Environment Adaptive Emergency Evacuation Route GUIDE through Digital Signage Systems

Dongwoo Lee¹, Daehyun Kim¹, Junghoon Lee², Seungyoun Lee², Hyunsuk Hwang³, Vinayagam Mariappan⁴, Minwoo Lee⁴†, Jaesang Cha⁴

¹ NAMUGA Co., Ltd, Seongnam, Korea
{d.lee, ginkokim}@namuga.co.kr
² Dept. of Electrical Information Control, Dongseoul College, Seongnam, Korea
{jhlee, alyssa}@dsc.ac.kr
³ Dept. of Electrical Engineering, Seoil University, Seoul, Korea
konae@seoil.ac.kr
⁴ Graduate School of Nano IT Design Fusion, Seoul National Univ. of Science & Tech., Seoul, Korea
vinayagam_m@hotmail.com, †alsdnya@gmail.com, chajs@seoultech.ac.kr

Abstract

Nowadays, the most of commercial buildings are build-out with complex architecture and decorated with more complicated interiors of buildings so establishing intelligible escape routes becomes an important case of fire or other emergency in a limited time. The commercial buildings are already equipped with multiple exit signs and these exit signs may create confusion and leads the people into different directions under emergency. This can jeopardize the emergency situation into a chaotic state, especially in a complex layout buildings. There are many research focused on implementing different approached to improve the exit sign system with better visual navigating effects, such as the use of laser beams, the combination of audio and video cues, etc. However the digital signage system based emergency exit sign management is one of the best solution to guide people under emergency situations to escape. This research paper, propose an intelligent evacuation route GUIDE that uses the combination centralized Wireless Sensor Networks (WSN) and digital signage for people safety and avoids dangers from emergency conditions. This proposed system applies WSN to detect the environment condition in the building and uses an evacuation algorithm to estimate the safe route to escape using the sensor information and then activates the signage system to display the safe evacuation route instruction GUIDE according to the location the signage system is installed. This paper presented the prototype of the proposed signage system and execution time to find the route with future research directions. The proposed system provides a natural intelligent evacuation route interface for self or remote operation in facility management to efficiently GUIDE people to the safe exit under emergency conditions.

Keywords: Digital Signage, Emergency Signage, Emergency Evacuation Plan, Evacuation Routing Guide, WSN, IoT, Intelligent Evacuation

1. Introduction

The man made or natural succession of disasters such as storms, floods, fires, landslides, earthquakes, and volcanic eruptions have claimed thousands of lives and caused material losses in these days. In particular, the
unplanned fire accident or fire outbreak events happens regularly inside the building environment which leads to fear, anxiety, and other physical troubles to livings inside the building. This kind unpleasant things happen inside the building due to the design of buildings and high-rises with different functionalities of people sophisticate establishments, has resulted in a greater complexity in building space.

The complex designs and designers mainly rely on signs for way finding as the main solution so the building usually have multiple exit signs. The installation of exit sign specifically at the intersection directing people to different places and make them to navigate throughout the building, as illustrated in Figure 1. This makes existing exit signage system quite often being unclear in the event of fire or any other emergency conditions.

The unclear exit signage system installation, the absence of facility management and inappropriate guidance poses a threat to the evacuees during emergency conditions though building followed the safety regulations. The reaches addressed that it is very difficult to find a proper evacuation path by livings under emergency, due to mental stress, time limitation, and environment visibility issues caused by emergency situations [1]. The safe evacuation is most important aspects to save lives under such a critical situations and the knowledge and installed facilities information use for evacuation is essential in tackling emergencies.

To improve emergency protection environmental safety, this research uses the convergence of wireless sensor networks and digital signage to deploy multi-point indoor security monitoring and emergency escapes. The WSN used to collect environmental information and continuous environmental information monitoring during an emergency would mark the location of the emergency condition source. In the case of an emergency condition, the emergency guide path algorithm compute the escape route using the environmental information and used the digital signage to guide people to safety by notifying instructions for escape path on display.

2. Related Work

In this proposed research, combines the IoT (Internet of Things) and Intelligent Evacuation Technologies to find people safe emergency evacuation route. The environment adaptation uses the WSN and an Evacuation Algorithm was developed for an Intelligent Evacuation System and GUIDE the people using digital signage system to provide improved evacuation safety.

The WSN is an important part of our day to day activity to know our environmental conditions which consists of many automatic wireless sensors in a real-time space. The most used in building wireless infrastructure for WSN is ZigBee. The ZigBee is a well-known low cost, low power and have ability to support a large number of wireless sensor network nodes. This WSN is normally used to monitor environmental information like
temperature, illumination, humidity, pressure, carbon dioxide, contaminants, etc. [2, 3]. There are many research has been executed on signage system to find a way to decrease the fatality rate and increase the efficiency of exit signage system. The signage system can determine the ingress route and egress route which can help the evacuees and the fire fighters to find their respective routes [4].

