Internet of Robotic Things Based Autonomous Fire Fighting Mobile Robot

Anantha Raj P
Assistant Professor: Department of Information Technology
BIT Sindri, Dhanbad
Jharkhand, India
anantharajpandi@gmail.com

Srivani M
Student: Department of Information Technology
Anna University, Chennai
Tamilnadu, India
sri.srivani94@gmail.com

Abstract– **Fire accident at the industries would cause heavy loss and it is a major danger to human lives. Early stage fire detection and taking small steps of firefighting action may avoid huge loss and saves human lives. Most of the fire accidents will not cause huge loss, if the firefighting action is taken on time. This paper proposes the idea of including the autonomous firefighting mobile robot in the traditional fire safety Internet of Things (IoT) system to perform early firefighting action. If the fire is detected, IOT system sends alerting message to fire safety department and initiates mobile robot to perform action. Firefighting robot reaches fire location by using path planning algorithm and performs firefighting action and sends the video stream of fire location to the control room. This early firefighting action stops the fire spreading and alerts the fire safety officers. In the meantime, fire safety officers can do better plan to handle the fire accident by watching the video sent by the firefighting robot. Industries which has lot of possibility of fire accident may use firefighting mobile robot with their existing fire alerting system.**

Keywords---Internet of Things; Internet of Robotic Things; Autonomous Mobile Robots; Fire Safety robots; Fire detection.

I. INTRODUCTION

Fire safety is an important aspect to be taken into account because it would save the firms from heavy loss and also it has an impact on saving human lives. Fire safety measures should be incorporated in many firms to prevent the uncontrolled ignition of fire. The fire safety systems prevents the disastrous damage to the environment and its surroundings.

In recent days, automation plays a major role in many areas. The autonomous systems reduces the human effort and helps the humans in all possible ways. Early phase fire espial can be performed by using the Autonomous Mobile Robot. An Autonomous Mobile Robot [1] is capable of performing high level tasks and comprehends high level objectives to accomplish high level goals. The Mobile Robot has the capability of taking intelligent actions in complex situations. These Mobile Robots are capable of handling dynamic environment, path planning, obstacle detection and avoidance, reducing power consumption and self-localization. An Autonomous fire extinguishing robot [2] has been developed to extinguish the fire by navigating the arena and avoiding obstacles. This robot can traverse through the map, interact with fire by detecting, extinguishing and firing an alarm. The robot also provides external communications by live camera feed and representation of map via Bluetooth.

Internet of Robotic Things is a recently developed field which mainly focuses on machine intelligence framework based on IoT and Robotics. In IoRT, the intelligent agents monitor the activities and integrates the data from the sensors to determine the finest course of action. Fusion of advanced Internet of Things and Robotic technologies gives rise to Internet of Robotic Things. The overall system architecture of IoRT is divided into 5 layers namely the hardware/robotic things layer, the hardware layer, the internet layer, infrastructure layer and application layer. A survey on Internet of Robotic Things [3] has been portrayed which illustrates the basic concepts, technologies and challenges for controlling and examining the events occurring at deployment sites.

The major contributions of this paper are highlighted below

- Design of an Autonomous Mobile Robot.
- Fighting fire using IoRT technique.
- A novel approach for helping the people in remote location

The rest of the section is organized as follows: section 2 illustrates the related work, section 3 describes the overall system architecture, section 4 explains the detailed design and implementation and section 5 describes the conclusion and future work.

II. RELATED WORK

A. Fire Detection System

An intelligent early fire detection system has been designed with certain machine learning techniques. This intelligent system uses soft computing approach to detect fire and it also has the capability to notify the respective authorities including fire department, police station, ambulance services and any other emergency departments. Structured forest for fastest edge detection algorithm [4]

978-1-5386-1508-9/18/$31.00 ©2018 IEEE

outperforms other models in terms of speed and accuracy. Fire accidents has been investigated in cotton mills by designing a mathematical model based on statistical hypothesis testing [5] such as t-test, F-test, z-test and so on. Certain evacuation measures are designed based on these measures. Extended Kalman filter based firefighting robot [6] has been designed for localization to withstand fire. Data from radar, Inertial Measurement Unit (IMU) and encoders are fused with the robot for localization in indoor fire environments.

