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Fire extinguishing robot (autonomous and fire proof)

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Abstract

In the recent years of development, Robot has become a part of our surrounding. Everyday there are experiments are performed to increase the ability of these machines to work on their own on the basis of AI integrated circuits and feedback or support system. With the development in the field of robotics, human intrusion has become less and robots are being widely used for safety purpose. The robot development is consisting of three elements which is the hardware, electronic, and programming. The robot has three DC motor, two for driving system and another single DC motor for ball suction subsystem and the fire blowing subsystem. Various sensors are also interfaced as a feedback to the robot such as photoelectric sensors, fibres optic sensor and RGB colour sensors. LCD display also gives the graphical information of the robot status to the user. For the programming part, C language is used to determine the robot action gain from the sensors input. This project, which is our endeavour to design a fire fighting robot. Comprises of a machine which not only has the basic features of the robot, but also has the ability to detect fire and extinguish it.

The need of the hour is making a device so fire proof material so that it can withstand the high temperature and compact and efficient to go through narrow passages like small passages balconies etc. The main purpose of the device should be that it can detect fire, even if it is small and take the necessary action to put it off. Many house hold item catch fire when someone is either sleeping or away and that lead many hazardous conditions in the fire is not putted off in time. till the present time, there are various form of robot and human communication are established by the use of Bluetooth communication between android smartphones and microcontroller, Arduino, etc.

Now there is a need AI controlled self-sensing Robots which can detect even a small hazardous fire and immediately come to effect and life of various creature can be saved.

Keywords: fire extinguisher robot, fire-fighting, micro controller, remote control robot, sensor, AI integration

1. Introduction

In the recent year of Indian development, we have witnessed several people have died due to the late action of Fire department to reach the point of incident. It was very difficult for them to reach the location in time as the place was in very dense and crowded area and the passages leading to the incident pace is also very narrow and difficult to withstand the high temperature. There was also the high risk for the life of the fire-fighting team. The recent news of fire broke in New Delhi area in which around 40 people died and 60 people were injured and rescued. This problem led to the development of compact autonomous and fire-proof robot which can pass through the narrow passages and go inside the affected area and self-apply the fire extinguishing function to blow out fire in effected region. This can help in fighting the need of automatic and efficient way to cope with fire incident having very high risk of endangered lives.

This research is dedicated to the development of such firefighting robot which can efficiently cope with the fire control in area which is difficult to reach by human force and also to develop the robot which can withstand the high temperature during action without failing. Technology has finally bridged the gap between firefighting and machines allowing for a more efficient and effective method of firefighting. Robots were designed to find a fire, before it rages out of control. The robots could one day work with fire fighters in reducing the risk of injury to victims.

