this robot demands of an operator who can easily control it from remote location without being involved in firefighting. The remote control system for this project is based on conventional RF technology but with different approaches. Accuracy of the control system has been satisfactory throughout this project. The fire eliminating performance and the robot movement speed was closed to the aspiration.

Keywords: RF, Tadpole, CO₂ fire extinguisher, DC motor.

1. Introduction

The modern concept began to be developed with onset of industrial revolutions for the use of complex mechanics and subsequent introduction of electronics. A huge part of industrial revolutions has been accelerated in modern times due to the evolution of robotic science. Like other modules of technology, the fire extinguishing system has also put a significant effort to merge it with robotic science. Involvement of robots instead of humans has been practiced since the end of the last decade and through this project another solution is tried by developing a fire extinguishing robot which will be operated by human operator through remote controlled system from a safe distance. It performs the whole task by means of some mechanisms, e.g. driving system to move towards the fire striking zone and steering system to control the direction of robot. Moreover, to suppress fire, there is a methodical system which allows CO₂ gas to escape from the extinguisher which will be directed towards the source.

2. Background

The proliferation of robotic technology has put much gravity on fire extinguishing system and some researches over this particular are much noticeable e.g. Thermite, LUF, Tehzeeb, SAFFiR etc. Thermite is based on technology developed for the U.S. Army, this squat little modular robot on tank treads is a small, powerful fire fighting machine that provides crews with a means for remote reconnaissance and fighting fires in hazardous areas safely and it is designed to be used in areas of extreme hazard, such as aircraft fires, refineries, chemical plants or nuclear reactors [1]. LUF is a radio controlled tracked vehicle or machine that clears the path for advancement of up to a distance of 1000 feet by incorporating a high capacity positive pressure ventilator and a “water beam” fog and this combination clears away smoke, heat, toxic gases and reduces the intensity of the fire, allowing firefighting and rescue teams to more safely approach the incident [2]. Tehzeeb is a type of rescuing robot that uses laser scanner module, a manipulator and map generation algorithms for localization and navigation in visually poor situation such as in dense smoke surrounding [3]. The Shipboard Autonomous

Firefighting Robot (SAFFiR), sponsored by the Office of Naval Research (ONR) is another type of bipedal, humanoid rescuing robot which uses thermal imaging to identify overheated equipment, and a hose to extinguish fire[4]. This robot is also capable of manipulating doors and fire hoses, and equipped with sensors to see and navigate through smoke.

3. Methodology

The implementation of this project involves the construction of fire extinguishing robot, interfacing with hardware such as motor driven circuitry, fire extinguisher pressing arm and steering system. Suppression is associated with involvement of a CO₂ fire extinguisher which is available in market. In this project there is a very little scope for human involvement-only for operating the remote control system. The entire system architecture of the fire extinguishing robot is shown in Fig.1.