B. Fire Fighting Robot

In recent days, catastrophic situations are increasing at a faster rate because of the natural calamities and human's negligence. Human's negligence provokes fire at many firms which leads to huge loss. A framework has been designed with two firefighting mobile robots [7] which addresses self-localization. The model is furnished with thermal infrared sensor and ultrasonic sensor for identifying fire and evading the obstacles. A Robotic system has been designed using arduino for quenching off the fire [8] in many places like schools, colleges etc. The system is designed with an arduino microcontroller, infrared sensor to control the robot movements and identify the location of fire. The system is also integrated with sprinkler which splashes the water at a preferred pressure rate.

A remotely controlled firefighting robot [9] has been designed which has thermal insulation system has incorporated inside it to communicate with trapped and injured victims. It can also deliver the audio and video to the control unit for controlling the fire. A firefighting robotic control system has been proposed which works without human effort. This automatic fire fighting robot [10] quenches off the fire by sensing through flame sensor. A fire extinguishing robot has been developed to suffocate the fire by using the water pump as controllers. ATMega8 [11] is used as the main microcontroller in the robot equipped with cameras and ultrasonic sensors. The robot has been designed to analyze and quench off the fire from the fire source using the flame sensors and extinguishing flames with CO2 [12]. The robot has the capability to detect the fire from multiple sources. A fireproof aerial robot platform [13] has been proposed to access the remote places, puts off the fire and evacuates the residents. The advantages of this robot is that it can endure the intermittent flame and navigating through the narrow space. A review of firefighting robots [14] has been portrayed which identifies the needs, requirements, challenges, future trends to accelerate smart and efficient operations.

III. SYSTEM ARCHITECTURE

In an indoor environment, many nodes are placed at different places especially where fire accident happens frequently. A node consists of micro controller and sensor array to detect fire. If any node detects fire, it will immediately send the information to the coordinator unit. Coordinator unit acts as the central unit which connects all the nodes and mobile robot using Wi-Fi communication.

Coordinator unit performs two different actions, one action is to send the fire accident to the fire safety department by generating alert message and the second action is to send information to the firefighting mobile robot. Mobile Robot consists of an indoor environment map, once the robot receives the fire accident location it plans the path from the current location to the fire location using A star path planning algorithm. The path name is referred to as a global path. Mobile Robot's planner converts the path information into discrete movement instructions.

