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New Concept for Indoor Fire Fighting Robot

AlHaza T[a*], Alsadoon A[a], Alhusinan Z[a], Jarwali M[a], Alsaif K[b]

[a]*Kacst , robotics and intelligent systems center*
[b] *King saud university / Kacst , robotics and intelligent systems center Hanol Inc.*

Abstract

In this paper, a new concept of indoor firefighting robot is proposed and developed. It has the capability to climb stairs and negotiate several types of floor materials inside buildings. It can withstand high temperatures up to 700º C for about 60 minutes using multiple thermal insulation technique. It can communicate with trapped and injured victims inside the fire seen and can send video and audio information to the control unit describing the fire environment inside the building. Several of those firefighting robots can be launched to work together collaboratively with the assistance of a remote control unit.

Keywords: firefighting robot; climb mechanism ; insulation technique.; remote control unit.;

1. Introduction

Casualties and property damage from fire continue to exist in fire disasters and new measures are continuously introduced. Toxic gases and flames continue to threaten disaster victims and rescue workers alike. While a range of fire-fighting robots have been developed and put in action worldwide, they have not yet contributed greatly to the fight. Most robots assist only in small ways, helping fight fires from a distance or monitoring outside fire scenes. An indoor fire-fighting robot is capable of performing rescue operations without risking personnel, including fire extinguishing and helping people at risk.

* Corresponding author.
E-mail address: alsaif@ksu.edu.sa

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The vast majority of the work on fire fighting robots is focused on fire detection algorithms and less on the mobility of the robot inside the building such as climbing stairs and obstacles. Fighting fire within the building requires good thermal protection of the electronic components of the robots. This kind of protection has been considered in the proposed firefighting robot.

Nam Khoon T. T et.al developed an Autonomous Fire Fighting Mobile Platform (AFFMP) that is equipped with the basic fighting equipment that can patrol through the hazardous site via a guiding track with the aim of early detection for fire. The tasks for the AFFMP once it navigates out of the patrolling route include the obstacle avoidance, locating for more precise location of fire source using front flame sensor and extinguish the fire flame. Their work was focused on outdoor fire fighting robot.

Taiser T, presented the design and assembly details of a robot developed to take part in an educational robotic competition. A control law based on Lyapunov theory was developed and implemented on a Programmable Logic Controller to control the robot.

Daniel J. Pack,David J. Ahlgren 1 conducted a design project to create an autonomous mobile robot that navigates through a maze searching for a fire (simulated by a burning candle), detects the candle's flame, extinguishes the flame, and returns to a designated starting location in the maze. The fire-fighting contest promotes interdisciplinary design and teamwork.

Kuo designed fire detection system using three flame sensors in the fire fighting robot. The adaptive fusion method was proposed for fire detection of fire fighting robot. He used computer simulation to improve the method to be adequate for fire detection. He incorporated the fire detection system in the fire fighting robot, and program the fire detection and fighting procedure using sensor based method.

Chee et.al. Conduced a good review paper about variety of technologies and state-of-the-art technology of fire fighting mobile robot. The paper also describes the first Malaysian designed and built fire fighting mobile robot, namely, MyBOT2000.

The proposed fire-fighting robot is capable of entering the most dangerous fires, fighting fire internally and rescuing people. It has the capability to climb stairs and can withstand high temperatures up to 700º C for about 60 minutes using multiple thermal insulation technique. It is equipped to supply the trapped persons with gas masks and oxygen breathing bottles.

2. System overview

The fire-fighting robot developed is a remotely controlled robot with two independent built-in fire extinguishing cylinders, built-in flame detection sensors and 3 mounted IR camera units. The exterior of the robot is Ag-coated, and it is operable under high temperatures (approximately 700º C). The interior features a mounted insulation board, designed to protect the interior from external heat. The crawler system steel chain is applied to move within fire scenes, and designed to climb stairs for the rescue work within buildings.