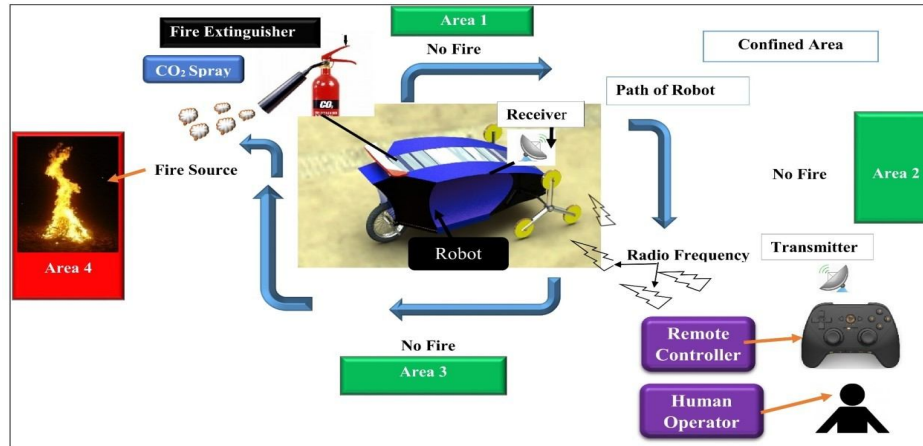


Figure 1: System architecture of the fire extinguishing robot

4. Design Methodology

Design of Chassis, Steering System and Protective body

A tadpole configuration (with two wheels out front and a driven one behind) has been inaugurated to minimize instability associated with motion [5]. In orthodox delta layout (one front wheel and two rear wheels), the vehicles center of gravity is not only high, but also well behind. In attempting to make a turn, the contraption becomes, in effect pendulum-albeit one swinging in a horizontal plane parallel to the road surface rather than vertically. And this yawing moment is amplified by gravity when heading downhill. The advantage of tadpole over conventional delta layout is that it puts center of gravity close to the steering axis, thus reduces its radius of gyration (i.e. the length of its imaginary pendulum arm) to something close to zero. This remarkably improves rollover resistance. In addition to this splendid configuration, the chassis of the robot is designed in such a degree that it could provide enough space to place fire extinguisher, batteries, circuit board, DC motors and other accessories. Moreover, a simple steering system has been designed for changing direction when necessary. This steering system comprised of riveted joints and knuckle joints at the two ends to ensure pliability. At the center of this system, there is a gear meshed with a pinion which will be driven by a DC motor controlled by a remote controller. The rotation of the gear makes the steering system twist. For instance, clockwise rotation of the gear can results in left turn while the anti-clockwise makes it to the right. Also, the robot will be driven by another DC motor connected with the rear wheel by a chain and sprocket mechanism. For forward and backward movements of the robot, this motor requires to be rotated in bi-directional too. Finally, a protective body has been provided to shield the fire extinguisher, circuit box, batteries, motors and other sensitive parts from the direct exposure of flame.

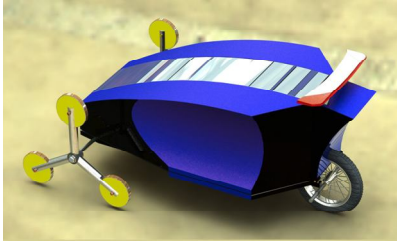


Figure 2a: Tadpole Configuration

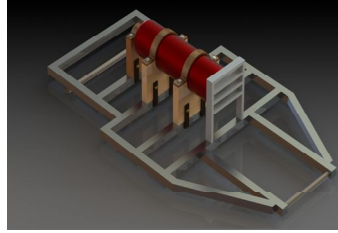


Figure 2b: Chassis Layout

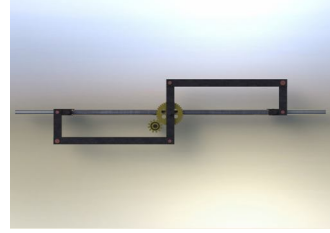


Figure 2c: Steering System

Design of the Fire Extinguishing System

This mechanism is mounted on the chassis and consists of a specially designed pressing arm (for pressing the top handle bar of extinguisher) in between two ball bearings housed over the chassis (Figure 3a). This allows the pressing arm to be rotated in 360°, however, only if the DC motor shafted with it permits so. Also, this motor will be controlled by the same remote control system used for the steering motor and robot driving motor and provided with bi-directional rotation. In this case, reverse directional rotation is necessary to unleash the pressing arm (green colored) from the top handle bar of the extinguisher when CO₂ is not required (Figure 3b).

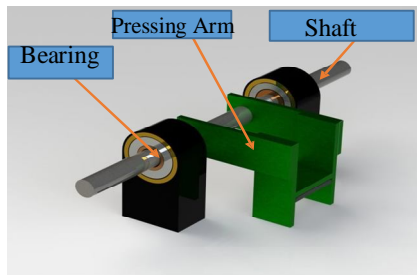


Figure 3a: Pressing Mechanism



Figure 3b: Pressing Mechanism with Extinguisher

This mechanism will be staged over the top handle bar of the fire extinguisher as shown in Figure 4:

