Prototyping of a Robotic Fire Vehicle Using Radio Frequency Technology

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Abstract- Fighting a raging fire is one of the toughest uphill battles in the public – safety world. Fire fighters try to put off fires with very little information, having no idea of the size and scope of the fire nor how many potential victims may be cut off from rescue (Na Gabbert, 2012). Fire losses throughout the world remain too high and firefighting too hazardous. This work aims to mitigate these losses via the prototyping of a robotic fire vehicle using radio frequency technology. The primary research method for this study is the literature review of the various types of limitation in existing firefighting systems and models, from the review carried out an improved firefighting robotic system was designed and built. The vehicle is loaded with a water carrying bottle. Two DC motors alongside a castor wheel are used for the locomotion and drive system of the robot, a DC water pump is used to spray jets of water through its suction action. These motors are controlled from a distance over a wireless communication between the Bluetooth HC-06 and a motor control app installed on an android phone. The Robot is programmed to stop and release sprinkles of water before the robot hits the target. An Arduino microcontroller is used for the overall desired operation. The entire system is powered by a 12V Lead – acid rechargeable battery. The robot has a dimension of 0.37 m by 0.28 m by 0.12 m and navigates through a modeled floor plan with an average velocity of 0.05 m/s to extinguish a simulated fire in 5 to 10 seconds. Experimental work has been carried out carefully and successfully, the proposed technique is confirmed to be very useful for engineering, research and safety purposes.

Keywords: Arduino microcontroller, chassis, robotics, actuator

1 INTRODUCTION

Since time immemorial, fire has been considered as one of the elemental forces influential to Life on the earth. The Greeks took fire as one of the unique four vital elements which make up the biosphere- beside water, earth and air, and they was close understanding in India, Ancient China and elsewhere. Fire possesses potent, vicious and enabling properties whether occurring within the physical and natural world or when kindled intentionally or by mistake. When in an uncontrolled state fire can and has caused devastation, hurt, and loss of life of prodigious degree (Woodrow, 2010). Economists and scientists have accepted fire as one of the many risks to life and properties, which must be dealt with. Over time, the understanding of fire has changed and advanced. Rather than being just an elemental force, modern science has led us to recognize fire as chemical process of combustion; the fiscal cost of fire is around 1% of gross domestic product in industrialized Nations –an approximation which remains widely acknowledged to date (Kurfess, 2005). The complexity of situations firefighters face is not linear. Some situations are far more complex than others which result in more risk of injury or death (Abinesh, Deepak, Chandraprakash, Gowtham, & Ananthi, 2008)

Our world is currently facing the global warming whereby the average temperature of our earth atmosphere and oceans is increasing year by year. Studies shows that our earth's mean surface temperature has increased by 0.8Celsius which is about two-third of the increment occurring since 1980. The global warming of the earth may lead to more forest fires and fire disasters will occur as everything gets more flammable due to the high temperature of our earth atmosphere. Therefore, fire extinguishing robots are needed to significantly reduce the damage cause by natural or human made fire disaster (Tushar & Satbhai, 2016).

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In an automated fire extinguishing robot (FireDroid), which can detect flame and extinguish the flame when fire occurs in a house, the fire extinguishing robot was able to sense the flame and move to the fire location. After the fire location is locked and flame distance is measured, water is pumped out from the water tank and the fire is extinguished completely (Boo, SiewWen, Leong, & Edwin, 2013) . In Multisensory Fire Detection Algorithm (MSFDA) for intelligent building where a proposed, fire-fighting robot is constructed using aluminium frame. There are six systems in the fire-fighting robot, including structure, avoidance obstacle and driver system, software development system, fire detection and remote supervising system. They designed the fire detection system using three flame sensors in the fire-fighting robot. The adaptive fusion method is proposed for fire detection of fire-fighting robot. If fire accident is true, the robot can find out fire source using the proposed method by fire detection system, and move to fire source to fight the fire.

Also in virtual modification of competition robot, which participated in Panitia Kontes Robot Cerdas Indonesia in 2006, a structure was created in MATLAB/Simulink with the assistance of the Virtual Reality Toolbox module (Joga, Mochamad, & Agus, 2007). Firefighting robot made by micron123 is used to compete in robot competitions. The function of this robot is to find a candle that contains the fire, and then extinguish the fire. This robot can also function to save victim in the competition. The work area cover by this robot is in most rooms, stairs and Sometimes can avoid obstacles this robot used aluminium to develop chassis. Designs are more focused on the round shape of the robot body. This robot used three dc servo motors. Robot movement operated by 2 wheels do major motion robot and one wheel for balance (Gerald, Michael, Shawn, & Jack, 1999). This robot brain is a mega microcontroller and has two main sensors; ping ultrasonic ranging sensor is used

to avoid obstacles and uvtron flame sensor as the sensor detects the presence of heat and fire (Mustapha, 2013).

