Faculty of Information and Communication Technology

HIGH RISE BUILDING EVACUATION ROUTE MODEL USING DIJKSTRA'S ALGORITHM

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DECLARATION

I declare that this thesis entitle “High Rise Building Evacuation Route Model Using Dijkstra’s Algorithm” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Nor Amalina Binti Mohd Sabri

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Information and Communication Technology.

Signature	:	……
Supervisor Name	:	Associate Professor Dr Abd Samad Bin Hasan Basari
Date	:	…….....

DEDICATION

Alhamdulillah

To my beloved Mother and Father

Siti Roha Abd Rahman and Mohd Sabri Isa

To my beloved Supervisors

To my beloved brothers

To my beloved friends

ABSTRACT

Evacuation of high rise building has become an issue nowadays as the modern development has increased tremendously with a very complex structure and design. The complexity and height of the building can affect the successfulness of the evacuation process, especially towards unfamiliar occupants in the building. Generally, they only know the route taken while they enter the building. Moreover, the available evacuation map provided by the building is not showing the shortest and safest path. Subsequently, they are hard to find the optimal route to escape. Furthermore, the shortest path algorithm needed additional features to produce better result. This research aims to assist the evacuees to find the shortest path in a high rise building using a shortest path algorithm. The objective is to design and develop an evacuation route using shortest path algorithm based on the evacuation map of the building. The method involves in this research starts with abstracting the original floor plan of the high rise building into CAD format. The floor plan is an important data to be used in this study, which is to design the evacuation route of the building. However, the original floor plan is visualised into 2D layout to gather the information on nodes and weights. The information then is used to generate a directed graph in order to obtain the shortest path results through the implementation of shortest path algorithm. The main algorithms involve is Dijkstra's algorithm and then an Ant Colony Optimization algorithm is used as hybrid versions of Dijkstra's algorithm. As a result, the evacuation route model is able to gain the shortest path and safest path consistently between Dijkstra's algorithms and hybrid version which is Dijkstra-Ant Colony Optimization (DACO). In conclusion, based on the results, the shortest path can be implemented into a computerized evacuation map of the high rise building which can assist evacuees in pre evacuation to find the shortest and safest path to evacuate.

ABSTRAK

Pemindahan bangunan tinggi telah menjadi satu isu pada masa kini seiring dengan pembangunan moden yang telah meningkat dengan ketara bersama struktur dan reka bentuk yang sangat kompleks. Kerumitan dan ketinggian bangunan menjejaskan kejayaan sesuatu proses pemindahan, terutamanya kepada penghuni yang tidak dikenali di dalam bangunan. Secara umumnya, mereka hanya tahu laluan yang diambil ketika mereka memasuki bangunan. Lebih-lebih lagi, peta pemindahan yang ada disediakan oleh bangunan itu tidak menunjukkan jalan yang singkat dan paling selamat. Kesannya, mereka sukar untuk mencari laluan yang optimum untuk melarikan diri. Tambahan pula, algoritma laluan terpendek memerlukan ciri-ciri tambahan untuk menghasilkan keputusan yang lebih baik. Kajian ini bertujuan untuk membantu mangsa untuk mencari jalan yang singkat dalam bangunan tinggi menggunakan algoritma laluan terpendek. Objektifnya adalah untuk mereka bentuk dan membangunkan laluan pemindahan menggunakan algoritma laluan terpendek berdasarkan peta pemindahan bangunan. Kaedah yang terlibat dalam kajian ini bermula dengan pengabstrakan pelan lantai asal bangunan tinggi ke dalam format CAD. Pelan lantai merupakan data penting yang akan digunakan dalam kajian ini, iaitu untuk mereka bentuk laluan pemindahan bangunan. Walau bagaimanapun, pelan lantai asal digambarkan ke dalam susun atur 2D untuk mengumpul maklumat nod dan pemberat. Maklumat kemudiannya digunakan untuk menjana graf berarah untuk mendapatkan keputusan laluan terpendek melalui pelaksanaan algoritma laluan terpendek. Algoritma yang utama yang terlibat adalah algoritma Dijkstra dan kemudian algoritma Pengoptimuman Koloni Semut digunakan sebagai versi hibrid algoritma Dijkstra. Oleh itu, model laluan pemindahan mampu untuk mendapatkan laluan terpendek dan laluan yang paling selamat secara konsisten antara algoritma Dijkstra dan versi hibrid iaitu Dijkstra- Pengoptimuman Koloni Semut (DACO). Kesimpulannya, berdasarkan keputusan, laluan terpendek boleh dilaksanakan ke dalam peta pemindahan berkomputer bangunan tinggi yang boleh membantu mangsa dalam pra pemindahan untuk mencari laluan terpendek dan paling selamat untuk berpindah.