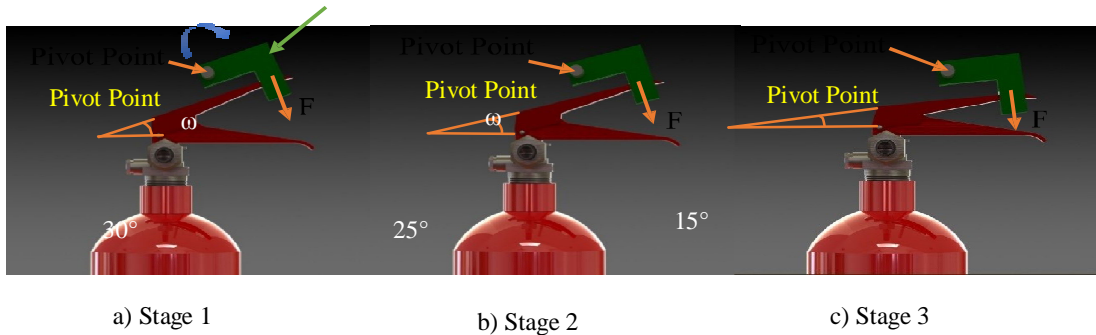


Figure 4: Progressive stages showing the pressing procedure of the top handle bar of a fire extinguisher by pressing arm mechanism

The torque required to press the top handle bar of the fire extinguisher is calculated by –

$$T = F \times r$$

Where, F=force required for pressing, r=turning radius.

5. Control System

The sole purpose of the control system is to control three distinct motors associated with the driving, steering and fire extinguishing mechanisms by a single remote controller. An overview of it can be shown by the following block diagram:

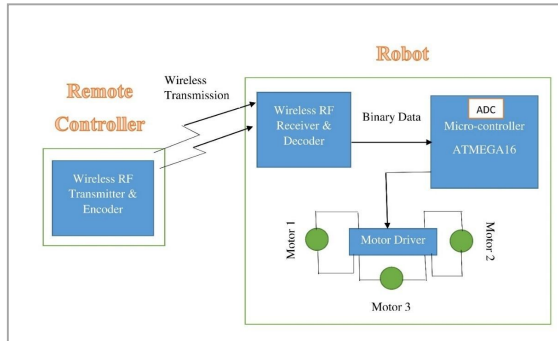


Figure 5: Block Diagram of Control

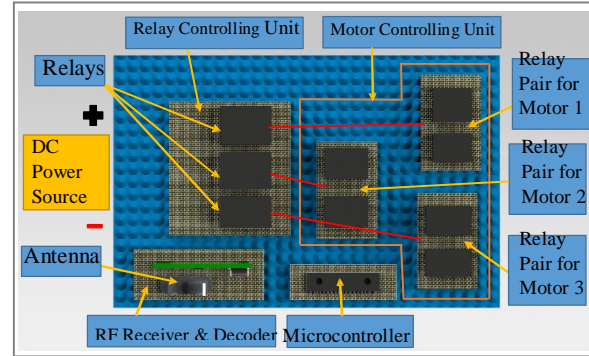


Figure 6: Relay Controlled Circuitry System

As mentioned earlier, the movement of the robot and fire extinguishing mechanism demand bi-directional rotation (table illustrates this) of the motors, it seems quite challenging to maneuver them via a single remote controlling unit. However, these difficulties had been eliminated by introducing a relay controlled circuitry system.

Table 1: Different type of movements produced with configuring all DC motors.

Rotation(+/-) of Motor1(Robot Driving Motor)	Movement of Robot	Rotation(+/-) of Motor2(Steering System Motor)	Movement of Robot	Rotation(+/-) of Motor3(Fire Extinguisher Pressing Motor)	CO ₂ Spray
Clockwise(-)	Forward	Clockwise(-)	Right Turn	Clockwise(-)	Yes
Anti-Clockwise(+)	Backward	Anti-Clockwise(+)	Left Turn	Anti-Clockwise(+)	Release the arm

The relays in controlling unit had shown in the diagram act as switches for the motor controlling unit (figure 6). This is because each of the motors needs to be commenced individually when required. This is done by the conversion of binary data into electric pulses in the microcontroller of the circuit panel where it receives its data from the RF receiver and decoder. The RF receiver gets its signals from the RF transmitter and encoder which is melded with the remote controller.

The motor controlling unit constitutes of three pairs of relays assigned for three motors mentioned above. They act as final switches for the motors for deciding in which direction these motors will be revolved based on the data available in the receiver.