More people have increased access to smart phones than in the last ten years, thus using the concept of frugal innovation: a system using (Bluetooth HC- 06) that can be controlled and incorporated into the everyday use of phones is necessary, previous works make use of push buttons, smart screen, pads, joysticks and RF transmitter and receiver for remote control which adds to the production cost. The work is carried out in order to develop a robotic fire-fighting vehicle that will extinguish fire by throwing jets of water at it; it does not sense the fire. Since it is an experimental model it can only fight class A type of fire and even at that it cannot put of large fires, also due to battery life it cannot stay outside for long period of time (Britannica, 2015).

2 METHODOLOGY

The primary methodology, as shown in Fig. 1, for this study is literature review of the various types of limitation in existing fire-fighting systems, and then upon this understanding an improved fire-fighting system will be designed. The next stage is the project implementation which has to deal with materials selection, simulations and performance test. The prototype has the following components:

i. The Mechanical part
ii. The Electronics (hardware and simulation)
iii. The Software part (programming)

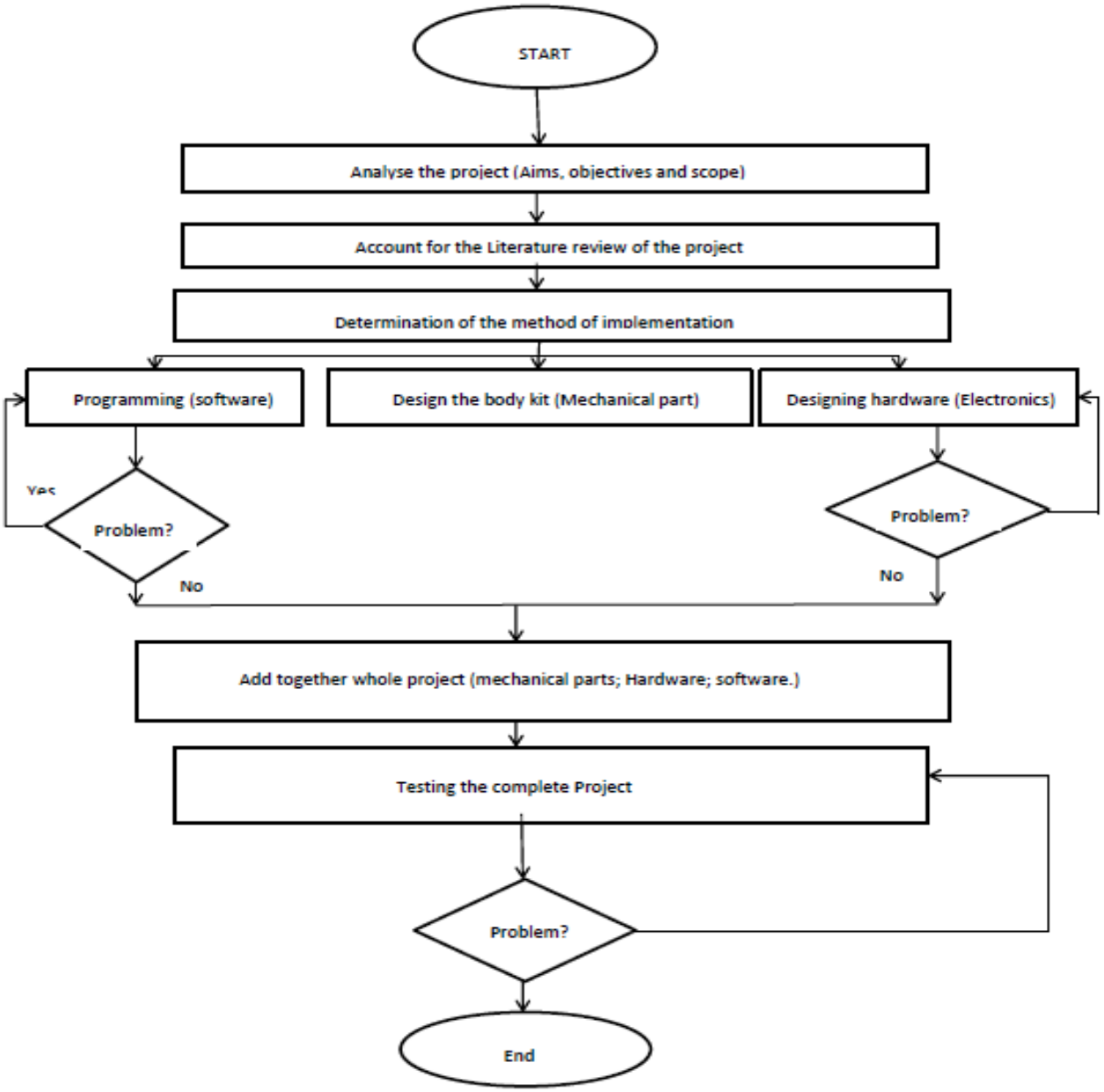


Fig 1: Methodology flowchart adapted from the conception of the project idea to the execution