The two fire extinguisher cylinders mounted in the robot and connected to injection nozzles which are mounted on a Pan/Tilt drive such that the injection direction can be adjusted to the desired angle. A solenoid valve is used to control the nozzle for short-term injection. It is possible to inject additional water or fluid after the extinguishers are depleted by connecting a hose to the rear valve of the robot. Fig 1 shows the conceptual configuration of the robot.

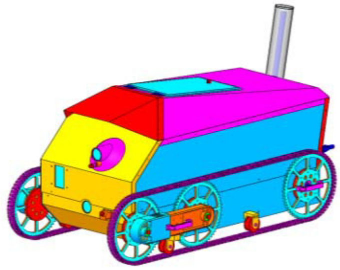

Fig. 1. indoor fire fighting robot concept

3. Mechanical design

The basic platform frame comprises of an aluminum profile which is lighter for its size, durable, and easy to process, useful in a range of applications. The aluminum profile installed in the platform is 20mm * 20mm, which is the thinnest of available commercial products. The profile is easy to assemble and different frames can be developed with minimum processing. It is also possible to mount components in desired positions using profile nuts, with motors and shaft brackets easily attached. The most fundamental feature of the mobile system is the transformable crawler, since the chain is rigid to change the shape of the track as shown in fig 2 , there must be an elastic element (spring) to allow for the shape to be changed. Springs are used to control the shaft distances between the two sprockets which can change depending on the compression of the spring. In the transformable crawler system, the compression in the spring is stronger when the track position is in its triangular shape and less when in its straight position.

The robot main chaises consists of 20mm x 20mm aluminum profile which easy to assemble and is considered durable. The system has two driving DC motors with power of 450W each. There is also a position motor to change the alignment of the front two sprockets as shown in fig 2.

The breakdown of the components is shown in fig 3. The mechanism used in the position control is shown in fig 4

