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An Analytical Study of Various Methods Used to Build an Autonomous Fire-Extinguishing Robot

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Abstract:- Expanding human population and growing industrialization, has led to a manifold increase in the number fire accidents. The physical limitations of humans to deal with these kinds of destructive fires combined with the adverse conditions, makes fire extinguishing an arduous task. The use of autonomous robots can reduce the errors and the limitations that are faced by human fire fighters. This paper is an effort to understand the various approaches that are possible to build such a robot. We compare and contrast the various design and construction steps that are involved in the process of building a fire fighting robot.

Keywords:- Fire Fighting, Autonomous Robot, Sensors, Micro Controller, Differential Turn

I. INTRODUCTION

Accidents that involve fire have been a cause of concern to mankind for a long time now. Fires are known to cause destruction on a small as well as a large scale. In spite of the best attempts made by human fire-fighters in the process of extinguishing fires, it is not always possible for them to tackle fires in the most efficient manner.

In this review paper we seek to explore the hardware and software components used to build a fire fighting robot, the techniques used for detection of source of the fire and the motion of the robot towards the source of fire. We present a comparative study of the methods used by the authors of different papers and also justify which methods we find to be the best applicable to build an efficient Fire Fighting robot.

A. Organisation

The review paper prepared by the authors is divided as follows, A general introduction to the topic, Background, Characteristic Features of the robot, various components of the robot explained in detail, explanation of working of the two model taken into consideration, comparative analysis and a conclusion of the paper.

B. Need for Fire Extinguishing Robots

Considering the challenges faced by a human fire-extinguishing team in arriving at the scene of fire accident, in the least possible time, and dealing with the fire with the few resources at their disposal, it is the need of the hour to find a solution by designing a fully automatic, Robotic Fire Extinguishing Vehicle, which can react more spontaneously to fires and carry out its fire-fighting mechanism more efficiently.

C. Motivation

The concept of process of automation of fire fighting that has come into being only in the recent times. This has been made possible by the advancement in the field of robotics and technology, in general. The research and development work in this field is still at its infancy, the group feels that there is immense scope for experimenting and research to understand the working of fire fighting devices and a lot of improvements can be made to existing models that have been developed.

D. Overview

The paper gives a detail comparative analysis to the reader of the various approaches and implementation methods that are being currently used in the field of robotics and also throws light on two specific cases and also gives a insight into what modifications and improvements can be made to the design and the approach and also the popular approaches in the industry.

II. FEATURES OF THE ROBOT

The authors of the paper, 'FIRE FIGHTING ROBOT: AN APPROACH' [1], have made an attempt to provide to the user an detailed explanation of the various concepts that were incorporated by the authors to develop the fire fighting robot. The authors make use of SMCL microcontroller and a combination of flame detectors. They attempt to develop a robot that is autonomous in its working and provide details on the components used to make the robot environmental aware via receptors and to process the information that is received from them. They seek to build a robot capable of fighting a simulated tunnel fire, industry fire and military applications.

The authors of the paper, 'Development of a Fire fighting Robot for Educational Competitions'[2], present the design and assembling details of a fire fighting robot developed to take part in an educational robotic competition. The focus of this paper is to provide an insight into the development process that is involved and the innovation that is required to deal with problems usually seen in real industrial environments. The students are required to make their robots under certain constraints and need to fulfil certain criteria. The paper gives a detailed description of one of the robots built by a group of students.

The robot that was build students for Robotic competition [2] has the following features:

The following were the minimum criteria for the robot to be accepted for the International competition.

1) The Robot is able to move autonomously for one meter on the competition field
2) Find the points of possible fire focuses using a sound signal to indicates when they are found
3) Robot needs to climb up and down in two slopes located randomly on the competition field

Features of the Fire Fighting Robot that was built by the group based on the research paper, 'FIRE FIGHTING ROBOT: AN APPROACH' [1]:

1) The fire sensors are capable of detecting fire from 2 m away.
2) The ultraviolet sensor detection range is 360 degrees.
3) The fire extinguisher works for a continuous time till fire extinguishers.
4) The robot moves at 2.5 ft/sec on a flat surface, accelerate from 0 to 1 ft/sec in two seconds.
5) The robot turns within a 6" radius and utilizes circular or octagon design in order to minimize possible impact area.

III. VARIOUS COMPONENTS OF THE ROBOT

A. Fire sensor

The Robot implemented in the paper, 'FIRE FIGHTING ROBOT : AN APPROACH'[1], use of UV sensors, it has the ability to detect a flame from a candle kept at a distance of 5 meters. The robot makes use of a Hamamatsu UV sensor that is mounted onto the Trekker sweeping sensor brackets. The following features of Hamamatsu UV TRON Flame Detector make it desirable to use[1]:

a) Lightweight
b) Low current consumption
c) Operates as high sensitivity UV Sensor
d) Narrow spectral sensitivity of 185 to 260 nm makes it solar blind, being completely insensitive to visible light
e) Does not require optical Visible-cut filters, thus making it easy to use

The Authors of the paper, 'Development of a Fire fighting Robot for Educational Competitions' [2], used two approaches to allow the robot to detect fire,

a) Detecting Temperature, makes use of temperature sensors that detect the change in surrounding environmental temperature to detect fire
b) Infra-red detection, makes use of some pairs of LED photo detectors to get detect changes in the infra readings in the environment.

