Jurnal Teknologi

Full Paper

Dijkstra-Ant Colony Optimization Algorithm for Shortest and Safest Evacuation in High Rise Building

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Article history
Received
20 October 2015
Received in revised form
8 February 2017
Accepted
15 February 2017

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Abstract

The successfulness of evacuation is defined by the ability of the evacuees to escape from the danger place safely in a short time. The three problems highlighted in this study are evacuees do not know the right route should they take to safe themselves especially in high rise building due to the complexity of the building. Moreover, the provided evacuation map in the building is commonly not showing the shortest and safest path to assist evacuees in choosing the best route. Furthermore, the shortest path algorithm needs additional features to support the directed graph in order to obtain the best result. The objectives of this study are to design and develop the evacuation route via the shortest path algorithm and to evaluate the evacuation route model in high rise building evacuation maps. The methods used are modelling the evacuation route from the original floor plan into 2D floor plan, and then generating the directed graph based on the distance between nodes and coordinate of nodes to generate the shortest and safest path based on the utilisation of Dijkstra's algorithm and Dijkstra-Ant Colony Optimization (DACO). The results obtained are proven consistent in generating the shortest and safest path with the same distance.

Keywords: Dijkstra's algorithm, Dijkstra-Ant Colony Optimization, Evacuation, Safest Path, Shortest Path

Abstrak

Kejayaan evakuasi didefinisikan berasaskan keupayaan mangsa menyelamatkan diri dari tempat bahaya dengan selamat dalam masa yang pendek. Tiga masalah yang terlibat di dalam penyelidikan ini ialah mangsa tidak mengetahui jalan yang sepatutnya diambil untuk menyelamatkan diri terutama di dalam bangunan tinggi disebabkan oleh struktur bangunan yang kompleks. Lebih-lebih lagi, peta evakuasi yang telah disediakan di dalam bangunan tidak memaparkan laluan terpendek dan terselamat dalam membantu mangsa membuat pilihan laluan yang terbaik. Tambahan lagi, algoritma laluan terpendek memerlukan ciri tambahan untuk membantu graf berarah untuk mendapatkan keputusan yang baik. Objektif yang terlibat ialah mereka bentuk dan mengembangkan laluan evakuasi via algoritma laluan terpendek dan menilai model laluan evakuasi dalam peta evakuasi bangunan tinggi. Kaedah yang digunakan ialah membina model laluan evakuasi daripada pelan asal bangunan kepada pelan 2D dan seterusnya menjana graf berarah berdasarkan jarak di antara nod dan koordinat nod untuk menghasilkan laluan terpendek dan laluan terselamat menggunakan algoritma Dijkstra dan algoritma Dijkstra-Pengoptimuman koloni semut (DACO). Keputusan yang diperoleh adalah konsisten dalam menjana laluan terpendek dan terselamat dengan mendapat jarak yang sama.

Kata kunci: Algoritma Dijkstra, Dijkstra-Pengoptimuman Koloni Semut, Evakuasi, Laluan Terselamat, Laluan Terpendek

1.0 INTRODUCTION

Evacuation means to save people [1] from danger to safe place [2] [3]. The important element needed in an evacuation process is to find the best evacuation route, while the evacuation route obtained should be as short and safe as possible in order to achieve success for evacuation.

Making a decision is one of the main problems during evacuation process, since evacuees generally need to know the right route to take them to safe places. Particularly in high rise building [4] [5]. Moreover, this would be more critical if the evacuees are unfamiliar with the building [6]. Furthermore due to the complexity of the building and spreading of hazard, the evacuation process becomes more difficult since evacuees need to decide the best path to be taken [7] as quick as possible.

Nowadays, high rise building structure is built with complex internal structure [8] besides bigger in size [9] these could make the rescue operation becoming more difficult. Building structure has an important role in contributing successfulness of evacuation. In order to avoid choosing dead routes or many kinds of route to reach destination, evacuees should know the structure of the building well [10]. The need of providing an evacuation map to each building [11] [12] and exit door placements [13] is essential to guide the occupants to follow the shorter path to the exit.