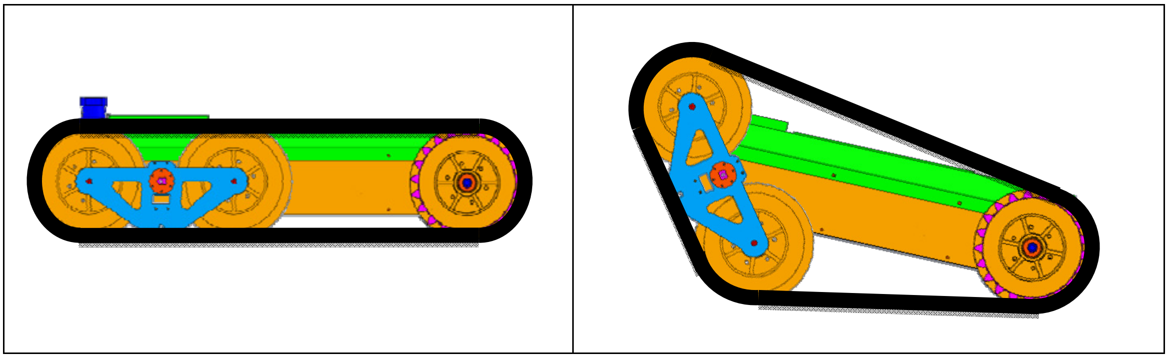

Fig. 2. Transformable crawler mechanism

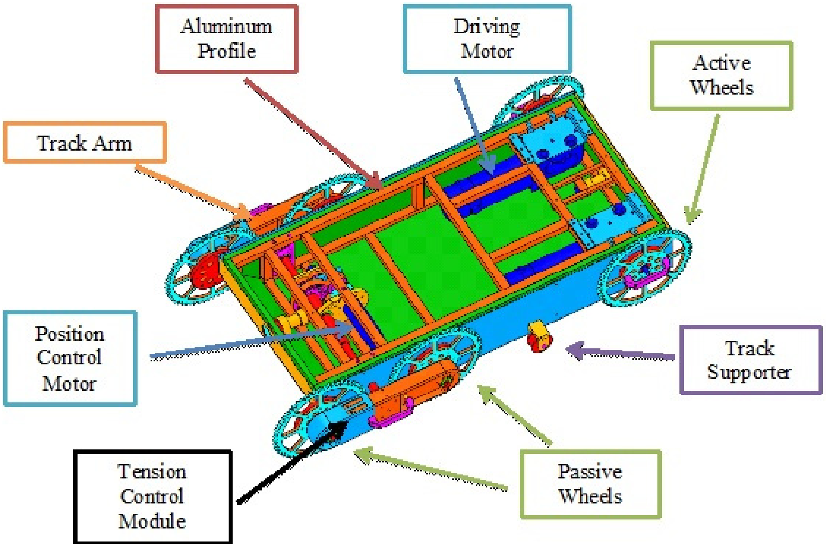

Fig. 3. Mechanical components of the robot

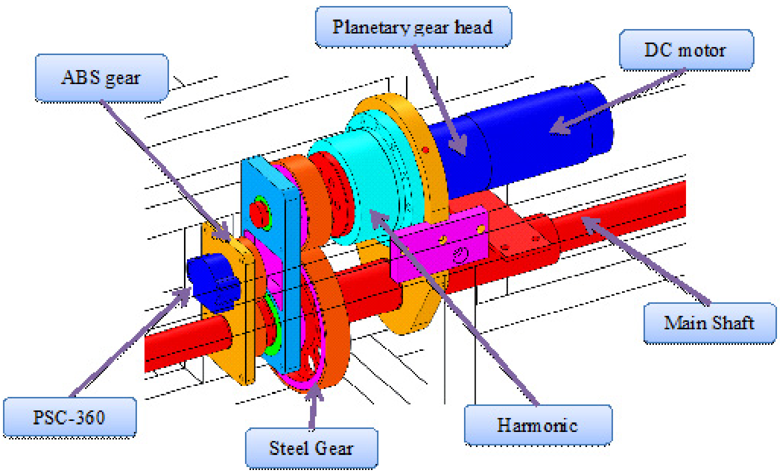

Fig. 4. Position control DC motor –gear head and harmonic drive to rotate the main shaft

Thermal insulation

The most important aspect of the fire-fighting robot is the thermal insulation system. As the operating environment for the firefighting robot is a fire scene, the operating temperature has been set to handle 700º C. The hardware inside the robot won't operate in temperatures over 70º C however, so all maintenance systems must keep the internal temperature below 70º C at all times. The thermal insulation system protects the robot interior from external flames and high temperatures as shown in fig 5. As shown, the robot case comprises 5 layers. The first protective layer is an Ag coating, as it is an excellent thermal reflector, reflecting most flames and high temperature. 50% of thermal energy is reduced upon passing through the first protective layer. The second protective layer