There are many research focused on sign cognition such as the effect of color and light, sound, location of signs, and comprehensible symbols and words, [5, 6]. The exit sign is identifiable from long distance at which the contrast of the arrow is increased [7]. The exit signs with different texts and images and made speculation and suggestion on the design to improve the visibility of the exit sign in emergency conditions [8].

The exit sign indication by laser beam installed within the signage system to help people follow a designed path [9] easily on emergency condition. The signaling the exit route by activating the appropriate signs with the effect of running light and The light source of the exit signs are distributed to form a running light and also can be individually controlled [10].

The present public spaces building are relying on fixed signage indicating the direction of exits and most of them lack clear route guidance and there is no way to confirm whether an escape direction is correct. This easily led people to make wrong judgments at the time of fire, and may enter danger area when emergency. These days all shopping centers and public building installed with digital signage displaying dynamically commercial advertisement and entertainment media contents in real-time [11].

3. Digital Signage as an Emerging Alert Device

The digital signage system are designed for defined uses like to provide information, entertainment, communication, advertisement, and enhance peoples overall experience in the building. The use of digital signage vary according to building business type to display the information like building layout plan to emergency evacuation routing map display. The most innovative uses of digital signage can the “life safety” informations, where a digital signage system augments the real-time fire alarm and building automation systems (shown in Figure 2). Digital signage is located near the traditional “exit” sign at egress points.

![Figure 2. Digital Signage as an Emergency Alert System](image-url)
In an emergency such as a fire alarm, for example if a stairwell is not safe for evacuation, the digital signage display can display the message such as “Smoke in Stairwell, Do not Enter, Safe area is particular area location”. This signage based emergency situation information can allow the fire command center or emergency command that responds to the alarms the ability to control the signage and view the situation through an optional camera, thus improving the evacuation and response. The Figure 3 illustrates the digital signage use for emergency information inside the building.

The deployments of digital signage systems are easy and facilitated by existing data networks, shortening commissioning times with minimum additional cost. The use content of signage systems are very flexible and can be tailored based on organization business and commercial needs. The visual media content distribution will continue to penetrate, evolve in future marketing strategy and be delivered through modern standard smart building infrastructure.

![Figure 3. Use of Digital Signage for Emergency Information](image)

4. Digital Signage Emergency Evacuation Route GUIDE

The proposed signage based environment adaptive emergency evacuation system model act as an emergency evacuation route GUIDE that links the real building and the building management model for facility management to solve the emergency exit problem to save the living’s life from injury. In this proposed research, the building management model is a prerequisite that must include information about WSN location, entire building traffic space information, exit sign location, signage locations, and exit doors location including emergency exit door. The Figure 4 illustrates that the proposed emergency digital signage system contains three core modules: emergency detection, emergency route selection, and digital signage display activation.
The environment adaptive emergency signage system integrates WSN, evacuation planning algorithms, digital signage multimedia technology and utilizes WSN collected environment condition information to find the emergency condition to find safe evacuation route. The system design have divided into five main modules to keep system reliability and functional integrity, functional entries and classification demand. They are WSN module, gateway module, central monitoring system, information broadcasting module, and signage system display control module. The overall conceptual diagram of the proposed system is shown in Figure 5.

The WSN module is the core of the wireless communication module for environmental data collection and transfer to the building management server. The environmental data integrates with this systems are temperature, humidity, illumination, carbon monoxide levels, etc. The sensors collect data and transfer the sensor data through the ZigBee protocol. The coordinator forward information between sensor device and gateway as a relay control for distance management. The gateway module integrated with ZigBee as well general wireless / wireless connectivity to connect remote server via internet / intranet.
The building management server is responsible for centralized building management and the analysis of environmental safety in real-time. The WSN module collect environmental information saved to the database through a central building management server and the analyses it to determine environmental emergencies. When an emergency occurs anywhere inside the building, the building management server controls the environmental information as well as take the prevention action in the personal places and then compute escape route in case of emergency using evacuation planning algorithm use of each WSN node environment informations stored in database.

In normal situations, the building management server collects and records environmental information from WSN nodes as environmental condition security surveillance indicators. The building management server connects to the remote digital signage to communicate recorded environmental information and adjust the media playback on display. When an emergency situation happens inside the building, the building management server starts the "emergency evacuation planning" algorithms, imports "environmental risk information from WSN node" and "the current state of the environment information" to the algorithm and the ratio is calculated by weighting the relationship between the environment and people who want to escape on emergencies. The computed escape route result is saved to the database trigger the event to the signage system so that digital signage can read the environment evacuation planning information with building layout and update the guide direction.

5. Real-Time Emulation Results

This paper real-time emulation considering the survival rate in the fire, smoke, and heat, it is clear that life is maintained inversely proportional to the amount of fire, smoke and temperature. The people who are in the emergency situation might have to fight to escape as quickly as possible to save lives. The proposed system was evaluated with different types of building maps and the emergency evacuation planning algorithms have to consider the environment complexity with multiple fire-points to determine the time need for escape.

