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Unmanned Firefighting Robot

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Abstract: The area of firefighting has always been one of the most dangerous one and there have been many losses of lives because of lack in advancement of technology. The methods currently applied in the field of firefighting are inadequate and inefficient and also they are relying heavily on humans who are prone to error. There has been always a threat to human firefighters lives during any explosions or any radioactive blasts where even extensive quality suits are of no use. There has been a recent trend that is to use robots instead of humans to handle fire incidents. This is because they can be used in situations that are very dangerous for any individual to involve themselves in. In our project, we develop a set of robots that is able to locate humans and extinguish fire in a given environment which is out of human reach. The robot navigates the effected area and avoids any obstacles that it faces in the process of its excursion. The infrared camera embedded robot will inspect intelligently inside the affected area so as to find the presence of human lives. The other robots will help in fire to get extinguished from a range where human reach is not possible. Because of this we can save the human lives inside the affected area without putting the lives of firefighters to a threat.

INTRODUCTION

Firefighters are the first responders to any kind of hazardous situation. Over the years, throughout the world, fire losses remain high and firefighting is strenuous and dangerous. Robotics are playing important roles intelligently as well as technologically that assist the emergency responses in harsh and hazardous firefighting environments which prevents operational personnel from entering inaccessible or unsafe regions. The firefighter plays a vital role in the excursion of fires during the period of incidence. There has been always a threat to the system of firefighters in many fire conditions. It has been very difficult for the firefighters to cope up with the losses of firefighters. In conditions which involves the explosive fires there has been always a high rate of deaths in terms of the firefighters who are considered to be the saviours of human lives (Fig. 1).

Similarly in case of fire accidents in the radioactive areas like that of any nuclear blasts there is also a threat for the human firefighters by the gases emitted by the radioactive elements. In these type of conditions its very difficult to locate the humans that are struck inside the affected area. So, to minimise the losses to the lives of human firefighters there has been always an urge to develop a robotic based firefighting system. A considerable body of unmanned remotely driven response robots has proven to lower certain risks for the emergency

Fig. 1: Firefighters killed in massive explosions

Fig. 2: Firefighting robot

team. They assist the responders and the experts with many new and innovative ways. The unmanned firefighting system is capable of extinguishing fires in dangerous areas like explosive fires and radioactive fires where there is always a threat to human firefighters (Fig. 2).

Concept: In our daily life, fire accidents are very common problem. This causes a great damage to property, economy and also losses to many lives. Fire accidents having serious consequence in terms of loss of human life, injury, damage to property. The concept of the model is to detect and extinguish fire using unmanned robotic firefighters. It will help to reduce the loss caused to human firefighters in the process of fire extinguishing and also will help to detect the humans stuck inside the effected area.

Existing system

Human based firefighter: The current system of firefighter involves the human powered firefighters. The human firefighters are able to extinguish the fires in the affected area. In this system the firefighters are carried to the affected area using the firefighter truck. This truck consists of water or foam according to the situation of the fire. The firefighters have to carry the pipes in the direction of fire and start to extinguish the fire. This system is totally dependent on human power and requires a lot of labour.

Fig. 3: Firefighting Robot helpful during explosive fires

Robot based firefighter: The other system that is on the way of implementation is the robotic firefighters. It has not been implemented globally but this system is likely to be implemented within few years.

Proposed system: Unlike the old method of fire extinguishing in which humans act as the firefighters our proposed system consists of robotic fire fighters powered by humans[1].

To diminish the disadvantage of the existing system where there is always a threat to human lives in explosive and radioactive areas, we implemented a set of human powered robotic firefighters. These are able to extinguish fires and detect human lives in the extreme conditions where its almost out of human range (Fig. 3).

This firefighting system consists of two sets of RC robots. An army of firefighters which will extinguish the fires from outside the affected area. The Inspection head embedded with infrared imaging camera goes inside the affected area and searches for the humans in the affected area. This system is able to extinguish fire in dangerous situations as well as its able to detect humans in the affected area.

Needs and requirements of robotic firefighting systems: In recent years, there is a growing conception in both scientific and technological field that being “smart” means to significantly enhance the self-determination of the system, in a manner that common human errors and faults can be sufficiently avoided. The concept of “smart” should contain the system autonomy or freedom and more importantly, system flexibility to many possible internal disturbances as well as external structured and unstructured disturbances. In this regard, smart can be featured as physical and cognitive incorporation and interactions of humans, machines as well as organizations to enhance and improve the system performance and manipulate the system resilience.

