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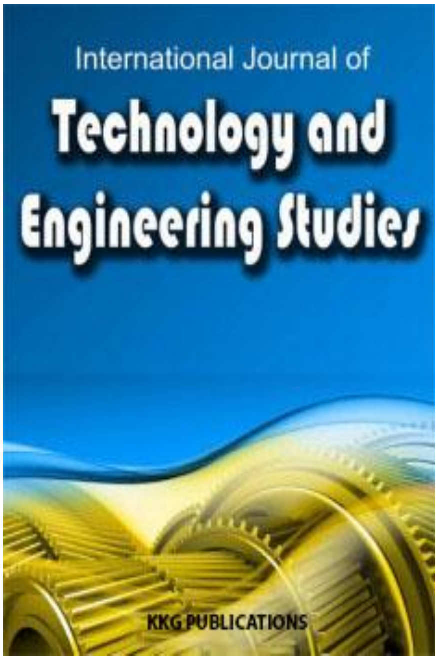

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Published online: 15 August 2015

To cite this article: N. N. Harimikti, N. S. Herman, S. A. Asmai and A. Fahmi, "Shortest path analysis for indoor navigation for disaster management," *International Journal of Technology and Engineering Studies*, Vol. 1, no. 2, pp. 48-52, 2015.
DOI: https://dx.doi.org/10.20469/ijtes.40003-2

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KKG PUBLICATIONS

International Journal of Technology and Engineering Studies

IJTES

Vol, 1, no. 2, pp. 48-52, 2015

SHORTEST PATH ANALYSIS FOR INDOOR NAVIGATION FOR DISASTER MANAGEMENT

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Keywords:
GIS
Indoor Navigation
Disaster Management
Emergency Navigation
Shortest Path Algorithm

Received: 13 April 2015
Accepted: 23 June 2015
Published: 15 August 2015

Abstract. In this paper, we identified the solution for problem occurred in indoor navigation during emergency time. The problem that may exist in indoor navigation is that it is difficult to analyse the network, so the shortest path algorithm does not work optimally. There are some existing methods to generate the network model. This paper will discuss the feasibility and accuracy of each method when it is implemented on building environment. Next, this paper will discuss algorithms that determine the selection of the best route during emergency situation. The algorithm has to make sure that the selected route is the shortest and the safest route to destination. The combination of network model and shortest path algorithm will give egress solution to the evacuee during emergency time.

INTRODUCTION

Offices and public buildings are not vulnerable to disasters. Fire and earthquake may happen anytime out of our concern. In this situation, good support in decision-making when disaster occurs is of critical importance to react accurately, fast and effectively [1]. The purpose is, of course, to reduce the number of victims and casualties. For instance, in case fire, some people are trapped in dangerous situation. They face problem while finding emergency exit or a safe place. Thus, there is necessity to find a solution to this challenging task and indoor navigation model is the answer.

An indoor navigation model was proposed and aimed at standardizing and investigating methods and algorithms for navigation in buildings [2]. Through this model, occupants are expected to get accurate guidance information that can guide them from one room to another until they reach designated place. This is called route guidance. In indoor navigation, the concept of route guidance must be considered for several reasons [3] which are specific design of map database, style of human displacement and particular needs of users which could be called user profile.

Most of the map databases are based on 2D graphical representation inherited from design plan [3]. Another way of representation is VRML or its successor X3D which are 3D graphics standard for 3D visualization [4]. However, these models do not define the semantic of the building, for example which door is exit door and which room is restricted for some user. To propose a navigation view of the building, a deeper knowledge of map objects is required in addition to more information about their topological relationship [3].

Fortunately, this problem could be overcome by these 3 models: City GML, IFC (Industry Foundation Classes) and GBXML (Green Building XML). City GML is commonly used to represent 3D urban object. It provides a geometric, topological and semantic data model. For indoor representation, level of Detail 4 (LOD4) is used [4]. Next, IFC is an exchange format for building model and contains object classes for storey, roofs, walls, stairs, etc. It is supported by most CAD-software [4]. Lastly, GBXML facilitates the transfer of building information stored in CAD. It enables integrated interoperability between building design model and a wide variety of engineering analysis tools and models [4].

