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ER-Track: A Wireless Device for Tracking and Monitoring Emergency Responders

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Abstract

In this paper we present a wireless wearable body area system for locating, tracking and monitoring emergency responders in harsh and remote environments. Tracking an emergency responder and monitoring their vital signs using various medical sensors is important in supporting the safety of the emergency responder. This work is the preliminary step towards the development of a collaborative real-time tracking and monitoring system for emergency responders. In this paper, we propose a design of a wrist worn wireless wearable body sensor device for localizing, tracking and monitoring an emergency responder. Any change in the physiological parameters like blood oxygen level, blood pressure and pulse rate of the emergency responder can be easily sensed and tracked, and could be used to provide a warning when a critical event is detected. This system uses an efficient iterative localization scheme for locating the emergency responder. The system could be used to send early warning alerts, route proper medical supplies to the area required, and for communication between the responders.

Keywords: Incident Commander; Beacon Node; Localized Node; Monitoring Centre; Position Estimation; Unlocalized Node

1. Introduction

In recent years, there has been a global increase in the number of natural hazards which cause a heavy loss to human life and infrastructure. An effective disaster management system is needed to reduce the impacts of natural hazards on common life. The emergency responders (ER) play a major role in effective and efficient disaster management. So there is an obvious need to improve the safety of the ER by continuously monitoring their position, sensing their vital signs especially in dangerous situations.

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Locating and tracking the emergency responders can massively improve the support for organizing and managing the real-time delivery of medical and food supplies for disaster hit people. This requires effective communication and information processing between various groups of ERs in harsh and remote environments. Locating, tracking, and communicating with ERs can be achieved by devising a body sensor system.

Several environmental factors have an effect on the location accuracy and capability to attain the position of emergency responders. GPS is one of the most popular location tracking systems, which needs signals from GPS satellites. In the presence of buildings, forests and dense foliage, the satellite signals might be blocked. For a large number of emergency responders, a simple solution of adding GPS to all nodes is not a feasible solution. In this paper, a fast and cost effective iterative localization scheme is used, which can estimates the positions of ERs by using RSSI. The 'ER-Track' consists of biomedical sensors contained in wireless wearable device that can connect to a monitoring center, which tracks the ER and monitors their vital signs.

The paper is organized as follows: Section II briefly discusses the related work done in the field of localization and health monitoring. Section III presents the architecture of the system. Section IV describes the localization scheme used for the system. Illustrative simulation results are presented in Section V and Section VI summarizes the findings of our analysis.

2. Related Work

Many studies on wearable healthcare systems for tracking and monitoring humans have been conducted in [1] [2] [3]. In [1], Fei and Yang presented a work which deals with a novel approach of interfacing medical sensors to a RF mote through a highly versatile Programmable System on Chip (PSoC) Mixed-Signal array from Cypress.

Many location discovery approaches have been developed to find the nodal position [4], [5]. In WSN, estimating the node position is very important for location based services. Some of the positioning systems like RADAR [6], APS [7] make use of approaches based on precise measurements.

Recently several location tracking systems based on Global Positioning System (GPS) have been proposed which is very useful in outdoor environments. As GPS is expensive and is not capable of determining the position of individuals in buildings and dense foliage, an efficient localization technique is needed. Localization is the task of determining the physical coordinates of a sensor node. It permits a sensor to estimate its own location based on information gathered from the sensor network.

Our work differs from the previous work in that we proposed a system which can track the position of the ER and monitor their vital signs while doing their work.

3. Architecture of the system

There is a prime necessity to enhance the safety of the ER by continuously monitoring their position and sensing their vital signs. An ER-Track worn by each ER could enhance their safety and their ability to do their job, to a great extent. An ER-Track is a wrist worn wireless body sensor device which locates the ER, tracks their activity and monitors their vital signs, such as pulse rate, blood oxygen level, blood pressure and body temperature, using biomedical sensors. Locating the ER could be possible with the help of a localization scheme and monitoring the vital signs by using biomedical sensors.