B. Microcontroller

The microcontroller used is a SMCL type or Motorola 6808/8051. The micro controller is Atmel or SMCL flash type's reprogrammable controller. [1]

The Robot developed for the competition [2] makes use of PLC. A PLC is equipment with many capabilities like network communication and complex calculation. The PLC is a SIEMENS S7-1200 family

CPU, specifically the CPU 1214C, that among other things, offers 2 PTO (Pulse Train Outputs) used to generate pulses to control the drives.

Most of the coding for the Robot is done in Embedded C, as if it a familiar language and it also provides a wide range of libraries that can be used by the coder.

C. Mechanical Structure of Robot

1. Overall Body of Robot

The fire fighting robot is constructed using aluminium frame. The contour of the fire fighting robot is cylinder. The diameter is 50 cm, and height is about 130 cm.[1]

The fire fighting robot that was developed for the purpose of the competition [2] had to be bulkier, having a weight around 25 kgs as it made use of a pneumatic system that is heavy and required a strong body framework that would provide the robot with the required stability.

2. Power Source

Fire extinguisher system will use a nominal voltage of 12.0V at most. The battery provides maximum power of 65 W and an average power of 7.8 Watts. It makes use of an auto charging system.[1]

The Robot makes use Two sets of batteries (24V = 12V + 12V) are used to power the robot. One is connected to drives and motors, while the other one provides PLC power, thus avoiding noise problem due to current peak while starting the motors.[2]

The power source must be good enough to ensure that the robot is able to successfully reach the source of fire and extinguish it. The decision of choosing a power source is a very crucial one as it ensures that all parts of the robot are able to work in an optimum manner. Too much of power could result in the hardware parts overheating or the robot to uncontrollable race. Too less power the robot may function in a very inefficient manner or not function at all. The concept of making use of an auto charging system is a good one but it also adds to the complexity of the system.

3. Motor

DC motors are generally more powerful than servos in terms of speed and torque. Microcontroller could not accurately control DC motors without a motor controller. The Robotic System makes use of 2 DC Servo motors, the command over which is possible by means of motion control card and driver devices. [1]

Step motors: The total mass allowed for the robots in competition is 25 Kg. Step motors were sized by compromising their weight against the torque needed to move the robot. In fact, the motors were oversized to avoid problems when moving the robot. [2]

IV. WORKING OF THE ROBOTIC VEHICLE

The Robot developed by the Authors [1], were divided into the following systems, the general structure, the obstacle avoidance and driving component, software development system, fire detection and the remote supervision system. The robot makes use of 8 ultra-sonic sensors to accurate detect the distance of the robot from the fire source. The sensory devices constantly provide data to the Micro controller, which interprets this data to detect whether a fire is present within its vicinity or not. Once the fire is detected, the fire alarm is set, the robot moves towards the source of fire and the fire is extinguished using a sprinkler device.

The robot for the Educational Competition by the authors [2] was built in stages with the aim of constantly improving on the design and the efficiency of the robot and at the same time to meet the criteria that was given to them. The basic model composed of an infra-red sensor to detect the fire and pneumatic system to extinguish the fire. On detection of fire by the sensors, PLC would set the fire alarm, the authors initially made use of an open loop system for co –ordinate detection and motion towards the source of fire. The authors realised that a closed loop system would work more efficiently, especially in a situation where the motion is to take place in a 3D plane. Various algorithms for path detection and tracking was tried and tested by the group to reach the fire in the least amount of time, when the source of fire was detected, compressed air will be used to extinguish it. The pneumatic system pumps air till the tank is empty.

The goal of the fire fighting vehicle is to extinguish fire in the least possible time and in an efficient way that would help save life and property. The robot must be of a heat resistant material to withstand high temperatures and prevent any damage to the robot. The most important step in developing a fire fighting robot is the sensitivity and accuracy with which it can detect the presence of a fire as it acts as the triggers for the robot to get into action.

V. COMPARATIVE ANALYSIS

A. Comparing the features of the robots

The robot developed by the authors [1] is more suitable for the task of extinguishing a fire in a 2 D scenario. The use of water to extinguish fire makes it ideal for use in case of fire caused by non-electrical sources. The use of differential turn by the authors in the robot is good for practical use as it helps to avoid collisions that might occur in a real life scenario. The light weight and size of the robot is an added advantage.

