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Reliability study on the adaptation of Dijkstra's algorithm for gateway KLIA2 indoor navigation

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ABSTRACT

This paper describes a reliability study on the adaptation of Dijkstra's algorithm (DA) in the indoor environment for navigation purposes. Gateway KLIA2 located at Sepang, Selangor, Malaysia has been chosen as the area for case study. Gateway KLIA2 is divided into 4 levels but this research focused on Level 2 only that consists of 129 shop lots. A survey conducted towards 68 public respondents before the adaptation and most of them responded that they are not aware of the surrounding of KLIA2 and are facing difficulties in finding the information or location of certain places inside the building. DA was chosen because it helps the users to navigate using the shortest path to destination. It is proven that through the adaptation of DA, we are able to provide the shortest distance for indoor navigation from current location to the destination location. *G*-INS is reliable based on the functionality and reliability testing conducted towards 15 users with the distance reduction of 47% t-test result of 0.01303 ($p<0.05$), indicates the system is accepted.

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1. INTRODUCTION

Navigation is the study of determining position and concerned in providing the way to destination location that avoid any circumstances [1]. There are two types of navigation which are indoor navigation and outdoor navigation [2]. For outdoor navigation, this type of navigation will used global positioning system (GPS) that used satellite system as information receiver about location and time [3]. For this research, the focus will be on indoor navigation. Indoor navigation does not need a lot of data because it uses the existing data available in the environment such as layout of the floor [4]. Thus, people can easily search and go to their indoor destination places.

Gateway KLIA2 has been chosen as a research area because it is a new and huge building, with each floor having different layout. This integrated complex mall is designed nearby Malaysia Airport KLIA2 with 350,000 square feet of retail space spanning over 4 levels and a fresh airport-within-a-mall concept "Gateway@KLIA2 Mall, 4-level shopping mall at the KLIA2 | Malaysia Airport KLIA2 Info". This place has been the main attraction for those who want to travel. Gateway KLIA2 is divided into 4 levels but the main focus area of this research is just one level which is level 2. Currently, the public is facing problems to navigate in Gateway KLIA2. Despite the signage and direction being provided, people just follow the path, no information or any cue about that [5-6]. Sometimes the signage is confusing to the public, so people just go around and do not have accurate information about their location [7]. Most of the public who is not aware about surrounding places in Gateway KLIA2 and just assumed their direction to certain places [8].

The target user for this research is the public who arrived at Gateway KLIA2 because they might not know or be aware about the surrounding of the area. They have problems searching for certain places in the building and will consume a lot of the time to find it. For example, those who has never experience being at an airport and they want to go for window shopping while waiting for the departure time. Consequently, they might miss the flight and delay their journey.

There are various types of algorithm that can be used to solve the shortest path problems such as Greedy Algorithm, Floyd-Warshall Algorithm, Bellman-Ford Algorithm and Dijkstra's algorithm. Among the algorithms, Dijkstra's algorithm (DA) is the best and suitable techniques to be adapted for this research. This algorithm is widely used in certain areas to calculate and solved shortest path problem such as computer network routing algorithm, robot pathfinder and route navigation. By implementing this technique into indoor navigation system INS, it can help the public to find the shortest path in a building and can reduce the time taken to the destination [9, 10]. Thus, DA is the best algorithm because it is suitable for this study which are to find the shortest path in single source and no negative edge [11]. Therefore, this paper presented indoor navigation system through the adaptation of DA using Gateway KLIA2 as the case study in order to overcome the problem. The public can get to know the shortest path from their current location to their destination using DA. It is also to ensure that the time taken to get to the destination is shorter, and able to save time moving around in an indoor environment.

2. RELATED WORK

In this section, we describe the shortest path techniques and the adaptation of DA.