The WSN implemented using Arduino UNO interfaced with temperature and humidity sensor with ProBee ZigBee connectivity and demonstrable digital signage system designed using Raspberry Pi 3 Linux based Open HW platform for proposed system evaluation. The server built-on host PC on LabView framework to monitor and execute the emergency evacuation planning algorithms. The Arduino UNO based WSN module sense the environmental condition and send the environmental sensed information to LabView based building management server framework via ZigBee. The LabView receives the sensor information and store it locally as well as display it on monitoring GUI. In background it execute the evacuation path planning algorithm according to environmental condition and send the control command to Raspberry Pi based digital signage system via Wi-Fi. The raspberry pi designed signage system render the media content on display according to the server command. This system design uses two modes, they are Environment-Safe mode and Environment-Escape Mode. The Environment-Safe mode represents the normal condition of the building and Environment-Escape mode represents the critical emergency condition of the building.

When emergencies situation observed from the environmental sensor, the building management server send the emergency event message to digital signage. In environment-safe mode, digital signage received the dissemination of information from the building management server as shown in Figure 6 (a). The digital signage receives the server emergency event via Wi-Fi and changes the signage rendering on display with the environment-safe Mode message into guiding arrows in escape Mode as shown in Figure 6 (b).
The emergency evacuation planning algorithm computation time is of great importance factor for a critical system like this. It’s important that the evacuation planning algorithm uses the different environment factors such as number of rooms, number of exits, number of fire points, and number of people in the rooms to compute the optimum safe evacuation route with short interval of execution time to save lives in emergency situation. This proposed approach manipulated that, importing small or large space maps does not make a big difference in computation time it being about 4~5 seconds.

6. Conclusion

In this paper, an environment adaptive emergency evacuation GUIDE using digital signage as an add-on value-added services to enhance the building safety measures. The proposed research aims to increase the usage and efficiency of the signage system and, also importantly, promote the use of building management system for facility management in the building automatic operation phase. This paper presents the fundamental design framework of the proposed system and illustrates in the design example. This design includes environmental monitoring and evacuation system which combines WSN, centralized environment monitoring and control, critical situation identification, evacuation path computation, digital signage control for media content rendering with evacuation GUIDE information, environmental population distribution and people positions as basis for escape guiding. This method uses to execute the evacuation planning to compute safe route and guide people while leaving the hazardous area as quickly as possible to save lives from danger. In use of the emulation application presented on this paper, one can get emergency guide and emergency escape notification in real time. The people can use the advantage of this proposed approach model that made aware of the danger at an early stage of emergency situation and follow the digital signage GUIDE as an escape guidance and flee the scene as quickly as soon as possible without getting doubts on escape route way.

Acknowledgement

This research was supported by a grant from the Fundamental R&D program for Technology of Material & Components funded by the Ministry of Trade, Industry and Energy, Republic of Korea.
References

[1] M.-G. Lee, K.-M. Yu and W.-C. Lai, "Implement a RFID-Based Indoor Location Sensing System Using Virtual Signal Mechanism," in Parallel and Distributed Processing with Applications (ISPA), Taipei, Taiwan, pp. 168-174, 2010.

[2] Y. Tseng, M. Pan and Y. Tsai, "A distributed emergency navigation algorithm for wireless sensor networks," IEEE Computers, pp. 55-62, 2006.

[3] K.-M. Yu, J.-Y. Liou, B.-H. Yeh, C.-W. Yu, C.-C. Tien, C.-H. Wang and P.-Y. Wang, "CALE: A Context-aware Living Environment Based on ZigBee Sensor Network," the Sixth International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2010), Hangzhou, China, pp. 243-246 2010.

[4] R.G. Deshpande, and A.E. Faltesek, “Building emergency path finding systems and method,” US Patent 7026947, (2006).

[5] B.L., Collins, “The Development and Evaluation of Effective Symbol Signs,” NBS Building Service Series, U.S. Department of Commerce, Washington DC, USA, 1982.

[6] B.L., Collins, N.D., Lerner, “Evaluation of Exit Symbol Visibility,” NBSIR 83–2675. National Bureau of Standards, “U.S. Department of Commerce,” Washington DC, USA, 1983.

[7] P.B., Boyce and Mulder, M.M, “Effective directional indicators for exit signs,” Journal of the Illuminating Engineering Society, 24 (2), (1995) 64–72.

[8] C., Tang, W., Wu, and C., Lin, “Using virtual reality to determine how emergency signs facilitate way-finding,” Applied Ergonomics, 40 (4), (2009), 722-730.

[9] M.R., Lehman, D., Gechtman, J.K., Fuller, and M.A. Hreha, “Laser director for fire evacuation path,” US Patent 6150943 A, (2000)

[10] N. Gmbh, “Method and apparatus for marking an escape route,” US Patent 6998960 B2, (2006)

[11] Cheng-Yan Yu,"Location-Aware Mobile Digital Signage System Based on Dynamic Advertisement Recommendation Algorithm”, Chung Hua University, 2010.