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

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Article Info

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.

Keywords:
Dijkstra’s algorithm
Indoor navigation system
Shortest path

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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.

| 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] |
| Floyd- Warshall Algorithm | Solving single-source shortest path problem [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

Reliability study on the adaptation of Dijkstra’s algorithm for gateway KLIA2... (K. A. F. A. Samah)
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=(V, W), all nodes in it stored in set V (v₀, v₁, v₂, .... vₙ ∈ V) and the weights of each neighboring nodes are stored in set W (W₀, W₁, W₂, .... Wₙ ∈ 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 ‘vᵢ’. All points in the weighted graph represented by the adjacency matrix A. A(i,j) mean that the distance between point ‘vᵢ’ and ‘vⱼ’ in matrix A and A(i,j)=∞ when there is no direct path or not an edge in G.
- Initialization, S={s}, V - S={v₀, v₁, v₂, .... vₙ ∈ V}. Select the points ‘vᵢ’ and make D(j)=min {D(i) | vⱼ ∈ (V-S)}. S=S∪vᵢ;
- Change the source point ‘s’ to point ‘vⱼ’∈(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. Gather 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 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.
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    |
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. Despite 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 GINS. Besides that, most of the nodes selection through GINS 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** | **159.50** | **13** | **77.8%** |
| Respondent2 | 157.37 | 13 | 77.4% |
| **Average** | **56.77%** | | | |
| G-INS | 52.93 | 6 | - |
| Respondent1 | 66.22 | 7 | 20% |
| **RT2** | **87.89** | **10** | **40%** |
| Respondent2 | 81.32 | 8 | 35% |
| **Average** | **31.67%** | | | |
| G-INS | 35.49 | 4 | - |
| Respondent1 | 55.11 | 4 | 20% |
| **RT3** | **61.95** | **6** | **40%** |
| Respondent2 | 72.94 | 8 | 35% |
| **Average** | **31.67%** | | | |
| G-INS | 21.82 | 1 | - |
| Respondent1 | 43.34 | 4 | 50% |
| **RT4** | **34.86** | **2** | **37%** |
| Respondent2 | 63.73 | 8 | 66% |
| **Average** | **31.67%** | | | |
| G-INS | 21.27 | 2 | - |
| Respondent1 | 49.36 | 5 | 57% |
| **RT5** | **65.51** | **7** | **68%** |
| Respondent2 | 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 whitneyu 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).
ACKNOWLEDGEMENTS

The research was supported by Ministry of Education Malaysia (MoE), and Universiti Teknologi MARA through the Fundamental Research Grant Scheme (FRGS-RACER) (600-IRMI/FRGS-RACER 5/3 (124/2019)).

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