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Emergency Navigation in Rescue with Wireless Sensor Networks

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Abstract - *Wireless sensor networks have major application in the navigation service. This application is widely used in various domains like military, industries and medical applications. The navigation application is the in-situ interaction between the sensor and the user. The proposed idea is to assist the people in escaping from hazardous area in case of emergency. It is to track the exit and dangerous area boundary so that people nearby dangerous area achieve mild congestion and the people away from danger avoid unnecessary detours. The first step is to establish potential map, then to build a hazard level map and finally planning a safe path for each user. Dynamic path is provided so that user's position is tracked according to their movement to the nearest exit point.*

Key Words: wireless sensor network, emergency navigation, dynamic path.

1.INTRODUCTION

The advances in the technologies such as communication and their related technologies have put their results in sensors and their networks. Also the advance made in the wireless sensor devices helps us in providing the wide usage of the sensors in the fields [1]. Nowadays, the interaction between the user and the physical sensors has been increased as the interest of the people increases and also to provide a safe environment to the users [2], [3]. Due to this, computers are used to better serve the people by monitoring on its own and also interacting with this geographic world. The users are provided with the mobile phones in order to communicate with the sensors. If emergency occurs, then the users are directed to get out of the dangerous area as soon as possible. This is done by the nomadic interaction of the users with the sensors.

In existing system, the users are directed to the destination path but the destination path is static and it cannot be changed. Due to this, the persons even when they are close to shortest exit are not directed to that path. Destination path is static and they are guided to that path even though it takes much time. In earlier days, the principles were based to monitor only the physical environment. Nowadays, it has increased communication between the in-situ user and the surrounding environment. Initially, the navigation of the person pursue for a critical path that is safe. The term safety does not mean an area that is far away, it refers to the area where less congestion occurs and less detours is encountered. It also has a fast reaction at the time of emergency. The next is human navigation will consume much time when compared to the process of traditional packet routing, as the time taken by the individual is more due to less speed in the movement. The process of packet routing scheme appears to be static which appears to be in contrast of the navigation of the human being which appears to be dynamic.

There are many solutions for the navigation at the times of emergency that is assisted with the wireless sensor network. One of the previous approaches [4] rely on the algorithm of exhaustive search that will flood the networks on the communication graph with the packets. These packets are used to do Breadth first search. The algorithm may be optimal for path length, but it is very expensive for communication. The next is the greedy geographic search in which the person greedily moves to the destination and traverse towards the dangerous zone that is found on the way. To find solution the problem is split up into two parts. First is constructing a graph with all nodes in them but with limited number of edges to form full graph communication and this is called as skeleton graph. Then shortest path are found using this skeleton graph. Another approach is [3] the users are given with the devices such as the smart phones in which the Bluetooth is used to communicate with the sensors.

During emergency the sensor network discovers a field and gives the user necessary information of guidance to the area of safety. The sensor network does not have a predefined memory of the location.

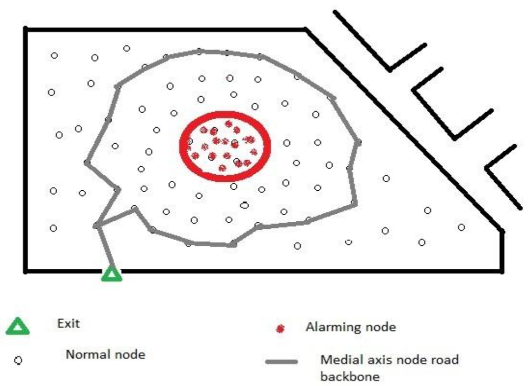


Fig-1: Shopping complex. Road map constructed using medial axis graph approach.

When emergency occurs existing system [6] focuses on finding the safest path for each and every user, but calculating congestion is not considered during the time in which sensor triggers. Smart way to avoid congestion is not calculated. Alternative path is not shown while ignoring the roundabout way to replace a part of the route. Proper navigation is not provided for the users. After emergency triggered the user don't find exit path efficiently because of the unknown place. In road map method, a single road map is implemented and all the users are guided through the same map which reduces the planning overhead but it may result in heavy congestion. The road map is designed by connecting the medial axis nodes. The exits and user nodes are connected to the medial nodes.