Exposure to the hazardous and chaotic fire environment, rather than to the fire itself is the most significant cause of injury and death in fires. The reachability of precise information in real-time on the

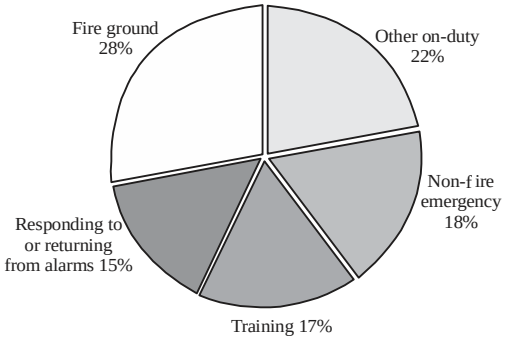

Fig. 4: Deaths of firefighters during duties

conditions directly at the center of the fire ground is a crucial factor in the guidance of rescue actions along with many feasible counter-plans. Unfortunately the firefighting environments are normally hard to reach and restricted in accessibility by obstacles, tumbledown architectures and visibility by smoke, dangerous gasses or dust. The search and rescue operations are beforehand unimaginable due to lack of situational conditions and real-time information for targeted decision making.

By the research we came to know about the difficulty of firefighters in the search operation of the individuals. The camera is not capable of detecting the overall internal views of the fire incidents. So, there is always a need for an automated system which will be able to detect the whole scene of the fire effected arena. During the fire incidence the smoke provides a difficulty in the process of excursion of fires. The visibility for the firefighters reduces and which becomes a setback for the firefighters. So, to recover this problem, there needs to be a system which will be able to reduce the smoke hindrance for the firefighters (Fig. 4).

By research we came to know that every day approximately 55 firefighters dies every day in the world. This needs to be reduced, so as to provide a security for the lives of human firefighters. A huge amount of researches has been devoted regarding human behaviour in fires and the simulation of the movement of individuals in such hazardous environment.

The entry time of firefighters and escaping time of individuals are largely depending on the obstacle free path of firefighting and rescue paths. Currently, robots do not fulfil the needs sufficiently for human firefighters.

To date, the functionalities of the firefighting robots are restricted into information collection, flame detection, remotely fire extinguishing, etc. and conventionally no heavy physical tasks are assigned. Despite considerable advancements in the development of sensor technologies and robotics for the fire excursion process there has been little interaction between robots and humans.

MATERIALS AND METHODS

Components: There are many different types of components that have been used to simplify the diagrammatic approach towards the design of the unmanned firefighting robots. The mainly used sensors are the various types of sensors and different interfacing devices governed by the MCU. Few components are listed below:

Temperature sensor: In the temperature sensor the transducers are used for the exact measurement of temperature at the point of incidence. It gives the electrical output to the existing temperature. The output voltage of the temperature sensor directly depends upon the Celsius temperature.

Smoke sensor: It is a colloid which consists of airborne liquids and solid particles as well as the gases emitted by combustion. Smoke is a undesirable consequence of fire. The smoke sensor detects the smoke and provides the required output to the MCU.

Flame sensor: A flame sensor is a flame detector which has been designed to detect and respond to the presence of any flame or fire.

Micro controller: MCU is the main controlling unit of the system. It takes or reads the data from the sensors and controls all the functioning of the system by manipulating the received data.

MCU also controls the movement of robot. If the sensor outputs are detected to be higher than the preset values then it indicates the existence or presence of fire. It also operates the water pump mechanism according to the need.

Motor driver: The motor driver is used to provide an interface between the logic signals from the MCU and the high current as well as the high voltage power, to drive the motor.

Optical indication and audio alarm: For indicating the conditions of the sensors, optical indicators are used. Mixed colour LEDs are used here. Microcontroller unit will turns ON only if any of the sensor output will be high and hence the microcontroller unit will turn ON the audio alarm for signalling the condition to other sensors.

