Multi-User Navigation: A 3D Mobile Device Interactive Support

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Abstract—**Multi-User navigation within an environment with the aid of 3D mobile support provides end users with additional mobility thought and improves mobility services' efficiency. A necessary approach of using mobile device for navigation aid is to display only a section of the view-front and to let users control the portion shown by conceptually moving on the orientation. There is a need for multiple users to be able to interact with themselves when they are within an environment and navigating with the aid of 3D mobile devices support, in order to meet-up with an appointment or to be aware of the locations of each other. Unfortunately, the predominant 3D mobile navigation system does not provide multi-user interactive services. Users cannot be aware of other users navigating within same environment using the same system on their mobile devices at the same time. This paper presents multi-user 3D mobile navigation system for providing multiple user awareness. The analysis of the results provides a unique visualization of multiple users using mobile devices to help them navigate to a target location by being aware of their whereabouts.**

Keywords-3D Model; Mobile-device; Multi-User awareness Navigation.

I. INTRODUCTION

Navigation can be generally defined as the process whereby people determine where they are, where everything else is, and how to get to particular objects or places [1]. It's common for people to go to where they've never been, this considers as the first visit to an unknown environment. As a result of this, people might need a guide or an aiding agent that will help them find their location when they visit for the first time. In most urban cities there are a lot of users' guide on sign boards and map layouts around streets, and also car GPS navigation guide like Garmin. However, information in all these kinds of guide is not enough to truly and accurately be a navigation guide. Quite a number of people nowadays have mobile devices, like mobile phones. Using these mobile devices for navigation aids will be a lot easier and will serve as an added mobile device service, but when it comes to integrating 3D model in mobile device there are some drawbacks. These are the complexity of the 3D model, the mobile device's 3D graphics support, the mobile device's small screen display and the mobile device's computing resources. Given the complexity of massive 3D models, a number of acceleration techniques that limit the number of primitives rendered at runtime would also be considered. These will include model simplification either by compression or any other method, use of sample-based representations, and many others.

Multi User 3D mobile interactive navigation support will be perceived as a feature of the mobile device's service because its implementation will provide a way to enhance user interactions. By incorporating 3D data-set into applications, it helps orients the user to the surrounding environment and helps him to stay connected to other people nearby. Unfortunately, these kinds of support are not yet widely available. Although there are some 3D mobile navigation systems, like the mLOMA (mobile LOcation-Aware Messaging Application) [2], there are no provisions for awareness and connections of multiple users in a nearby environment, i.e. users cannot be aware of other users navigating within an environment using the same system on their mobile devices at the same time.

The motivation for this work is that new services and applications of 3D graphics techniques for visual interactive navigation have already achieved practical standards on desktop computers. While the computing resource constraint in mobile devices puts a drawback on 3D graphics application implementation, mobile devices can still stand as a feasible device that will aid navigation in simple and user friendly means. In this respect, there is an evident need for the development of 3D interactive environments on high capability platforms that can be accessed, visualized and navigated by remote mobile users dynamically. Based on the fact that mobile device's resources and applications are continually becoming better in computing power, memory, storage, wireless networking capabilities, Global Positioning System (GPS) receiver, and most of the current mobile devices are embedded with high resolution graphical hardware, there is an opportunity for tracking and navigation in an outdoor environment.

This study applies spatial and navigation orientation techniques using the voronoi diagram and bidirectional A* pathfinding in order to provide a 3D mobile application for multi user navigation support in an environment. This study attempts to map an environment into a set of points and regions and evaluate the shortest path within those points and regions. This led to the development of a 3D model of an environment, and integration of the sets of points and regions established with the shortest pathfinding technique in order to incorporate them into mobile devices for navigation aids.

The remaining part of this paper is organized as follows: section 2 discusses related work, section 3 provides the system structure and in section 4 we go through the experimental process. Section 5 discusses the results and finally section 6 presents the conclusion of the work.

