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A Preliminary Study: Indoor Navigation System for Wheelchair Users in KLIA2 using Dijkstra Algorithm

K. A. F. A. Samah[1], S. Hamzah[2], N. A. Deraman[3], A.G. Geogiana[4], M. N. H. H. Jono[5], Z. Othman[6]
[1]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Melaka Kampus Jasin, Melaka, Malaysia, khyrina783@uitm.edu.my
[2] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Melaka Kampus Jasin, Melaka, Malaysia, saleha@uitm.edu.my
[3]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Melaka Kampus Jasin, Melaka, Malaysia, noora465@uitm.edu.my
[4]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Melaka Kampus Jasin, Melaka, Malaysia, geogiana@uitm.edu.my
[5]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Melaka Kampus Jasin, Melaka, Malaysia, hasrol@uitm.edu.my
[6]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Melaka Kampus Jasin, Melaka, Malaysia, zainab_othman@uitm.edu.my

ABSTRACT

This paper describes a preliminary study for wheelchair users in the indoor environment for navigation purposes study using Dijkstra's Algorithm (DA) named as Gateway KLIA2 Wheelchair Indoor Navigation system (GK-WINs). Gateway KLIA2 located at Sepang, Selangor, Malaysia has been chosen as the area for the case study. Gateway KLIA2 is divided into 4 levels but this research focused on Level 1 and 2 only where the focal points are Arrival Hall, Express Rail Link (ERL) and Transportation Hub. A survey conducted towards 60 public respondents that related or having an experiment with the wheelchairs user. Despite the floor plan layout is available, yet the wheelchairs user has difficulties due to the eyesight limitations, movement limitations and communication barrier due to different language used. DA has been chosen as it helps users navigate the shortest path to the destination. As a result, wheelchairs users were able to find the shortest distance for indoor navigation from the current location to the destination location. GK-WINs is accepted based on the functionality and reliability test that been carried out against 9 users. In spite of the system reliability results show that the reduction distance is less than 30%, the t-test shows the good results of 0.01757 *($p<0.05$)* and H_1 is supported as there is a significant difference between with and without the GK-WINs.

Key words : Dijkstra's algorithm**,** Indoor navigation system Shortest path, Wheelchairs user

1. INTRODUCTION

Navigation is defined as the ability or process of planning and taking there a route for a ship or other vehicle [1], also declared as a study of determining position and concerned in providing the way to destination location that avoid any circumstances [2]. As defined by [3], the factor that indoor navigation exists because of inaccessibility of classic navigation specially Global Positioning System (GPS) in indoor environments. In addition, indoor navigation as identified by [1],[3], it can support commercial activities, for instance, research of the product, deployed for security reasons, evacuation of complex buildings, meeting coordinator, driver parks in large building and route identification for visitors. 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],[5]. Thus, people can easily search and go to their indoor destination places.

[6] stated that either of the wheelchair is manual or electric, the user of wheelchair deserve to enjoy the degree of freedom in exploring and negotiating the environment. Nevertheless, the studies by [7],[8],[9] contended wheelchair user's participation in daily life is inversely than normal people due to difficulty moving around and the problems on environmental access even though the recent technology of wheelchair are promising. This is supported by [9] that claimed wheelchair users are often at a disadvantage when travelling to a new place, paths are usually used as close proximity to pedestrian paths), do not contain information on route accessibility for people with disabilities (PWD), and lack of support for individual preferences [10]. This is because the environment varies easily affected them and having a short trip can be difficult to achieve for wheelchair users.

Gateway KLIA2 has been chosen as a research study because it is a huge and new building, with different layout in each floor. The size of this building is measured to be at least 350,000 square feet meter with four level which are level 1, 2, 2M and 3. The main focus area of this project are at level 1 and 2 where the focal points are Arrival Hall, Express Rail Link (ERL) and Transportation Hub.

Currently, people who is using wheelchair has a movement limitation around the Gateway KLIA2 due to certain location in Gateway KLIA2 are not suitable and they required more effort for the wheelchairs user to move around [4], [6], [7], [9]–[12]. As claimed by [13], more walkalators are needed in KLIA2 to ease wheelchair user movement. In addition, wheelchairs user has to use elevator whenever they want to go to the different floor.

