Faculty of Information and Communication Technology

MODELLING AUTONOMOUS EVACUATION NAVIGATION SYSTEM (AENS) FOR OPTIMAL ROUTE USING DIJKSTRA'S ALGORITHM

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DECLARATION

I declare that this thesis entitled "Modelling Autonomous Evacuation Navigation System (AENS) For Optimal Route 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.

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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 Doctor of Philosophy.

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Date	:	.....

DEDICATION

To

my beloved husband Zaharudin Ahmad,

my children; Muhammad Zafri, Nurzahirah Dinah, Nurzarifah Irdina, Nurzahra Aqilah and Muhammad Zharif,

my parents; Hj Abu Samah Hj Mamat and Maritah Hj Ros,

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ABSTRACT

Evacuation wayfinding is the process of route/pathfinding or searching from one location to a safety destination. During fire evacuation in a building, the safest and shortest path wayfinding, so called as an optimal route is a big challenge faced by people who are unfamiliar with the building environment, especially when the hazards spreads inside the building. Furthermore, the development in high-rise building and complexity of floor plan layout has greatly influenced indoor wayfinding. Currently, the static signages implemented in buildings such as building floor plan system (BFPS) and *"exit signage"* are unable to provide information and guidance whether the exit is inaccessible or overcrowded. In addition, there is no structured or systematic way to help occupant's navigation that can provide direction to the safe path. Moreover, fire detection system and evacuation system operate independently whereby fire alarm control panel system (FACPS) only receives the signal and thereafter, the evacuation process takes parts without any information about the hazardous fire location. Current evacuation preparedness in wayfinding using human as an agent and the disintegration of the information will lead to a safety issue. Therefore, this study has modelled a conceptual framework for *"Autonomous Evacuation Navigation System*" (AENS) by adapting the systems thinking (ST). The ST itself is a conceptual framework that examines, reframes the problem and finds the solution. Through ST adaptation, all subsystems were integrated and using the "*Dijkstra's algorithm"* (DA) by modifying its function from shortest path algorithm to safest and shortest algorithm, to the nearest exit. DA modification was done through the restriction of the node directions and additional *"pseudo code"* function. The values for zone location of fire detectors, which detect any abnormalities, updated into the matrix distance table and will not be considered for the shortest path calculation, in which the distance value will be updated as "∞" or 999. Then, the modified DA has been implemented into the proposed conceptual model. The evaluation and validation have been executed through a case study using Pathfinder simulation software and experimental model as to support the hypothesis. As a result, 79.7% and 44.7% reduction of evacuation time were recorded at two different floor plans layout for unfamiliar occupants. Additionally, the hypothesis result shows a significant difference in evacuation time taken using AENS for simulation and experiment result respectively. In conclusion, AENS using DA modification has contributed to the development of the systematic ways for evacuation preparedness, thus providing a navigation mechanism to solve the problem of indoor wayfinding and specifically to lead the unfamiliar occupants to an optimal route.