Typically, evacuation plan is drawn based on the floor diagrams showing the suggested paths to the exit or safe endpoint. The evacuation plan needs to clearly illustrate the routes, unobstructed and is always clear [14] to guide the evacuees in the building [15]. However, the plan is commonly drawn the path without any consideration on safety and shortest path. The evacuation plan is needed in guiding the evacuees to the shortest path.

Additionally, the shortest path algorithm which is Dijkstra's algorithm needs additional features to support better results. Dijkstra's algorithm has high computation and low efficiency in solving the large number of nodes as agreed by Bu & Fang (2010). The weaknesses of the algorithm lie on the runtime and memory usage [17]. This research study attempts to overcome the weakness of Dijkstra's algorithm with the Ant Colony Optimization in terms of bio inspired approach, the obtain result is renamed as DACO (Dijkstra's-Ant Colony Optimization).

The problems are solved based on the two proposed objectives which are to design and develop an evacuation route via shortest path algorithm and to evaluate the evacuation route model in high rise building evacuation maps.

2.0 METHODOLOGY

The research flow chart in the Figure 1 shows the step involve in generating shortest and safest path by utilizing Dijkstra's algorithm and DACO.

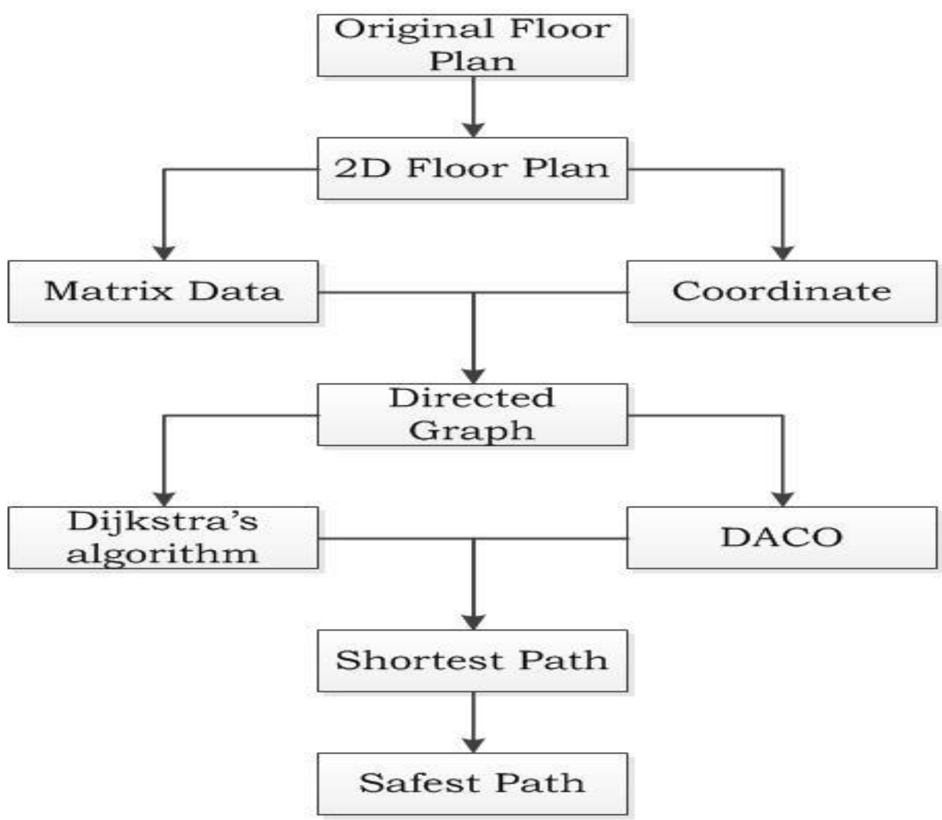

Figure 1 Research flow chart

Based on Figure 1, the original floor plan of the building is gained and converted into CAD format. The CAD format is the second step of the methodology, the 2D floor plan is derived to represent the original floor plan in 2D image. In the 2D view floor plan, each door is assigned as node and the path between connected nodes are created. The distance between nodes and coordinate of the nodes is also generated from this step. The distance of the nodes is collected into matrix data to generate directed graphs. Then the directed graph utilise the used of Dijkstra's algorithm and DACO to generate shortest and safest path.