2.1. Shortest path techniques

Shortest path algorithm (SPA) is an algorithm related to a "search algorithm" on searching the shortest path among the obstacles that can be measured based on the [12]. SPA is classified into three categories, which is single-source SPA, single destination SPA, and all-pairs SPA [12]. The previous study by [13] have reported a search algorithm that is generally evaluated based on four criteria, which is completeness, time complexity, space complexity and optimality. It was concluded that completeness is not critical as compared to other criteria and due to only the need for the best route (optimality) [14]. Table 1 shows the algorithms and their description.

Table 1. Algorithm's description

Algorithms	Details
Dijkstra's Algorithm	Find the minimum value through all nodes [11, 15] Can be interpreted as breadth-first search (carried out all steps include unnecessary steps [15] Solve single-source shortest path problem [16]
Floyd- Warshall Algorithm	Computing of the shortest path between all pairs of nodes [16] Use a matrix of length as input [16] Faster executing [15]
Bellman- Ford Algorithm	Computes shortest path from single source node to all of other nodes [16] Simple execute [16] Returns Boolean value whether or not there is negatives [16]
Johnson's Algorithm	Find the shortest paths between all pairs nodes [16] Combine Bellman-Ford algorithm and Dijkstra's algorithm to quickly find the shortest paths [16]

In conclusion, there are various differences between algorithms. Besides, to use these algorithms, user must be clear about the problems and choose the right algorithm. This research aimed to find destination in Gateway KLIA2 from a single source location and not allow any negative edge. Thus, DA was chosen as the technique to find the shortest path. Despite Bellman-Ford Algorithm is also a single source node, yet it considers the negative edge which not suitable for this research. Negative edge is a situation where the algorithm only compares the first two node and get the shortest weighted without comparing with other nodes. The result from the negative edge is not suitable for this research because the objective is to calculate the shortest path from current location to desired destination location

2.2. Dijkstra's algorithm

Murota and Shioura contended that the well-known algorithm for the single-source shortest path problem is Dijkstra algorithm (DA) and it is a directed graph with the non-negative edge length which is a classical combinatorial optimization problem [17]. This is supported by [18] that mentioned DA produces the shortest path and it is a graph search algorithm that solves the single-source shortest path problem for a graph with the non-negative edge path costs. This algorithm can be applied in transport, logistic management and other network optimization [19]. DA applying the greedy algorithm's approach as the problem solving methods for the single-source shortest problem. The problem of finding the single-source shortest path from a specified node *'i'* to another node *'j'*, stated as follows:

- A weighted connected simple graph with all weights positive, G=$\langle V, W\rangle$, all nodes in it stored in set V (v_0, v_1, $v_2 \ldots\ldots v_n \in V$) and the weights of each neighboring nodes are stored in set W (W_0, W_1, $W_2 \ldots\ldots W_n \in W$) and all points starting from the source point of the shortest path are stored in set S. When initializing, only the specific zone value is stored in V-S. $D(j)$ representing the distance between the source point 's' and the point 'e_j'. All points in the weighted graph represented by the adjacency matrix A. $A(i,j)$ mean that the distance between point 'v_i' and 'v_j' in matrix A and $A(i,j)=\infty$ when there is no direct path or not an edge in G.
- Initialization, $S=\{s\}$, V - $S=\{v_0, v_1, v_2 \ldots\ldots v_n \in V\}$. Select the points '$v_j$' and make $D(j)$=min $\{D(i) \mid v_j \in (V$-$S)\}$, $S=S\cup v_j$;
- Change the source point *'s'* to point 'v_j'$\in(V$ - $S)$ and $D(j)=D(i)+A(i,j)$, if $D(j) > D(i)+A(i,j)$.
- Repeat steps (2) and (3) until obtaining the shortest path from the source point *'s'* to the rest of the nodes is obtained.

DA solves the shortest path problem effectively and considered as an optimal algorithm with a full understanding of the environment [20] and suitable to solve the routing issue in navigation. The statement also supported by [21-22], the theory of DA is order of path length increasing gradually to search out the shortest route.

