FIRESIGHT: A System for safety and Assistance for Firefighters

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Abstract— In this paper, we introduce a safety monitoring and indoor location tracking and navigation system (FIRESIGHT) using Bluetooth and RFID technology. FIRESIGHT continuously monitor the firefighter's health, detects hazardous gases, enables them to communicate easily and helps them to find the nearest exit location. We envision that the FIRESIGHT system will save significant number of fire fighters and victims' lives.

Index Terms— Health monitoring, wireless communication, Indoor localization and tracking, Wi-Fi, RFID.

1 Introduction

Firefighting is one of the riskiest jobs in the world. Firefighters selflessly put their own lives in danger to save people trapped inside buildings engulfed by fire. In this case, monitoring of their health becomes important. Firefighters find communication with the base station very hard too. Conventional communication devices cannot be easily used during rescue operations. Leakage of toxic or flammable gases will also put the firefighters' life in danger. The mental state of firefighters during a rescue operation is not completely stable due to loss of visibility, urgent condition of victims and many other environmental factors. In such a situation, if the firefighters get confused about the location of the nearest exit door, then lives of both firefighters and victims are jeopardized

To tackle these problems, the firefighters' health must be continuously monitored. Their heartbeat and temperature are the most vital signals of their wellbeing and they can be used to measure their safety. A wireless and instant communication device must be designed through which the firefighters can talk easily with other officials. Toxic and hazardous gases' leakage must be detected in time before the firefighter enters the particular room. Indoor localization and navigational systems designed for firefighters should meet the following requirements: 1. provide navigational directions to guide the firefighters to the nearest exit door, and 2. enable them to continuously monitor the location of the firefighter in the burning building.

In this paper we introduce FIRESIGHT a multi-resolution system that is inexpensive to deploy and maintain. The firefighter will carry a passive RFID reader. In the environment, we deploy passive RFID tags (R-tags) on the walls. We also deploy a base station that includes information about the building, receives real-time updates about the firefighter location through the Wi-Fi and computes the directions to the closest exit. The server software also displays the firefighter location on the building map which can be viewed by both the firefighter and the Fire Chief.

We envision that FIRESIGHT can be used in a broad spectrum by the fire department. For wide deployment of such a system, each commercial building will be required to deploy the proposed infrastructure and share the building blueprints and tag deployment with the fire stations. It is evident that the FIRESIGHT system will save significant number of fire fighters and victims lives.

The paper is organized as follows. Literature survey is presented in Section 2. FIRESIGHT architecture is discussed in Section 3. Evaluation and results are presented in Section 4. The conclusions are reported in Section 5 while Section 6 includes Future Work.

2 Literature Survey

There are several systems that are deployed to help firefighters in distress. In many of the fire stations in India, they use rope for safety and tracking purpose of firefighters. If in case there is any danger, the signal is passed through rope by pulling it in a predetermined sequence. Firefighters' heartbeat can be tracked by using noninvasive piezoelectric detection [1]. In [2] the system includes wireless motes which are contained in smoke detectors and EXIT signs. These motes will keep broadcasting their IDs while firefighters will carry their own motes that keep listening for transmissions from other motes. Location tracking is based on signal strength measurements. Firefighter can see their location on their head-mounted display. Fire Chiefs outside the building can also monitor location of firefighters on the server. The "transfer motes" are deployed throughout the building to carry data collected by firefighters to Fire Chief. The drawback of this approach is that loss of "transfer motes" can disrupt the system operation. FINDER [3] uses Ultra Wide Band (UWB) technology to establish communication among firefighters. A firefighter in need of help sends UWB pulses which are received by other firefighters. Using this signal, injured firefighter can be tracked. The disadvantage of this system is that there is no communication between the firefighters and the Fire Chiefs which results in the fact that the Fire Chief will not be able to locate the firefighters in distress.

FIRESIGHT uses multiple wireless technologies, (RFID and Wi-Fi/cellular) to collect information required to compute the firefighter location as well as transmit this information to the Fire Chief.

3 System Architecture

FIRESIGHT system architecture is created with the following goals in mind:

1. The system is easy to use by the firefighter and incident commander.
2. The hardware cost is low
3. The system maintenance cost is low
4. Leverage existing resources such as 1) the communication network (i.e., Wi-Fi or Bluetooth), 2) fire detector.
5. Low user access delay

