Design of Indoor Evacuation Route Simulator

Gang-Hee Jung, Yoon-Young Park, Dae-Yeon Noh, Young-Wook Cho, Se-Yeob Kim

Abstract Background/Objectives: As modern buildings are becoming bigger and more sophisticated due to advancement in building technology, such advanced model changes of them have caused great loss of lives and property damage when disaster situations such as fire and gas leak occur indoor.

Methods/Statistical analysis: As for the way to disaster preparedness, world powers such as the United States have been researching related simulators, focusing on disaster response rather than disaster recovery. Against this backdrop, this study shows a guidance simulator to ensure that people evacuate safely and quickly with possible evacuation routes in the buildings to minimize loss of lives damage caused by gas leak and fire. First, we developed the shortest possible distance between people and exits, and then we studied requirements to apply it to disaster situations.

Findings: Map data should be generated by understanding locations of corridor where people can use from a design drawing of target building, and graphs should be formed by connecting points of each location of corridors in order to offer the evacuation routes. It should be also be possible to calculate and display optimal paths from each location to the exits through a proper routing protocol. This study shows that the shortest distance guidance simulator gets the scalability facilitated by functionally isolating map data, graph formation, routing protocol, and topology formation. In this regard, the simulator is designed and implemented so that evacuation routes can be guided to respond to disaster situations, applying requirements to it.

Improvements/Applications: If the evacuation route guiding simulator is applied to the evacuation route guiding navigation, it is possible to further minimize the casualty damage.

Keywords: Escape route guiding system, Simulator, Routing Protocol, Disaster relief communication, Indoor Disaster situation

I. INTRODUCTION

Modern buildings are becoming bigger and more sophisticated due to advancement in building technology, and we spend 80 to 90% of our time in daily lives indoors[1]. As the amount of time we spend indoors is increasing and the buildings are getting bigger and more complex, these changes have caused great loss of lives and property damage when disaster situations such as fire and gas leak occur indoor.

Most nations have operated disaster communication network to reduce the damage[2]. Disaster Relief Network is equipped with unitary Incident command systems, such as national emergency management agencies; EOC (Emergency Operation Center), ICS Post (Incident Command System Post) and disaster relief agencies; hospital, fire, and police services[3].

As disaster situations are getting bigger and more complex, existing voice-centered disaster narrowband network is evolving into broadband network capable of date communication, such as video and message transmission as well as voice.

The scale of indoor disaster's diffusion depends on a building's structure and material. In this regard, it is possible to lost Golden Hours for rescue and escape. It is also likely to cause loss of lives and property damage by delay time for understanding the building's structure and the number of people in the building even though a rescue is under way through The Disaster Relief Network. Instead of Disaster Relief Network, therefore, systems such as WSN and BMS[4] installed in buildings should be used to respond to the event of disaster itself before rescue. As of today, many researchers have been studying the way to safely evacuate survivors through WSN/IoT based evacuation route guidance/alarm system with advanced wireless communication technology and high sensor fidelity.

This study shows that the shortest distance guidance simulator is implemented to smoothly launch a test bed for a WSN/IoT-based escape route guiding system and proposes an escape route guiding system ensuring the scalability in the event of disaster[5].

The plan of this paper is as follows, First, we wrote about a disaster simulation as a related research on the page 2. Then, we explain about that the shortest distance guidance simulator on the page 3. On the page 4, we propose an escape route guiding simulator in the event of disaster. Finally, we put the conclusion of this paper on the page 5.

II. RELATED WORKS

2.1. The necessity of computer simulation to deal with disaster situations.

The United States have focused on disaster response while Korea has spent a huge budget on disaster recovery in disaster situations. Advanced countries support disaster response effectively and quickly through computer simulation in the event of disaster, including such facility operations. In this way, they are trying to prevent collateral damage from the disaster[6].

2.2. Big-scale Escape Simulation

2.1.1. Distributed Emergency Simulation

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As disaster situations are getting bigger and more complex, techniques for disaster prediction are also getting more complex. To address the changes, various combination and formats are required for different situations, such as earthquake, fire, and collapse. This system is to focus on performing Distributed Emergency Simulation, which can make the most out of separate simulation.