3. RESEARCH METHOD

In this section, the methodology for the adaptation of DA divided into two phases: gather the information and design and developments phases.

3.1. Gether Information

A survey was conducted to the public at KLIA2 to 68 respondents. 70.6% responded that they are not familiar with the specific location of the places in Gateway KLIA2. Consequently, they took a longer time to find the destination or to get information about the surrounding of Gateway KLIA2. Longer time taken is caused reflected by lack of information due to the prediction path not being provided [23]. Table 2 shows the distribution method used to search for certain places in Gateway KLIA2.

Table 2. Method used to search places in gateway KLIA2

Method	Percentage response
Follow the signage	39.7%
Search the main directory	29.4%
Search the information counter	26.5%
Ask from other people	4.4%

From the same survey, 89.7% respondents claimed that they took longer time to go to the destination in KLIA2 due to by the lack of information and their prediction path not being provided. Moreover, they were not aware of their current location due to lack of accurate location when they move independently [24]. As a result, people might get lost in the big building if there is no proper method to navigate them to the destination [25]. This can make them panic when they are not able to find what they are looking for. Therefore, this research is proposed in order to help the public navigate to the destination in the shortest time duration.

3.2. Design and development

At this phase, four activities are involved to cater for the objective on how to adapt the DA into the study.

3.2.1. Indoor floor plan layout

Gateway KLIA2 is divided into 4 levels which are Level 1, Level 2, Level 2M and Level 3 but this research focused on Level 2 only that consists of 129 shop lots. The 2 dimensional (2D) floor plan that has been imported into AutoCAD as in Figure 1 and nodes of certain location and lines of distance from one node to another node have been drawn following the original measurement floor plan scale which is 1:350. This is the most important and critical step because we need to get the actual distance of the shop lots.