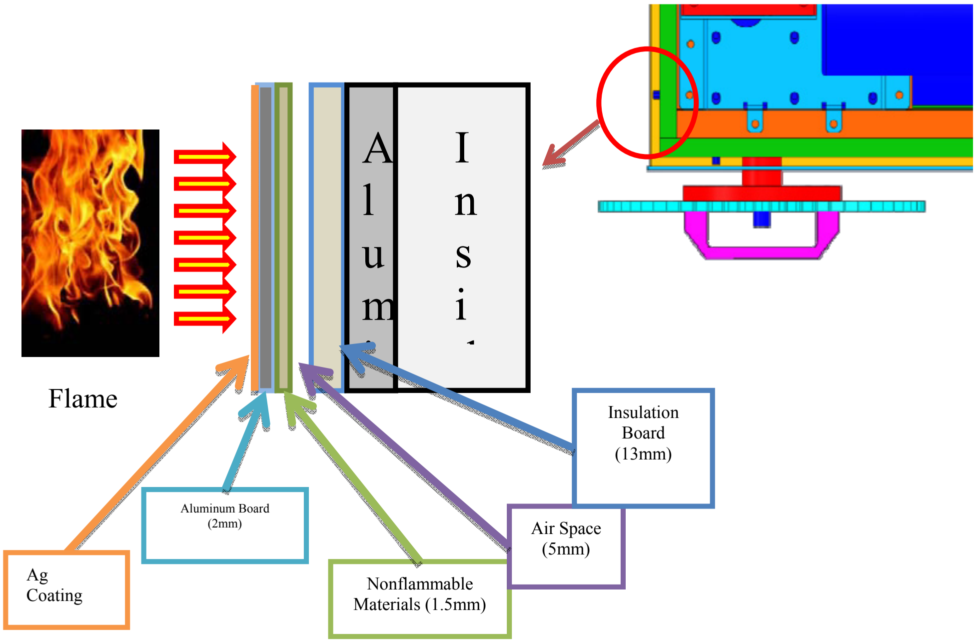

Fig. 5. The thermal insulation

is a 2 mm thick aluminum board. This board is not good for thermal insulation but it protects the robot from obstacles or falling objects at a fire scene. The third layer is nonflammable material affixed within the aluminum case. This material looks like cloth, but is nonflammable nature and has low thermal conductivity. The fourth layer is an air barrier. This air layer blocks heat conducted through the case from outside. Any heat penetrating to the 4th layer is greatly reduced. Upon reaching the last insulation board layer, most heat will be blocked. The insulation board is 13mm thick, nonflammable, non-heat conductive of and easy to process, ideal for robot applications.

The insulation board is shown in the figure above. It is composed of easy to process material and is maintained in the shape of Styrofoam, which can be applied to the whole robot. Care must be taken when assembling, as it is hazardous to skin. In addition, a bad odor is generated if it is heated, as the organic material it contains can combust. It has been heat treated to remove the odor prior to assembly.

Extinguishing System Overview

The extinguishing system was designed to focus on putting out fires remotely. Via a camera image if a fire is detected by the flame detection sensor, a user can access the scene of fire. The pan/tilt module mounted nozzle enables precise aiming at the ignition point and an attached laser pointer helps identify the exact destination point. When the solenoid valve is operated by remote control, the extinguishing fluid is sprayed, which can be verified via camera image while the extinguisher fluid is sprayed for accurate fire extinguishing.

A solenoid valve is used to remotely control the extinguisher. The solenoid is switched ON when power is supplied and OFF when not. Two extinguishers are mounted on top of the platform and a Y duct is used to connect the solenoid valve and the hoses of both extinguishers. A nozzle is attached to the solenoid valve outlet, and if switched ON, extinguishing fluid sprays out the nozzle.

The extinguisher has a fire extinguishing capability of A3 and B4, spraying a microbial chemical fluid, non-toxic and eco-friendly. As no secondary combustion is generated where the microbial chemical is sprayed, fire can be extinguished with minimal use. As power extinguisher is difficult to clean up after use, and gas extinguisher has the shortcoming of a short injection distance, fluid extinguisher was selected.

The two extinguishers built in the firefighting robot are connected in parallel to each other and injected through a single nozzle, permitting a long spraying period. The spraying time provided by default is approximately 70 seconds. If two extinguishers are connected in parallel and sprayed through a single nozzle, the injection time can extended to approximately 2 or 3 minutes. Fig 6 shows the main components of the extinguishing system.

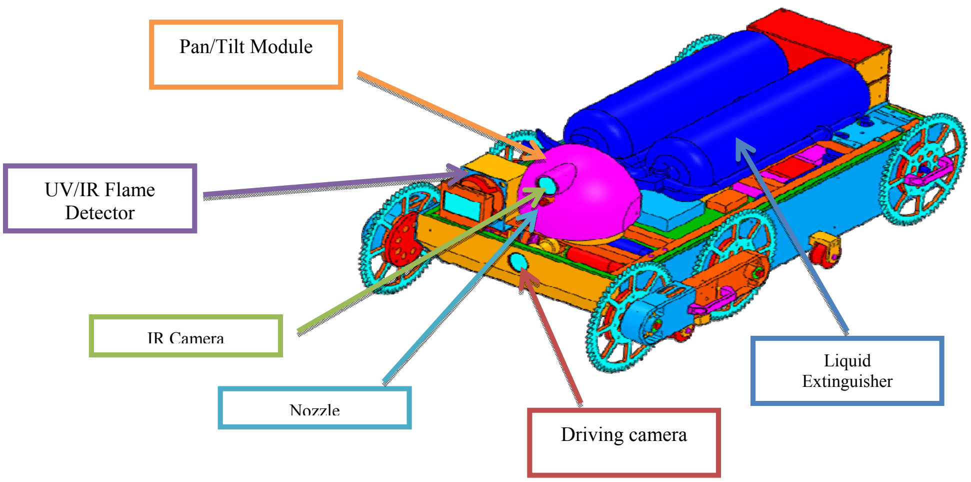

Fig. 6. Components of the extinguishing system.