Relay and driver circuit: A relay driver IC is an electro-magnetic switch that will be used whenever we want to use a low voltage circuit. To attach a relay with a microcontroller, interfacing is required Water pumps controlled using relay as they have inductive loads. Relays and the pins in the processor have driver circuit in

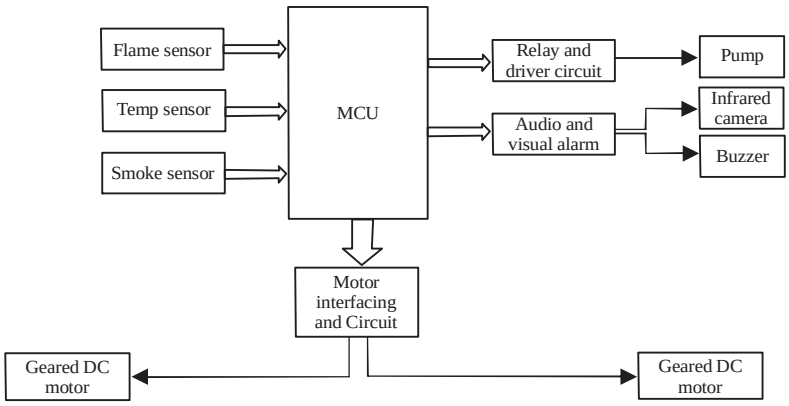

Fig. 5: Architecture of the firefighting robot

between them. For boosting the current the output of the MCU is fed to the relay circuit. The result is magnetization of the relay.

Water pump: It helps to pump water at the required. It works on the output and signals from the processor. When excess smoke, temperature and flame is detected it starts pumping water. As instructed by the microcontroller unit, the relay becomes energised when it is connected to the water control unit.

Infrared waves: The wavelengths which are visible up to 1mm are known as IR waves. IR photodiodes help us in detecting fire as when a fire burns or a flame is present, then a infrared wave is emitted from the source which can easily be detected the IR photodiode. This technique is used to design a sensor board.

Rf module: An RF module or a radio frequency module is a small electronic device which is used for transmission and reception of radio signals between two devices. Without any physical connection, transmission and reception of serial data is possible.

Architecture: The interconnection of all the components present in our system defines the architecture of the system. The widely used sensors i.e., the flame sensors and the temperature sensor plays a vital role in our system. The MCU (Micro Controller Unit) is the main central unit of the system. All the sensors detect the conditions outside environment and sends the data to the MCU. The MCU senses the data and sends it to the relay and the driver circuit. The pump acts according to the signal received from the MCU. The audio and visual alarms also receive the signal from the MCU. According to the signals the infrared camera starts to operate and the buzzer starts to buzz as soon as it sees any humans trapped inside the affected area (Fig. 5).

Circuit diagram and working

The robot is able to detect fire and extinguish it in different stages as mentioned below: Mode 1(Automatic Mode)-Stage 1: Detection of Fire: In the circuit diagram of the sensor module, IR photodiodes are reverse biased. The cathode or the terminal where current flows out are connected to the 5V through, the resistors of 1M (milli ohm) each. Voltage is given as input to the ADC pins of microcontroller device (ATmega16) across the photodiode. Anodes or positively charged electrode are attached to the ground state. When IR or infra-red waves fall on the infrared photodiode, the resistance of the IR photodiode falls down from 850-350kΩ which in turn reduces the voltage across the photo diode. This causes the voltage to alter at the ADC pin. By proper quantization or signal processing, the absence and presence of the flame can be determined. IR photodiodes are connected to the sensor board to helps us detect the fire. The LED light glows only if fire is detected. The cone or gap of detection of the IR photodiode is quite large which causes a disturbance and hence decreases the resolution and consistency of the system[2]. By properly covering and guarding the IR photodiodes, this problem can be solved (Fig. 6).

Specimen code for autonomous mode

```
For remote (transmitter)
[stextbox id = ”grey”]
if (check_bit (&PIND, 4) = = 0)
{
{I = ’h’; //autonomous mode
printf (“%c”, i)
}
For robot (receiver)
while (1)
{
scanf (“%c”, &ii)
_delay_ms (10);
switch (ii)
{
{case ‘h’: //autonomous mode
autonomous()
break
[/stextbox]
```