Furthermore, wheelchairs user takes a long time to reach the desired place compared to people without the wheelchair [12]. They were facing eyesight limitation to find the right path to reach the desired places. [6] reported the dissatisfactions and problems of the wheelchairs user in which, they were incapable of prediction due to obstacles such as limited accessibility in the shops, streets, high building, cafes, busses, trains, public building and airports. There is a need to integrate the navigation system [14] to overcome this problem. Moreover, communication barrier occurred between tourists from another countries due to different language. It makes difficult for a foreigner who is a wheelchair user to ask a help and find the right direction. People find it is difficult to explain something towards someone who are from different culture because they tend to express in their own culture conditioning [15]. Consequently, they might miss the flight and delay their journey [16].

In order to solve the shortest path problem, there are various types of algorithm that can be adapted such as Bellman-Ford algorithm (BFA), Greedy algorithm (GA), Dijkstra's algorithm (DA), Johnson's algorithm (JA) and Floyd-Warshall algorithm (FWA). DA is the suitable and best techniques to be used for this research compared to other algorithms. This algorithm is widely used in certain areas to calculate and solved shortest path problem such as robot pathfinder, computer network routing algorithm, and path navigation [17]. By implementing this technique into indoor navigation system, it can help the public to find the shortest path in a building and can reduce the time taken to the destination [18]. Thus, DA is the best algorithm because it is suitable for this study which using single source with no negative edge in order to find the shortest path in [19].

Therefore, this paper present the preliminary study in order to help the wheelchairs user get to know the shortest path to their destination using DA. It is also to ensure that the time taken to get to the destination is shorter, even wheelchair users have to use elevator, and able to save time moving around in an indoor environment especially in limited capability.

2. RELATED WORKS

In this section, we describe the shortest path techniques and the details of DA as the technique for this research.

2.1 Shortest Path Techniques

Shortest path algorithm (SPA) is an algorithm related to a search algorithm or in graph theory on searching the shortest path among the obstacles and it has applications in communication, transportation, and electronics problems [16], [20]. SPA is classified into three categories, which is single-source SPA, single destination SPA, and all-pairs SPA [16]. The previous study by [17], [21] 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) [5], [10], [11], [17].

FWA, DA, JA, and BFA is the top algorithms for computing and routing the shortest path [10]. These algorithms find solution in the single-pair, single-source, and single-destination shortest path problem. The FWA is one of the algorithm that applying dynamic programming, in which, it given by a graph analysis algorithm and find the shortest path between all pairs of vertices, whereby the Johnson's algorithm will identify the solution in all pairs shortest path problem. If the weightage of the edge is negative, BFA will obtains solution in the single-source problem.

FWA is faster when the graph is dense, despite [16] claimed that Johnson's algorithm is faster than FWA on sparse graphs. In addition, FWA has better cache performance than the sparse matrix implementation because dense matrix computations typically have a higher ratio of floating-point operations to memory. The DA does not require the distance matrix to be represented as a dense matrix, thus making the algorithm more memory efficient for sparse graphs [19]. Despite the time complexity is faster than BFA, yet DA cannot be used to solve the graphs that have negative edge weights. Nevertheless, since this research is focusing on direct single direction, thus DA is chosen as the best SPA for this research [17], [22]. Table 1 shows the algorithms and their description by [16].

2.2 Dijkstra's Algorithm

As contended by [23], 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. This is supported by [20], [22], [24] that mentioned DA produces the shortest path, solves the graph with single-source shortest path problem and it is the non-negative edge path costs. This algorithm can be applied in transport, logistic management and other network optimization [14]. DA applying the greedy algorithm's

Table 1: SPA Comparison Description

Algorithms	Negative Edge	Single Source	All Sources	Time Complexity	Space Complexity
Dijkstra's Algorithm		✓		O(|E| + |V|Log|V|	$O(v^2)$
Bellman-Ford Algorithm	✓	✓		O(VE)	$O(v^2)$
Floyd-Warshall Algorithm	✓		✓	$O(n^3)$	$O(n^3)$
Johnson's Algorithm	✓		✓	$O(V^2 \log V + VE)$	

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:

1. 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……$v_n \in V$) and the weights of each neighboring nodes are stored in set W (W_0, W_1, W_2……$W_n \in W$) 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.