Our Approach :

In order to solve the problem of improper navigation and static datasets an approach is introduced. Dynamic short path is provided so that the users are directed to the shortest exit at a speedy rate. The word dynamic itself says constant changing. The users are tracked according to their location periodically and path is provided to the destination in dynamic manner. Datasets are designed in a dynamic manner. Map level implementation is made for navigating the persons from one place to another. The first method is to establish a potential map. Potential map is designed to navigate the people those who are away from the hazardous area. A different path is shown to those who are away from the dangerous region since they are vulnerable to congestion that people near the hazardous area. The second is to build a hazard level map to provide path for the users nearer to the dangerous area and branches different path to avoid congestion.

These people should experience a mild congestion in order to save the life of the people. Potential map and hazard level map are combined to form Compound level map. The final method is to plan a safe path for each and every user in that area.

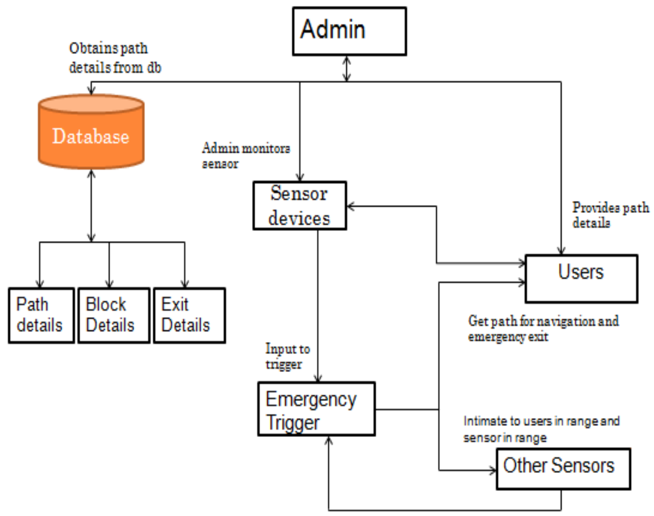


Fig-2: System architecture

2.PROBLEM SPECIFICATION

During the time of emergency such as fire accident or explosive, threatens the safety of the persons surrounding that area. At this moment the users should be navigated to the safer place in faster rate. Fig 1 depicts the navigation path and the dangerous area. The path is used to evacuate the people from the hazardous are in a safe manner. The assumption, objective and the requirements are as follows:

2.1 Assumptions:

We assume a field containing dangerous area as marked in Fig 1. (red nodes in Fig 1). These areas may disappear, shrink or expand as time passes. There is finite number of dangerous areas. Sensor node will trigger "yes" alarm if it lies in hazardous area and "no" alarm if it lies in safe area. The sensor function s is given as s= {0, 1}, which represents "0" resides out of hazardous area and "1" resides in hazardous area. We assume that people are carrying mobile phones with them that communicates easily with the sensors. The persons are able to track the nearby sensors by the direction and strength of the wireless signal [7].

There will be a way to escape from the dangerous area when users are not completely surrounded by hazards. But in cases of completely surrounded by hazards, the users depend on rescues like helicopter or fire service to remove obstacles [8].

2.2 Objectives:

The main objective is to assist the people in escaping from a dangerous area quickly in case of emergency with guaranteed safety by providing dynamic short path and map level implementation.

2.3 Requirements:

The requirements include

- Location free – location information is not required. It also reduces the cost.
- Guaranteed safety – escape track should be safe away from hazardous region.
- Scalable – path for evacuation should not be too long and it should be of lightweight.
- Evacuation time – total time taken for evacuation process must be minimized. It is the time taken from occurrence of emergency to user's exit time.
- Congestion adaptive – users are diverted through different paths to avoid congestion.

3. DESIGN PRINCIPLES

The design principles involve the steps: Constructing compound map, Designing medial axis graph, skeleton graph, shortest path navigation, Dynamic datasets and Dynamic path.