The utilising of two algorithms which are Dijkstra's algorithm and DACO algorithm are able to gain the shortest and safest path. The Dijkstra's algorithm is chosen due to its efficiency in optimizing field to provide a safer evacuation plan [18][19][20]. Dijkstra's algorithm are able to find the shortest distance among a node to all other nodes [21] [22] [23]. However, the Dijkstra's algorithm has a few limitations which are high computation and low efficiency in solving large network of nodes. The limitations are solved using extended version of Dijkstra's algorithm in bio inspired approach which is DACO. DACO involved a smaller amount of nodes compared to Dijkstra's algorithm to reduce the computation time and moreover, the DACO uses the coordinate of nodes instead of weight between nodes to obtain the result compared to Dijkstra's algorithm. The shortest path is the calculation of distance between source node and destination node, the source node is defined as the current place of the evacuees while the destination node is the safe place to escape from the building [24]. The safest path is determined by enhancing the shortest path results by considering the presence of hazards along the route between source and destination node.

3.0 RESULTS AND DISCUSSION

Figure 2 shows the 2D floor plan from node 3 until node 21. Node 3 represents the room where the start place is defined. While, node 21 is the staircase to exit the building. From the 2D layout plan, the distance between nodes involved is collected into the matrix table (Table 1).

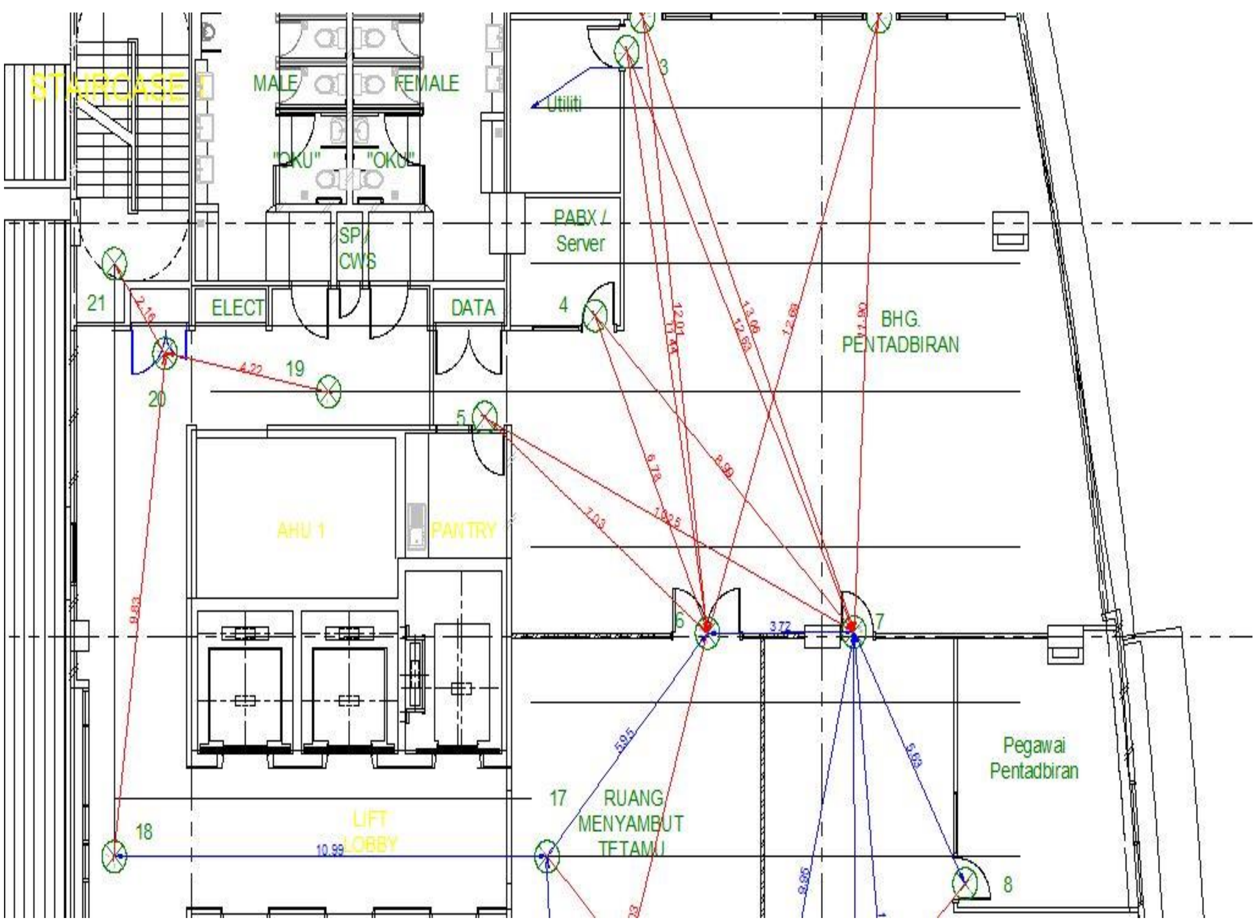

Figure 2 2D Floor Plan from Node 3 – Node 21

Table 1 Matrix Data Shortest Path from Node 3 to Node 21