4. Electrical design

Communications

2.4GHz frequency range has been chosen. According to the experiment, 5.8GHz range couldn't reach far enough, and 1.2GHz communication device requires significant hardware modifications. Therefore, 2.4GHz range device is the best choice that we can implement in Saudi Arabia.

Dipole antenna on the modem provides about 800m coverage in the open space, and this coverage can be extended with directional antenna.

Driving DC motors

We selected high-performance motors for high-speed determination of the ability to be able to climb stairs and avoid obstacles. We used one motor to change the position of the robot as discussed last section, the type of motor used is as follows

D & J WITH – (Rated Torque: 570 C) – (Max Speed: 7000 RPM) – (Rated Current: 2.1A) – (Voltage: 24V) - (Power: 34.7W max 50W).

For the driving motors, we used two DC motors from MOTION TECH MOTORS – (Max Torque: 18.03 kg.cm) – (Max Speed: 5100 RPM) – (Rated Current: 22.58 A) – (Voltage: 24V) – (Power: 450W) (max 738.3 W).

We considered motor drivers from Robo Cube Company with the following specs
(Supply Voltage 10 ~ 30 V), Continuous Current (Impulse Max Current) 40A (80A), Continuous Power (1000 W).

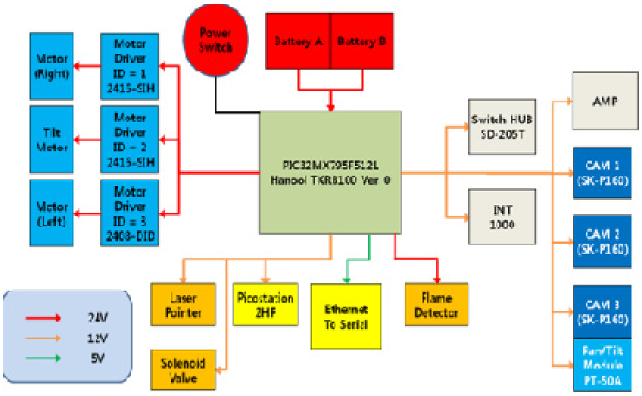

Fig.7. Block Diagram of Platform Power Harnessing

5. Operation control unit OCU

The OCU Software would be divided into two types, control software and video Software. Control software is built in the data Modem using WLAN to send and receive the commands to control the robot, current robot status, sensor commands and return values.

While video software connects to the built in Video Server installed on the platform that is connected to the WLAN, shots video images selected by user and display the camera images on the OCU screen. TCP/IP is used to send/receive the robot data. In this way, multiple programs can be executed and managed.

Software is connected with MR3 Client COM+ Library. This library is developed using the COM+ method and is able to interface with different programming language libraries also It is able to operate with C++, VB, C#, Delphi etc.

In the control GUI program, it is expressed in 2D to express its movements and graphically show the status and platform position for easier control and view these kinds of visual aid will enhance the user's operation performance. Below is a screen shot of the control GUI program Laptop is docked in to the docking station and Xbox360 controller, wireless modem are connected to that docking station. There is a battery for supplying power to the modems. OCU has total two LCD panels, and the first screen will be used to show a camera image data, and the other LCD will be used as Navigation system. Fig 8 shows The Fire Fighting Robot OCU Block Diagram and fig 9 shows the OCU hardware.