2. Initialization, $S = \{s\}$, $V – S = \{v_0, v_1, v_2……v_n \in V\}$. Select the points '$v_j$' and make $D(j) = \min \{D(i) \mid v_j \in (V - S)\}$, $S = S \cup v_j$;
3. Change the source point *'s'* to point 'v_j'$\in (V – S)$ and $D(j) = D(i) + A(i,j)$, if $D(j) > D(i)+A(i,j)$.
4. 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 single-source shortest path problem effectively and to be found as an optimal algorithm due to its full understanding of the environment [22] and suitable to solve the routing issue in navigation. The statement also supported by [25], 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 area divided into two phases: gather the information phase and design and developments phases.

3.1 Gather Information Phase

The survey was conducted to 60 respondents that related or having an experiment with the wheelchairs user as to trigger the current problem faced by the wheelchairs user in Gateway KLIA2. 88.3% of respondents agreed that the wheelchairs user

face a movement limitation while in Gateway KLIA2 because of the crowded environment, despite 76% of them were accompanied. 74.8% responded that wheelchair user spend and took a longer time and effort to find the desired place.

From the same survey, 75% of them claimed that it is difficult to find the signage due to eyesight limitation to find the right path to reach the desired places. Moreover, they were not aware of their current location due to lack of accurate location [26] when they move independently [6], [18]. As a result, people might get lost in the big building if there is no proper method to navigate them to the destination [6], [25].

3.2 Design and Development

There are four activities involved in this phase in order to cater the objective for this preliminary study using DA.

3.2.1 Indoor Floor Plan Layout

The building of Gateway KLIA2 consist of four levels which are Floor 1, Floor 2, Floor 2M and Floor 3, as shown in Figure 4.1. However, the main focal point of this project are Arrival Hall, ERL and Transportation Hub. The Arrival Hall are located at Floor 2, ERL also located at Floor 2 while Transportation Hub located at Floor 1.

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.

3.2.2 Distance Matrix Table

The value of the actual distances obtained from the first method was stored as a guideline in a matrix table to establish the shortest path by programming the DA coding using MATLAB software.

This table of matrix number stored the details distance of the nodes in the floor plan. Information of the distance used to construct the MATLAB's shortest route algorithm.

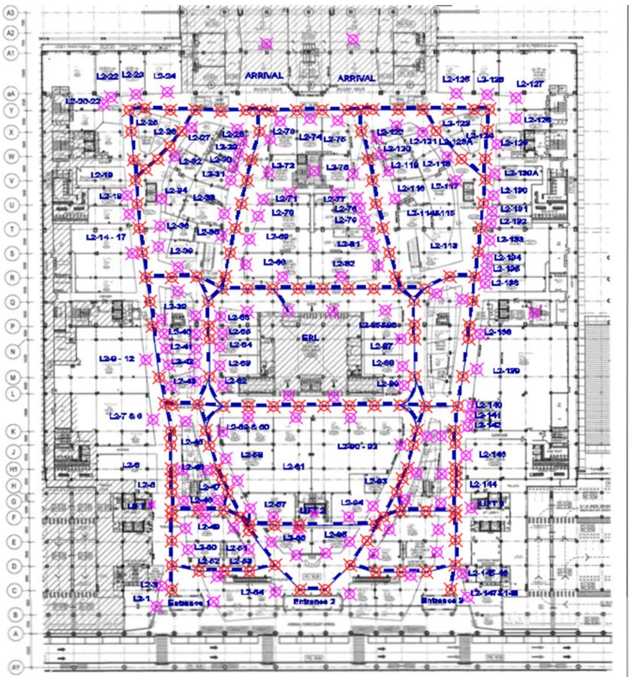

Figure 1: AutoCAD Drawing Node and Distance of Floor Plan Level 2 in Gateway KLIA2

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

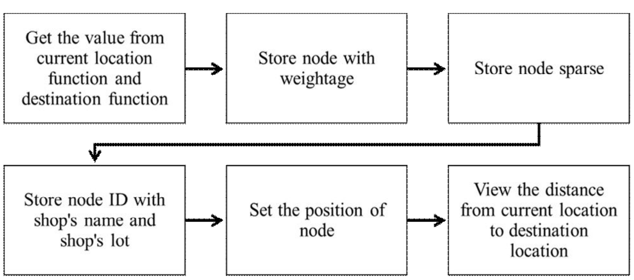

Figure 2: Steps involved in Specific MATLAB Function

3.2.4 Navigation Map

Figure 3 shows the navigation maps of the system. Based on Frame 1, from the user interface, the user started the navigation by choosing the current location of the user. Then user proceed to the Frame 2 for navigation choosing the available destination that consist of three location which are Arrival Hall, ERL and Transportation Hub as shown in Frame 4. Furthermore, the Frame 5 provided the shortest route based on navigation that has been used. Lastly, the final navigation process is displayed the value distance of shortest route as shown in Frame 6.