Node	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0	0	0	11.44	12.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	6.78	8.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	7.03	10.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	3.72	0	0	0	0	0	0	0	0	0	5.95	0	0	0	0
5	0	0	0	3.72	0	0	9.95	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	5.63	0	7.04	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	9.95	0	0	0	0	0	0	0	0	0	7.63	0	0	0	0
8	0	0	0	0	11.56	0	4.01	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	13.03	0	4.11	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	6.83	9.01	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	6.22	8.23	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	2.27	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	2.27	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	5.34	4.78	0	0	0	0	0	0
15	0	0	0	5.95	0	0	7.63	0	0	0	0	0	0	0	0	10.99	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.99	0	0	9.83	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.22	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.16
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The matrix data shows the connection between nodes, the first node is node 3 in the 2D floor plan, while node 21 in the 2D floor plan is renamed as node 19 for Dijkstra's algorithm (DA). The renaming of the nodes are shown in Table 2.

Table 2 Rename of node

Node 2D Floor Plan	Node DA
3	1
4	2
5	3
6	4
7	5
8	6
10	8
11	9
12	10
13	11
14	12
15	13
16	14
17	15
18	16
19	17
20	18
21	19

Based on the renamed nodes, the result on directed graph is obtained which is showing the results of shortest path based on DA as shown in Figure 3.