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligence
DA	-	Dijkstra's Algorithm
ACO	-	Ant Colony Optimisation
DACO	-	Dijkstra-Ant Colony Optimisation
ABC	-	Artificial Bee Colony
CPU	-	Central Processing Unit
OS	-	Operating System
OR	-	Operation Research
RAM	-	Random Access Memory

LIST OF PUBLICATIONS

Published in Journal

1. Nor Amalina Mohd Sabri, Abd. Samad Hasan Basari, Burairah Husin, Khyrina Airin Fariza Abu Samah, The Utilisation of Dijkstra's Algorithm to Assist Evacuation Route in Higher and Close Building. 2015. *Journal of Computer Science,* 11 (2), pp. 330-336.

2. Nor Amalina Mohd Sabri, Abd. Samad Hasan Basari, Burairah Husin, Khyrina Airin Fariza Abu Samah, Simulation Method of Shortest and Safest Path Algorithm for Evacuation in High Rise Building. 2014. *Applied Mathematical Sciences,* 8 (104), pp. 5163-5172.

Seminar/ Workshop/ Conference Papers

1. Nor Amalina Mohd Sabri, Abd. Samad Hasan Basari, Burairah Husin, Khyrina Airin Fariza Abu Samah, Ant Colony-Dijkstra's Algorithm for Evacuation Preparedness in High Rise Buildings, *ICOCOE 2015*, Phuket Thailand, 10 – 13 June 2015.
2. Khyrina Airin Fariza Abu Samah, Burairah Hussin, Abd. Samad Hasan Basari, Nor Amalina Mohd Sabri, A Comparison Study on Reliability of Autonomous Evacuation Navigation System: Experimental and Modelling Simulation, *ISoRIS 2014*, Malacca Malaysia, 15-16 October 2014.
3. Khyrina Airin Fariza Abu Samah, Burairah Hussin, Abd. Samad Hasan Basari, Nor Amalina Mohd Sabri, Modelling Conceptual Framework for Autonomous Intelligent Evacuation Wayfinding in Unfamiliar Building: Replacing Human with Intelligent Agent, *International Conference in Applied and Theoretical Information Systems Research*, Taipei Taiwan, 18-20 June 2014

CHAPTER 1

INTRODUCTION

1.1 Background

A natural disaster is an unexpected occurrence that may happen anytime and anywhere. The disaster such as earthquake, floods, tsunamis and hurricanes may bring invariably massive destruction to the community and organization systems (Lagaros and Karlaftis, 2011). Most people are unaware about the prevention or safety awareness to face the natural disaster or any emergency. Other than natural disaster, hazardous such as tornadoes, toxic spills and fire may also bring catastrophic consequences and destruction (Chen et al., 2012). The danger was reported to happen in many places either in an open place, close place, indoor or outdoor.

According to the previous statistic reported by Fire and Rescue Department Malaysia (BOMBA) relate to the fire incident as listed in Table 1.1 , there are 14 types of fire cases take place in Malaysia throughout 2013. Nowadays, evacuation on fire become the most popular (Zheng et al., 2013) safety problem (Gao, 2013) and required attention (Jirasingha and Patvichaichod, 2011).

Bil	Jenis Kebakaran/ Negeri	PLS	KED	PP	PRK	SEL	KL	NS	MEL	JOH	PHG	TRG	KEL	SBH	SWK	LAB	PUT	JUMLAH
1	Bangunan dan isinya	43	547	387	294	1216	797	222	232	514	254	176	174	469	458	31	3	**5,817**
2	Kenderaan	17	182	212	322	876	265	218	111	465	170	71	86	129	169	7	13	**3,313**
3	Mesin	5	1	33	16	41	4	9	21	17	16	7	0	19	11	0	3	**203**
4	Alat Perkakas	26	12	113	141	279	15	43	23	283	51	54	70	38	100	0	24	**1,272**
5	Petrol	2	3	0	1	8	1	1	1	1	0	0	0	1	2	0	0	**21**
6	Bahan Kimia	0	0	0	0	2	1	0	0	0	0	0	0	0	2	0	0	**5**
7	Gas	7	13	115	76	131	8	10	36	95	32	27	39	49	19	0	9	**666**
8	Kapal Terbang	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
9	Kapal Laut	0	3	1	2	3	0	0	0	1	4	2	2	4	4	0	0	**26**
10	Kebun	3	23	16	44	248	0	18	25	276	38	6	19	36	39	0	0	**791**
11	Hutan	22	18	57	78	337	21	189	152	123	133	31	29	145	134	1	3	**1,473**
12	Belukar/ Lalang	151	771	344	1578	2816	167	396	724	1692	510	710	188	437	653	146	8	**11,291**
13	Gerai	3	12	7	11	49	23	13	3	13	14	1	5	8	5	0	0	**167**
14	Lain-lain	133	612	761	1209	1632	605	449	401	1098	411	342	302	243	358	15	23	**8,594**
	Jumlah	**412**	**2,197**	**2,046**	**3,772**	**7,639**	**1,907**	**1,568**	**1,729**	**4,578**	**1,633**	**1,427**	**914**	**1,578**	**1,954**	**200**	**86**	**33,640**