The architecture of the proposed system is shown in the Fig 1. The proposed system employs a fast and precise iterative localization scheme to locate the ER. After locating all the ERs, the system communicates with the monitoring centre about the accurate position of each ER. The system also senses the vital signs of each ER, which are then processed and transmitted to the Monitoring Centre using a Zigbee connection. The Monitoring Centre contains a server which gathers all the data sent by the ER-Track and stores it in the database. The Monitoring Centre is controlled by an Incident Commander, a chief officer who manages the entire ER groups. The Incident Commander is supposed to know the exact position, activity and the health condition of each and every ER. With the help of ER-Tracks, the Incident Commander identifies the current position of each ER and checks their health conditions. If there is any abnormality in vital signs is detected, the system generates an alert message and the Incident Commander can make a decision to remove the ER from the region. An ER-Track incorporates a display panel which shows the readings of the vital signs. This assists the ER to be aware of their health. The system allows efficient communication between ERs and the Incident Commander.

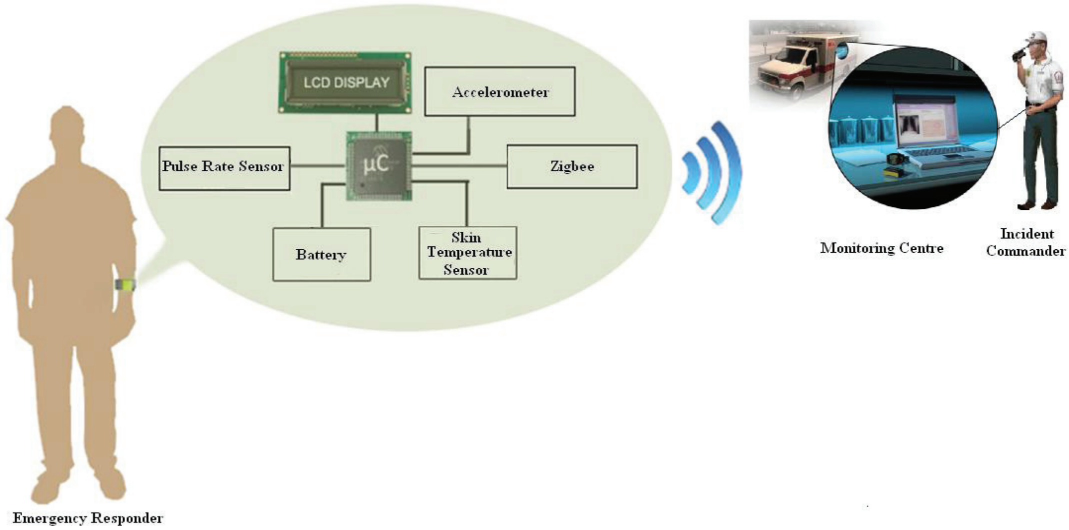


Fig. 1. Architecture of the system

The main functionalities of an ER-Track are:

a) Locating the ER: The ER could be located in harsh and remote environments using the iterative localization scheme. The system locates each and every ER, by estimating the position, by minimizing the difference between measured distance and estimated distance.
b) Activity Tracking: Once the system locates the ER, it starts tracking their activity using an acceleration sensor integrated in the system. This information can be helpful for the health analysis of the ER.
c) Vital Sign Monitoring: An ER-Track is capable of monitoring the vital signs of an ER such as pulse rate, blood oxygen level, blood pressure and body temperature. ER-Tracks support the safety of the ERs by sensing their vital signs and communicating this to the Monitoring Centre, where Incident Commanders can respond appropriately.
d) Health State Analysis: The ER-Track wirelessly sends the vital signs of each ER to the Monitoring Centre and there the health analysis of each ER is performed.
e) Emergency Detection: The Monitoring Centre verifies the vital reading of each ER. If the system notices any sign of abnormality in ER, an alert mechanism is initiated and if required, the ER should be removed from the location.

Above all, the ER-Track is a wearable device proficient for supporting the safety of the ER in harsh environments.