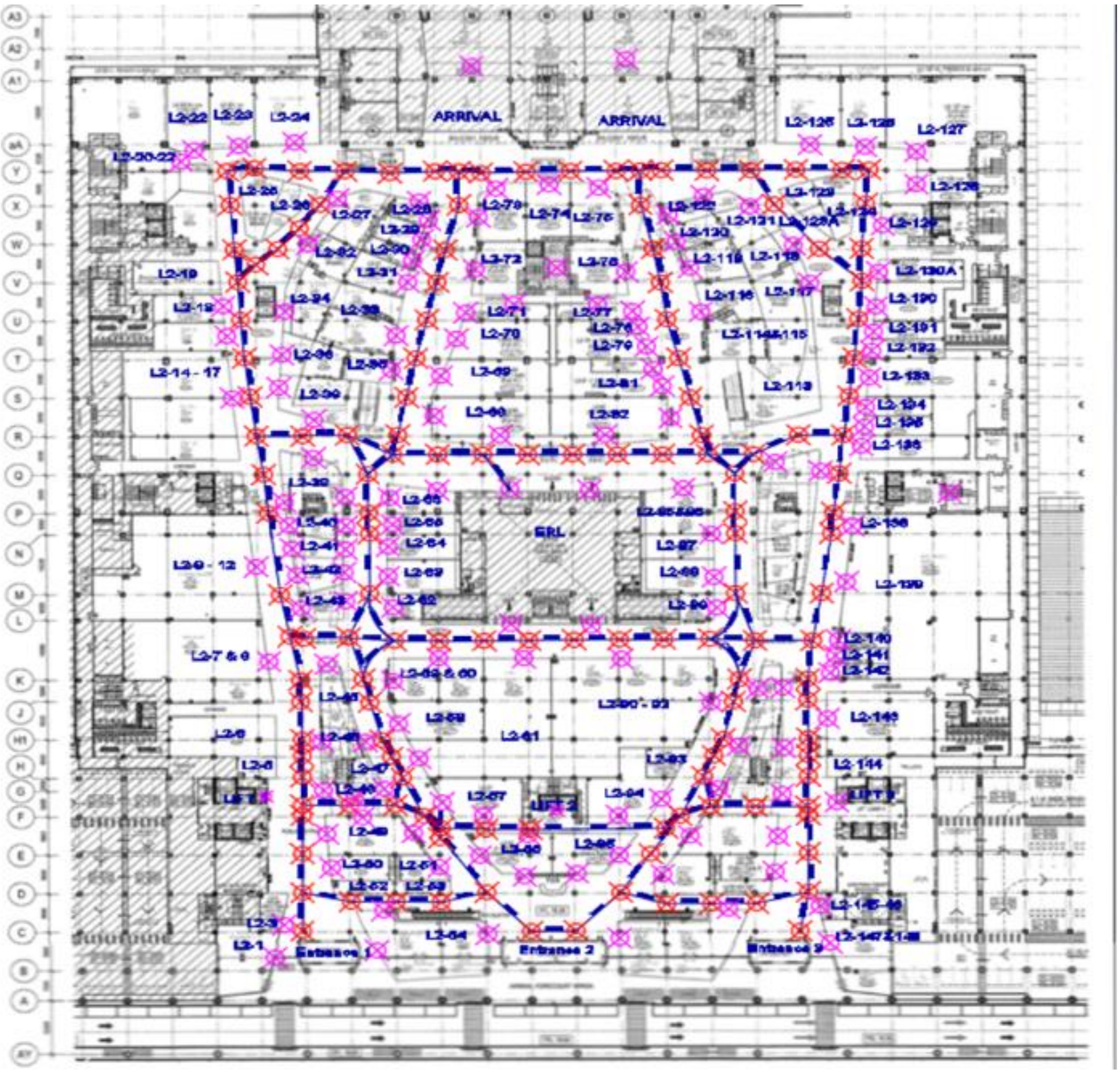

Figure 1. AutoCAD drawing node and distance of floor plan level 2 in gateway KLIA2

3.2.2. Distance matrix table

The value of the actual distances gained from the first activity were stored in a matrix table as guideline to create the shortest path by program the coding of DA using MATLAB software.

3.2.3. Dijkstra's algorithm implementation using MATLAB

For the adaptation of DA, few coding in MATLAB was implemented with the specific function steps involved as in Figure 2. The value in the matrix table included in the coding according to the node position in an array form.

3.2.4. Flowchart diagram

For this research, flowchart diagram is described as the step by step process to be implemented by users in order to get destination location by using shortest path in a building such as Gateway KLIA2. Based on Figure 3, the system start by showing the user interface. Then, user select their current location. The system point the node of current location that have been selected by user. After that, user select their destination location. Lastly, the prototype system will generate the output by using DA and shows the shortest path node to destination location for user to follow.