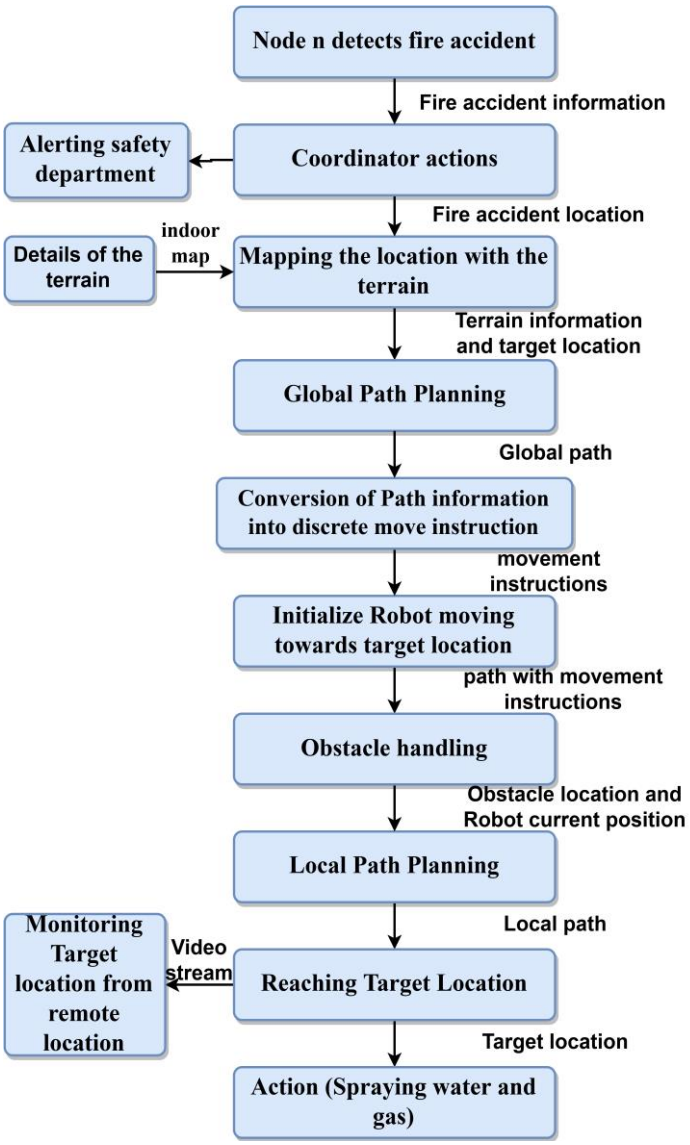

Fig. 1. System Architecture

The planner then initiates the robot to move based on the discrete movement instruction to reach the target location. Planner is furnished with obstacle handling unit to handle the obstacle while moving towards the destination. If there is any obstacle in the path, ultrasonic sensor detects the obstacle and the planner plans the alternate path from the current location to reach the target location. The process of avoiding the

obstacles and finding the alternate path is performed by dynamic path changing algorithm. Finally, the mobile robot reaches the fire accident location and performs the necessary action to stop the fire. It will also send the video of the fire location to the web server. Fire fighters can use this video stream to understand the situation and take decision on next course of action.

IV. DESIGN AND IMPLEMENTATION

A node consists of array of sensors and arduino micro controller. Many nodes are placed in different locations of the indoor environment where the fire accident possibility is more. Sensor nodes and firefighting mobile robot is connected with central coordinator node through wireless medium. Central coordinator is a Raspberry Pi processor which controls entire IoRT system. If a node detects fire, it will notify central coordinator. Central coordinator sends information to fire safety officers and initiates mobile robot to perform firefighting action.

A. Hardware Requirements for IOT environment

- Gas sensor
- Thermal sensor
- Arduino micro controller
- Power unit
- Wi-Fi device
- Jumper cables
- Mini breadboard

Sensor array contains gas sensor and thermal sensor which is connected with arduino micro controller using mini breadboard and jumper cables. Sensor array is used to monitor the environment to detect fire. Arduino controller continuously receives the data from sensor array and checks whether there is change in the values or not.

B. Hardware Requirement for Robot Design

- Mobile robot chassis
- Raspberry Pi
- DC motors (four piece)
- L293d motor driver
- Raspberry Pi Camera
- Pan Tilt unit for camera
- Lithium polymer battery (for motors)
- Power bank 5V (for Raspberry Pi)
- Ultra sonic sensor
- Jumper cables

Figure 2 describes the parts of the Mobile Robot. Raspberry pi is a credit card size processor which is used to connect and control all the parts of the robot. Ultra sonic sensor is used to detect the obstacles. Voltage divider circuit is created to regulate input from ultra-sonic sensor. Lithium polymer battery is used to provide power to four different 12V Direct Current (DC) motors. DC motors are connected with L293d driver which can control the DC motors in forward and reverse directions. L293d is controlled by program written in Raspberry Pi processor. Pan tilt unit is used to control the direction of Raspberry Pi camera. Camera is attached with Raspberry Pi camera interface which is used to take video at target location. Pan tilt is attached with robot which can rotate the camera more than 180 degrees. 5V power bank is used to provide continuous power supply to Raspberry Pi. The entire circuit is placed on the mobile robot chassis. There are some jumper cables and mini bread board which are used to make the entire circuit.