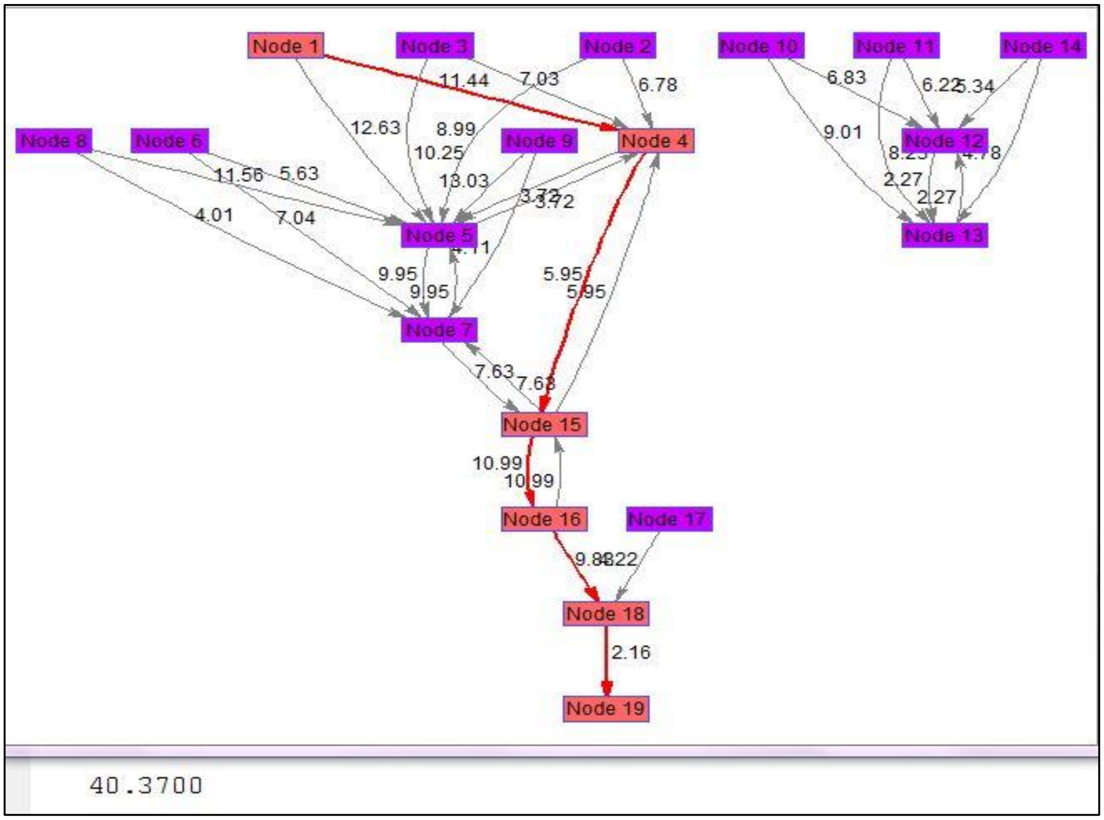

Figure 3 Results DA Shortest Path from Node 1 – Node 19

The shortest path obtained is 1> 4> 15> 16> 18>19 with distance 40.37 m. The enhancements on shortest path result by removing the edge between nodes 4 to 15 to obtain safest path are shown in Figure 4 below.