3 PROTOTYPE COMPONENTS

The individual components of the robotic fire vehicle are discussed in this section. Fig. 2 shows the interconnection between these components while Fig. 3 gives the circuit diagram for the robot.

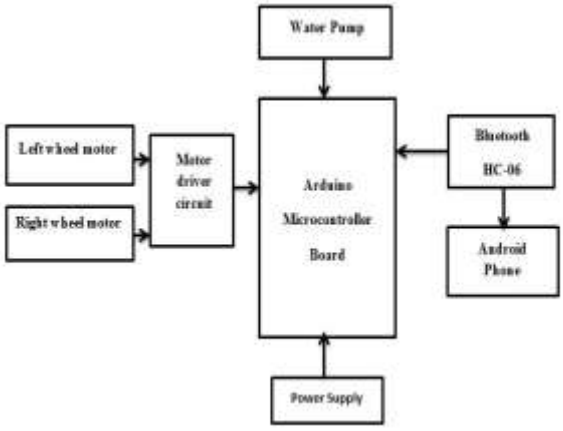


Fig. 2: Implementation of functions by the Robot

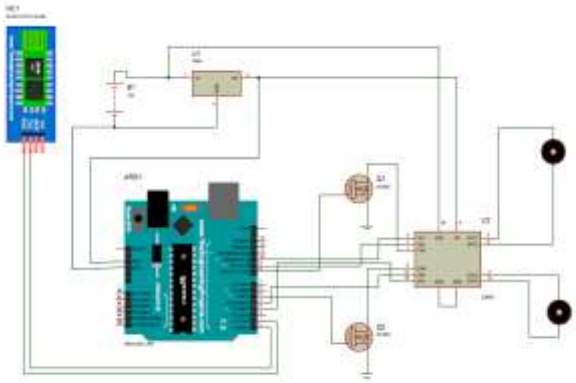


Fig. 3: Circuit Diagram for the Robot

3.1 THE ARDUINO MICROCONTROLLER

The Arduino microcontroller is like a little control centre that is set to receive instructions, using lines of code, an Arduino can be used to blink an LED on or, read the estimation of a sensor and showcase on a graphical user interface, the essential Arduino communicates with the computer using its specific standard USB cable.

3.2 BLUETOOTH HC-06

Bluetooth HC-06 is an electronic serial module that is utilized for changing over serial port to Bluetooth, it comprise of Bluetooth serial interface module and Bluetooth connectors that empower straightforward remote communication between electronic gadgets it discovers.

3.3 BRUSHED DIRECT CURRENT MOTORS.

The purpose of direct current motor is to create rotational motion, they require direct current source and are capable of operating with adjustable speeds over a wide range and are perfectly suited for accurate and flexible speed control using pulse width modulation. They are cheap, easy to control but wears off its brushes after a period of time.

3.4 DC WATER PUMP

A pump is a gadget that moves liquids (fluids or gasses), or some of the time slurries, by mechanical activity. Pumps can be arranged into three noteworthy types based on the approach used to move the liquid as: direct lift, removal, and gravity pumps. In this project it is used for throwing water.

3.5 12V BATTERY

In electronic circuits powered by direct current, the voltage source is generally a battery which delivers a consistent voltage and a steady current through a conductor. A 12V battery is a rechargeable electrochemical cell having an electrolyte, they are flexible, cheap and can be charged and discharged easily, their significant downside is weight.

3.6 MOTOR DRIVER L293D

Motor drivers are utilized to portray the manner of development of the robot. It is utilized to give high voltage and high momentum as a yield to run the motors which are utilized as a part of the undertaking for the development of the In its basic method of operation, two DC engines can be driven all the while, both in forward and turn around course.

3.7 SOLIDWORKS SP2.0

The body kit of this robot was designed using solidworks 2015 SP 2.0. It has two wheels at the rear side and a free castor wheel at the front that is used to stabilize and rotate the robot 360^0. It was designed to be a single layer hexagonal piece of plywood with room to accommodate all the necessary hardware on the board, this include the circuit board and its respective components, DC water pump and the water tanker. Each component was designed in the part section and was coupled together in the assembly section the, choice of a hexagonal shape was based on stability of the system and ability to navigate around corners.