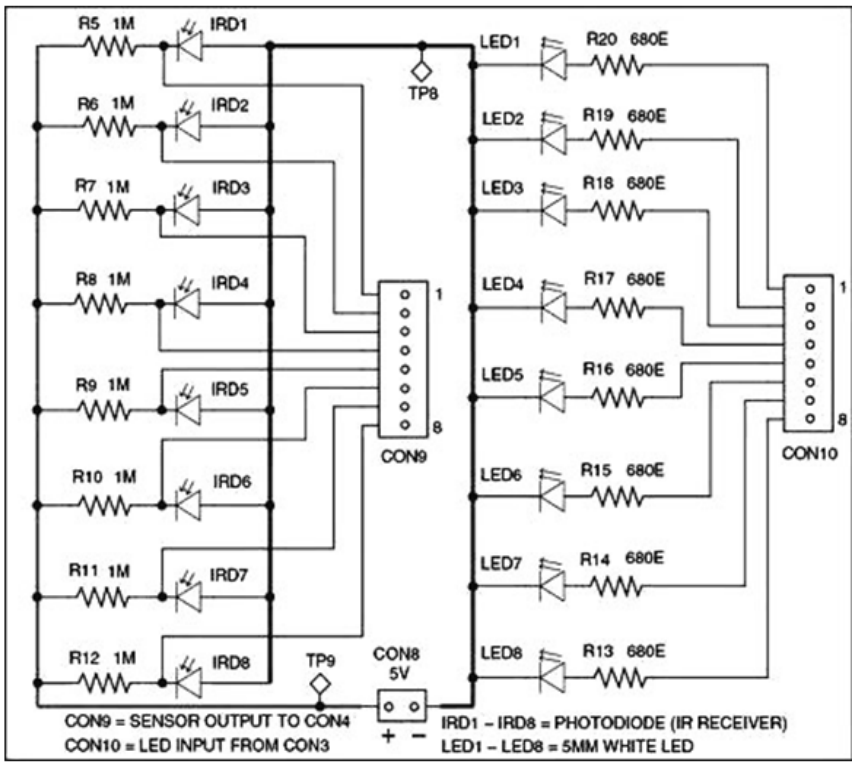

Fig. 6: Circuit diagram of sensor module

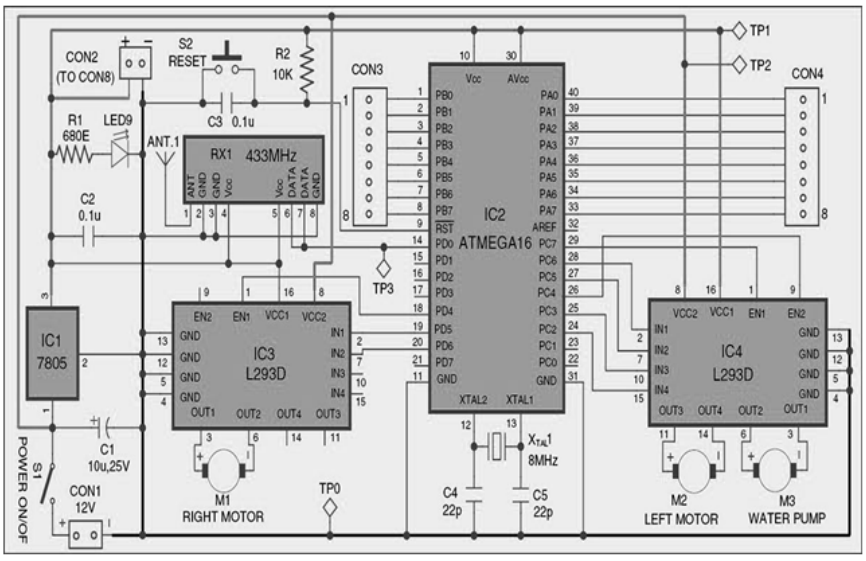

Fig. 7: Circuit diagram of main module

Stage 2; fire extinguishing: The sensors give a constant feedback which is fed to the main module. This helps to find the position of the fire with respect to the robot[3]. The main module of the firefighter contains an Atmega 16 micro controller device, two L293D stepper motor driver ICs to drive the motors, a water pump and RF receiver. The basic requirement of the process is to get the orientation of the front sensor in such a way that it is in front of the fire, so that, the nozzle of the water pump places itself directly above the fire source (Fig. 7). When this position is achieved, the pump starts and extinguishes the fire. The robot moves with the help of two stepper