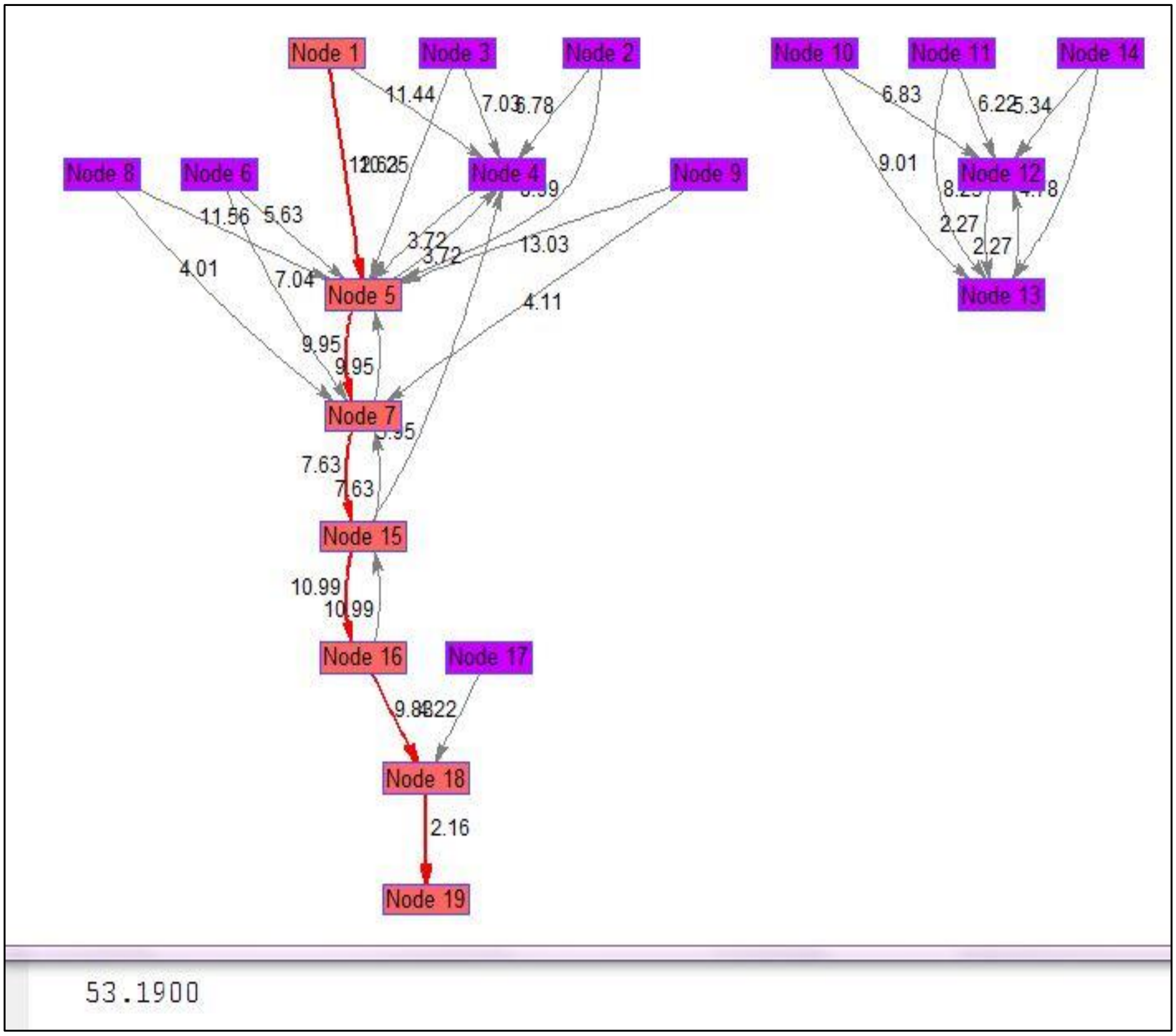

Figure 4 Results DA Safest Path from Node 1 – Node 19

The safest path is obtained through the other node compared to shortest path which are 1> 5> 7> 15> 16> 18>19 and distance is 53.19 m. The safest path is derived to considering the presence of hazard on the danger path. In this case, the path between nodes 4 to 15 is considered as unsafe. Subsequently, the new result is derived as safest path results and the distance is increased.

The second algorithm is DACO, Table 3 shows the comparison on the number of nodes in 2D floor plan, DA and DACO. The nodes are different because the nodes are renamed ascendingly in each algorithm.

Table 3 Coordinate DACO Shortest Path

Node 2D	Node DA	Node DACO	x axis	y axis
3	1	1	-579158.4	-2360237.1
6	4	2	-577109.2	-2371490.7
17	15	3	-581184.7	-2375821.6
18	16	4	-592179.2	-2375821.6
20	18	5	-590886.7	-2366080
21	19	6	-592179.2	-2364343.7

The DACO algorithm uses different input compared to DA. The DA uses the distance of nodes while the DACO uses the coordinate of nodes. It shows that DACO can generate a new result based on the coordinate which is the length between nodes. The shortest path using DACO is shown in Figure 5.