Table 1.1 : Statistic of fire in Malaysia 2013 Source (BOMBA, 2013)

It stated that fire incident in the building was listed as top three with total lost 5,817 cases. Compared to the first rank is forest or environment burning and second are others with 11,291 and 8,594 cases respectively. The cases for building are believed to increase more as the building development is increased over a year.

When a natural disaster or emergency happens, the evacuation process is conducted in order to save the victim (Ekizoğlu, 2009). Evacuation means rapid removal of people temporarily from building or disaster in a threatened area as rescue or precautionary measure.

The complex buildings or places and human behavior during the evacuation process will affect the successfulness of evacuation in order to find the best evacuation routes. The best evacuation route is considered by the time consuming and the safety of the evacuees. Hence, finding the shortest path in a safest way is very important. Time consuming also can be measured by the total distance of the path taken to arrive the destination and it can be understood that short distance requires short time.

Preparation for pre-evacuation is important (Filippoupolitis and Gelenbe, 2009) and decision making during an emergency situation has to be done in perfect timing in order to reduce the evacuation time (Jirasingha and Patvichaichod, 2011). Making the best decision during the evacuation is very difficult for the evacuees. Most of the times they do not know which are the best route they should choose to reach the exit, especially in a high rise building since they are unfamiliar with the building structure. Moreover, the building layout arrangement has changed due to the spreading of hazard presence and the task of finding the safe route is more difficult.

Another point of view, the critical step in disaster emergency management is the evacuation planning (Garg, 2011). Furthermore, Khyrina et al. (2013) states that it is important to reduce, prevent and optimize the emergency management. In addition, it should be done in a timely manner to avoid injuries and minimize the evacuation time, especially in the building which is the challenging problem since it involve the evacuees who did not know where to go (Filippoupolitis and Gelenbe, 2009). When facing any emergency, the significant thing to do is to find a shortest path or rational path to save life from any risk as suggested by Bu and Fang (2010). A good planning is needed to evacuate the victim from the area which is in danger to a safe area. This evacuation planning can overcome the evacuees' problem in finding the best evacuation route. They just have to follow the given instruction and easily find the exit route. Evacuation is a challenging problem (Filippoupolitis and Gelenbe, 2009; Winter et al., 2011) especially in the building since most of the times the evacuees do not follow the optimal evacuation route.

Moreover, the difficulty in finding the best evacuation routes is due to the conditions along the route change in the course of the evacuation procedure. Once again, evacuees hard to find the exit route by the fact that they have no knowledge about the area and the location affected by the hazard (Filippoupolitis et al., 2012).

The other reason why the evacuees hard to find the best evacuation route is the modern building currently tend to be large scale, multi-functional and complex as reported by Wang et al. (2011).

The other term used to mention about the task of on finding path to the destination node from start node is called routing (Yussof et al., 2011). The base concept of routing people to safe place is using the direction indicator to navigate trapped people in closed building (Chen, 2009). The well-marked indicator is used as an indicator to show the ways to exit. He also stated that the indicator must be set in staircase, entrance or obvious places where people easily see it during the any emergency situations. Helping the evacuees finding the evacuation route easily are very important tasks to reduce the evacuation time and save people from hazards. Finding an exit route in exact time and cooperation among the evacuees are the key factors in making the evacuation process going smoothly. Moreover, Fu et al. (2013) identifies the compliance from the evacuees give the large impact on the successfulness of the evacuation process. If the evacuees do not give any cooperation during the evacuation process, unfortunately the evacuation time will be longer than expected. In order to manage crowd or evacuees behavior during the evacuation process, a good evacuation management should be proposed. Garg (2011) generates a set of schedule for the movement of evacuees to complete the evacuation in minimal time.

Evacuation and crowd management are very important to avoid congestion during the evacuation. This is because people tend to find the exit route through what they perceive as the shortest path and lead to congestion (Desmet and Gelenbe, 2013a). More behavioral aspect is added regarding the pedestrian evacuation such as people may ignore the warning as irrelevant (Lämmel et al., 2010), they may not go to the nearest exit and they have a tendency in following the other people during the evacuation.