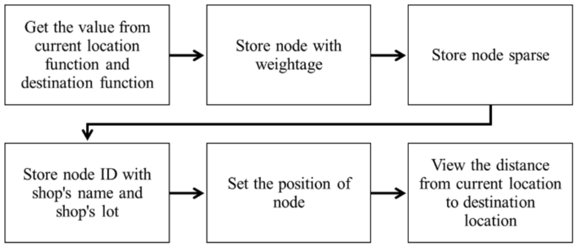

Figure 2. Steps involved in specific MATLAB function

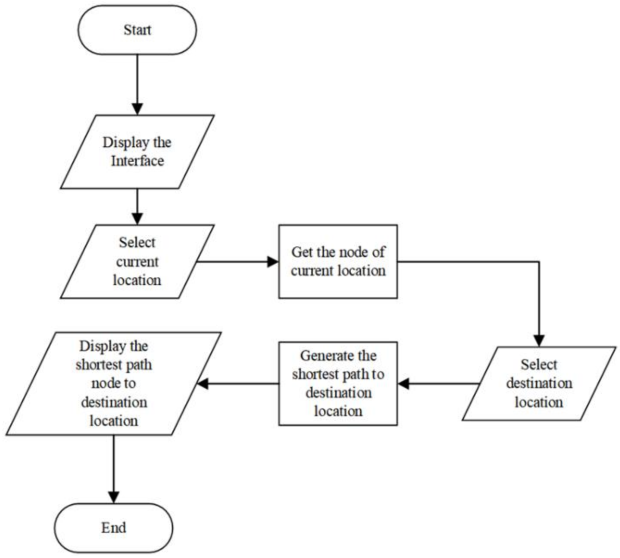

Figure 3. Flowchart diagram for user

4. RESULTS AND ANALYSIS

This section discusses the results and findings gained from the study for Gateway KLIA2 Indoor Navigation system (*G*-INS) through the adaptation of DA. There were two types of testing used which were functionality testing and reliability testing. Functionality testing focused on the function of all the buttons and process in the system, while reliability testing focused on the comparison distance that was shortest path for users to navigate.

4.1. Functional testing

The functionality of the system was tested five times (Test1 until Test5) based on the menu provided in the prototype to make sure the function meets the requirement and works correctly for the user, and the result is depicted in Table 3. All test shows the positive result of the functionality test from Test1 until Test5. Figure 4 shows the snapshot of the prototype for the user to use. Figure 5 and Figure 6 shows the system functionality by selecting the current location and the destination and finally Figure 7 shows the result of the system which provides the navigation and total distance, *m*.

Table 3. Functionality test result

Component	Test1	Test2	Test3	Test4	Test5
Select current location	Ok	Ok	Ok	Ok	Ok
Select shop's category	Ok	Ok	Ok	Ok	Ok
Select shop lot under shop's category	Ok	Ok	Ok	Ok	Ok
Select user destination	Ok	Ok	Ok	Ok	Ok
Click "Output"					
• Navigation	Ok	Ok	Ok	Ok	Ok
• Distance	Ok	Ok	Ok	Ok	Ok
View output - distance	Ok	Ok	Ok	Ok	Ok
Click "Clear All"	Ok	Ok	Ok	Ok	Ok
Click "Close"	Ok	Ok	Ok	Ok	Ok