2. Requirements and Challenges of Robot Assisted Fire-Fighting Systems

During the last two decades, there is a growing conception in both scientific and technological domains that being "smart" means to significantly enhance the autonomy of the system, in a manner that troublesome human errors can be sufficiently avoided. As indicated in [5], the concept of "smart" should contain the system autonomy and, more importantly, system resiliency to many possible internal disturbances as well as external structured and unstructured dynamics. In this regard, smart can be featured as physical and cognitive integration and interactions of humans, machines as well as organizations to boost 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 conditions directly at the centre of the fire ground is a crucial factor in the guidance of rescue actions together with 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 Proceedings of the 22nd International Conference on Automation & Computing, University of Essex, Colchester, UK, 7-8 September 2016 gasses or dust. Therefore, the fire scene is an information-poor environment due to lack of information on location of fire, firefighters and victims, and the search and rescue opportunities are previously unimaginable due to lack of situational conditions and real-time information for targeted decision making. It is found that a restricted visual field and obscured cameras augments the distress of firefighters working under pressure. The exposure time of individuals and unobstructedness of firefighting and rescue paths are of paramount importance for the operational efficiency of firefighting and rescue particularly during and after the incidences. The term unobstructedness refers to the guarantee of adaptability to the physical environments change, for instance, ceilings, floors, or walls collapse, furniture relocates. The prevailing high-tech localization and navigation systems are generally not adaptable to these dynamic changes, wherein thick smoke, high temperature, gusts of air, noise, obstacles and falling debris hinder the propagation of the ultrasound, radio, and laser signals conventionally utilized for localization and perception [6]. In smoke laden circumstances with restricted visibility, the exposure time is extremely relying on the dynamic knowledge of the growing fire and the three-dimensional movement of smoke within such environments. Human behaviours (e.g. initial response, movement redirections as well as walking speed [7, 8] make firefighting operation difficult to conduct [9, 10]. A large amount of research has been devoted regarding human behaviour in fires and the simulation of the movement of individuals in such hazardous environment. To date, the prediction and sensing of visibility are typically reliant upon empirical and static data from preinstalled and infrastructure based location systems for various targets and do not take into account the hybrid dynamic concentrations, wherein those systems typically fail in environmental conditions changes (e.g. temperature rises, furniture moves, floors collapse), and power failure. The entry time of firefighters and escaping time of individuals are largely depending on the unobstructedness of firefighting and rescue paths. Currently, robots do not sufficiently enhance human confidence. Necessary capabilities to such robots are the perceived visibility of the surroundings, heavy physical tasks (HPT) such as obstacle avoidance, forcible entry, sweeping and loading to guarantee the paths unobstructedness. Ideally, these capabilities should be available as a function of the dynamic fire environment. 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 firefighting there has been little interaction between robots and human perceptions of visibility as recorded in field trials and the equivalent numerical infrastructure simulations of visibility in a dynamic firefighting scene.

3. Fire-Fighting Robot

Robot

A robot is a machine especially one programmable by a computer capable of carrying out a complex series of actions automatically. Robots can be guided by an external control device or the control may be embedded within. Robots may be constructed to take on human form but most robots are machines designed to perform a task with no regard to how they look. In other words a robot is a machine designed to execute one or more tasks repeatedly, with speed and precision. The branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing is robotics. Robots have replaced humans in performing repetitive and dangerous tasks which humans prefer not to do, or are unable to do because of size limitations, or which take place in extreme environments such as outer space or the bottom of the sea.

Fire Extinguishing Robot

Fire Extinguish Robot Fire extinguishing robot reduces the risk of firefighting. The fire sensor helps the detect fire and smoke, etc. These types of robots are very helpful for fire squad. An automatic fire extinguisher robot is a hardware-based model used for extinguishing the fire automatically during fire accidents. This robot will move in a direction with respect to the fire intensity with the help of ZIGBEE communication. The robot shield is coated with some special material that is capable of withstanding very high temperature. During fire accidents this robot has to follow the black strips on a white floor and can extinguish the fire on the fired place. It takes long time for human to take action on extinguishing the fire. Even if we put fire alarms, it takes long time for the fire brigade to reach the location. By that time, it can cause huge loss of properties. This robot does not require any human presence. It can start extinguishing the fire immediately so that the fire does not spread a lot and can be controlled easily. As soon as the fire starts, human fire brigade is also informed to be on the safe side. The robot finds its applications in rescue operations during the fire accidents where possibilities for service men to enter the fire prone area is very less and also during wars to perform rescue functions. The most added advantage of this robot is that it turns on automatically as it detects the fire around its surroundings by using thermocouple.

Feature

1. This robot can move both forward and reverse direction and can turn in both left and right direction.
2. The movement of the robot is controlled by sensors and manipulators on the basis of feedback provide by sensors or the command given by controller.
3. It can sense the fire using fire high dense smoke with help of sensors.
4. It accumulates a water tank and water pump to extinguishing fire.
5. A power source is used to drive the circuitry.

4. Different fire-fighting platforms

Fire, smoke, darkness, water, power outages and noise may hinder a firefighting, searching and rescue system from working, and the personal protective equipment (PPE), gloves as well as facemasks prevent standard mobile computers from working. Conceptually, a smart firefighting and rescue system should contain risky intervention, information gathering, storage, exchange, analysis, and integration from a variety of sensor networks and dynamic databases for environmental surveillance, decision recommendation and support. Challenges and difficulties are associated with each of the aforementioned domains.