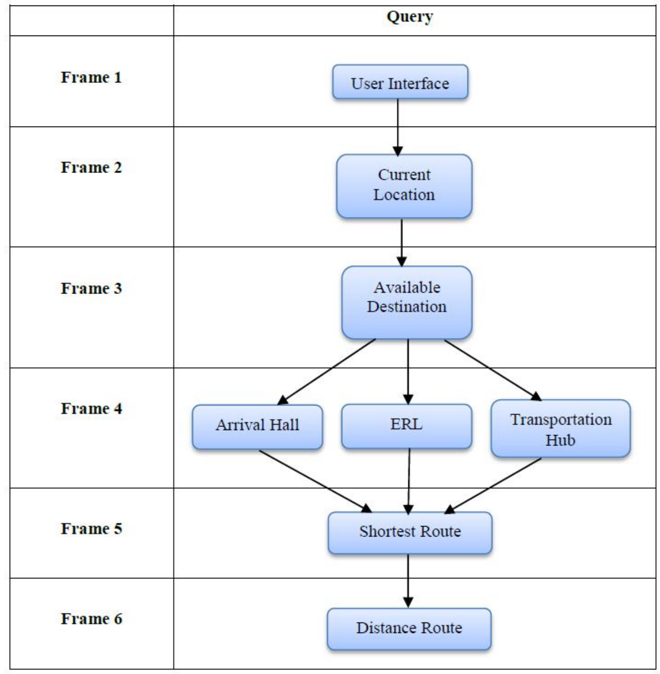

Figure 3: KLIA2 Wheelchair System Navigation Map

4. RESULTS AND ANALYSIS

This section discusses the results and findings gained from the study for Gateway KLIA2 Wheelchair Indoor Navigation system (GK-WINs) 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 Functionality 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 2. All test shows the pass result of the functionality test from Test1 until Test5. Figure 4 shows the snapshot of the prototype main menu. 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 2: Functionality Test Result

Component	Test1	Test2	Test3	Test4	Test5
Select Location	Pass	Pass	Pass	Pass	Pass
Select Destination	Pass	Pass	Pass	Pass	Pass
Click Route	Pass	Pass	Pass	Pass	Pass
View output - distance	Pass	Pass	Pass	Pass	Pass