3.1 Constructing compound map

The compound map is a combination of potential map and hazard level map [6].
The potential map is used to track the exit and provides the navigation to the user so that they can reach the exit with few detours. A potential function f based on hop count is established. It is given by f: V→D for the exit 'e', D is the distance of hop count from each node to exit. The exit initiates flooding across the network. After getting messages from 'e', each and every node knows the hop count distance d to e, and the distance is given by (d, e).
The hazard level map tracks the area of hazard and branches different path to avoid heavy congestion, that is, users are directed across paths so that it does not appears to be crowded like the road map of single lane. Hazard level map is built when an emergency event is detected by the sensor, and is initiated by the nodes that border emergency event. The hazard level node has a sensed value of 1 and the safe node has a sensed value of 0. An interim band is present which separates the hazard node from the safe node. Local updating of the navigation path is done during the time of emergency. Simpler way to design hazard map is to let the boundary of emergency area node to flood with huge hop counts. Since hop counts that are larger are safer that hop counts of smaller.

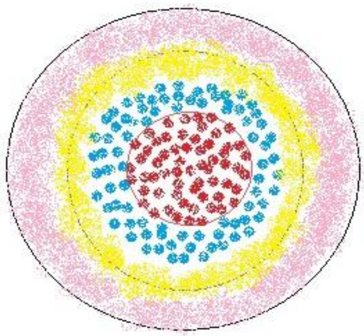


Fig-3: Hazard level map with interim and safe zones. Interim is coloured blue and safe zones are given in yellow.

3.2 Designing medial axis graph

A medial axis graph is designed for providing safe path to the users [8]. Let sn be the nodes in the safe medial axis graph. The sn separates safe area into cells and borders them. These nodes are used as a backbone for navigation during emergency. Sn can be identified by local flooding. The nodes bordering hazardous area broadcast their condition by sending ID's. Each node records hops to 2 closest hazardous area. If those 2 numbers are same then that node is said to be the medial node. After this the user nodes and exit are connected to the medial node. In this case, if exit is not medial node then a path should be established from medial node to exit.

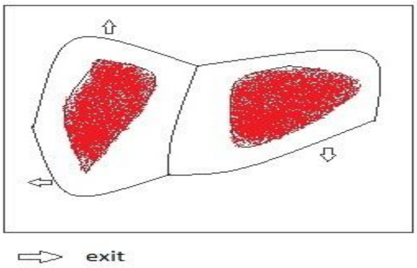


Fig-4: Medial axis graph

3.3 Skeleton graph

Navigating a field during hazardous area is similar to the problem where the path is planned in existence of barriers. There are two ways to solve this problem (1) geographic scheme and (2) exhaustive search. In first scheme, the person greedily moves towards the exit and pass through the hazardous areas on their way. The communication in this scheme is less but it creates many suboptimal paths. The second scheme floods the networks. This algorithm is optimal while considering path length but communication cost is relatively high.
The solution to the above given problem is that a skeleton graph is designed. It is constructed by taking all the nodes from the original graph and connecting those nodes with minimal paths to form a graph with complete communication. Next, paths of minimal exposure and short paths are found. The path information is not maintained in

the system. The path is encountered only when the query is raised.

3.4 Shortest path navigation

The shortest path algorithm uses breath first search in communication graph. The graph's source node is flooded with search packets. Every node has the information from the source of how many nodes it has travelled and last visited node. The shortest path provided in this paper is not the regular shortest path used to find the navigation for the same destination. The destination point is calculated to be dynamic according to the user's location to provide safe and quick navigation. The shortest path can be found from starting location to any other location, not just the desired location.
The graph used is weighted graph, where the weight assigned to the edge is a non negative value w(e). A path is sequence of vertices where p=(v1,v2,...,vn) such that vi=vi+1.

