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Control Of An Autonomous Industrial Fire Fighting Mobile Robot

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ABSTRACT

This paper describes the construction and design of a fire fighting mobile robot (FFMR). The system controls two optically isolated D.C. geared motors. The robot performs analog to digital conversion on 5 infrared sensors: two to control the motion of robot and three for candle detection. The extinguishing system is comprised of a D.C. water pump and a water container. The experimental results are included to illustrate the detailed operational mode of the FFMR.

Keywords: Autonomous Mobile Robot, Micro-controller, Fire Extinguisher, Candle, Pump and D.C. geared motor.

INTRODUCTION

Robot is a machine that looks like a human being and performs various complex tasks. There are many types of robots such as fixed base robot, mobile robot, underwater robot, humanoid robot, space robot and medicine robot etc. Fixed based conventional manipulators have limited workspace due to their fixed based structure. It is possible to increase the workspace of the robots by a mobile platform. These types of robots are called mobile robots and play an important role in mining, military, forestry and security etc. Mobile robots have many applications where human lives are very dangerous, for example: extinguishing fire in tunnels, in industries, hospitals, laboratory and in house uses.

Control problems are very complicated due to external disturbances and robot environment. In the past literatures, many algorithms have been developed to design or improve the model for fire fighting robots (1–5). In (6), a fire fighting robot that detects fire with multiple sensors is proposed. A new swarm robotic platform for a fire detection task called FiFiBot is proposed in (7). In (8), an intelligent sensor based security system that contains a fire fighting system in our daily life is designed.

In this paper, an autonomous fire fighting mobile robot (FFMR) is proposed. The robot performs analog to digital conversion on 5 infrared sensors: two to control the motion of robot and three for candle detection. This paper is presented as follows. System model, block diagram and components are included in Section II. Experimental results and discussion are included in section III. In Section IV, applications of FFMR and future improvements are presented. Section V gives conclusion.

METHODOLOGY

System model, block diagram and components

The Figure 1 shows block diagram of the system. The basic theme of this paper is to sense the flames coming out of fire and ultimately extinguish fire. For this, infrared sensor is used as input sensor which is connected at different levels of the robot chassis. The infrared sensor senses the infrared rays coming out of the fire and it feeds the signals to the microcontroller. The microcontroller in turn control the extinguishing system. The pumping motor in extinguishing system controls the flow of water coming out of pumping system. Also for the control of movement of robot, infrared sensors are used. These sensors send the signal to the microcontroller telling it whether they are on the black line or white line. Accordingly the microcontroller performs a set of operations and controls the robot movement through D.C. geared motors. This is fully automatic process and no manual support is needed. In this paper, microcontroller Atmega 32 is used. The Atmel is good platform for robotics application. Thus the real time fire extinguishing can be performed.