3.8 ARDUINO PROGRAMMING LANGUAGE

The open source Arduino environment makes it easy to write code and upload it to the input output board, the code called a sketch is a set of instructions for the Arduino to carry out, the creation of a sketch involves three main parts; variable declaration, the setup function and the main loop function. For this project the source code for motor control and direction was downloaded and edited to fit the design of the circuit.

3.9 THE MOTOR CONTROL ANDROID APPLICATION

The android application was built online using MIT (Massachusetts Institute of Technology) app inventor, this application communicates with the robot wirelessly through radio frequency for the control and direction of all the motors.

4 DESIGN ANALYSIS

The designing of the body kit were based on some notions. The operations of the robot will not affect the placement of internal components which are needed by of the robot. The centre of gravity is reduced to stabilize the robot when it is static or in motion and also reduced is the weight of load the robot will carry to decrease the power requirement of the robot (Majid, 2012) .

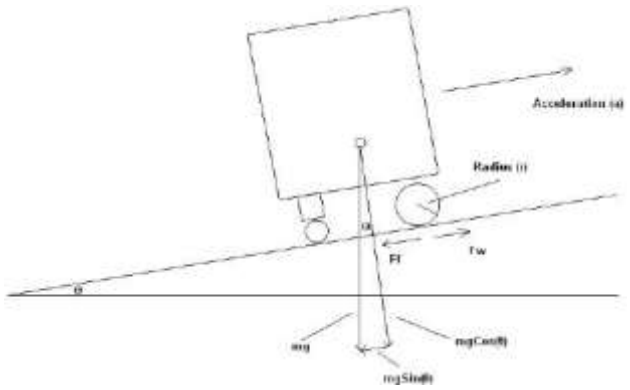


Fig. 4: Free body diagram of a simple Robot

The simple free body diagram of a simple robot with two drive rear wheels drive wheels and a front caster is shown in Fig. 4. The numerous forces acting on the robot are as shown in Equations (1) – (7) (Neal, 2015) .

$$F = ma \quad (1)$$

The principal forces acting on the robot are;
The force dragging the robot down towards the middle of the earth due to gravity

$$W = mg \quad (2)$$

On a free body diagram, the force of weight is broken down into its two components.
The force pulling the robot back down the incline

$$Fg = mg\sin\theta \quad (3)$$

The force holding the robot onto the incline

$$Fn = mg\cos\theta \quad (4)$$

The torque of the robot

$$T = Fw \times r \quad (5)$$

Maximum Mass of the robot = 15 Kg
Weight of the robot: 15 x 9.8 = 147 N
Maximum Speed: V = 0.1 m/s
Maximum incline to climbs: $\theta = 20°$
Reach maximum speed in two seconds: a = 0.05 m/s^2
Drive wheels is 0.085m in diameter: r = 0.0425 m

$$T = m(a + g\cos\theta)r \quad (6)$$

$$T = 15(0.05+9.8 \times \cos 20) \times 0.0425$$

$$T = 5.903\text{N-m}$$

Two drive motors are used thus;

$$T \text{ per motor} = 2.952\text{N-m}$$

Revolution per minute of motors

$$Rmin = \frac{V}{2} \pi r = \frac{(0.1 \times 60)}{2} \times 3.142 \times 0.0425 = 22.5$$

$$\sim 23 \text{ Rev/min}$$

Power required by motors

$$P = T * W \quad (7)$$

$$W = \frac{R_{min} \times 2 \times \pi}{60} = 2.41 \text{ rad/second}$$

$$P \text{ m} = 5.903 \times 2.41 = 14.23 \text{ watts}$$

Actual Motor Choice Power

$$Pa = 2(IV) = 2 \times 1.87 \times 6 = 22.44 \text{ Watts}$$

Power required by DC water pump (fire suppression)

$$Pd = IV = 2 \times 12 = 24 \text{ Watts}$$

Estimated Power used up by microcontroller and other electronic components

$$Pe = 0.12 \times 5 = 0.6 \text{ Watts}$$

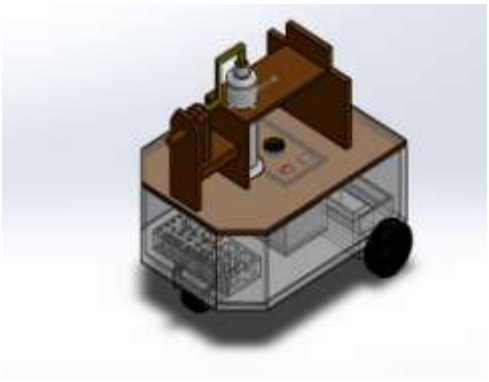
Total electrical power supplied by the battery system