Moreover, it is important to understanding the human and social behavior during extreme events to improve the crowd safety, also accurately understand the behavior to reduce mitigate losses and damages (Bu and Wan, 2010). Manage the crowd or human behavior can make the evacuation process runs smoothly and determine the successfulness of the evacuation process.

Furthermore, Duan et al. (2012a) find out the optimization strategy is needed to decrease the fatal and properties during evacuation as the design of building become more complex especially in large public building. The Optimization based method was declared as a useful tool in functioning as a generator for evacuation plans.

Additionally, other than optimization method, the simulation based approaches are agreed to act as predominant paradigms in studies of evacuation (Zong et al., 2013; Yang et al., 2012) in providing practical tools for evaluating performances of evacuation in a building or network (Fang et al., 2011). In other point, to determine the potential or fault of the evacuation area, the simulation method is the best choice (Jirasingha and Patvichaichod, 2011). Simulating and analyzing the risk and process of evacuation are worth in making evacuation in the real world more efficient and safer (Lin et al., 2012).

1.2 Problem Statements

From the previous studies, most of the problems are to find the best optimal evacuation route either in open or closed area based on various issues. However, evacuees are difficult to find the best optimal route, especially in high rise building due to the complexity of the building.

The main challenging issue of this research is evacuees hard to find the best path towards the exit especially in high rise building (Kruminaite and Zlatanova, 2014; Khyrina et al., 2013). The difficulty is to decide the best path need to follow (Goodwin et al., 2013). It is important to find the short evacuation time in order to escape from a building safely (Wang and Liu, 2012). Moreover, the factor that contributes to the difficulties of finding the best path is the environment changes due to the spread of ongoing hazard. Moreover, evacuation and rescue operation can be difficult because of the complex internal structure of the building (Wu and Chen, 2012) and increasing in size (Goetz and Zipf, 2012).

The characteristic of the building is also the main contribution in the successfulness of evacuation. Evacuees should know well the building infrastructure to avoid them from choosing a dead route or choosing many kinds of route towards the destination (Koh and Zhou, 2011). In addition, it is occurs in large building with a high dense population faced unique challenges (Li, 2014) and complicated to handle (Luo et al., 2014). On the other point, the complexity of the high rise building increases the rate of fire occurrences due to the heavy density of the building respectively. This happens contributed from the fast growing of urbanization of the country and the whole world (Kaitao et al., 2012). It is important to ensure the building is tested on the efficiency and the ability of a fire evacuation (Saelao and Patvichaichod, 2012). According to Occupational Safety and Health Administration (OSHA), each building needs to provide an evacuation map (Hadzic et al. 2011; Ribeiro and Almeida 2012) and exit door placements (Kamkarian and

Hexmoor, 2012). The aim is to inform the resident about the path they should choose while emergency.

It is usually a generated map based on the floor diagrams indicate the route to exit or safe destination. The marked is clearly illustrated the routes, unobstructed and always clear (Aedo et al., 2012) to guide evacuees in the building (Sacharidis and Bouros, 2013). However, it also can be an issue as the provided evacuation map is not reliable in finding the best shortest path and commonly shown the path without any consideration of safety and shortest path.

When referring to the shortest path algorithm which is Dijkstra's algorithm, this algorithm needs additional features in generating a better result. Weaknesses of Dijkstra's algorithm have been raised in previous works where the algorithm has high computation and low efficiency if involve a large number of nodes (Bu and Fang, 2010). Furthermore, the Dijkstra's algorithm derives the shortest path results based on the weight between nodes and not the coordinate of the nodes in the directed graph.

Based on the review above, the problem statement can be concluded as below:

I. Evacuees found difficulties to find the best optimal routes especially in high rise building due to the complexity of the building.
II. Inadequate information on evacuation maps for evacuees to find an escape route as it does not provide the shortest and safest path information.
III. Shortest path algorithm (Dijkstra's algorithm) needs additional features to support the directed graph.

1.3 Research Questions

This research preliminary aims to propose a model for determining evacuation routes in a high rise building. Based on the problem statement above, the research question that will lead this research can be concluded as follows:

1. What is the appropriate shortest path algorithm for evacuation route?
2. How to develop evacuation route model in high rise building?

1.4 Research Objectives

The objectives of the research are given as follows:

1. To identify the shortest path algorithm for evacuation route.
2. To design an evacuation route via shortest path algorithm.
3. To develop the evacuation route hybrid model in high rise building evacuation map.

The research objectives will answer the research questions of this study. Thus, the relations among problem statements, research questions and research objectives are described as in Table 1.2.