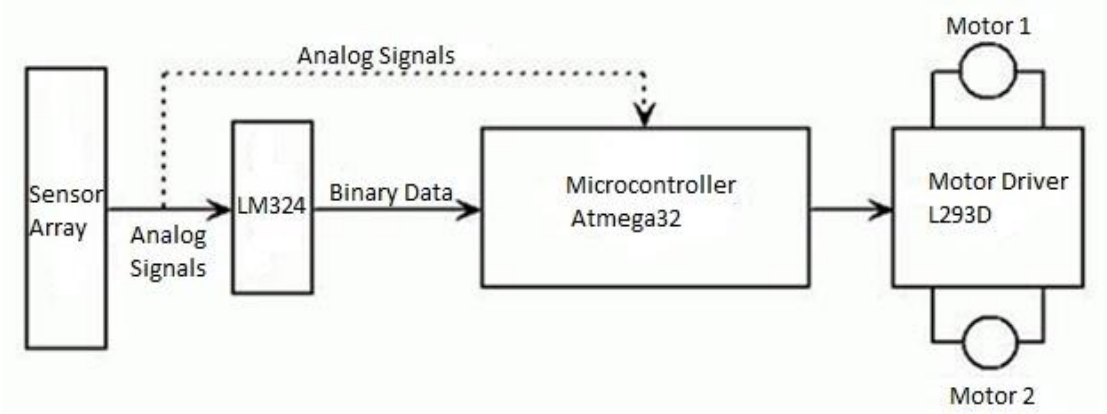

Figure 1. Block diagram of industrial fire fighting robot

Microcontroller

A microcontroller is a computer on a single integrated circuit containing memory, a processor core and programmable input/output peripherals. It is designed for embedded applications.

The Atmega 32 (Figure-2) has the following features: 1024 bytes EEPROM, 2 Kbyte SRAM, 10-bit ADC, 32 Kbytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 32 general purpose I/O lines as shown in Figure 3. The other details related to the microcontroller are similar as given in reference [9-10].

Figure 2: Atmega 32

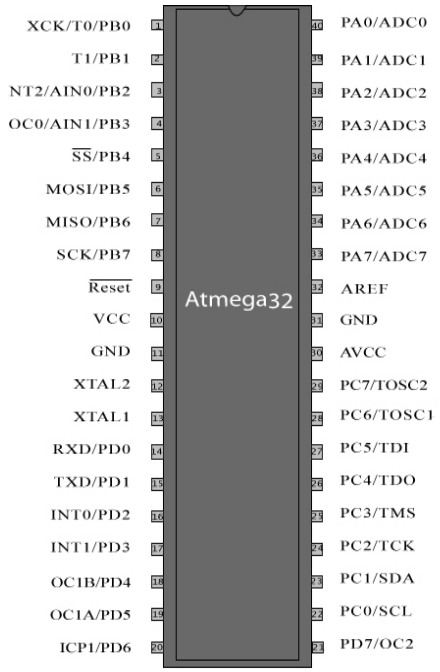

Figure 3: Pin diagram of Atmega 32

Mechanical Part -The robot is based on the four wheel drive system which provides more stability to the robot. The chassis is made of hard plywood so that it can bear the weight of all the components.

Motors – Four 100 rpm motors have been used to run the robot. The motors give high torque due to which robot is able to maintain balance between speed and weight.

Power- A 6-9 V rechargeable battery or a 9 V D.C. adapter can be used as power source.

Pumping System: The pumping system consists of a mini submersible type water pump that works on 6 V D.C. and a water tank. It is extremely simple and easy to use. A small pipe is used to carry water from pump outlet.

Sensors: An infrared sensor is a sensing device that picks up radiation in the infrared band. Infrared detection works because fire gives off heat, which emits radiation in the infrared band. Five infrared sensors have been used for the motion of robot and flame detection purpose.

RESULTS AND DISCUSSION

In industries, robots have a predefined path for motion. In this paper, we have the following arena for motion of a fire fighting mobile robot.

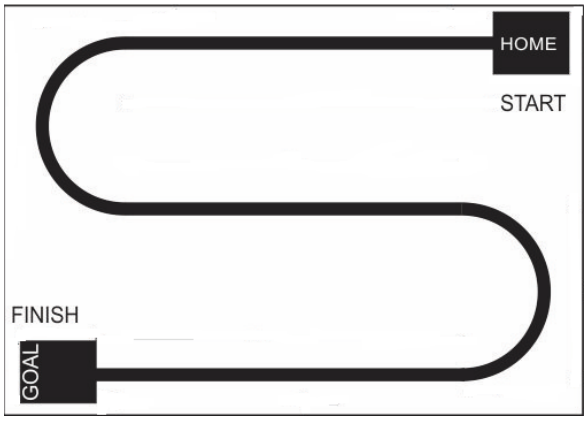

Figure 4: Arena for movement of FFMR

In this paper, the following fire extinguishment robot model is developed and its performance is shown in figures 6-8.

