OPTIMAL PATH PLANNING ALGORITHMS IN VIRTUAL ENVIRONMENTS

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Dedicated to my beloved Father, Mother, Brothers, Sisters, Abang and Teachers

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ABSTRACT

Path planning algorithm is a common algorithm applied in many fields of research specifically in robotic, games and Virtual Environments (VEs). Meanwhile, VE is a cutting edge technology that can add realistic visualization of a real world. Interaction within a VE requires animated characters to participate in such a way that they are able to navigate as well as plan the tour. Normally, in a large virtual exhibition area, a visitor tours to multiple sites before reaching the final destination. This may lead to several problems such as collision with obstacles, time-consuming journey, inefficient searching process and high utilization of computer memory. The main aim of the research was to find an efficient route tour approach that combines path finding, path planning and path optimization algorithm. In relation to that, A* algorithm was used as a path finding technique to plan a collision-free-path journey from one location to another. A* algorithm was also incorporated with Cell Mapping technique to speed up the searching process. In addition, Extended Prim algorithm was applied to shorten the travelling time and a virtual exhibition area was used as a domain to execute and analyse the algorithms performances. The results show that the Extended Prim algorithm has succeeded in reducing the travelling time up to 60 percent. Furthermore, the results also revealed that the searching process and computer memory utilization significantly improved up to 22 percent and 55 percent, respectively. It was also found that the combination of A* algorithm and Cell Mapping technique can be applied to a wide range of VE’s sizes.

ABSTRAK

Algoritma perancangan laluan merupakan satu algoritma yang sering menjadi tumpuan bidang penyelidikan khususnya di dalam bidang robotik, permainan video dan persekitaran maya. Manakala, persekitaran maya pula adalah satu bidang teknologi terkini yang berupaya mentransformasikan dunia sebenar ke dalam bentuk visual. Di dalam persekitaran maya, lazimnya karakter animasi haruslah berupaya untuk merancang dan menentu arah laluan. Lazimnya, bagi persekitaran pameran maya berskala besar, pelawat akan mengunjungi banyak lokasi sebelum tiba ke destinasi yang terakhir. Situasi sedemikian akan mewujudkan beberapa masalah dalam perancangan laluan seperti perlanggaran dengan halangan, masa perjalanan yang panjang, diikuti dengan carian laluan yang tidak efisien dan penggunaan memori komputer yang tinggi. Justeru, penyelidikan ini bertujuan untuk mencari satu pendekatan carian perjalanan yang efisien dengan menggabungkan teknik pencarian laluan, perancangan laluan dan pengoptimuman laluan. Lanjutan daripada itu, algoritma *A** dan teknik *Cell Mapping* telah digabungkan bagi meningkatkan prestasi carian. Manakala algoritma *Extended Prim* telah digunakan untuk menyelesaikan masalah pengoptimuman laluan dengan mengurangkan masa perjalanan. Persekitaran pameran maya telah dijadikan sebagai kes kajian bagi melaksana dan menguji algoritma ini. Hasil kajian membuktikan bahawa algoritma *Extended Prim* berjaya meminimakan masa perjalanan dengan pengurangan masa sebanyak 60 peratus. Manakala teknik *Cell Mapping* telah berjaya mengurangkan masa carian dan penggunaan memori komputer, masing-masing sebanyak 22 dan 55 peratus. Hasil kajian juga menunjukkan bahawa gabungan algoritma *A** dan teknik *Cell Mapping* dapat diimplemen terhadap sebarang saiz persekitaran maya.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AGV	-	Automated Guided Vehicles
TSP	-	Traveling Salesman Problem
PRM	-	Probabilistic Roadmap
IDA*	-	Iterative Deepening A*
BSP	-	Binary Space Partitioning
RTS	-	Real Time Strategy
SNA*	-	Synchronous Admissible A*
GA	-	Genetic Algorithm
MST	-	Minimum Spanning Tree
BIP	-	Broadcast Incremental Power
NP	-	Non Determine Problem

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter describes the organisation of whole thesis. The thesis emphasizes an optimal path planning algorithm for Virtual Environment. The optimal path planning algorithm is required in Virtual Environment to solve the wayfinding problems during navigation in Virtual Environment domain or virtual world. Section 1.2 discusses the motivation inspired this research. Section 1.3 lists the research problems. Section 1.4 states the research main goal, whereas Section 1.5 clarifies the research objectives. Meanwhile, Section 1.6 lists the research scope to restrict the research objectives. Section 1.7 discusses the contribution of this research and finally Section 1.8 gives a brief outline of this thesis.

