Flexible Intelligent Exit Sign Management of Cloud-Connected Buildings

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Abstract

Emergencies and disasters can happen any time without any warning, and things can change and escalate very quickly, and often it is swift and decisive actions that make all the difference. It is a responsibility of the building facility management to ensure that a proven evacuation plan in place to cover various worst scenario to handle automatically inside the facility. To mapping out optimal safe escape routes is a straightforward undertaking, but does not necessarily guarantee residents the highest level of protection. The emergency evacuation navigation approach is a state-of-the-art that designed to evacuate human livings during an emergencies based on real-time decisions using live sensory data with pre-defined optimum path finding algorithm. The poor decision on causalities and guidance may apparently end the evacuation process and cannot then be remedied. This paper propose a cloud connected emergency evacuation system model to react dynamically to changes in the environment in emergency for safest emergency evacuation using IoT based emergency exit sign system. In the previous researches shows that the performance of optimal routing algorithms for evacuation purposes are more sensitive to the initial distribution of evacuees, the occupancy levels, and the type and level of emergency situations. The heuristic-based evacuees routing algorithms have a problem with the choice of certain parameters which causes evacuation process in real-time. Therefore, this paper proposes an evacuee routing algorithm that optimizes evacuation by making using high computational power of cloud servers. The proposed algorithm is evaluated via a cloud-based simulator with different “simulated casualties” are then re-routed using a Dijkstra’s algorithm to obtain new safe emergency evacuation paths against guiding evacuees with a predetermined routing algorithm for them to emergency exits. The performance of proposed approach can be iterated as long as corrective action is still possible and give safe evacuation paths and dynamically configure the emergency exit signs to react for real-time instantaneous safe evacuation guidance.

Keywords: Emergency Evacuation, Exit Signs, LED, Cloud Connected Building, IoT, Building Management System, Routing Algorithm, Dijkstra’s algorithm, Emergency Navigation, Cloud Computing, WSN, LBS
1. Introduction

The present construction of the buildings around the world have become complex and augmented. The increasing building size and human population growth in urbanized societies has aggravated the difficulties in evacuation plan in disasters due to the insufficient resources availability for unanticipated massive demands and destructive crowd behaviours of evacuees. The emergency evacuation has experienced a few stages in the fast development of information and communications technology trends like human experience driven, wireless sensor network (WSN) based indoor navigation system driven, and cloud based indoor navigation system driven.

The WSN based indoor navigation system driven enabled through connected emergency exit system. The emergency exit system design integrated with control system and wireless sensor networks to address the problem of indoor navigation at emergency situations. The Internet of Things (IoT)-based intelligent fire emergency system enable exit directional guidance intelligent using location based service (LBS) technology according to the time and location of a disaster or emergency occurred.

There are different emergency exit navigation algorithms have been analyzed and presented to resolve solutions of highly dynamic and complex transshipment emergency exit escape route problem. The Dijkstra’s shortest path algorithm can achieve good performance to guide all the evacuees to the optimal path and causes severe congestion in densely populated environments. The finding algorithm to perform optimal solutions in different scenarios is difficult task on varying initial conditions such as occupancy rate, such as occupancy rate, distribution of evacuees and disaster source location.

This paper propose a cloud connected IoT enabled emergency exit sign design for evacuee routing algorithm that optimizes evacuation by making using high computational power of cloud servers on critical emergency situation. The proposed algorithm optimize the evacuation process by performing faster-then-real-time evaluation in cloud servers and customize optimum safe evacuation routes for routes for fatalities in the simulation and aid the evacuation process in real-time.

2. Related Work

The indoor position and navigation in dangerous indoor environments [1], [2] has raised much interest in terms of research opportunity over the last decade [3] due to the enormous losses in human and property with the increasing occurrence of man-made and natural disasters. The most important application areas which used to mimic an emergency evacuation process for emergency building management system where flow-based models [4], [5], queuing models [6], [7] and potential-maintenance models [8], [9] and all this model are proposed to seek an optimal exit routing solutions.

The flow-based models optimum routing path estimation imitate the evacuation path routing planning problem as a minimum cost network flow problem. In this flow-based model, the evacuees are considered as continuous flows and capacity of nodes and edges is reflected by the restriction of flows. The graphical model of the hazardous environment used to solve optimal solutions with time extended and expanded network by duplicating the original network for each discrete time unit. This can be solved using linear programming algorithms to get optimal solutions and this approach achieves optimal solutions but do not consider the spreading of hazard environment.