$$PT = 22.44 + 24 + 0.6 = 47.04 \text{ Watts}$$

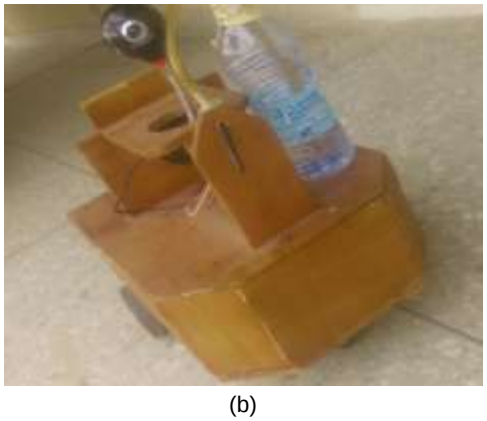
Maximum Energy of Battery (Emax) = 12 x 7.2 = 86.4 Watt-Hour (This meets the demand of the total power)
Discharge time of battery = 86.4/47.04 = 1.84 Hours

5 IMPLEMENTATION AND EVALUATION

From the performance test conducted the flow rate of the water pump was observed to be 1.32 x 10-5m^3/s, this value was attained by using a stopwatch to determine the time it will take for a litre (1 x 10-3 m^3) of water to get emptied, the time taken was 76 seconds, the rate of flow of water gradually increased from 0 - 7 seconds before it became uniform, the positional placement of the pump determines how fast it will pump and how much energy it demands. The efficiency of the pump depends upon the pump's configuration and operating conditions such as rotational speed, fluid density and viscosity. For a typical pumping configuration work is imparted on the fluid.



(a)



(b)

Fig. 5: Pictorial view of both the (a) designed and (b) constructed fire vehicle Robot

The robot was programmed to move right, left, backward and forward, at the Bluetooth HC-06 end the two motors and water pump are interfaced to the microcontroller to control the movement of the robot, the red soft button on the centre of the graphical user

interface is for stop, F9 button is to put on the water pump and the left, right, forward and backward soft buttons for their respective direction, a depression of any of this button will send serial communication to the Bluetooth module which sends command to the microcontroller to switch the relays, the relay in turn allow current to be channelled to the motors which effects the motion, the Bluetooth range is 5 – 8 m. It was a bit disappointing to note that although the motors were gotten from the same source (rechargeable electric fans) with similar ratings their speed were not exactly the same, it was assumed that since the specifications and manufacturer of the fan are same the torque/speed would be same unfortunately it was not(it could be due to mechanical faults from the factory of the manufacturer or better still the costly assumption made) this was discovered during the testing of the whole system, the effect is that it would limit the linear motion of the robot (i.e. it cannot travel perfectly on a straight line), pulse width modulation was used to adjust this speed to be as close as possible.

(a)

(b)

Fig. 6: showing the performance testing process and circuitry

It took the robot 7 to 10 seconds to extinguish the simulated fire created by lighting pieces of paper with a matchstick and noting the time it takes for the fire to get extinguished. There is an inverse relationship between the pump flow rate and time taken to extinguish fire; the greater the flow rate the lesser time it takes to extinguish fire. The whole system is powered by a 12V rechargeable lead-acid battery; it discharges very quickly when powering the entire system thus limiting how long it can last, to curb this battery was refilled with acid and recharged. An experience realized during the course of this project is that not all specification written on data sheets are true, this could be due to the low quality components imported from Chinese companies based on compromise.

6 Conclusion

A robot that will navigate a controlled terrain and extinguish fire by throwing water at it by means of wireless communication with an android phone have been developed from cheap, easily obtainable and workable locally sourced materials, It resolves to stimulate technology innovation to accomplish a dependable and effectual result to the problems of fires as it concerns the safety of humans and their possessions. Experimental work has been carried out carefully and successfully with little lapses, the proposed technique is confirmed to be very useful for engineering and safety purposes, as it is known in recent times Nigerians are tired of colossal fire disasters, to curtail such misfortunes technological power must exceed human power because human life is invaluable. Since this preliminary work cannot address the entirety of all the features within the framework, through a joint effort of various entities modifications can still be done to improve on the development of the robotic fire vehicle, the suggested recommendation will include the use of more sensors coupled with digital image processing technique for fire detection; adaptation of artificial intelligence for an semi-autonomous mode with humans still in the control loop and the utilization of better materials for future fabrication

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