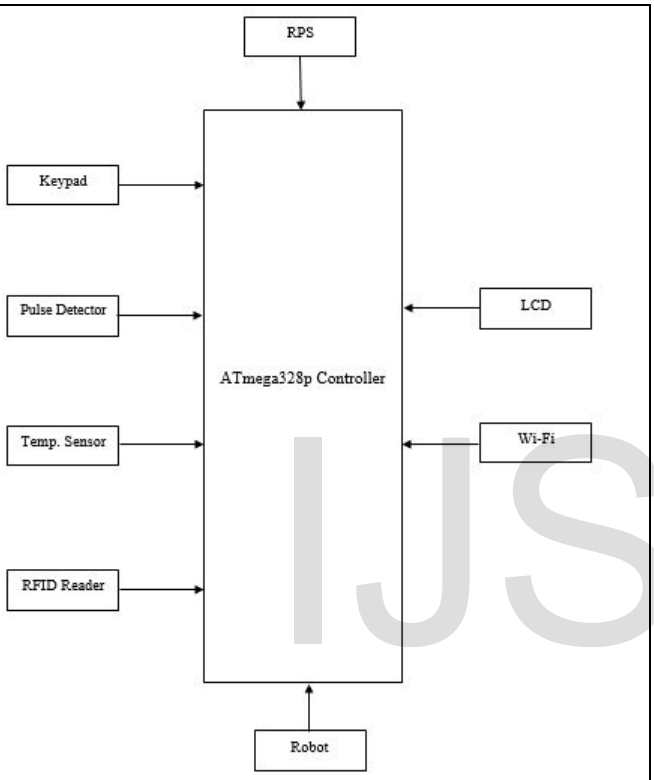

Fig 1: Block Diagram of FIRESIGHT showing the various components used in the system. The Arduino processor is at the centre, with all the other components connected to it.

The system architecture is composed of the following components: Environment in which we deploy the tags and tracks, firefighters' equipment and the base station. Details on each one of these components are provided in the following subsections.

3.1 Environment

The environment includes passive RFID tags (R-tags). The R-tags provide very accurate location. These tags are deployed at some certain points inside the building. Using this technology, we get a better localization of the firefighter.

3.1.1. Passive RFID tag (R-tag)
R-tags are densely deployed in the building located at each door of the building placed both at 4 ft height as well as on the baseboard level. Proximity of 2-3 cm is required to transfer data from RFID tag into the reader. Granularity was the main reason behind selecting this technology for FIRESIGHT. There are other RFID readers having high distance range to read RFID tags but we want exact location of the user which can be obtained only if user is very close to the required RFID-tag. Other reasons for selecting these R-tags were their cost and the fact that they do not need any power source. R-tags have ten-digit IDs which can be used to uniquely identify the cards or positions.

3.2 Firefighters' Equipment

The firefighter carries a PDA with an integrated passive RFID reader. In future versions of the FIRESIGHT the PDA will be replaced by a smart phone. This section describes the PDA based client software which includes the R-tag scanning and transmission module and the display Module for visual representation.

3.2.1 R-tag Scanning and Transmission Module
Every R-tag has a unique identifier (UID). On scanning an R-tag, the RFID processing module extracts the UID and sends it the server over a wireless network.

3.2.2 Display Unit
The display unit fetches appropriate maps stored in the PDA for respective floors. These maps are then imported on a PDA screen to display them to the user. Once the current location is displayed to the firefighter, it is also sent to the base station (Fire Chief) using Wi-Fi. This is important information as the Fire Chief should be aware of firefighter's current location in a building.

3.2.3 Keypad
A 3x3 keypad is used for communication of firefighters to base station. Some predefined messages are assigned to each key like "need back up", "found survivor".

3.2.4 Gas detecting robot
An obstacle avoiding robot is designed which can also be manually controlled by the firefighter using an Infrared remote. The robot is also fitted with gas detecting sensors which warn the firefighter of the impending danger by sending him appropriate messages.

3.2.5 Processing element
A microcontroller (Arduino) is used as the processing element. This is the heart of the system. It serves as the medium of communication between the firefighter and the base station. All the sensors are connected to this.

3.2.6. Pulse Detector
This sensor is used for monitoring the pulse of fire fighter. When the sensor goes below a certain limit, the warning message is send to base station for rescue of the fire fighter. The system continuously monitors the pulse of the fire fighter. The threshold for pulse detection is given as 550.

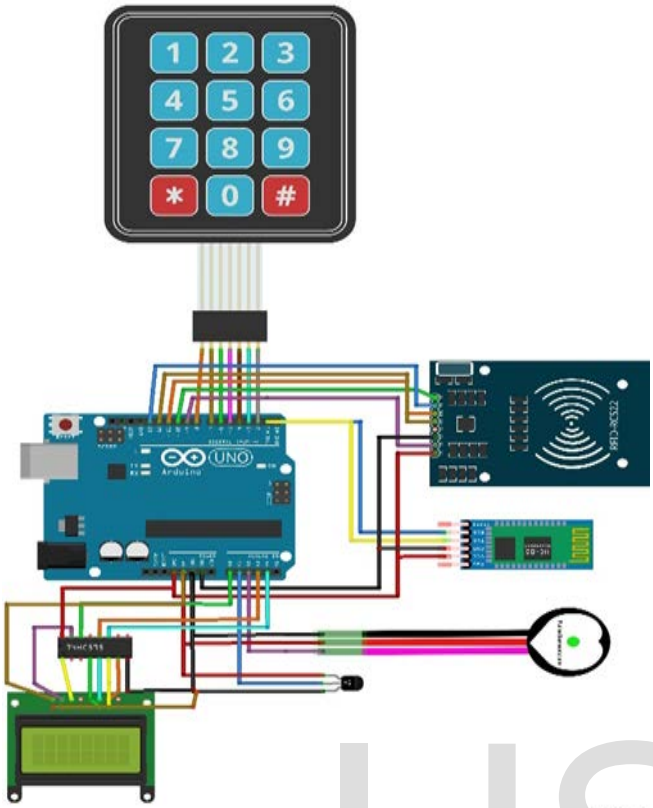

Fig. 2. Representation of the hardware connections.