1.2 Research Overview

Path is a line on route along which something travels or moves. In between, path planning is the art of deciding the route to take, based on expressed in terms of the current internal representation of the terrain. On one hand, path finding is the execution of this theoretical route, by translating the plan from the internal representation in terms of physical movement in an entity space. In the field of virtual environment or computer animation, path planning is an algorithm to find the path of motion. Path planning is also used to control motion. This research defines path planning as a deriving path to be taken by animated character from source to the destination by implementing some mathematical calculations or algorithms. Furthermore, an optimum path is a sequential path or known as path tour that meet several optimality criteria.

Meanwhile, Virtual Environment has been identified as a technology to visualize an event and environment. Virtual Environment can be applied in various applications and described realistic visualization such as virtual museums, virtual stores as well as virtual exhibition. Virtual Environment is defined as a representation of actual world in three dimensional graphical worlds. It may consist of three main components i.e. space, crowd and movement or navigation. Many classical Artificial Intelligent (AI) planning problems involve navigation. Navigation may simply described as moving around the world, planning the routes, reaching desired destinations without bumping into things and so forth. Besides, navigation may consist of locomotion and way finding. Locomotion simply involves moving towards landmarks that are visible within the space, whereas way finding is the ability to plan efficient routes, find specific locations and recognize the destination when reaches (Darken and Sibert, 1996).

Usually, interaction within a VE specifically in virtual exhibition area requires users to participate in such a way that, they are able to navigate as well as plan the tour. Thus, path planning is essential technique to optimize navigation in VE. The optimal tour may be defined as the generated paths that connect all desired destinations not only in a shortest distance but satisfy appropriate optimality criteria. Therefore, this research is aimed at integrating a path finding, path planning and path optimization algorithm to produce an efficient route tour for navigation of animated character in VE. The result is performed in simulation event and executed in virtual exhibition area.

The requirement of planning the optimal tour or navigation is obvious especially in complex environments such as a building with multiple floors and rooms as well as battlefields with a lot of obstacles and crowd. There are a lot of issues to produce an optimal route tour. The first one is to search the minimal path from one location to another location. On the other hand, for a workspace cluttered with obstacles, the real distance between two locations is actually the length of a collision-free path, and this information is not known prior to the search process. The path is generated using search algorithm. This thesis describes how the A* algorithm is used to compute the path where animated character is guided to reach the desired destination. The A* algorithm is chosen due to its heuristic admissibility guarantee to produce the best path if such path exist.

Furthermore, the visit involves touring more than one site and another challenge is to generate an optimal traversing sequence through the user-specifies locations of interest. When there are several locations to traverse, the problem of determining an optimal traversing sequence involves the classical “Travelling Salesman Problem (TSP)”, which is known as Nondetermine Problem (NP) - complete. For this reason, optimization is required and this thesis applies Prim algorithm as a solution.

As the virtual world become larger, it will contain more objects and may entail problematical and complex searching algorithm. The algorithm searching area has to be synchronized to the size of the virtual world. A larger and dense searching area affects the searching performance, in term of high memory consumption. Therefore this thesis introduces Cell Mapping technique to enhance the searching algorithm to make it more flexible and to adapt in various layout as well as large scale VE.

Inspired from above problems, a proper and effective route plan is essential for moving through the virtual world. As a solution, this thesis proposes the optimal path planner. The output of this path planner is a list of direction that will be converted into a motion for animated character. A directive method has been adopted as a technique to convert the motion animation. Initial conversion is in 2D motion. The users can simply identify the points or destinations they wish to visit and the animated character will automatically guide them walking through the desired destinations. The rest of path generation is hidden from the user. In this thesis, several virtual exhibition areas have been developed as a domain for simulating the navigation of animated character.

1.3 Motivation

One of the motivational factors inspired to further this research is a path planning as a core component in most game and virtual reality industry. As game and virtual reality become a commercially growing fast and a billion-dollar industry, a realistically gaming experience and visually interesting movement are important features to compete in market. Most of related applications adopt artificial intelligence techniques in path planning to produce the best route for the game character to move from starting point to the goal destination. Moreover motion planning algorithm is implemented in sophisticated camera techniques and realistic characters and objects features. It has also been used for designing better user interfaces and providing better navigation techniques specifically in VE.