6. Expression for Calculating Success Rate of the Control System

Success rate can be defined as the ratio of total number of successful trials to the total number of trials performed.

$$\text{Success rate} = \frac{\text{Total no. of successful trials}}{\text{Total no. of trials performed}}$$

7. Experimental Setup and Construction

The final construction of the prototype of the robot is shown below (Fig. 7 and Fig. 8). For this prototype, the microcontrollers are coded with C programming language.



Figure 7: Photograph of the robot

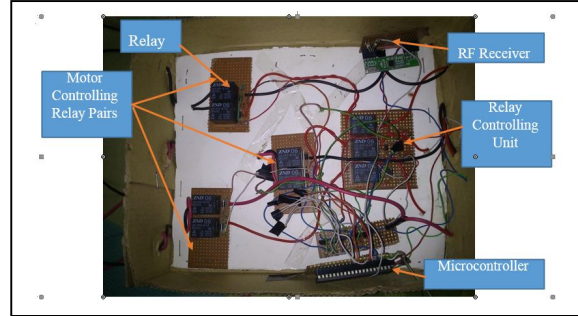


Figure 8: Photograph of the Circuit Board

8. Experimental Results and Discussion

Velocity of the robot = $1.9669125 \text{ ms}^{-1}$.

Discharge rate of CO₂ gas from the fire extinguisher = $0.8658 \text{ cm}^3/\text{s}$.

Torque required to press the main arm of the CO₂ fire extinguisher = 100 kg-cm.

An experiment has been performed to observe the extinguishment of fire by testing on some materials like papers, woods, plastics, clothes etc. and the time required for suppression was calculated which the table below illustrates:

Table 2: Measurement of time regarding extinguishment of fires associated with different types of objects.

No. of trial(s)	Type of object(s)	Average time of fire extinguishing (sec)
1	Cloth	2.8
2	Plastic	2.4
3	Paper	2.6
4	Wood	5.8
5	Kerosene	9.0

From the observation, it can be noticed that requirement of time was quite lesser for the objects mentioned except for kerosene. For measuring control systems' success rate, twenty five trials had been performed regarding three major systems followed.

Table 3: Measurement of success rate of control system on different parameters.

Success Rate of Control System	Percentage (%)
Robot driving system	88
Steering System	80
Pressing Arm	92

9. Conclusion

The technologies has been used to develop this firefighting robot are literally familiar but the implementation was unlike. RF module has been tactfully merged with the control system to make it much utilitarian operating system. The response area is larger than conventional fire extinguishing robot because of radio frequency module. Although there were many constraints, the robot can extinguish fire spraying CO₂ into the explosive area. The purpose of this research on this fire extinguishing robot is to nurture the knowledge of engineering in robotics that would be a convenient application for a real-world robot in extinguishing fire with efficacy and save more innocent people's lives in future. For future enhancement of this project, some supplementary attributes may be added by assimilating stair climbing feature to this robot and in this case Wearable Depth

Sensor can be used to detect obstacle like stairs. Thermal imaging technology can also be incorporated for detecting objects in highly heat concentration zone.

References

- [1] Szondy, D. (October 5, 2012). Thermite fire-fighting robot removes fire fighters from harm's way. Available at <http://www.gizmag.com>, Retrieved: October 2014.
- [2] [www.nrt.org/production/NRT/RRT3.nsf/Resources/May2009ppt2/\\$File/LUF-60_Presentation_to_Chiefs-2.pdf](http://www.nrt.org/production/NRT/RRT3.nsf/Resources/May2009ppt2/$File/LUF-60_Presentation_to_Chiefs-2.pdf). Retrieved: June 2014.
- [3] Young-Duk Kim; Yoon-Gu Kim; Seung-Hyun Lee; Jeong-Ho Kang; Jinung An; "Portable Fire Evacuation Guide Robot System", Intelligent Robots and Systems, IEEE/RSJ International Conference, 11-15 October 2009. Pages: 2789-2794.
- [4] White, T. (April 2, 2015). Marketing Sailors 'SAFFiR' - Navy Unveils Firefighting Robot Prototype at Naval Tech EXPO. Available at www.navy.mil. Retrieved: July, 2015
- [5] Gulati Vikas, Mehta Sameer, Kashyap Ankur, Pawar Kartik. (2012). Design and FEA of a Recumbent Trike. Indian Journal of Applied Engineering Research, ISSN 0973-4562. (Vol. 7) No. 11.