Using models above, the structure of the building can be represented into deeper models as described by [5], which are geometrical and logical model. In geometrical model, the interior structure is seen as aggregation of several different types of objects (rooms, stairs, etc). In logical model, each room/crossing/exit is represented with node and paths are

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represented with link. Using geometrical model, it is difficult to extract path for route guidance. Therefore, logical model is more preferred because routes from node to node can be calculated easily [5].

In addition, to generate the route guidance quickly, the representation of the map should be in 2D model. The calculation would be very time consuming if the calculation was based on 3D model [6]. This approach can be achieved by creating 2D map model of each floor. The map changes from one to another as the occupant moves from floor to floor.

In emergency situation, the spatial information of the building is not enough for decision-making. To support good decision-making, some additional considerations must be highlighted in the calculation. As the accessible path may change as the time is passing, the algorithm should be fast enough to respond to these changes, for instance the exit is suddenly blocked. Also, as more people come to one path, the path will become crowded and the movement speed of the people will decrease. In this situation, multipath or alternate route would be good since it distributes people to prevent congestion. One important point in the calculation is that it does not necessarily find the "shortest" or "fastest" route, but the "safest" [5].

Objective of the Study

The current research objective is to propose and develop a network model for indoor navigation for emergency situation as well as to explore and simulate available shortest path algorithm to select the best route.

LITERATURE REVIEW

Network Analysis

Adjusting line algorithm using "step into corridor" This algorithm was used by [6]. From every door (access granting plane) opening into the corridor a point in the corridor is created. This point corresponds to the point where people 'step into the corridor', and is computed by making one step (1m) from the door into the corridor. Starting from the door midpoint, the step distance in the direction orthogonal to the door plane, directed into the corridor, is used.

Voronoi Diagram

Voronoi diagram was used by [7] and [8]. The Voronoi diagram represents a subdivision of space into regions whose points are closer to a generating vertex than any other element. Centerline algorithms using the Voronoi diagram begin by sampling the polygon boundary and constructing the Voronoi diagram. The intersections between the Voronoi edges converge to the polygon centerline, as the boundary sampling rate is increased. One problem with this method is the difficulty in joining centerline segments from separate but adjacent hallway polygons.

Quadtree

Quadtree was firstly developed by [9]. The most studied quadtree approach to region representation, termed a region quadtree, is based on the successive subdivision of the image array into four equal-sized quadrants. If the array is not homogenous, it is then subdivided into quadrants, subquadrants, etc. until blocks are obtained (possibly single pixels) that are homogenous; that is, each block is entirely contained in the region or entirely disjoint from it. Each array that is resulted is considered as a node. The example of using quadtree can be found in [10].

From description above, we can conclude the pros and cons of each method in the table 1 below.

TABLE 1
METHOD COMPARISON OF NETWORK ANALYSIS

Method	Pros	Cons
Adjusting line algorithm using "step into corridor"	Coarse, therefore requires less computation	The result is less detailed
Voronoi diagram	Can be applied to shapes which do not have straight but curved edges	Difficult to join centerline segments from separate but adjacent hallway polygons
Quadtree	Considers any blockage along the path	Requires more computational cost

Shortest Path Algorithm

Dijkstra

Developed by [11] the classical algorithm for route planning maintains an array of tentative distances $D[u] \geq d(s, u)$ for each node. The algorithm visits (or settles) the nodes of the road network in the order of their distance to the source node and maintains the invariant that $D[u] = d(s, u)$ for visited nodes. We call the rank of node u in this order its Dijkstra rank rks(u). When a node u is visited, its outgoing edges (u, v) are relaxed, i.e., D[v] is set to $\min(D[v], d(s, u) + w(u, v))$. Dijkstra's algorithm terminates when the target node is visited. The size of the search space is O(n) and n/2 (nodes) on the average.

Floyd-Warshall

This algorithm was developed independently from each other by [12]-[17]. Instead of computing a path from a given start node to all other nodes (or a single destination node), all shortest paths, i.e., from each node to all others, are computed within a single loop. As a result we obtain a matrix Dist, where Dist[i, j] denotes the distance from node i to node j. Furthermore a matrix Next can be computed where Next[i, j] represents the successor of node i on the shortest path from node i to node j. Floyd-Warshall's algorithm has a time complexity of O(n3), which is equivalent to performing Dijkstra's algorithm n times. However, [13] stated that Floyd is usually faster than executing Dijkstra's algorithm for each node.