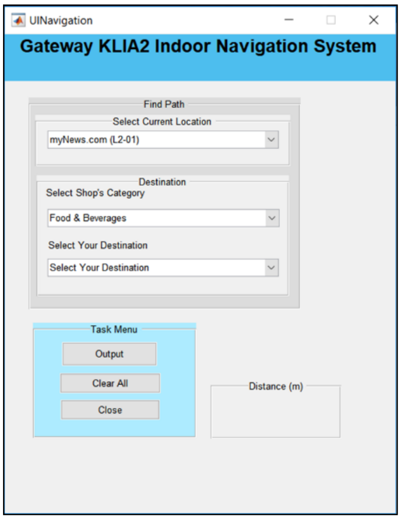

Figure 4. Main menu for *G*-INS

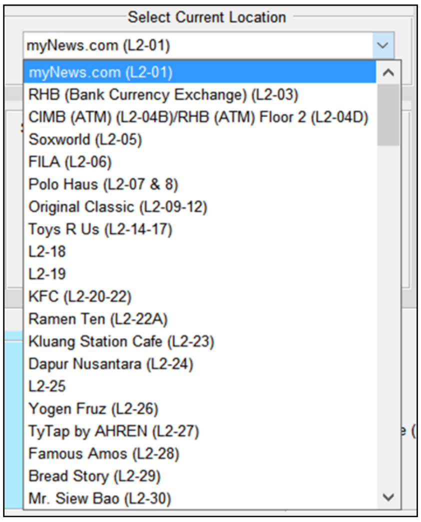

Figure 5. Selection from current location

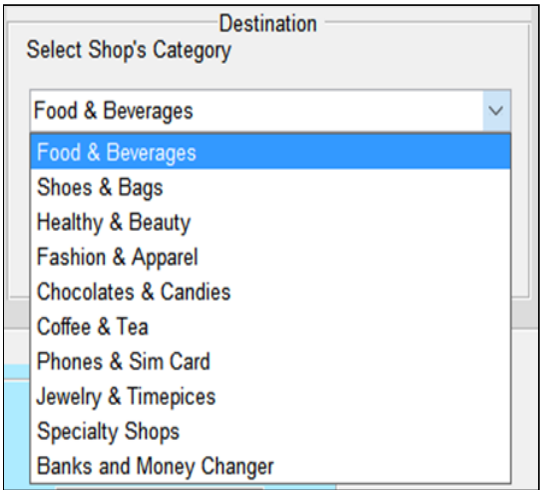

Figure 6. Selection to destination

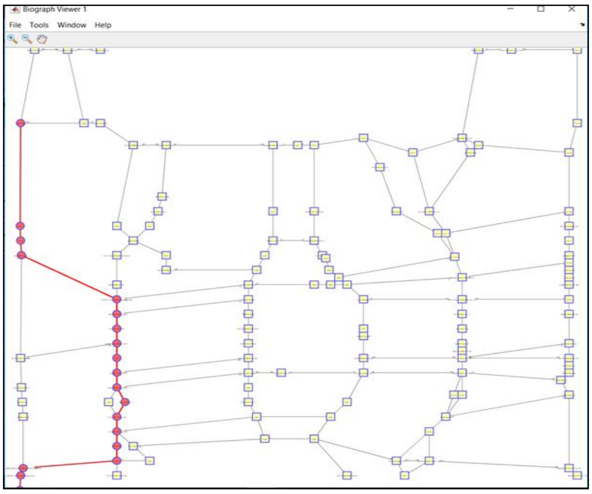

Figure 7. Output of the *G*-INS

4.2. Reliability testing

For the reliability testing (RT) of the system, few steps were involved:

- Identify five RT for different current location and different destination location as in Table 4.
- Each of the RT's have been tested towards three different respondents through a survey.
- All of them were given hardcopy paper that stated their specific RT task together with the floor plan of KLIA2. Respondents need to mark their node selection (in the paper) based on the task given. Then, they need to return back the hardcopy paper.
- For each of the RT task, calculate the node distance manually and record the distance.
- Compare both results and calculate the percentage of difference.

Table 4. Reliability testing for gateway KLIA2 indoor navigation system

RT	Current location	Destination location
RT1	myNews.com (L2-01)	Vern's (L2-51)
RT2	Toys R Us (L2-14-17)	Bread Story (L2-29)
RT3	L2-31	Uniqlo (L2-67 & 68)
RT4	Baskin Robbins (L2-106)	Jaya Grocer (L2-139)
RT5	L2-121	Subway(L2-119)

Table 5 shows the comparison reliability for RT1 until RT5 with specific average distance reduction of 56.77% for RT1, 31.67% for both RT2 and RT3, 51% for RT4 and 64% for RT5. Despites the RT2 and RT3 showing distance reduction of less than 50%, and overall average of RT's is 47%, yet there was significant reduction using the *G*INS. Besides that, most of the nodes selection through *G*INS is less than the nodes selection by the user.

Table 5. Comparison reliability using *G*-INS for RT1 until RT5

RT	Testing	Distance (m)	Total Nodes	% Reduction
	G-INS	35.49	4	-
	Respondent1	41.81	5	15.1%
RT1	Respondent2	159.50	13	77.8%
	Respondent3	157.37	13	77.4%
			Average	**56.77%**
	G-INS	52.93	6	-
	Respondent1	66.22	7	20%
RT2	Respondent2	87.89	10	40%
	Respondent3	81.32	8	35%
			Average	**31.67%**
	G-INS	35.49	4	-
	Respondent1	55.11	4	20%
RT3	Respondent2	61.95	6	40%
	Respondent3	72.94	8	35%
			Average	**31.67%**
	G-INS	21.82	1	-
	Respondent1	43.34	4	50%
RT4	Respondent2	34.86	2	37%
	Respondent3	63.73	8	66%
			Average	**31.67%**
	G-INS	21.27	2	-
	Respondent1	49.36	5	57%
RT5	Respondent2	65.51	7	68%
	Respondent3	64.67	6	67%
			Average	**64%**