ABSTRAK

Mencari jalan keluar semasa pengungsian adalah proses pencarian atau penemuan laluan dari satu lokasi ke destinasi yang selamat. Semasa pengungsian kebakaran dalam bangunan, mencari laluan yang paling selamat dan terpendek, yang dikenali sebagai laluan optimum menjadi satu cabaran besar yang dihadapi oleh penghuni yang asing dengan persekitan bangunan itu, terutama apabila bencana merebak di dalam bangunan. Tambahan pula, pembinaan bangunan tinggi dan pelan lantai yang kompleks mempengaruhi pencarian laluan dalam bangunan. Pada masa kini, papan tanda statik dilaksanakan dalam bangunan seperti sistem pelan lantai bangunan (BFPS) dan papan tanda keluar tidak memberikan maklumat dan petunjuk samada jalan keluar tidak boleh dilalui atau terlalu sesak. Di samping itu, tiada cara yang berstruktur atau sistematik yang memberi petunjuk kepada penghuni supaya menuju ke laluan yang paling selamat. Tambahan pula, sistem pengesan kebakaran dan sistem pengungsian beroperasi secara berasingan, di mana sistem panel kawalan penggera kebakaran (FACPS) hanya berfungsi untuk menerima isyarat dan selepas itu, proses pengungsian mengambil alih untuk bertindak tanpa maklumat lokasi bencana kebakaran. Persediaan pengungsian masa kini menggunakan manusia sebagai ejen dan maklumat yang tidak berintegrasi akan menyebabkan timbulnya isu keselamatan. Justeru itu, kajian ini telah merekabentuk rangka kerja konsep untuk "Sistem Autonomi Pandu Arah Pengungsian" (AENS) dengan mengadaptasikan sistem pemikiran (ST). ST merupakan rangka kerja konseptual yang mengkaji, merangka masalah dan mencari penyelesaian. Melalui adaptasi ST, semua sub sistem diintegrasikan dan menggunakan "Algoritma Dijkstra's" (DA) yang fungsinya diubahsuai dari algoritma laluan terpendek kepada algoritma laluan paling selamat dan terpendek, menuju jalan keluar terdekat. Pengubahsuaian DA dilaksanakan melalui ketetapan arah nod dan menambah fungsi pada "kod pseudo". Zon lokasi alat pengesan kebakaran yang mengesan sebarang abnormaliti dikemaskini nilainya dalam jadual jarak matrik. Zon tersebut tidak akan diambilkira dalam pengiraan laluan terpendek di mana nilai jarak dikemaskini ke "∞" atau 999. Seterusnya, DA yang diubahsuai telah dilaksanakan ke dalam model konsep yang dicadangkan. Penilaian dan pengesahan kajian telah dilaksanakan melalui kajian kes menggunakan simulasi perisian Pathfinder dan model eksperimen bagi menyokong hipotesis. Hasilnya, pengurangan masa pengungsian sebanyak 79.7% dan 44.7% telah direkodkan pada dua struktur pelan lantai yang berbeza untuk penghuni yang asing. Tambahan pula, keputusan hipotesis menunjukkan perbezaan yang ketara bagi masa pengungsian yang diambil menggunakan AENS untuk keputusan simulasi dan eksperimen masing-masing. Kesimpulannya, AENS menggunakan pengubahsuaian DA berjaya memberikan sumbangan kepada pembangunan persediaan pengungsian yang sistematik untuk menghapuskan penggunaan manusia sebagai ejen, lantas memberikan pandu arah untuk menyelesaikan masalah mencari laluan dalam bangunan dan khususnya untuk membantu penghuni asing menuju laluan yang paling optimum.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ACO	-	Ant Colony Optimization
AENS	-	Autonomous Evacuation Navigation System
ANNs	-	Artificial Neural Networks
ASET	-	Available Safe Egress Time
ASSR	-	Algorithm for Safest and Shortest Route
BFPS	-	Building Floor Plan System
BS1	-	Blockage Scenario 1
BS2	-	Blockage Scenario 2
DA	-	Dijkstra's Algorithm
ERM	-	Evacuation Route Matrix
ERMt	-	Emergency Response Management
ERT	-	Emergency Response Team
FA	-	Floyd Algorithm
FACPS		Fire Alarm Control Panel System
FRDM	-	Fire and Rescue Department Malaysia
FWA		Floyd Warshall algorithm
GA	-	Genetic Algorithm
HST	-	Hard Systems Thinking

ID	-	Identification
NA	-	Without AENS
OR	-	Operational Research
OSHA	-	Occupational Safety and Health Administration
PM	-	Preventive Maintenance
PSO	-	Particle Swarm Optimization
RFID	-	Radio Frequency Identification
RO	-	Research Objective
RP	-	Research Problem
RQ	-	Research Question
RSET	-	Required Safe Egress Time
SI	-	System Integration
SODA	-	Strategic Options Development and Analysis
SOP	-	Standard Operating Procedures
SPA		Shortest Path Algorithm
SSM	-	Soft Systems Methodology
SST	-	Soft Systems Thinking
ST	-	Systems Thinking
WSN	-	Wireless Sensor Network
YA	-	With AENS
2D	-	2 Dimensional
3D	-	3 Dimensional

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