4. Localization Scheme for the System

The main focus of the system is to facilitate a large number of ER networks with location tracking capabilities in a fast, effective and low cost manner. The main intention of the localization scheme is to locate and track the ER in harsh environments An ER-Track with a localization module will efficiently estimate the position of each ER and minimize the probability of error.

This beacon based localization scheme begins with placing a group of beacon nodes. Beacon nodes are nodes whose position is known. The exact position of each ER is computed with the help of the beacon nodes. Each and every ER determines their position with the help of these predefined positioned beacon nodes. These position estimate values are transmitted to the Monitoring Centre for further proceedings. The Incident Commander checks the current position of each ER and starts tracking them.

The major assumptions are:

i. Area of the region is known,
ii. Few beacon nodes with predetermined position,
iii. All unlocalized nodes are deployed randomly.

The main aim of this scheme is to localize the unlocalized nodes using the least amount of beacon nodes. Unlocalized nodes are those nodes whose coordinates have to be estimated.

Our localization scheme is an RSSI based position estimation which computes the (x,y) coordinates of each unlocalized node based on the coordinates of localized nodes (x,y). A nodes position is estimated by minimizing the difference between the actual and the estimated distance, and thereby make it possible for a node to estimate their (x,y) coordinates. Each node estimates the distance of its neighbor using RSSI method. The traffic in the network is limited to those nodes which are in the communication range of the localized nodes.

Consider a region with 'n' beacon nodes whose x and y coordinates are xActual and yActual. In the initial phase, beacon nodes (with their predefined position) are placed in the region. The 'n' unlocalized nodes labeled 1, 2, …., n are placed randomly at unknown distinct locations in the region. Initially, the beacon nodes estimate the position of some unlocalized nodes. After knowing their positions, these newly localized nodes act as localized nodes. Localized nodes are those nodes which recognize their position. . Newly localized nodes can propagate their x and y coordinates among other nodes and assisting other unlocalized nodes to compute their coordinates. The information exchange between localized nodes and unlocalized nodes is facilitated with these coordinates. The localized nodes send their location values to all unlocalized nodes in their range. Using these transmitted location values, unlocalized nodes determine their position. As every unlocalized node can estimate its distance from the localized node, this localization scheme offers good performance at low complexity.

During localization, the information is passed within the neighborhood of a node, which results in high communication efficiency.

4.1. Position Estimation

In this RSSI based position estimation, every node has a maximum transmission range of 'R'. Each node communicates with their neighbor using received signal strength. Based on this measured signal strength, the distance between the nodes is estimated. Each node determines its distance to its neighboring nodes and shares it with them. The measured signal strength between two nodes contains the information about the distance between those nodes.

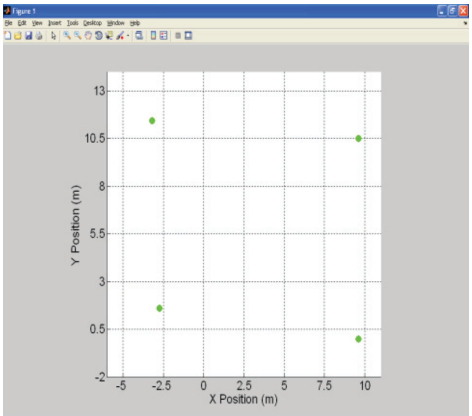
Let d_{ij} be the actual distance to the localized node '$_i$'. Suppose the actual position of an unlocalized node '$_j$' is (x_j,y_j) and it is going to acquire the distance dij to the $_i{}^{th}$ localized node whose position is (x_i, y_i), $1 \leq {}_i \leq n$. Then the distance between nodes '$_i$' and '$_j$' is

$$d_{ij} = \sqrt{}(x_i - x_j)^2 + (y_i - y_j)^2 \quad (1)$$

The actual and estimated position for node '$_i$' is x_i and x_j and for node '$_j$' is y_i and y_j respectively.