A* Search

The intuition behind goal directed search is that shortest paths 'should' lead to the general direction of the target. A∗ search [14] achieves this by modifying the weight of edge (u, v) to $w(u, v) - \pi(u)+\pi(v)$ where $\pi(v)$ is a lower bound on d(v, t). Note that this manipulation shortens edges that lead towards the target. Since the added and subtracted vertex potentials $\pi(v)$ cancel along any path, this modification of edge weights preserves shortest paths. Moreover, as long as all edge weights remain non-negative, Dijkstra's algorithm can still be used. The classical way to use A∗ for route planning in road maps estimates d(v, t) based on the Euclidean distance between v and t and the average speed of the fastest road anywhere in the network. Since this is a very conservative estimation, the speedup for finding quickest routes is rather small.

Bellman-Ford

Bellman-Ford algorithm is another algorithm to compute the shortest paths from a single point to all the other points in weighted network. Unlike other algorithms, Bellman-Ford path-finding algorithm allows not only positive but also negative weights in a graph, as long as there is no negative cycle. However, [15] stated that the efficiency of Bellman-Ford algorithm is lower than Dijkstra's algorithm for the same problem.

Johnson's

Johnson's algorithm is developed by [16] and uses Bellman–Ford and Dijkstra's algorithm in its application. It allows some of the edge weights to be negative numbers, but no negative-weight cycles may exist. The Bellman–Ford algorithm is firstly used to compute a transformation of the input graph that removes all negative weights, then allowing Dijkstra's algorithm to be used on the transformed graph.

From description above, we can conclude the pros and cons of each algorithm in Table 2 below.

TABLE 2
SHORTEST PATH ALGORITHM COMPARISON

Algorithm	Pros	Cons
Dijkstra	▪ Single vertex to another ▪ Non-negative weighted graph	Fails with negative edge
Floyd-Warshal	▪ All pairs of vertices ▪ May contain negative weight ▪ Produce adjacency matrix for all nodes	▪ Complexity $O(n^3)$ ▪ Requires more spaces to store matrix
A* Search	▪ Single vertex to another ▪ Use calculation of Euclidean distance	Requires Euclidean distance of each point
Bellman-Ford	▪ Single vertex to another ▪ May contain negative weight	The performance is slower than Dijkstra
Johnson's	▪ All pairs of vertices ▪ May contain negative weight ▪ Transforms negative weight to non-negative	Needs two steps: Bellman-Ford to transform graph and Dijkstra to find shortest path

RESEARCH MODEL

Figure 1 shows the current research model. Network analysis part will transform 2D building environment into network model. This network model will become input for shortest path algorithm, combined with link cost, to generate evacuation guidance. Link cost is weight of the network that is heavily influenced the by condition of the building during emergency time.