ALGORITHM

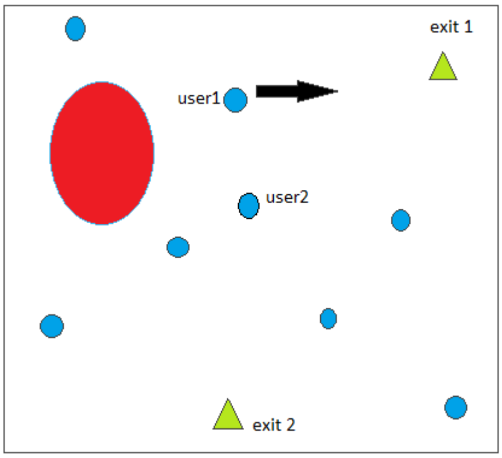
1: for each vertex v in graph g
  1.1: label v as unvisited
  1.2: set d(v) = &infinity
  1.3: set source(v) = undefined
2: set d(0)=0
3: while any vertex is unvisited
  3.1: call unvisited vertex with smallest & delta u
  3.2: label u as visited
  3.3: for each neighbour n of u
    3.3.1: if d(u) + w(u, n)< &delta(n)
      3.3.1.1: set d(n) = d(u) + w(u, n)
      3.3.1.2: set source(n) = u
4: end

3.5 Dynamic datasets

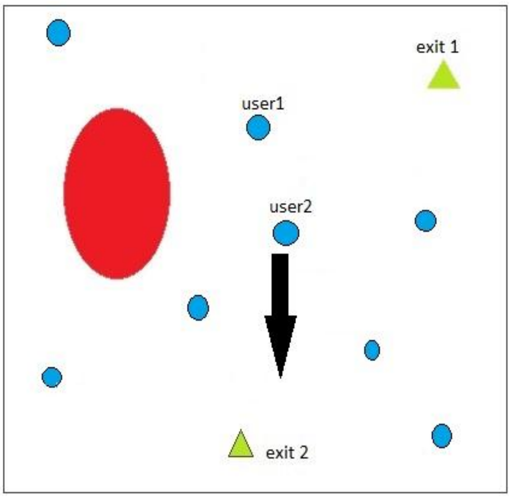
The datasets are designed in highly dynamic manner. The paths stored in the datasets are dynamic and the changes are updated periodically so that the user are provided with the appropriate path for navigation.

3.6 Dynamic path

The word dynamic itself denotes "constant change". Dynamic path is provided to the user to escape from a hazardous area in case of emergency by providing the shortest and the safest path in a rapid manner. The navigation is provided from the source of the user to the exit. The destination path appears to be dynamic since movement of users are irregular. When there are large number of users and less number of safety exits then it results in congestion. This may increase the time of evacuation which results in vulnerability of the human life.



(a)



(b)

Fig-5: Dynamic path
(a) User1 is nearer to exit 1 and given path through exit 1.
(b) User2 is provided with navigation path for exit rather than providing the same exit path as exit 1.

For example consider a field, which has two exit points (exit 1 and exit 2) and two users. Dynamic path finding works as, if emergency occurs the user1 is provided with the information that exit 1 appears to be shorter, since user1 is close to exit 1. And for user2 the information is provided as exit 2 is shorter, which helps him/her to navigate quickly out of the dangerous area rather than providing the same exit 1 as destination.

4.PERFORMANCE EVALUATION

The efficiency and the scalability of the proposed algorithm is evaluated through large scale simulations and comparing performance with the existing system. The simulation is done by deploying sensor nodes in rectangular area. The network range varies from 1000 to 15000. For each trial about 5 internal users are generated to navigate them outwards by inserting dangerous area inside the rectangular area. The number of exit can be set to 2 or 3 and the algorithm does not rely on location information.

To evaluate the efficiency of the path we compare the route length planned 'l' with shortest path length that does not go through hazardous area Sop . The ratio is given by l/Sop. If the ratio is closer to 1 then the algorithm is better. The run time of the algorithm is O(|V|2).According to the size of the danger zone the size of the skeleton graph varies. When compared to full graph the size of skeleton graph is smaller than that of full graph. For a field with 1024 sensors with danger zone, the skeleton graph appears to be of size 377.

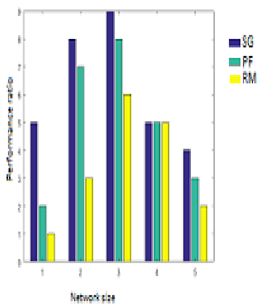


Chart 1: Performance ratio of calculating shortest path. SG-Skeleton Graph , PF-Potential Field Approach , RM-Road Map Approach

5 CONCLUSION

We have proposed a dynamic path and dynamic datasets using map level implementations in order to provide emergency navigation for the fast evacuation of the users from the hazardous area. Knowledge about the location information is not required.

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