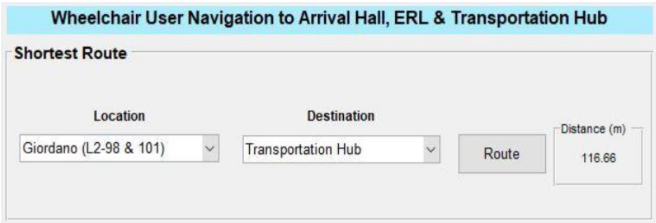

Figure 4: Steps involved in Specific MATLAB Function

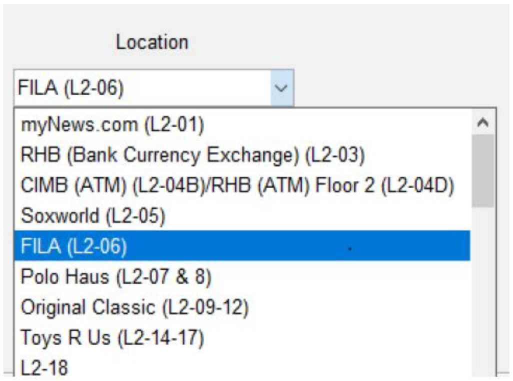

Figure 5: Steps involved in Specific MATLAB Function

Figure 6: Steps involved in Specific MATLAB Function

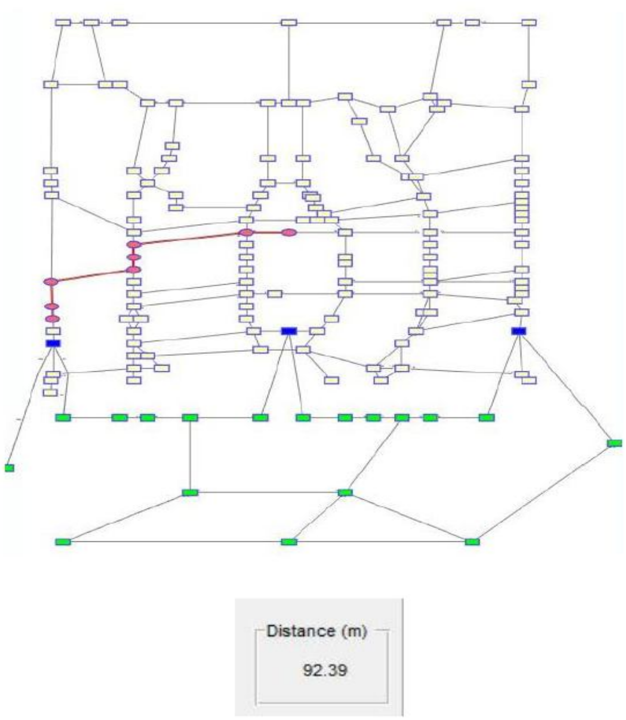

Figure 7: Steps involved in Specific MATLAB Function

4.2 Reliability Testing

Few steps were involved for the reliability testing (RT):

1) Identify three RT for different current location and different destination location as in Table 3.
2) Each of the RT's have been tested towards three different respondents through a survey.
3) 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.
4) For each of the RT task, calculate the node distance manually and record the distance.
5) Run the Gateway KLIA2 Wheelchair Indoor Navigation system (GK-WINs) according to the RT task and record the distance.
6) Compare both results and calculate the percentage of difference.

Table 3: Reliability Testing for GK-WINs

RT	Current Location	Destination Location
RT1	KFC	ERL
RT2	Giordano	Transportation Hub
RT3	House of Mini	Arrival Hall

Table 4 shows the comparison reliability for RT1 until RT3 with specific average distance reduction of 31.33% for RT1, 13% for RT2 and 17% for RT3. Despites the all RT's showing distance reduction of less than 50%, yet there was slightly reduction using the GK-WINs.

Table 4: Comparison Reliability using GK-WINs for RT1 until RT3

RT	Testing	Distance (m)	Total Nodes	% Reduction
RT1	(GK-WINs)	77.8	6	-
	Tester1	105.32	9	26%
	Tester2	106.07	10	27%
	Tester3	131.44	12	41%
			Average	**31.33%**
RT2	(GK-WINs)	116.66	8	-
	Tester1	123.38	7	5%
	Tester2	140.29	5	17%
	Tester3	140.29	5	17%
			Average	**13%**
RT3	(GK-WINs)	153.87	15	-
	Tester1	187.16	17	18%
	Tester2	181.19	19	15%
	Tester3	187.16	17	18%
			Average	**17%**

In order to prove the hypothesis that the GK-WINs is able to minimize the time taken to destination, t-test been measured with the H_0: There is no significant difference in the experimental time taken using GK-WINs and H_1: There is a significant difference in the experimental time taken using GK-WINs. The t-test result as in Table 5 indicates a two-tailed p-value of 0.01757 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 GK-WINs.

Table 5: Mann Whitney U test for without and with GK-WINs

Mann-Whitney U test of Two-Sample		
	Without GK-WINs	With GK-WINs
Min	114.277	77.800
Max	9.020	4.300
Median	124.470	97.230
Mean	144.700	116.110
p-value	0.01757 *	
***p<0.05**		

5. CONCLUSION

In this research, the main objective was to study on the adaptation of the DA for wheelchair users in Gateway KLIA2. The proposed idea Gateway KLIA2 Wheelchair Indoor Navigation system (GK-WINs) been developed to navigate the shortest path for wheelchair user from their current location to destination location that is Arrival Hall, ERL and Transportation Hub. The Arrival Hall are located at Floor 2, ERL also located at Floor 2 while Transportation Hub located at Floor 1. As we know that wheelchair users have the constraint in using the escalator, and only lift can be used as the medium to change to the other level, thus this research has cater it in the 2D floor plan. As a result, we can conclude tht conclusion, with this development of GK-WINs, it able to help wheelchair users to navigate themselves in an indoor environment. This preliminary study also give the contribution towards the study in indoor environment after been tested for functionality and reliability. This system can be built in a mobile-based manner for future work, cover all four levels of Gateway KLIA2 and use the Indoor Positioning System (IPS) feature in real time.

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