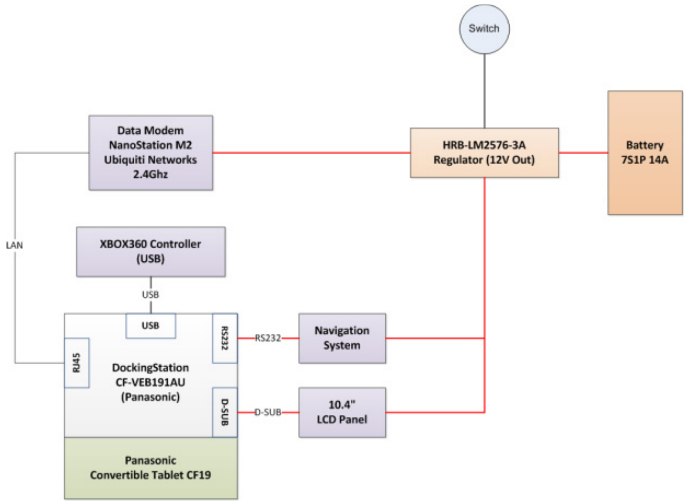

Fig. 8. Fire Fighting Robot OCU Block Diagram

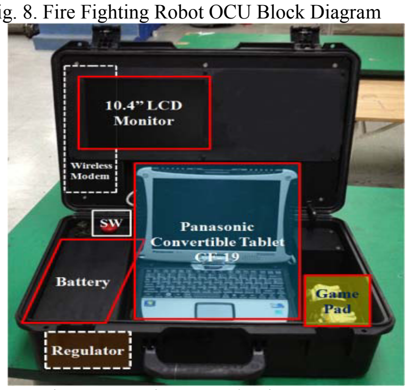

Fig. 9. Operation control unit OCU

6. Cameras and sensors

The Huviron SK-P160 pipe camera

It has effective 410,000 pixels with 6 IR LEDs. Three cameras are installed in the robot. There is one in the front of the platform, one at the back and one above the nozzle. It also has waterproof rating of IP68.

Fig. 10. Huviron SK-P160 Waterproof IR Camera

FS-30-ID Flame Detector

Flame can be expressed in several different ways such as heat, smoke, combustion gas, and heat radiation. The light released from fire has various wavelength depends on the temperature of the flame. The rays that can be radiated from fire are ultraviolet ray, visible ray, and infrared ray. By analysing characteristics of these rays with high resolution spectrum analyser, the flame detector can recognize the flame.

When remotely operating the fire-fighting robot, it is important to detect flames. If a camera image is not adequate to detect flames, a flame detecting sensor mounted at the platform front can be used, to detect flame via the UV and IR emissions from the flames. On detecting flame, it warns the user of such detection via OCU. The sensor, like the camera, is housed in transparent quartz lenses as well. Quartz lenses are were processed into squares and placed in triple layers, with a 5 mm air layer placed between each lens to prevent heat conduction.

Firesoft -30-ID is chosen that uses microprocessor to increase its functional reliability. Firesoft-30-ID could detect ignition source of ultraviolet (UV/185~260nm wavelength) and Infrared (IR/4.3um) p. It also excludes false alarm factors such as solar light, halogen light, metal light, flash, and welding light.

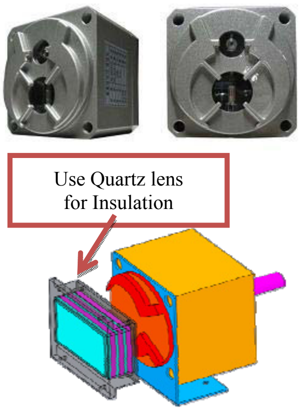

Fig. 11. FS-30-ID flame detector and insulation

7. Summary and conclusion

In this paper, a remotely controlled indoor tracked firefighting robot is proposed and developed. It has a good thermal insulation system in order to keep the internal electronic components within reasonable temperature when the robot is exposed to 700 c fire for 60 minutes. It can climb stairs and can communicate with trapped and injured victims inside the fire seen and can send video and audio information to the control unit describing the fire environment inside the building. Several of those firefighting robots can be used to handle the fire at an early stage inside large buildings. Water hose can be attached at the rear of the robot to continue fighting the fire when the chemical distinguishing agent is depleted.

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