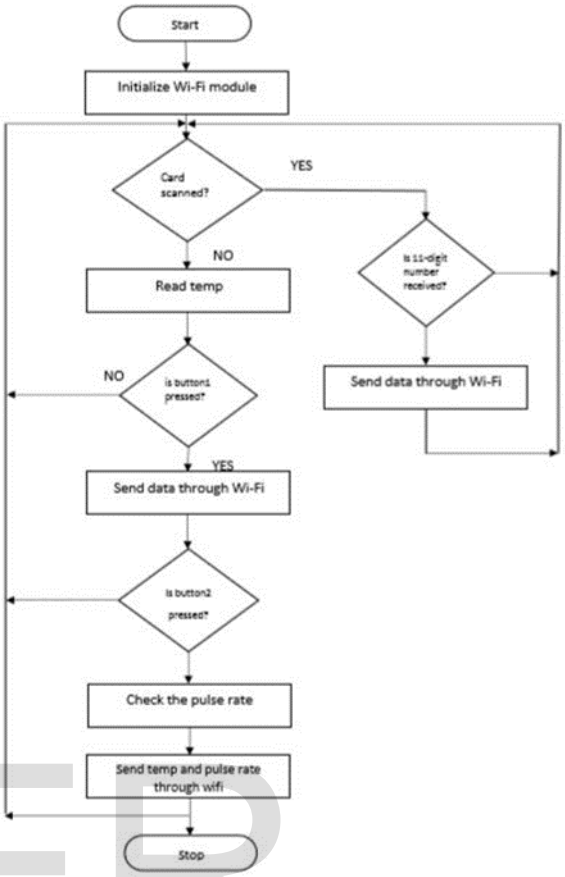

Fig. 3. Flowchart depecting the flow of control of the FIRESIGHT system.

3.3 Base Station

It consists of a vehicle where the Fire Chiefs continuously monitor pulse rate of fire fighters and their locations. The firefighter can communicate with the base station in case of any emergencies. It can help the firefighters if necessary.

Navigation Module

The navigation module is responsible for producing shortest path between two points. The user software sends an UID to the base station. The base station contains the RFID database which consists of UIDs of all deployed R-tags along with their node location (IDs). UID sent by the user is compared with existing UIDs in the Database. On finding a match, the corresponding node IDs are used as source and target IDs for calculation of the shortest path between two points.

Runtime Module: Display Unit

The display unit is responsible for all visual representation. Due to the special properties of the Spatial database, it is possible to display the data stored in tables. As explained above, a new table is generated containing the shortest path between two nodes and this table is then imported and displayed at the base station (Fire Chief). By looking at the path displayed on the screen, the Fire Chief can give voice directions to firefighter. The diagram containing the shortest path is also sent back to the firefighter PDA through the Wi-Fi network.

4 Results

Test correctness of pulse and temperature monitoring

The heartbeat and body temperature of the user is monitored and is displayed on the base station system. The values are found to be accurate.

Test correctness of robot and gas detection

The robot is found to function properly and successfully avoids obstacles. It also detected the leakage of inflammable gases.

Test correctness of navigation instructions

The user walks to each and every door and reads the R-tags located at that door. This displays the shortest route for the user to reach to the nearest Exit door. All results, i.e., the shortest route displays were correct.

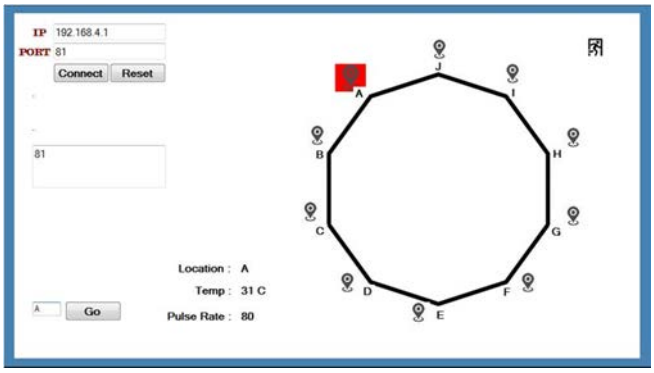

Fig. 4. A snapshot of the Base Station GUI. This GUI is also relayed to the firefighter but in a view only mode.

5 Conclusions

We have shown that the proposed FIRESIGHT system was able to successfully monitor the firefighters' heartbeat and temperature and display it on base station computer. The robot also successfully detected the presence of flammable gas in a room. We also tracked the firefighter on a particular floor inside a building using RFID. Firefighter location and Shortest route between firefighter's current location and the nearest exit door were indicated in a GUI developed at base station (Fire Chief).

6 Future Work

We plan to test our system in harsh environments similar to actual scenario where fire is involved. In order to reduce failure of system due to equipment damage, we also plan to increase redundancy of RFID-tags throughout the building.

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