The Snake Fighter, Anna Konda, shown in Fig. 1 is able to push against external obstacles apart from a flat ground and capable of obstacle-aided locomotion and extinguishing fire using a nozzle mounted at the front of the robot, with hydraulic medium in the joint actuation. A combined utilization of water is realized for hydraulic joint actuation, fire extinguishment and robot cooling under high temperature.

LUF60 shown in Fig. 2 is a popular firefighting robot equipping with an air blower and a water beam fog. The monitor nozzle has a flow rate up to 800 GPM and it is capable of blowing the water beam up to 80m. For the sake of enhancing the mobility in the harsh condition of high temperature, rubber track system is equipped with heat resistance rate up to 400 degrees Fahrenheit. The rubber track system also enables the capability of descending and ascending the stairs.

A humanoid firefighting robot, SAFFiR shown in Fig. 3, utilizes a bio-inspired geometry with parallel actuated biped using linear actuators, it is capable of omnidirectional walking, balancing in sea state conditions, traversing obstacles and manipulating fire suppressors.

Parosha Cheatah GOSAFER is designed for rough terrain and capable of operating in several environmental conditions using a 10 road wheels for high mobility. A mixture of water and cutting agent is equipped and being ejected via a nozzle on a glance at high pressure to cut through most of the known construction materials very quickly. A powerful firefighting robot TAF 20 shown in Fig. 4 can sweep away the obstacles via bulldozer blades and clear smoke from burning buildings with a high-powered fan. It is also able to spray water mist or foam from 60m and blast water for 90m. Remote control and operation can be facilitated up to 500m away to send the robot into environments hazardous to firefighters.

Fig 1: The Snake Fighter Anna Konda

Fig 2: LUF60 [13].

Fig 3: SAFFiR [14].

Fig 4: TAF 20 [16].

Thermite 3.0 [17] is a small firefighting robot is capable of fitting into restricted space. It has integrated multiple HD analogy video cameras and optional Infrared (IR) FLIR. As an electrically powered Unmanned Ground Vehicle (UGV), FIREMOTE [18] can be remotely operated through a control panel and tracked outside the dangerous area. The control panel has a daylight viewable monitor that a software dashboard can be displayed with the robot's parameters as well as video feedback for navigation. FIREMOTE is equipped with a monitor, colour navigation camera, local cooling system and variable pattern nozzle. ArchiBot-M [19] has an independent suspension system. It is capable of ascending and descending stairs and working under high temperatures, since it is waterproof and equipped with a cooling system. More interestingly, the Sweden-made firefighting robot Brokk 50 [20] is capable of forcible entry, rescue, excavation, notching, carrying payload within unsafe or extreme environment.

Fig 5: Brokk 50 [20].

The comparison of the prevailing robot-assisted firefighting platforms with key features is presented in Table I. The emerging and prosperous developments of robotics, ICT technologies as well as data informatics have provided a variety of effective and promising solutions to many practical problems in emergency responses. However, open challenges and difficulties alongside huge, complex and tough tasks associated with emergencies in firefighting are still far from being fully addressed. The requirements and challenges are identifies as follows:

Robot	Type	Operating Region	Capabilities	Operating Mode	Perception	Portability	HPI	Country of Origin
Anna Konda	Snake-like robot	Indoor/ Outdoor	Fire extinguishment/ Visual perception	Obstacle-aided Autonomous	Thermometer/ Visual camera	Medium	Poor	Norway
LUF60	UGV	Outdoor	Fire extinguishment/ Smoke dispelling/ Stair climbing	Remote control/ Rubber track system	Visual camera	Poor	Poor	Germany
SAFFiR	Humanoid robot	Indoor	Omnidirectional walking/ Manipulating/ Fire suppression	Parallel actuated Autonomous	Thermal IR sensor/ Visual camera	Poor	Medium	United States
Parosha Cheetah GOSAFER	UGV	Outdoor	Fire extinguishment/ Cutting Extinguisher	Remote control/ Rubber track system	Thermal image camera/ Laser range finder/ Acoustic detection	Poor	Medium	Sweden
TAF 20	UGV	Outdoor	Fire extinguishment/ Smoke dispelling/ Obstacles sweeping	Remote control/ Rubber track system	N.A	Poor	High	Germany
Thermite 3.0	UGV	Indoor/ Outdoor	Fire extinguishment	Remote control/ Rubber track system	3D analog video cameras/ Optional Infrared FLIR	Medium	Poor	United States
FIREMOTE	UGV	Outdoor	Fire extinguishment/ Visual perception	Remote control/ Rubber track system	Visual camera	Poor	Poor	United Kingdom
Archibot	UGV	Indoor	Fire extinguishment/ Stair climbing	Remote control	Visual camera	Medium	Poor	South Korea
Brokk	Excavator-like robot	Indoor/ Outdoor	Demolition/ Stair climbing	Remote control/ Hybrid locomotion	N.A	Medium	High	Sweden

Fig 1: Comparison of Firefighting Robotic Platforms with Key Features

- *Traversability and dexterity*: Higher degree of travers ability and dexterity of firefighting robotic platforms are required for the ease of accessing and operating in areas inaccessible and hostile to humans.
- *Heat/Radiation resistance*: The firefighting operations require the robots to be resistant to heat and radiation and to have impact resistance mechanisms. Besides, the on-board equipment and apparatus such as sensors, machine tools and other on-board components must be heat resistant as well or cooling systems is necessary to provide protection such as water-based cooling system.
- *Supervised and semi-supervised autonomy with effective human-robot (H2R) teamwork*: The robots are required to be controllable via some intuitive H2R interfaces. The robots should be equipped with sensory capabilities (e.g., temperature/gas/pressure/noise sensor, sonar, radar, and camera) and machine tools (e.g., gripper, welding tool, and fire hose nozzle) in compatible with given tasks. Besides, the robots should be able to monitor the fire ground situation and meanwhile, report the collected information to firefighters and command Centre.
- *Portability*: In most circumstances, firefighters are sent to the fire ground as soon as a fire or other emergency is reported. Thus, the firefighting robot needs to be lightweight and convenient to carry to rapidly cope with the fire emergency. Besides, it is also important that the deployed robots can be safely withdrawn by firefighters.
- *3D perception*: In smoke laden circumstances with restricted visibility, the robots need to be capable of acquiring the dynamic knowledge of the growing fire and the three-dimensional movement of smoke within such environments.
- *Heavy physical tasks*: The robots should be designed to perform heavy physical tasks such as heavy payload, obstacle sweeping and force entry when and where needed particularly in search and rescue.
- *Flame detection and fire extinguishing*: A firefighting robotic platform should have the ability of assisting firefighters in fire flame detection and extinguishing with launched or on-board extinguishing medium.
- *Situation awareness and intuitive control*: the firefighting robotic systems should have the capabilities to communicate with the firefighters and to facilitate machine-to-machine (M2M) communications.
- *Dexterous manipulation and manoeuvrability*: A robotic system needs to have the capability of dexterous manipulation and high degree of manoeuvrability to cope with the rough terrain in emergency response, such as omnidirectional driving, adaptation to dynamic uncertainties, climbing over obstacles, ascending and descending stairs, etc.

5. Working Method module

Obstacle detection Module

- To check for the obstacles in front of the Robot.
- If obstacle is found within the range of Robot then take the required action.

Fire detection Module

- The robot will move through the area and detect the fire.
- If the temperature at certain place is more than the threshold set then start the water sprinkler.
- Else if not found then it can continue the search for remaining area.

Fireman Module

- When robot move through the affected area it can operate automatically and if disfunction then can be manually override.
- When obstacle detected the robot will select the different path to reach the location.
- The camera on the robot will allow fireman to analyse the situation and control if any misconduct of robot is found.