This system is also managed by a central control center because it requires data transmission among Information collection, operation process, and separate simulation. A host of people can be rescued at the very begging of disaster situations, and it can also help people effectively investigate the cause of situations after they occour.

2.1.2. Cellular Automata based evacuation simulation

In order to safely rescue a slew of people at the beginning of disaster, we have modeled walking patterns in pedestrian, and Floor Field Model, microscopic walk model based on Cellular Automat, has been studied in the reference [7]. This study has been designed as a two-dimensional CA model, and the factor that has impact on their patterns is defined as field, called floor filed. The field has two values; a fixed value, such as a value determined by building's structure, exit, current position, and distance, a dynamic value, such as a size, width, spacing, virtual path.

2.1.3. Network flow based evacuation simulation

In references [8], Network flow-based escape routing algorithm has been studied, which is different from other researches to only focus on the shortest distance through routing metric. As for the use of the shortest distance algorithm only, the same paths are provided to every survivor, and as for the use of the network flow algorithm only, it only offers wide corridors. That was the problem that we tried to solve.

There are two types of nodes; Node refers to a point where decision making is required such as a fork or moon, and a path between nodes is represented by an Arc.

2.2. Small-scale Escape Simulation

Small evacuation personnel simulation refers to a system in which some individuals guide people to evacuation routes through WSN / IoT communications built in buildings rather than evacuate large numbers of people in the early days of a disaster.

2.2.1. Evacuation route guidance system using mobile application

In references [9], system to guide the optimal escape route has been studied through a mobile application of a survivor. This is not a study of the disaster situation in indoor. This study, however, is a system that receives many sensor data (weather, radioactivity, etc.) from a mobile device and guides the victims to the route with the smallest cumulative damage from the current location to the evacuation route.

2.2.2.IoT-based evacuation route guidance system in the event of subway fire

In references [10], it has been studiedfor guiding IoT-based fire evacuation routes that can be applied to subways. Although the disaster communication network was finalized with the PS-LTE network, it was mentioned that the disaster-relief terminal was not developed and that there was no separate evacuation guidance system, so it relies on manual broadcasting such as voice broadcasting. To solve this problem, the authors have studied the evacuation route guidance system based on IoT.

2.2.3. Indoor fire escape routes algorithm by prediction of temperature variation

In references [11], It improves data reliability through multilevel clustering of Gaussian Mixture Model unlike systems based on fire data collected by WSN-centered sensor network. It has been also studied to develop route system with the least amount of damage through prediction of temperature variation.

III. THE SHORTEST DISTANCE ESCAPE ROUTE GUIDING SIMULATOR

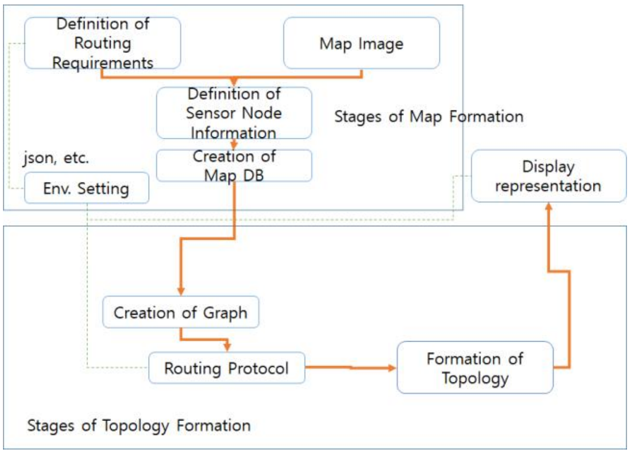

Figure 1.Flow chard of the shortest distance escape route guiding simulator

Figure 1 shows the entire system about the shortest distance escape route guiding simulator. First of all, requirements from positions between sensor nodes, roles and types, and routing protocol shall be defined, depending on a target building. Defined requirements are supposed to be save in configuration file.