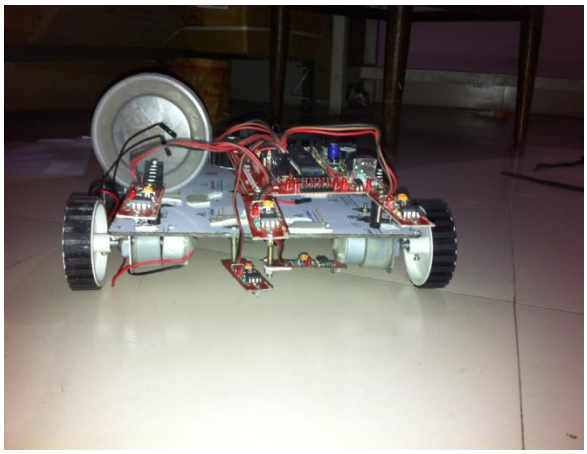

Figure 5: Fire fighting mobile robot

The FFMR moves to the fire location and use five infrared sensors to detect fire event. If the fire event is true, the FFMR must fight the fire source using extinguisher.

Whenever a flame gets detected by the robot, its motion will stop and the pumping mechanism of the robot gets turned on to extinguish the fire with the help of water. Robot will be able to detect flames coming out of fire if a fire blows up in or around its path. Since a small amount of water can also decrease the intensity of flames coming out of fire, therefore the pumping mechanism will work for a definite amount of time to ensure that the fire is completely extinguished. There is no doubt that different kind of fires need different type of fire extinguishing material. Therefore every material should be tested. But for now we will consider water as our major extinguishing material which can be later on replaced by best suited extinguishing material for a particular type of industry.

In Figure 6 and Figure 7, the robot is following its path using PID controller. The robot continues to do so until and unless it detects fire which is shown in Fig 8. After that the robot performs operations as explained in section IV.

Figure 6

Figure 7

Figure 8

IV. APPLICATIONS OF FFMR AND FUTURE IMPROVEMENTS:

Some of the advantages of industrial fire fighting robot are:

- Can be used as a mobile surveillance system.
- Can be used as a fire extinguisher at places out of human reach.
- Can be used in security system.
- Can be used in chemical and oil industry, nuclear plants, mine fields and dangerous substance transport.

The present work can be extended in several ways and some of them are given below:

- For detecting fire with 100% accuracy so that the robot can differentiate between industrial fire and an ordinary flame, we will be adding three more type of sensors i.e. temperature sensor, smoke sensor and thermal sensor.
- To save people who get trapped in the fire, we will again use transmission of wireless signals to the fire fighting person so that they can easily locate the people and hence save a lot of precious time
- We can replace water in pumping system with pressurized carbon dioxide to fight with fires caused due to electric short circuits.
- For domestic use, we will try to implement motion planning using neural networks so that the errors can be minimized in mapping of the house.

In this paper, the robot is limited to work in an environment which allows it to move on a particular path. This path can be laid only in industries which offer other equipments which are non mobile. But since every industry doesn't offer this type of environment, therefore the robot cannot be used in every industry. Therefore to use the robot in every industry, we will be using the SLAM (Simultaneous Localization and Mapping) technique so that the robot moves in directions having no obstacles and thus explore each and every corner of an industry. Moreover for obstacle detection we will be using a sonar sensor and an infrared sensor.

For the fire detection purpose infrared sensors have been used but IR sensors can give false reading. Therefore to minimize the error, we will add smoke sensor, temperature sensor and a camera for image processing using MATLAB.

CONCLUSION

This paper gives a detailed mechanism about the real time industrial fir fighting mobile robot that can move through a model structure, find a candle and then extinguish it with the help of pumping mechanism. The movement of the robot is controlled by the sensors which are fixed on the mobile platform. Experimental results are carried out for a four wheel mobile robot to illustrate the proposed methodology. The results show that the proposed robot model is successfully implemented.

ACKNOWLEDGMENTS

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