6. Working of Fire Fighting Robot

There are several possibilities a fire can start in any remote area or in an industry. For instance, in garments, cotton mills, fuel storages electric leakages will result in immense harm. Also, it's a worst-case scenario, causing heavy losses not only financially, but also conjointly destroying areas surrounding it. Robotics is the rising answer to guard the human lives, wealth and surroundings. A Firefighting robot is designed and built will be designed with an embedded system. It should be able to separately navigate through a modelled floor plan, whereas actively scanning for aflame. The robot will even act as a path guide in normal case associated as a fireplace device in an emergency. These robots are designed to search out a fireplace, before it ranges out of control, will sooner or later work with fire fighters greatly reducing the danger of injury to victims. The Firefighting robot project will help generate interest as well as innovations within the fields of robotics while operating towards a sensible and obtainable solution to save lives and mitigate the danger of property harm.

The fire extinguishing system is activated once the Flame Sensors detects that there is a fire source and the distance between the Autonomous Fire Fighting Robot and the fire source is closed enough. The fire extinguishing system that is commonly used in the Autonomous Fire Platform is the DC Fan in order to blow off the candle flame. There are some other alternatives of fire extinguisher tools, for example, the robotic snuffers or computer-controlled CO_2 streams that can be used as the fire extinguishing system. Table 2 shows the different classes of fires caused by various materials while Table 3 shows the various types of fire extinguishers that can used to put off each class of fires.

Class of Fires	Materials
A	Solids (Paper, Wood, Plastic).
B	Liquids (Paraffin, Petrol, Oil).
C	Gases (Propene, Butane, Methane).
D	Metals (Sodium, Lithium, Manganese, Aluminium, Magnesium, Titanium in the form of swarf).
E	Electrical Apparatus.
F	Cooking oil & fat.

Fig 2: Class of fire

Types of Fire Extinguisher	Characteristics
Water	-Cheapest and commonly used to put off Class A fire. -Not suitable for Class B fire.
Foam	-Slightly expensive than water type. -Used to put off Class A and B fires. -Not suitable for fire involves electricity.
Dry Powder	-Multipurpose Extinguisher. -Used for Class A, B, and C fires. -Best for running liquid fires (Class B). -Effectively extinguishes Class C Gas fire.
Carbon dioxide	-Ideal for fires involves electrical apparatus. -Disadvantages: Fire might re-ignite for Class B liquid fire.
Wet chemical	-Used to put off Class F fire.
Metal	-Used to put off Class D fire.

Fig 3: Type of fire extinguisher.

7. Conclusion and Future Scope

At present the robot is capable of throwing water with high flow rate only. At future the robot will also capable of throwing water with controlled robotic arms and the object detection using cameras on it. It can be used as further extension of the project to achieve all the features.

Firefighting is an evolving research area, benefitting from rapid advancements of technologies and driven by our ongoing pursuit for robot-assisted risky-intervention, localization and navigation, early rescue as well as environmental surveillance. This paper gave an overview of the state-of-art in robot- assisted smart firefighting systems, the localization and navigation support methods and discussed the potential applications for the ease of realizing smartness in emergency responses towards firefighting. The main concentration of this research was on developing a robot machine which can automatically detect fire and take the required measure to quickly diminish the fire. To reach the place where it is difficult to reach by human force in least possible time. To go within the fire affected region and extinguish from inside, basically a quick surgical combat machine.

Conventional firefighting robotic platforms and traditional methods for localization and navigation support have limited capabilities and performance for firefighting operation. To facilitate sufficient autonomy as well as resiliency during firefighting practices, humans' critical role needs to be realized through the advancements of H2R and M2M interactions. In this regard, the emerging Cyber Physical Systems (CPSs) technology becomes crucial enabling factors, which feature a tight combination of, and coordination between, the computational and physical elements of the system and integration of computer and information-centric physical and engineered systems. The introduction and integration of appropriate and promising technologies and systems will therefore facilitate the utilization and fusion of a wide range of real-time information and data not only during the fire emergency incidents but also the pre-incidents and post- incidents. These data and information can be potentially provide valuable input for decision support systems and therefore enhance the efficiency of fire protection and firefighting operation.

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