Furthermore, the importance of security in building design has been expressed by Atlas (1989). Generating different patterns of optimal paths will help the designer as well as the evaluator to design and evaluate the building structure in terms of security. The spatial design of a building affects the movement of occupants. In complex buildings with a large population, such as places of assembly, the movement of people towards the exits under emergency situations is a major concern. Traditionally the layout design is governed by the building fire codes. However, the building fire codes merely govern the design of the capacity of individual components, and do not guarantee that smooth egress will occur. Full-scale egress exercises may be needed to examine the layout arrangement in order to understand the layout problem. However, such exercises may be time-consuming, or may be impossible when the building has yet to be constructed. Therefore, a computer simulation or virtual environment technology can be used to overcome these weaknesses to simulate the egress pattern, and also can assist building designer and facility manager to plan the optimum spatial arrangement as well as to manage the crowd flow during emergency situations.

On the other hand, in many areas of manufacturing such as machine layout, motion planning and mechatronics, the requirement for an optimum path is evident. The optimal path planning has an impact in improving efficiency and throughput such as PCB assembly. For example, system based on free range robots has indicated that a robot which is able to move along the optimum path saves energy and yields higher output. A similar requirement for optimum path planning exists in the electronic industry in the printed circuit board (PCB) assembly process. PCB assembly consists of placing electronics devices on a board to create a bigger component. Time reduction which leads to an increase in production depends very much, whether in improving quality or productivity, on the sequence of component insertions.

1.4 Statement of The Problem

The main problem of this study is to produce the optimal route tour that satisfies the optimum cost for animated character travelling in large VE. Followed by this problem, the following questions have to be satisfied.

i) How to plan a collision free path in VE?
ii) What are the parameters that satisfy an optimum cost of route tour?
iii) How to simulate the animated character to follow the route tour?
iv) How to apply a small-scale algorithm into a large-scale environment?

1.5 Main Goal

The main goal of this research is to produce an efficient optimal path planning algorithm in large Virtual Environment.

1.6 The Objective

The objectives of this research are as follows:

i. To analyse current path finding, path planning and optimisation algorithm which accommodate in virtual environment.

ii. To generate the best path from one location to another location without colliding with obstacles in the environment.

iii. To produce the optimal tour path that traverses all desired locations.

iv. To produce a solution in applying a small-scale optimal path planning algorithm into a large scale of virtual environment.

1.7 Scope of the research

The research includes the following areas:

i. This research implements Prim algorithm to optimize the route tour. Moreover the research mostly concentrates on shortest distance and mode in selection the node sequence as parameters concern to produce an optimal route tour.

ii. A* algorithm is implemented to generate the collision free path and executed in offline mode.

iii. Cell mapping technique is used to enhance the small-scale searching algorithm in order to be applied into any expandable virtual world.

iv. The directive method is used to convert generated optimal route tour into a list of direction in order to move and simulate the animated character.

1.8 Contribution of The Study

The research produces several contributions. Generally, the research proposes an optimal path planning algorithm which is a hybrid technique between Extended Prim algorithm and A* algorithm with Cell Mapping technique. This hybrid algorithm is used to solve path optimisation problem in any scale of VE. The contributions of this research are as follows:

i. The Extended Prim algorithm as an optimisation algorithm has reduced the number of iterations in producing an optimal sequence of nodes. Therefore, Extended Prim algorithm has shortened the travel time.

ii. Furthermore, the research has merged A* algorithm with Cell Mapping technique which using windowing search concept to produce an efficient and adaptive searching algorithm that can accommodate its implementation into a flexible large-scale VE. The

Cell Mapping technique has maintained the search window matrix in a small scale. Hence the search process becomes efficient when the domain of searching area becomes larger.

iii. A* algorithm with Cell Mapping technique has reduced the number of expanded nodes to increase the usage of computer memory.

iv. A* algorithm with Cell Mapping technique has also reduced the searching time.

1.9 Thesis Outline

This section presents how this thesis is organized in different chapters. **Chapter 2** presents a critical review of the literature related to the topic area of path planning in virtual environment. It discusses related problems arise with current methods and solutions. Within the path planning, it includes the discussion on how to produce an optimal path in a larger virtual environment. **Chapter 3** is the wide description of research methodology, which provides a rich discussion about the flow of this research that how actually this research has been divided into different phases and how the operational and experimental work has been carried out. **Chapter 4** presents the overall Model of Optimal Path Planner. The purpose and function of every process or module in the model is described in detail. **Chapter 5** demonstrates the implementation and experimental analysis of optimization in path touring. It includes the discussion and summary of the results finding using this new algorithm. Meanwhile, **Chapter 6** presents the Cell Mapping technique to accompany A* algorithm in searching the path. This chapter discusses this new technique is capable to improve the path searching in term of lower number of expanded nodes and searching time. Finally, **Chapter 7** concludes the thesis by proposing future work and the possibility for the enhancement of knowledge in the field of virtual environments, computer animation and all related field.