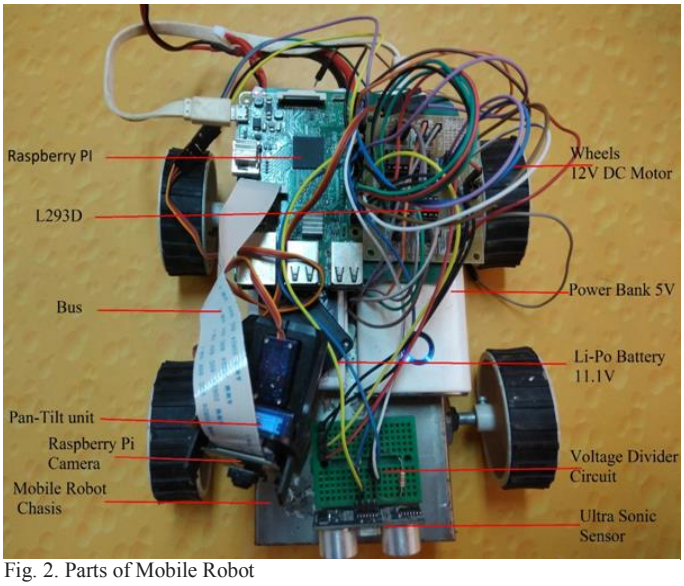

Fig. 2. Parts of Mobile Robot

C. Software Requirements

- Raspbian operating system
- VNC server and viewer

Raspbian operating system is installed in memory card for Raspberry Pi processor. VNC viewer and server software is installed in computer and raspberry pi to design the initial configuration since screen is not connected with raspberry pi.

D. Environment Setup

The following figure 3 shows how the environment is setup to do the experiment. Node contains sensor array and micro controller which is deployed in various places as shown in Figure3. All the nodes and mobile robot are connected with central coordinator. Central coordinator controls and coordinates the entire system. It performs two major tasks such as sending information to the firefighting officers and sending the fire accident location information to the mobile robot. Mobile robot's planner plans the global path from the current location to the target location by using A star path planning algorithm. The planner then converts the path into discrete movement instructions. Mobile robot performs the following movement instructions turn right (), turn left (),

move forward (), move backward (). Dynamic path changing algorithm is used to change the path, if any obstacle is found in the path. Obstacle handling unit identifies the obstacle in front of the mobile robot while moving towards the destination.

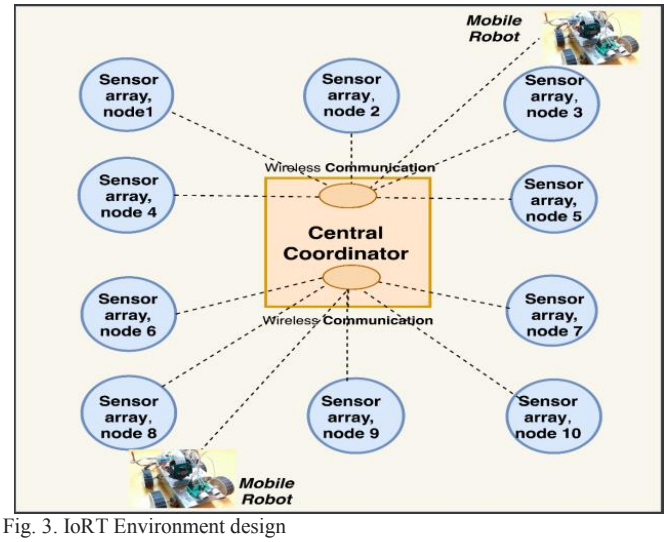

Fig. 3. IoRT Environment design

If it detects any obstacle, the dynamic path changing algorithm creates new path from current location of mobile robot to reach the target location. Finally, the robot reaches the fire location and sprays water in that location.

V. DISCUSSION

Safety and security are the two important aspects to save human lives. In this paper, the Autonomous Mobile Robot acts intelligently by transmitting the message to the fire safety officers, controllers and takes initial actions to stop fire. The entire system is designed in such a way that the mobile robot serves instantly by taking immediate actions. The system acts as a safety and security system with the integration of the Mobile Robot to perform necessary and needed actions in disastrous situations.

The main challenge of existing autonomous IoT based firefighting system is that it detects fire, alerts the people and sprinkles water or chemical to stop the fire. It sprays water not only in the detected areas but also in the surrounding areas. The proposed system focuses on the design of IoRT based instant autonomous mobile robot which can reach the fire location quickly, take immediate actions and sprays more water on a particular fire location rather than spraying the water in all the nearby locations.