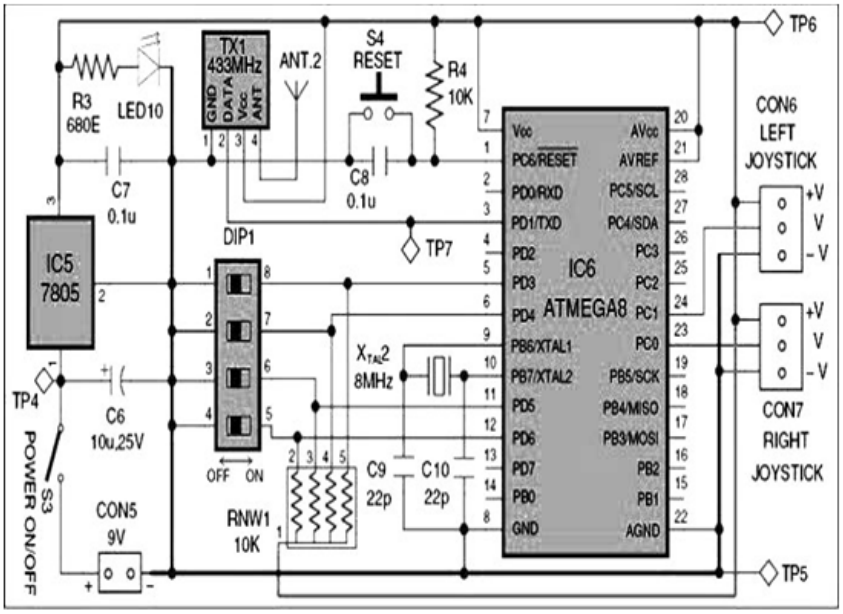

Fig. 8: Circuit diagram of RF remote

Table 1: Mode selection using switch

Mode select	PD3	PD4	PD5	PD6
Manual	1	1	1	1
Reset	0	1	1	1
Autonomous	1	0	1	1
Water pump on	1	1	0	1
LED test mode	1	1	1	0

motors. The sense of rotation of the stepper motor is controlled by the controller. It works according to the feedback from the sensor module.

Mode 2 (manual mode)-stage 3: Radio Frequency Module Communication: The firefighting robot is controlled by the operator with the help of a wireless remote controller (circuit diagram) that uses an RF module for the communication purpose with the robot Table 1. The remote consists of switches, push buttons and joysticks which controls the overall movement of the robot. With remote the human firefighter can control the speed and also the direction of the foam/water which is going to be the throughput of the pump[4].

For each and every command, the remote sends a specific character to the robot it is received and the corresponding operation is performed according to the signal recieved (Fig. 8).

Stage 4; Detecting humans using the infrared camera: The final stage of the robot includes the detection of humans inside the affected area. The robot navigates the arena and uses the Infrared camera to detect the if there are any humans inside the area. If it detects then using the buzzer it indicates the human firefighters about the victim inside the arena (Fig. 9).

Fig. 9: Infrared camera human detection

RESULTS AND DISCUSSION

The unmanned firefighting robot is able to move in all direction as it's a RC controlled robot. It can easily detect fires and is very helpful in the process of extinguishing of fires in dangerous areas. The robot is able to detect humans stuck inside the affected area by the use of the infrared embedded camera onto it. It is also able to assist the human firefighters in the areas where there is a high risk of death to the human firefighters. This robot is helpful for the reduction of deaths of human firefighters.

CONCLUSION

The fire extinguishing robot designed is an amateur attempt at creating an unmanned firefighting machine

which aids the human firefighters in fighting with the perilous situation of fire. When the fire occurs in buildings, factories and some closely packed areas then there is always a difficulty for the human fire fighters to reach out.. Similarly in case of explosive fires there was always a threat for human firefighters. In such cases, a robotic firefighter, as designed in this project, can be very efficiently used for fire fighting, with precarious free human intervention. The conclusion is to provide security for human life and also for the human firefighters. To reduce the death tools of human firefighters this sensory based firefighting robot system is introduced. This will reduce the amount of death tolls of human firefighters and will help in fire extinguishing with least human intervention as well as with high accuracy.

Future scope: Based upon the responses and reports obtained as a result of the significant development in the working system of the robotic firefighting system, the project can be further extended to meet the demands according to situation. In the future, this project can be expanded in the field of Artificial Intelligence (AI) as well as Machine Learning (ML). using these upcoming technologies, this system can be implemented in a very great manner and also the possibilities of errors will be reduced. AI can be used in place of infrared camera for the detection of humans trapped inside the fire affected area. The sensors used can be modified to good ones i.e. sensors having filters which will be a great means to minimise minor errors.

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