Figure 2.Positions of nodes on the map image

The routes in the target building and nodes' positions are shown in Figure 2. Coordinates of corridors were calculated based on a design drawing, and then the routes that can transfer to other direction are defined as node. As shown in Figure 3, each node has scalar value in the following order; <Node type, X axis, Y axis, Horizontal, Vertical>.

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```
11    3 4486 1211 420 0
12    0 5256 1650 100 215
13    0 5256 1005 100 0
```

Figure 3. The sample map data (partial)

Node type is comprised of 4 types; number 0 to 3, and here are the roles of each node. Number 0 is a virtual Map Node to draw map data, which is shown in Figure 2. Number 1 is a Beacon Node to identify a user's location. Number 2 is a User Node. Next number 3 is an Exit Node that a user has to move to finally. X and Y values show nodes' coordinates that make them at the top-left corner of a building have (0,0). The value of horizontal and vertical is a correction value to determine whether adjacent nodes exist, showing the distance on those nodes and width of corridors.

```
> Adjacency list of vertex A
> head(1): B
> Adjacency list of vertex B
> head(3): E > D  > A
> Adjacency list of vertex C
> head(1): E
> Adjacency list of vertex D
> head(3): F > E  > B
> Adjacency list of vertex E
> head(3): D > C  > B
> Adjacency list of vertex F
> head(2): G > D
> Adjacency list of vertex G
> head(3): I > H  > F
> Adjacency list of vertex H
> head(4): L > J  > I  > G
> Adjacency list of vertex I
> head(2): H > G
> Adjacency list of vertex J
> head(3): L > K  > H
> Adjacency list of vertex K
> head(1): J
```

Figure 4. Created graph (partial)

As shown in Figure 4, Graph is formed through a linked list based on requirements that are defined as aboveand node information.

	A	B	C	D	E	F	G	H	I	J	K	L:	M	N	O	P
A	0	904	2483	1460	1580	2291	5344	5429	5795	6200	6339	6970	7615	7065	10335	11085
B	904	0	1579	556	676	1387	4440	4525	4891	5296	5735	6066	6711	6151	9431	10181
C	2483	1597	0	1023	903	1854	4907	4992	5358	5763	6202	6533	7178	6618	9898	10648
D	1460	556	1023	0	120	831	3884	3969	4335	4740	5179	5510	6155	5595	8875	9625
E	1580	676	903	120	0	951	4004	4089	4455	4860	5299	5630	6275	5715	8995	9745
F	2291	1387	1854	831	951	0	3053	3138	3504	3909	4348	4679	5324	4764	8044	8794
G	5344	4440	4907	3884	4004	3053	0	85	451	856	1295	1626	2271	1711	4991	5741
H	5429	4525	4992	3969	4089	3138	85	0	366	771	1210	1541	2186	1626	4906	5272
I	5795	4891	5358	4335	4455	3504	451	366	0	1137	1576	1907	2552	1992	5272	6022
J	6200	5296	5763	4740	4860	3909	856	771	1137	0	439	770	1415	855	4135	4885
K	6339	5735	6202	5179	5299	4348	1295	1210	1576	439	0	1209	1854	1294	4574	5324
L	6970	6066	6533	5510	5630	4679	1626	1541	1907	770	1209	0	645	85	3365	4115
M	7615	6711	7178	6155	6275	5324	2271	2186	2552	1415	1854	645	0	730	4010	4760
N	7065	6151	6618	5595	5715	4764	1711	1626	1992	855	1294	85	730	0	3280	4030
O	10335	9431	9898	8875	8995	8044	4991	4906	5272	4135	4574	3365	4010	3280	0	750
P	11085	10181	10648	9625	9745	8794	5741	5272	6022	4885	5324	4115	4760	4030	750	0

Figure 5.Example of the calculated value output of distance between adjacent nodes in matrix format

In figure 5, it shows the computed shortest distance to EXIT node for each node in the form of a metric. In this study, the shortest route was calculated using dijkstra algorithms among various shortest route algorithms. At this time, since the user aims to guide the exit as quickly as possible, the routing metric is set to the shortest distance.