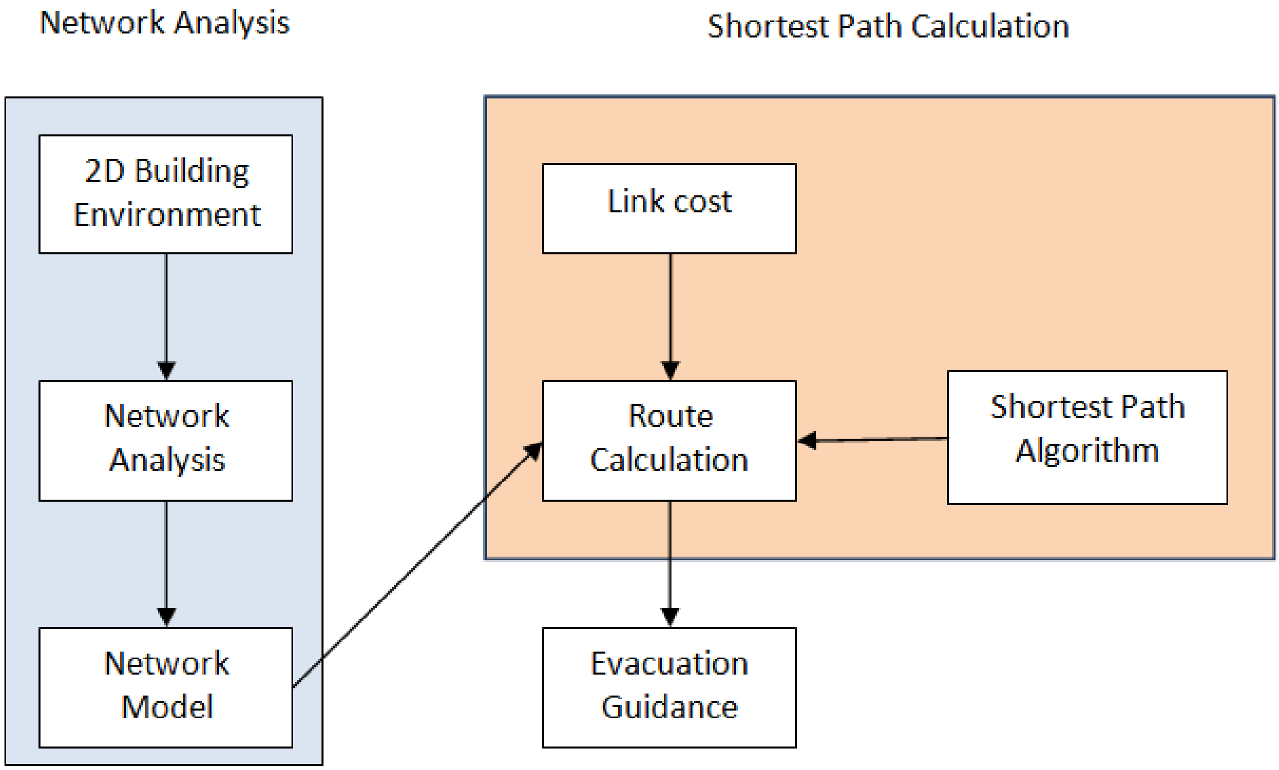

Fig. 1. Research Model

DISCUSSION

The main consideration of route guidance during emergency time is speed and accuracy. In terms of speed, the route guidance must be generated fast and should be very adaptive to network condition. The shortest route is not always the safest route during emergency time. Therefore, in term of accuracy, the generated route must be the safest and shortest, which avoids dangerous places.

From the network models in previous part, quadtree has good accuracy because it is very detailed, but it falls in term of speed because of the complexity. On the other hand, adjusting line algorithm using "step into corridor" and Voronoi diagram have advantage over quadtree in term of speed because they are less complex. However, adjusting line algorithm using "step into corridor" is the least accurate network as compared to the others. Therefore, we choose Voronoi diagram as the best choice for network model because of its speed as well as accuracy.

In previous part, we also discussed about shortest path algorithm for use in this research. The shortest path algorithm that must be noted in terms of accuracy is A* Search. It uses Euclidean distance to destination node and does not see the whole network, therefore there may be a case where the best route will be neglected. Another algorithm, Floyd-Warshal, falls in speed because it has $O(n^3)$ complexity. The other three, Dijkstra, Bellman-Ford and Johnson's, may be good choices for calculating the best route. However, in term of performance, Dijkstra is the best among them. Dijkstra falls when calculating negative value in link cost but in this research we do not use negative value for link cost.

CONCLUSION

An indoor navigation model was proposed and aimed at standardizing and investigating methods and algorithms for navigation in buildings [2]. Through this model, occupants are expected to get accurate guidance information that can guide them from one room to another until they reach designated place. During emergency situation, this model is expected to help people who face problem while finding emergency exit or safe place. Moreover, the route generated must not only be short but also safe.

The network model should exhibit a detailed network in order to give detailed guidance to the users or evacuees, but it must not sacrifice the computational cost because time is important during emergency situation. The model must also elaborate with suitable shortest path algorithm. The shortest path algorithm must be adaptive to changes because the condition of the network frequently changes during emergency situation which is reflected by link cost that may change from time to time.

We consider Voronoi diagram and Dijkstra's algorithm as the main components to generate route guidance during emergency time.

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— This article does not have any appendix. —