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# A Safe Ordered and Speedy Emergency Navigation Approach

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**Abstract:**
In case of emergencies, navigation services guides people to exits while keeping them away from emergencies so as to save human lives. For emergency navigation to be quick, early and automatic detection of potential dangers, and quick response with safe paths to exits are the core requirements, both of which depends on proper and continuous monitoring of the surrounding and reliable data transmission. Wireless sensor networks (WSNs) are a natural choice of the infrastructure to support emergency navigation services, as they are relatively easy to deploy and of affordable costs, and their ability of ubiquitous sensing and communication. Although many efforts have been made to WSN-assisted emergency navigation, almost all existing works neglect to consider the hazard levels of emergencies and the evacuation capabilities of exits. Without considering such aspects, existing navigation approaches may fail to keep people farther away from emergencies of high hazard levels and would probably encounter congestions at exits with lower evacuation capabilities. A Safe, Ordered, and Speedy Emergency Navigation Approach, which takes the hazard levels of emergencies and the evacuation capabilities of exits into account and provides the mobile users the safest navigation paths accordingly is used. We formally model the situation-aware emergency navigation problem and establish a hazard potential field in the network, which is theoretically free of local minima. By guiding users following the descend gradient of the hazard potential field, SEND can thereby achieve guaranteed success of navigation and provide optimal safety. The effectiveness of SEND is validated by both experiments and extensive simulations in planar (2D) and cubic (3D) scenarios.

**Index Terms:** Emergency navigation, situation-aware, sensor networks, exit capability, hazard potential field.

## I. INTRODUCTION

Wireless Sensor Networks (WSNs) have been widely considered as one of the most important category of networks [1]. Enabled by recent advances in microelectronics mechanical systems and wireless communication technologies, tiny, cheap, and smart sensors deployed in a physical area and networked through wireless links and the Internet provide unprecedented opportunities for a variety of civilian and military applications, like environmental monitoring, battle field surveillance and industry process control [2],[3]. Distinguished from traditional wireless communication networks, (cellular systems and mobile ad hoc networks (MANETS)), WSNs have unique characteristics and constraints. Denser level of node deployment, higher unreliability of sensor nodes, self-configurable, application specific, severe energy computation and storage constraints, which present many new challenges in the development and application of WSNs. This work is based on WSN-assisted emergency navigation problem by utilizing the sensor network infrastructure as a cyber-physical system. In this scenario, people are equipped with communicating devices like cell phones that can communicate with the sensors. Incase of emergencies where the users are trapped in the hazard field, the sensor network explores the emergencies and provides appropriate guidance information to the mobile users, so that the users can be eventually guided to the safe exit points through pervasive interactions with sensor nodes. All of the existing studies do not take the impact of different hazard levels of emergencies and different capabilities of exits into account. They mainly treat emergencies equally and lead internal users to a nearby exit without considering the exit's evacuation capabilities. Such strategy would probably guide a majority of people to the same exit, which potentially causes extreme congestions at the exit and significantly increases the emergency navigation time while leaving other exits of low usage. Hence, it is rather necessary to take the evacuation capabilities of exits into consideration during the emergency navigation Therefore, we can arrive at the plain conclusion that a practical and efficient emergency navigation scheme should be situation-aware, which means that we should take into account both the hazard levels of concurrent emergencies and the evacuation capabilities of exits.

**To address this kind of issue SOS:**

A Safe, Ordered, and Speedy Emergency Navigation Approach is proposed which is based on the SEND Algorithm which is elaborated in[4]. The Safe, Ordered, and Speedy Emergency Navigation Approach which takes the hazard levels of emergencies and the evacuation capabilities of exits into account and provides the mobile users the safest navigation paths accordingly. Motivated by the fact that natural gradient of some physical quantities always follows a natural diffusion law, we thus propose to model the hazard levels of emergencies and the evacuation capabilities of exits as hazard potentials with positive and negative values, respectively. Then we establish a hazard potential field in the network, which is theoretically free of local minima. By guiding users following the descend gradient of the hazard potential field, our method can thereby achieve guaranteed success of navigation and provide optimal safety to users..