The robot that was developed for the competition [2] is more practical to use in a real life scenario as it considers motion in a 3D plane. The robot is also able to avoid obstacle that might come in its path. It makes use of compressed air to extinguish fire which can be used in a wider range of fire extinguishing tasks. But this also adds to the weight and increase in the overall size of the robot.

The combinations of the above features is highly desired as the fire fighting robot in a real life scenario will have to deal with a multitude of hurdles before it can reach and extinguish the fire. It is highly desirable for the robot to be self-starting i.e. it should be sensitive to change in environmental parameters. Once the robot detects the presence of fire within its range it should be able to overcome obstacles and move through uneven terrains. [3]

B. Comparing the overall structure of the robots

1. Ability to detect fire

The robot in developed by the authors in the paper, 'FIRE FIGHTING ROBOT : AN APPROACH' [1], makes use of UV TRON Flame Detector. This good in detecting fires in certain conditions only and but it is easier to implement as it doesn't require additional filters and at the same time is inexpensive.

The robot developed for authors [2] made use of Infra-red sensors to detect the presence of fire in its vicinity. It was found by the authors that the use of infra-red proved to be better, as its response was faster and more accurate than temperature detection

Even though UV sensors have a lot of desirable features, yet it is not suitable for detection of fire. A combination of Infra –red and smoke sensors make an ideal combination for detection of fire as it can detect fire from other sources as well.

2. Mechanical structure of Robot

The robot developed by the authors [1] is compact and cylindrical is shape and lightweight and makes use of an aluminium framework. While the fire fighting robot that was developed for the purpose of the competition [2] is bulkier and weighs around 25 kgs.

Aluminium is a good choice for building small and medium scale fire fighting robots as it is pretty cheap, light, strong, resistant to corrosion and easy to work with, however, it is not suitable for the purpose of load bearing.[5] Steel is stronger than aluminium and offer more benefits of being easier to solder. It is suitable for use in rough terrain but not suitable for medium sized or small sized robots.

3. Comparing the working and the efficiency of the robot

The robot [1] makes use of 8 ultrasonic sensors that aids the robot to calculate the distance that must be traversed to reach the source of fire. Use of a large number of sensors increase the overall range of the robot but has to process a larger number of input received from these sensors. The robot makes use of UV TRON Flame Detector to detect the source of fire and raise an alarm. Being light weight and also because of its ability to take a differential turn, it is ideal to use on a flat terrain. The robot is able to move at a speed of 2.5 ft/sec which reduces the time to reach the fire source but increases the complexity that is involved in coding the stopping condition of the robot, as the robot risks getting too close to the fire source.

The robot that was developed for the educational competition [1] made use of an open loop system, and then finally a close loop system to implement the model. The robot was built in stages with constant improvements and modifications made to it so as to suit the requirements of the competition. The overall model is more practical. The authors made an attempt to implement path tracing and obstacle avoidance. The robot is slower as it moves by means of a robot chassis and also it is bulky as the pneumatic system using a compressed air cylinder

VI. CONCLUSION

This paper attempts to give a detailed comparative study of the approaches that the authors of the two papers have taken in an attempt to build a fire extinguishing robot and the have compared them in terms of their logics, hardware and software components, that determine the efficiency of the robot in dealing with a fire accident. A fully autonomous fire fighting robot could help save lives and operate in an environment where humans can't reach, in the quickest of time.

REFERENCES

[1]. Ratnesh Malik, S. S. Kumbhalkar, 'Fire Fighting Robot: An Approach', Indian Streams Research Journal, Vol.2, Issue.II/March; 12pp.1-4.

[2]. Taiser T. T. Barros, Walter Fetter Lages, 'Development of a Firefighting Robot for Educational Competitions', RiE 2012, Prague.

[3]. V.J. Lumelsky and A.A. Stepanov, "Path Planning Strategies for a Point Mobile Automaton Moving Amidst Unknown Obstacles of Arbitary Shape", Algorithmica, Vol. 2, No. 4 pp403-430, 1987

[4]. Goto, Y. Strntz, A., "Mobile Robot Navigation: The CMU System", IEEE Expert, Vol. 2, No. 4, winter, 1987

[5]. Martin, F. Robotic Explorations, a Hands-On Introduction to Engineering, Upper Saddle River, New Jersey: Prentice Hall, 2001.

[6]. Ren C. Luo, Kuo L. Su, 'Autonomous Fire-Detection System Using Adaptive Sensory Fusion for Intelligent Security Robot', IEEE/ASME Transactions On Mechatronics, VOL. 12, NO. 3, JUNE 2007

[7] Alexander Zelinsky, 'A Mobile Robot Navigation Exploration Algorithm', March 2001.

[8] Chia Song-Hiang, Su Hsu-Shan, 'Mobile Robots Based Intelligent Fire Detection and Escaping System', October 2012.