```
> Current User's position (  1924,   280 )

> User cur. pos. C to Next node ( E,  1421 cm )

> User cur. pos. E to Next node ( D,  5299 cm )

> User cur. pos. D to Next node ( F,  5179 cm )

> User cur. pos. F to Next node ( G,  4348 cm )

> User cur. pos. G to Next node ( H,  1295 cm )

> User cur. pos. H to Next node ( J,  1210 cm )

> User cur. pos. J to Next node ( K,   439 cm )

> User cur. pos. K
>> Finished
```

Figure 6.The process from a randomly created user's position to the Exit Node

Figure 6 shows the conclusion representing the process of arbitrarily generated users' movement to Exit Node. The distance to Exit Node is outputted, passing through each node. At this point, the distance value 1424 is the distance to next C node from user's current position.

IV. PROPOSED ESCAPE ROUTE GUIDING SIMULATOR FOR DISASTER

Conditions that we should consider are defined to apply the shortest distance exit guiding simulator that outlined above to disaster situation.

4.1. Outline of Escape Route Guiding Simulator

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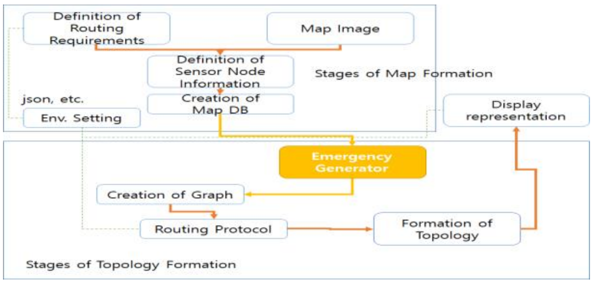

Figure 7.Flow chart of the possible shortest distance escape route guiding simulator

As seen in Figure 7, unlike Figure 1 that forms topology though routing protocol soon after forming a graph, it adds the Emergency Generator step, enabling disaster recognition between graph generation step and routing protocol step. This step collects disaster information from each node by a generated graph to form a new topology through routing protocol, conducting conformance testing of escape route.

4.2. Necessary Components for Escape Route Guiding Simulator

4.2.1. Routing Metric

In order to quickly guide users, the shortest distance escape route guiding algorithm as outlined above configures routing metric as the shortest distance. However, the shortest routeis also required to safely and quickly guide survivors. Therefore, we should minimize thecumulative damage caused by the process of user's movements to exits.

In order for each node's information to recognize a type of nodes, a coordinate of nodes, a correction value, and disaster information that mentioned above, parameters in disaster information, including temperature, possibility of fire, gas concentration, and detection of gas, should be added. Next, the metric graph as in figure 5, based on this information from routing protocol, is formed, and then each node chooses adjacent nodes that have the lowest metric to guide users to exits.

4.2.2. The Selecting Escape Route for Multiple EXIT Nodes

The current system is implemented, assuming single EXIT node. But real buildings are consisted of multi- exit as well as single-exit. To consider these circumstances, it is advised to provide the optimal escape route even in multi EXIT node-based situation.

Each node converts two-dimensional routing metric tables as in figure 5 into three dimensional tables and calculates separate routing metric table for each EXIT node. Then, each node also sets the node with the smallest metric value in the routing metric table as the EXIT node to obtain the evacuation path.

4.2.3. Additional node types for supporting multi-layered structure

The current system is implemented, assuming single EXIT node as well as single layered structure. But real buildings are consisted of multi-layered structure.

There are four types of nodes. To reflect the multi-layer structure, we need to add node types, which means upstairs and downstairs. Also, we must add integer variables that imply the current layer of each node's properties.

It is possible to reflect the change of stratum that occurs in the process of moving the survivors.

V. CONCLUSION

In this paper, we have been studied to minimize loss of lives caused by indoor disaster situations such as gas leak and fire. The system has implemented the simulator to conduct survivors into safe and quick escape routes, and it has been testified through a test bed. It allowed usto propose necessary requirements and the shortest escape route guiding system as well to apply it to actual disaster.

Our subsequent research topic is to implement guide system of multi-Exit nodes after correcting map data. Then we will implement a project for multi-layered structure, and finally routing algorithm will be extended into WSN/IoT-based routing protocol, considering sensor network and Dijkstra algorithm as well.

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