The queuing models are commonly used to analyze the time latency on estimated routes and redirect evacuees accordingly to save the life of occupancy. The network product solution based on computationally efficient algorithm [7] to predict the evacuation time [10] with respect to average arrival and departure rates at each observation point in the emergency evacuation location. The potential-maintenance models treat an emergency environment as an “artificial potential field” and assign each on-site WSN sensor with a potential value in accordance with distance to exits, distance to hazardous zone, etc. The evacuation routes are generated along sensors with higher potential value to sensors with lower potential value to find safe evacuation path.
3. Cloud Connected Emergency Exit Management

The proposed cloud connected flexible intelligent emergency evacuation system consists of user layer, cloud layer, network layer, and end device layer as shown in Figure 1. The user layer is deployed on handheld smart devices and is responsible viewing for collecting on-site building environmental status information and exchanging data with cloud servers. The cloud layer harnesses massive internetworked computers on server-side for the emergency exit management system to provide a cloud platform.

The evacuees use smart devices to take snapshots of the environmental scenario when a disaster or emergency situation occurs, and upload to the cloud layer to identify the escape routes information for evacuation. The cloud layer contains a data interpretation module and a navigation module. The data interpretation module possesses a sensor information and that can extract the environmental condition from the uploaded information and present exit side and determine the location of evacuees and status of environment.

![Figure 1. Cloud Connected Emergency Exit Management System Architecture](image)

The navigation module maintains an emulated environment status for the conduction of emergency evacuation navigation algorithm. The emergency navigation emulator is a distributed emulator platform that can dispatch workload to inter-connected high performance servers. The each interconnected server is associated with one significant position such as doorway in the built environment and maintains information observed by traversed evacuees in real-time from IoT enabled emergency EXIT sign device.

In this approach servers will send packets to gather information from other servers rather than synchronizing collected data among all servers periodically. The user layer and the cloud layer can communicate via gateways with Long-Term Evolution (LTE) or Wi-Fi Internet connectivity. The navigation module processes environment condition and find the optimum safety information using Dijkstra’s shortest path algorithm and update the safe evacuation path to the user smart device.

The IoT enabled emergency EXIT end device designed with sensor interface and push the environmental condition sensor data to the cloud server via LTE and/or WiFi connectivity to find optimum safety exit path information to guidance to find the right escape route in critical emergency situation.

4. System Emulation and Analysis

The proposed intelligent cloud connected emergency response system is designed to improve the evacuation safety and reliability shown in Figure 2. To evaluate the proposed intelligent cloud connected emergency exit sign system, designed using Arduino based open hardware platform built-in with Wi-Fi and ZigBee / Bluetooth connectivity.
The human cognitive characteristics and intelligent emergency evacuation equipment concepts are utilized for the development of an effective human safe evacuation system that alters the evacuation directions according to the in-building environmental situation, location of the user need to escape from the emergency condition and location of the emergency damage occurred inside the building.

The LTE or WiFi connectivity used to connect the emergency exit cloud server built-in with wireless connectivity to access the building environment condition and to configure & control according to building emergency condition. The ZigBee interface used connect with local emergency management server if available at emergency conditions. The bluetooth connectivity used to connect the people with smart device to support self-evacuation aid.

Figure 2. Proposed Cloud Connected Emergency Exit System

The network connected emergency exit sign sensor nodes designed to measure the physical and environmental conditions such as the temperature and pressure. The IoT enabled exit sign system connected gateways that collect sensor information from the nodes wirelessly and relay the information to the connected cloud server, and smart device based user interface software for storing, managing, analyzing, and utilizing the collected information.

The Arduino and Raspberry Pi Open source based designed emergency exit sign end device shown in Figure 3 (a).

(a) Exit Sign End Device                    (b) Cloud Web User Interface

Figure 3. Emulated Emergency Exit Sign End Device
The cloud server gather the environmental information from emergency exit sign end device and user smart device. To find the optimum safety evacuation path, the cloud server process the environmental condition information of the each emergency exit end device node and then find the optimum safety evacuation path using Dijkstra’s shortest path algorithm. The web based cloud user interface for emergency exit sign is shown is Figure 3 (b).

The cloud server update the processed emergency exit path information on smart device android application of the person who requested emergency exit evacuation route and the smart device application build with building emergency sign map interface to show emergency safe evacuation path aid. This android application shows visual exit map with route and direction to move on. This research shows that emergency exit sign evacuation paths during building emergency situations on building shows that less than 60%. The proposed approach increase the emergency exit sign evacuation paths during emergency situations more than 90%.

5. Conclusion
In this paper, the proposed emergency evacuation route finding based on cloud server using building environmental condition of each exit point locations is evaluated in real-time scenario in building. The proposed cloud server based emulated routing algorithm to increase the survival rate of an evacuation process. In contrary to the traditional algorithms which gives delayed feedback loop response between living sensory data and routing decisions, the proposed cloud based routing algorithm predict the result of emergency exit routes and re-calculate optimal paths for perished civilians in the real-time emulation. The experimental results indicates that the presented algorithm achieves improved survival rates. This approach use the massive environmental information uploading and downloading in short interval of time after the onset of an emergency event, is avoided.

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