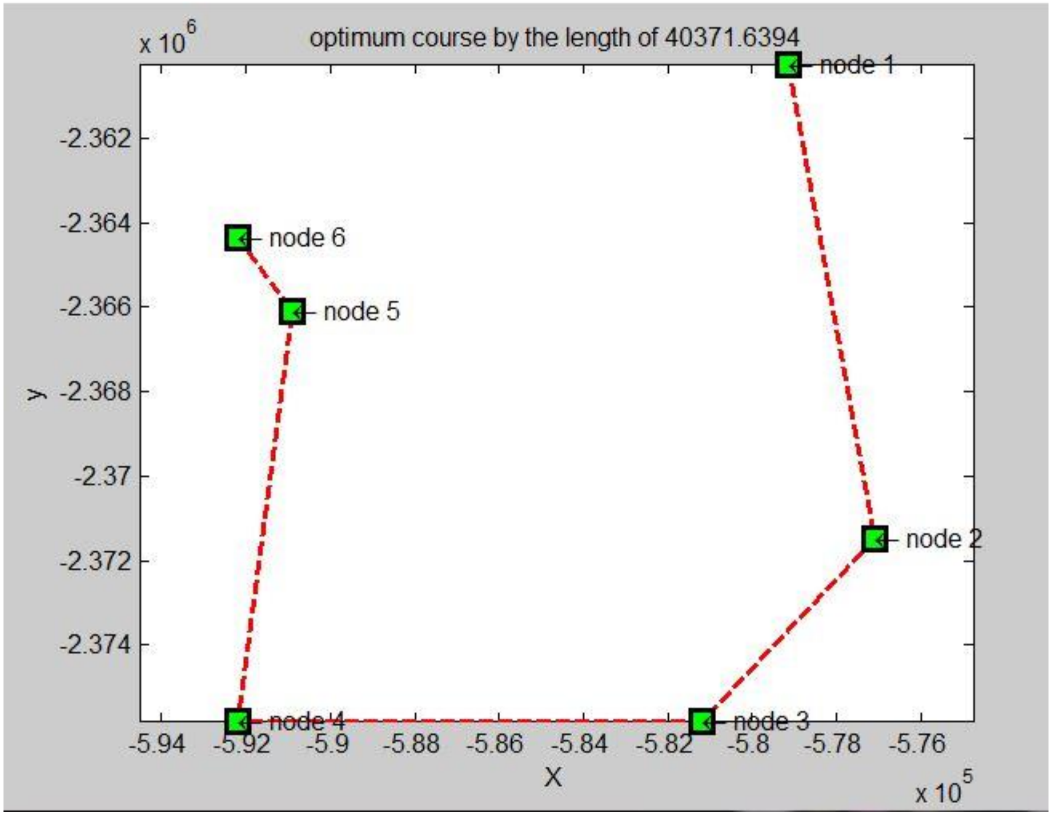

Figure 5 Results DACO Shortest Path from Node 1 – Node 6

The path taken is from 1> 2> 3> 4> 5> 6 and the distance is 40371.6394mm converted into 40.37 m. Compared to the result using DA and the node involved in 2D floor plan, the nodes involved are the same to each other. The coordinate of the nodes for safest path is shown in Table 4.

Table 4 Coordinate DACO Safest Path

Node 2D	Node DA	Node DACO	x axis	y axis
3	1	1	-579158.4	-2360237.1
7	5	2	-573390.9	-2371470.8
9	7	3	-575725.2	-2381142.2
17	15	4	-581184.7	-2375821.6
18	16	5	-592179.2	-2375821.6
20	18	6	-590886.7	-2366080
21	19	7	-592179.2	-2364343.7

The safest path is obtained as Figure 6 below.