5. Simulation Results

This node level distance estimation reduces the network traffic drastically. Once the distance estimate of each unlocalized node is obtained, the position estimation can be done to determine the nodes' locations. To determine the location of the nodes, we compute the coordinates of unlocalized nodes with respect to the localized nodes.



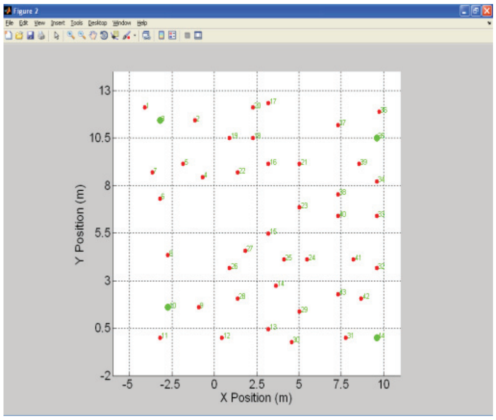


Fig. 2. (a) Beacon node placement; (b) Unlocalized node placement

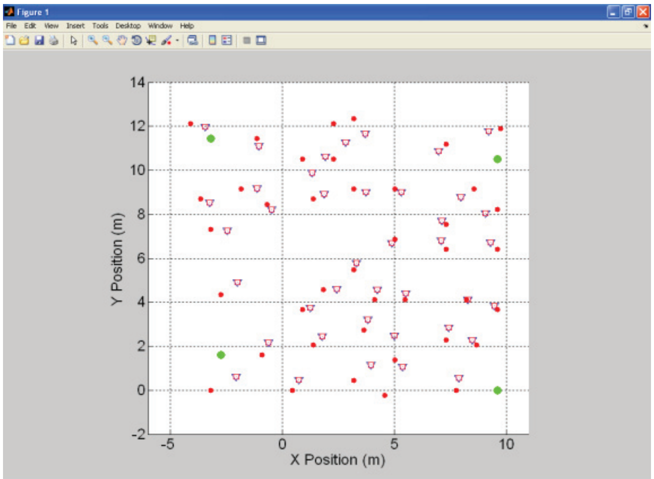


Fig. 3. Actual and estimated positions of nodes are shown

The localization scheme simulation is done in Matlab. We consider a sensor network with the area size 40×40 square areas. The basic simulation takes four beacon nodes and forty unlocalized nodes using a RSSI method. In a two dimensional scenario, position of an unlocalized node can be determined if its distance from atleast three nodes is available, along with the position of these nodes.

The first step in the localization simulation is to place the beacon nodes in known locations as shown in Fig 2 (a). The big green color dots are beacon nodes, placed in known positions. The second step in the simulation is to place the unlocalized nodes as shown in Fig 2 (b). The small red color dots are unlocalized nodes whose position is unknown and coordinates have to be estimated. In the Fig 3, the big green color dots are beacon nodes and the small red color nodes are unlocalized nodes. Blue color inverted triangles are the estimated position of unlocalized nodes.

Using the four beacon nodes, the position of some unlocalized nodes is determined. After getting the position, these newly localized nodes provide their location information to the unlocalized nodes within their range and start assisting them to determine their estimate position. This process continues in the succeeding localization process.

6. Conclusion

This paper presents wearable device architecture for monitoring the emergency responders (ERs) and also a necessary location tracking scheme for building a fast and efficient wireless sensor network. The localization scheme presented show the principal ways of constructing such nodes and estimates the distance to its neighbors using localized nodes. The simulation result shows that the iterative localization scheme can minimize the probability of error. Since the traffic in the network is limited to those ERs who are in communication range, the distance estimation can perform efficiently, reducing the network traffic significantly. By implementing such a fast and effective localization scheme, the location information of the emergency responder can be easily tracked. This scheme can fulfill our main objective of providing a cost-effective and care efficient context aware monitoring system for emergency responder's. The RSSI based localization scheme is relatively inexpensive and consumes low power considering its operation and can easily be implemented in hardware. This system helps to increase disaster relief capabilities and the safety of emergency responders.

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