Mobility of the robot makes the firefighting system to reach the fire accident region closer so that it can concentrate more on particular place Limitation of this project is that, robot does not behave intelligently after reaching particular position. Adding more intelligence to the robot by integrating computer vision and machine learning will help to detect the core fire area.

VI. CONCLUSION AND FUTURE WORK

The main aim of this research is to design Internet of Robotic Things environment to do early action against fire accident in industries to avoid huge loss. An autonomous firefighting mobile robot has been added with traditional fire safety IoT system to perform early action. Industry with higher possibility of frequent fire accident may use this system to avoid huge loss. In the future work, integration of certain machine learning and computer vision frameworks and extra sensors may be added to increase the performance accuracy of the system. Machine learning technique to predict the fire accident will be much helpful to increase the effectiveness of this IoRT system.

REFERENCES

[1] Raj, P. A., & Sendhilkumar, S. (2017). Design of an Autonomous Mobile Robot Prototype for Monitoring Indoor Environment. *6*(8).

[2] Hassanein, A., Elhawary, M., Jaber, N., & El-Abd, M. (2015, July). An autonomous firefighting robot. In *Advanced Robotics (ICAR), 2015 International Conference on* (pp. 530-535). IEEE.

[3] Ray, P. P. (2016). Internet of Robotic Things: Concept, Technologies, and Challenges. *IEEE Access*, *4*, 9489-9500.

[4] Sultan Mahmud, M., Islam, M. S., & Rahman, M. A. (2017). Smart Fire Detection System with Early Notifications Using Machine Learning. *International Journal of Computational Intelligence and Applications*, *16*(02), 1750009.

[5] Shanmuga Sundaram P, Raj Pradeesh. T, S. Aravind Raj and Jaya krishna. K. (2016). A Case Study on Investigation of Fire Accident Analysis in Cotton Mills.

[6] Kim, J. H., & Kim, G. I. (2016). Extended Kalman Filter Based Mobile Robot Localization in Indoor Fire Environments. *International Journal of Mechanical Engineering and Robotics Research*, *5*(1), 62.

[7] Memon, S. F., Kalwar, I. H., Grout, I., Lewis, E., &Panhwar, Y. N. (2016, March). Prototype for localization of multiple fire detecting mobile robots in a dynamic environment. In *Computing for Sustainable Global Development (INDIACom), 2016 3rd International Conference on* (pp. 395-400). IEEE.

[8] Student, B. E. (2018). Arduino Based Fire Fighting Robot with High Pressure Water Sprinkler. *International Journal of Engineering Science*, *16804*.

[9] AlHaza, T., Alsadoon, A., Alhusinan, Z., Jarwali, M., &Alsaif, K. (2015). New Concept for Indoor Fire Fighting Robot. *Procedia-Social and Behavioral Sciences*, *195*, 2343-2352.

[10] Singh, D., Das, S. K., Das, E., Agrawal, M., & Patel, V. (2018). Arduino And Sensors Based Fire Fighting Robot. *i-Manager's Journal on Instrumentation & Control Engineering*, *6*(2), 37.

[11] Siregar, B., Purba, H. A., Efendi, S., & Fahmi, F. (2017, March). Fire Extinguisher Robot Using Ultrasonic Camera and Wi-Fi Network Controlled with Android Smartphone. In *IOP Conference Series: Materials Science and Engineering* (Vol. 180, No. 1, p. 012106). IOP Publishing.

[12] Suresh, J. (2017, June). Fire-fighting robot. In Computational Intelligence in Data Science (ICCIDS), 2017 International Conference on (pp. 1-4). IEEE.

[13] Myeong, W., Jung, K. Y., & Myung, H. (2017, August). Development of a fire-proof aerial robot system for fire disaster. In World Congress on Advances in Nano, Bio, Robotics and Energy (ANBRE). IASEM Conferences.

[14] Liu, P., Yu, H., Cang, S., & Vladareanu, L. (2016). Robot-assisted smart firefighting and interdisciplinary perspectives.