## II. RELATED WORK

Previous works in sensor networks we aim to achieve global objectives through local decisions at each node, based only on data available in the node's neighborhood. In this paper[5], we diffuse information away from source nodes holding desired data, so as to establish information potentials that allow network queries to navigate towards and reach these sources through local greedy decisions, following information gradients. We compute these information potentials by solving for a discrete approximation to a partial differential equation over appropriate network neighborhoods, through a simple local iteration that can be executed in a distributed manner and can be re-invoked to repair the information field locally when links fail, sources move, etc. The solutions to this equation are classical harmonic functions, which have a rich algebraic structure and many useful properties, including the absence of local extrema, providing a guarantee that our local greedy navigation will not get stuck. Unlike shortest path trees, which can also be used to guide queries to sources, information potentials are robust to low-level link volatility as they reflect more global properties of the underlying connectivity. By exploiting the algebraic structure of harmonic functions such potentials can be combined in interesting ways to enable far greater path diversity and thus provide better load balancing than is possible with fixed tree structures, or they can be used to answer range queries about the number of sources in a certain regions by simply traversing the boundary of the region. Potentials for multiple information types can be aggregated and compressed using a variant of the q-digest data structure. The paper [5] provides both analytic results and detailed simulations supporting these claims and provides real time navigation in dynamic environment which is quite useful. As elaborated in [6] Mobile sensors can move and self-deploy into a network. While focusing on the problems of coverage, existing deployment schemes mostly over-simplify the conditions for network connectivity: they either assume that the communication range is large enough for sensors in geometric neighborhoods to obtain each other's location by local communications, or assume a dense network that remains connected. At the same time, an obstacle-free field or full knowledge of the field layout is often assumed. We present new schemes that are not restricted by these assumptions, and thus adapt to a much wider range of application scenarios. While maximizing sensing coverage, our schemes can achieve connectivity for a network with arbitrary sensor communication sensing ranges or node densities, at the cost of a small moving distance; the schemes do not need any knowledge of the field layout, which can be irregular and have obstacles holes of arbitrary shape. Simulations results show that the proposed schemes achieve the targeted properties. This improves the network coverage and minimizes the sensing overlap. Genetic Algorithm which is used in [6] finds an optimal path in the simulated grid environment. GA forces to find a path that is connected to the robot start and target positions via predefined points. Each point in the environmental model is called genome and the path connecting Start and Target is called as Chromosome. According to the problem formulation, the length of the algorithm chromosomes (number of genomes) is dynamic. Moreover every genome is not a simple digit. In this case, every genome represents the nodes in the 2D grid environment. After implementing the cross over and mutation concepts the resultant chromosome (path) is subjected to optimization process which gives the optimal path as a result. The problem faced with is there may be chances for the loss of the fittest chromosome while performing the reproduction operations. The solution is achieved by inducing the concept of elitism thereby maintaining the population richness. The efficiency of the algorithm is analyzed with respect to execution time and path cost to reach the destination. Path planning, collision avoidance and obstacle avoidance are achieved in both static and dynamic environment.

## III. PROBLEM FORMULATION

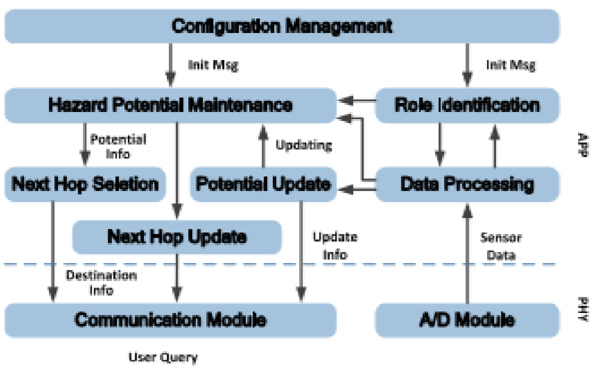
Existing navigation approaches may fail to keep people farther away from emergencies of high hazard levels and would probably encounter congestion's at exits with lower evacuation capabilities. The main challenge is how to define the safety properly, incorporating the impacts of both different hazard levels of emergencies and different capabilities of the exits at the same time.