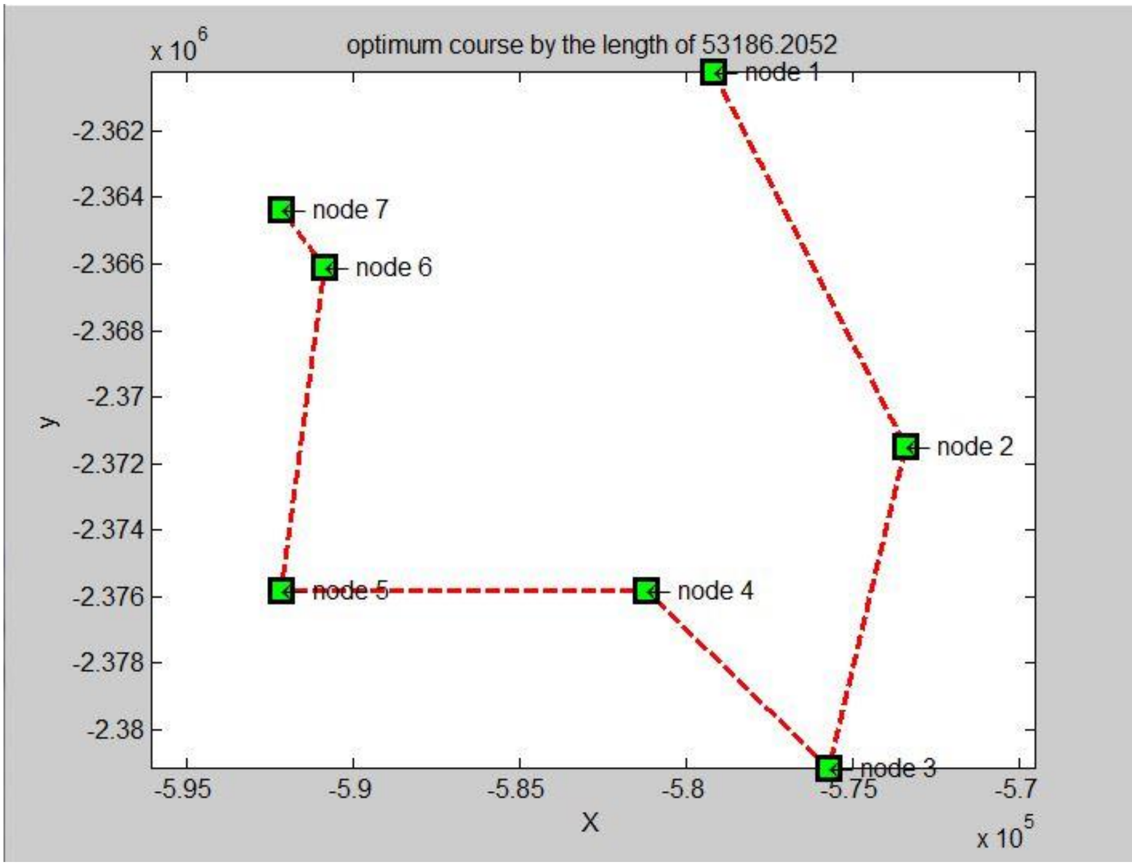

Figure 6 Results DACO Safest Path from Node 1 – Node 7

The path taken are 1> 2> 3> 4> 5> 6> 7 and distance is 53.19 m. Table 5 shows the summary of result obtained from the both algorithm.

Table 5 Summary of Results DA and DACO

	DA	DACO
Shortest Path	1> 4> 15> 16> 18>19	1> 2> 3> 4> 5> 6
Distance	40.37 m	40.37 m
Safest Path	1> 5> 7> 15> 16> 18>19	1> 2> 3> 4> 5> 6> 7
Distance	53.19 m	53.19 m

Based on the results, the distance and path taken are consistent to each other. This results support the use of DACO as extended version of Dijkstra's algorithm in bio-inspired approach. The both algorithms using the same input which is the path distance and able to compute the shortest and safest path and displayed in evacuation plan.

4.0 CONCLUSION

In this study, finding the shortest and safest path using Dijkstra's Algorithm and Dijkstra-Ant Colony Optimization (DACO) Algorithm are discussed by using evacuation route simulation model via MATLAB program. The methods involve converting original floor plan into 2D floor plan, then generating the directed graph based on the distance between nodes and coordinate of nodes. Finally, the shortest path is calculated using the two selected algorithms which are Dijkstra's Algorithm and DACO, the results between two algorithms are consistent. The DACO algorithm is proven as a substitute of Dijkstra's algorithm in bio inspired approach. The future improvement of the safest path can be obtained using Ant Colony Optimization.

Acknowledgements

The authors would like to thank Faculty of Information and Communication Technology (FTMK), Universiti Teknikal Malaysia Melaka (UTeM) for supporting this research. This research is also part of a Master by research study in at FTMK and funded under Fundamental Research Grant Scheme (FRGS) number FRGS/1/2013/ICT07/02/2/F00162.

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