In order to prove the hypothesis that the *G*-INS is able to minimize the time taken to visit the selected POI, t-test been measured with the H_0: There is no significant difference in the experimental time taken using *G*-INS and H_1: There is a significant difference in the experimental time taken using *G*-INS. The t-test result as in Table 6 indicates a two-tailed p-value of 0.01303 in which p-value < 0.05. Therefore, H_0 is rejected with this sufficient evidence, significant (*p-value<0.05) and H_1 is supported as there is a significant difference in the reliability testing between with and without the *G*-INS.

Table 6. Mann Whitney U test for without and with *G*-INS

Mann-Whitney U test of Two-Sample		
	Without *G*-INS	With *G*-INS
Min	47.310	21.270
Max	73.710	39.500
Median	61.590	28.655
Mean	73.706	34.202
p-value	0.01303*	
***p<0.05**		

5. CONCLUSION

In this research, the main objective was to adapt the DA for gateway KLIA2 indoor navigation system that can navigated user with shortest path from their current location to destination location. Thus, this research attempts to show the shortest path by using DA technique. The challenging task of this research is to get the distance from one shop to another shop from floor plan layout that consist of 129 shop lots. The 2D graph with their distance followed the floor plan layout. In conclusion, with this development of INS, this research hopes that will help user to navigate themselves in an indoor environment. Furthermore, this research can give contribution towards the study in INS. The system was tested for functionality and reliability. Both testing provides significant impact of the recommendation system. For future works, this system can be developed in mobile-based, cover all four level of Gateway KLIA2 and used real-time function which is indoor positioning system (IPS).