## IV. PROPOSED SYSTEM

We propose to utilize cubic extrapolation. The reason why we choose cubic extrapolation is threefold. First, we aim to design a localized protocol with the capability to be implemented in large scale sensor networks. Cubic extrapolation fits our requirements by using only local and incomplete information to reduce the redundancy of the iteration. Second, the memory of each sensor in the network is limited due to the hardware constrains of the sensors. Cubic extrapolation uses only a constant number of the past time series to estimate multi-step forward values of the hazard potential. Last but not least, considering the dynamics of sensing environment, cubic extrapolation is an input-adaptive method, which is robust in dynamic environments. Our proposed algorithm guarantees successful navigation and generates optimal paths in terms of safety. We present the implementation of our algorithm in a real sensor network test bed, where every sensor node maintains a short list of variables, which record the status of this node. The implementation process mainly consists of three steps: initialization, hazard potential field establishment and path construction. The information of the sensor, including sensor ID, convergence threshold, role detection threshold, safe exit information, etc, is in the charge of the configuration management component. The communication module receives queries from trapped users and sends the path information back to them. It also takes charge of notifying its neighbor sensors the hazard potential status.

## V. SOS: A SAFE, ORDERED, AND SPEEDY EMERGENCY NAVIGATION APPROACH

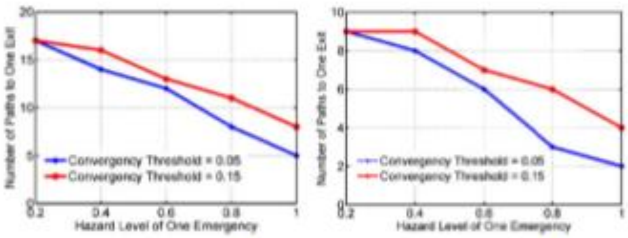
Our enhance proposed SOS, a safe, ordered, and speedy emergency navigation algorithm in WSNs. To minimize users' evacuation time, we have converted the emergency evacuation problem to a traditional network flow problem and used push-relabel algorithm to solve it. Our results of large-scale simulations have shown that SOS is better than existing approaches in terms of average evacuation time, last evacuation time, and network overhead.



## VI. EXPERIMENTAL RESULTS

To validate the correctness of our algorithm in 3D scenarios, we implement a test bed in a 3D building. The building has three exits. Similar with the 2D experiments, we conduct two groups of experiments. For the first group of experiments, we test the impact of different hazard levels of emergencies on our algorithm. In the first experiment, two sensors are set as emergencies with Potential ¼ 1, and the sensors at positions of exits are set the same evacuation capabilities with Potential ¼ 1.

In the second one, we change the hazard level of the right emergency to be less hazardous with Potential ¼ 0:5. After conducting our algorithm, the path graphs established with different settings .It is shown that the established navigation paths are inclined to avoid the sensors with higher hazard level. The objective of the second group of experiments in 3D scenarios is to test the impact of evacuation capabilities of exits on our algorithm. In the third experiment, we set three exits the same evacuation capabilities with Potential ¼ 1 and no sensors sensed emergencies. In the fourth one, we set the three exit sensors different evacuation capabilities: the exit sensor at the western part of the building has the least evacuation capability with Potential ¼ 0:5, and the other two have equal evacuation capabilities with Potential ¼ 1. After conducting our algorithm, the established path graphs are shown in Figs. 8e and 8f. We can see from the results that exeunt with higher evacuation capabilities cover a larger area of sensing field than exits with lower evacuation capability. As can be seen in the four 3D experiments, our algorithm can also provide the correct solution in 3D scenarios.




(a) The network in Fig. 5 (b) The network in Fig. 7

## VII. CONCLUSION AND FUTURE WORK

**This paper conducts the first work on:**

A Safe, Ordered, and Speedy Emergency Navigation Approach by considering a more general and practical problem, where emergencies of different hazard levels and exits with different evacuation capabilities may coexist. We first model: A Safe, Ordered, and Speedy Emergency Navigation problem and formally define the safety of a navigation path. We then propose a fully distributed algorithm to provide users the safest navigation paths, as well as an accelerated version that can significantly boost up the speed of the navigation. Both experiments and extensive simulations in 2D and 3D scenarios validate the effectiveness of SOS. We are currently devoting to conducting a small-scale system prototype under more complex scenarios. In the future, we would like to explore modeling the hazard speed in the context of emergency navigation. We also plan to cooperate with the local Fire Department to test our prototype, like the fire-fighting exercises, to provide more evidences on the real effects on user safety in real scenarios.

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