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REFERENCES

[1] S. Taneja, B. Akinci, J. H. Garrett, and L. Soibelman. "Algorithms for automated generation of navigation models from building information models to support indoor map-matching," *Automation in Construction*, vol. 61, pp. 24-41, 2016.
[2] S. Al-hadhrami, M. A. Al-ammar, and H. S. Al-khalifa. "Ultra wideband indoor positioning technologies : analysis and recent advances", *Sensors*, vol. 16, no. 5, pp. 1-36, May 2016.
[3] T. Khalifa, N. Sahar, N. Ramli, and M. Islam. "Circularly polarized microstrip patch antenna array for GPS application,"*Indonesian Journal of Electrical Engineering and Computer Science*, vol. 15, no.2, pp. 920-926, 2019.
[4] J. Pearson, S. Robinson, and M. Jones. "BookMark: appropriating existing infrastructure to facilitate scalable indoor navigation," *International Journal of Human-Computer Studies*, vol. 103, pp. 22-34, July 2017.
[5] Z. Yin, C. Wu, Z. Yang, and Y. Liu. "Peer-to-peer indoor navigation using smartphones," in *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 5, pp. 1141-1153, May 2017.
[6] J. Huovilainen. "Dynamic and intelligent evacuation system for tunnels," In *Proc. 5th International Conference Tunnel Safety and Ventilation*, pp. 192-196, 2010.
[7] V. A. Oven, and N. Cakici. "Modelling the evacuation of a high-rise office building in Istanbul," *Fire Safety Journal*, vol. 44, no. 1, pp. 1-15, 2009.
[8] H. W. Hamacher, S. Heller, and S. Ruzika. "A sandwich approach for evacuation time bounds,"*Pedestrian and Evacuation Dynamics. Springer*, Boston, MA, pp. 503-513, June 2011.
[9] K. A. F. A. Samah, B. Hussin, and A. S. H. Basari. "Modification of dijkstra's algorithm for safest and shortest path during emergency evacuation," *Applied Mathematical Sciences*, vol. 9, no. 31, pp. 1531-1541, January 2015.
[10] S. K. Debnath, R. Omar, and N. Abdul Latip. "Comparison of different configuration space representations for path planning under combinatorial method," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 1, no. 1, pp. 401-408, 2019.
[11] W. Shu-Xi (2012). "The improved dijkstra's shortest path algorithm and its application," *Procedia Engineering*, vol. 29, pp. 1186-1190, 2012.
[12] A. A. A. Zakzouk, H. M. Zaher, and R. A. Z. El-Deen. "An ant colony optimization approach for solving shortest path problem with fuzzy constraints," *2010 The 7th International Conference on Informatics and Systems (INFOS)*, Cairo, pp. 1-8, 2010.
[13] S. Russell, and P. Norvig. "Artificial intelligence:A modern approachprentice-hall," *Englewood cliffs*, NJ 26, 1995.
[14] M. Zakaria, S. Mutalib, S. Abdul Rahman, S. J. Elias, and A. Shahuddin. "Solving RFID mobile reader path problem with optimization algorithms," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 13, no. 3, pp. 1110-1116, 2019.
[15] K. Gutenschwager, S. Volker, A. Radtke, and G. Zeller. "The shortest path: Comparison of different approaches and implementations for the automatic routing of vehicles," *Proceedings of the 2012 Winter Simulation Conference (WSC)*, Berlin, pp. 1-12, 2012.
[16] S. Sivakumar, and C. Chandrasekar. "Modified dijkstra's shortest path algorithm," *International Journal of Innovative Research in Computer and Communication Engineering*, vol. 2, no. 11, pp.6450-6456, 2014.
[17] K. Murota, and A. Shioura. "Dijkstra's algorithm and l-concave function maximization," Mathematical Engineering Technical Reports, vol. 145, pp. 163-177, Marchb2012.
[18] N. R. Shankar, and V. Sireesha. "Using modified dijkstra's algorithm for critical path method in a project network," *International Journal of Computational and Applied Mathematics*, vol. 5, no. 2, pp.217-225, 2010.
[19] Y. Deng, Y. Chen, Y. Zhang, and S. Mahadevan. "Fuzzy dijkstra algorithm for shortest path problem under uncertain environment," *Applied Soft Computing Journal*, vol. 12, no. 3, pp. 1231-1237, 2012.
[20] H. Bi, and E. Gelenbe. "Routing diverse evacuees with Cognitive Packets," *2014 IEEE International Conference on Pervasive Computing and Communication Workshops (PERCOM WORKSHOPS)*, Budapest, pp. 291-296, 2014.
[21] Y. Huang, Q. Yi, and M. Shi. "An improved dijkstra shortest path algorithm", In *Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering*, pp. 226-229, 2013.
[22] Y. Z. Chen, S. F. Shen, T. Chen, and R. Yang. "Path optimization study for vehicles evacuation based on dijkstra's algorithm," *Procedia Engineering*, vol. 71, pp. 159-165, 2014.
[23] P. Gaweł, and A. Jaszkiewicz. "Improving short-term travel time prediction for on-line car navigation by linearly transforming historical traffic patterns to fit the current traffic conditions," *Procedia-Social and Behavioral Sciences*, vol. 20, pp. 638-647, 2011.
[24] A. Muzaffar, and W. Yan. "Long-range wireless sensor networks for geo-location tracking : design and evaluation," In *2016 International Electronics Symposium (IES)*, pp. 76-80, 2016.
[25] D. P. Hutabarat, H. Hendry, J. A. Pranoto, A. Kurniawan, S. Budijono, R. Saleh, and R. Hedwig. "Human tracking in certain indoor and outdoor area by combining the use of RFID and GPS," *2016 IEEE Asia Pacific Conference on Wireless and Mobile (APWiMob)*, Bandung, pp. 59-62, 2016.