II. RELATED WORK

The interactive 3D mobile navigation scheme means the interaction is between different users and their mobile devices for the intention of aiding navigation in an environment. One of the unique aspects of the system we developed is the dynamic interactivity (that is the interaction of many users at the same time by being aware of each other) and finding the shortest path within the environment to reach their destination. 3D virtual tour application was developed in [3], where multiple mobile clients using M3G navigate through and interact with each other in a shared 3D space, although the details of the implementation were not disclosed. Hyungeun et al. [4] present a novel focus and context interface for providing multiple location cues for off-screen objects in an immersive 3D environment by mapping methods from 3D spherical coordinates to 2D orthogonal fish eye which tackles the problems of existing 3D location cue displays, such as occlusion among the cues and discordance with the human frame of reference. Although this method seems complicated, the whole aim is to provide an easier means of navigation. In an evaluation, the participants could find the target object for a given location cue faster and more accurately with their novel approach. Quax et al. work on examining remote rendering possibilities from the viewpoint of encoding, where a single encoding server with a dual core 3GHz CPU could serve 25 clients [5]. This addresses the problems with downloading complex 3D models over the Internet which could be difficult to transmit, render and store, especially for low-end devices like mobile devices.

Yan and Kunhui [6] present the adoption of certain technology to accelerate graphic applications for 3G mobile phones, which are to compress and display 3D graphics with restriction on mobile phone's screen and also attach attribute information for displaying 3D objects. Thus, this will improve the display of 3D models in a small screen mobile device. Simulation results showed that the 3D building was displayed in high-speed rate, and changed smoothly with a strong sense of 3D. Then, in their work, Guan et al. [7] present a recognition-driven navigation system for large-scale 3D virtual environment. Their proposed system contains three parts: virtual environment reconstruction, feature database building and recognition-based navigation. The acquired images in their system were partitioned into patches of different sizes for fast retrieval. When a user navigates the real world with a handheld camera the virtual navigation happens at almost no delay after the real world navigation. Pecchioli et al. [8] describe that the use of a 3D framework may allow a closer adherence to the real world as it respects the spatial relationships among various parts. With this idea, they presented a novel method to access spatial information through the interactive use of a synthetic 3D model, reproducing the main features of a corresponding real environment. There has been an increase over the years in research on 3D and its applications in mobile devices for navigations. This study is part of the on-going research that is set to provide its contributions.

III. SYSTEM STRUCTURE

The system structural design is represented in Fig. 1. It comprises of GPS signal source coming from the satellite and the ground client/server structure that includes the designed 3D model of the environment in the left hand side of the server at the center and the mobile clients on the right hand side. The system is designed based on the remote rendering of 3D data-set from the server to the mobile device clients. The spatial design orientation is based on the GPS received signal by the mobile device on-board GPS receiver and a desktop GPS receiver signal modules, as well as using voronoi diagram to set the different locations and regions within an environment. The navigation orientation is designed using the bi-A* pathfinding technique in order to determine interactive forward and backward shortest path distances to navigate to the destination within an environment. The server hosts and renders the 3D data-set on low bandwidth networks. Thus, client's requests are processed at the server and the feedbacks generated are sent back to the clients.

Our application is developed using C++ and the 3D model is designed using Autodesk 3DsMax 2010. The final 3D model is exported to VRML 2.0 through the VRML exporter. The 3D model is designed for zone A to zone D of IIUM Gombak campus, which is within the administrative and academic area of the IIUM Gombak campus. The remote rendering involves responding to the client request by the server. Remote rendering was described by Hesina and Schmalstieg [9] as out-of-core rendering. Remote rendering has been used to describe a situation where the rendering is performed remotely and final frames sent to the clients. In this case, the mobile device acts as an interface, where the manipulation commands are transmitted to a server, which renders the scene and sends back the resulting images. The remote render server gets its world state information directly from the server, thereby ensuring the consistency for all connected users. The application is designed in such a way that it will allow only those nodes which lie in a view region to be loaded, and nodes are search by enclosed voronoi region while the shortest pathfinding are searched by square grids as the basis for the underlined environment. The orientation of the navigation is initiated by the client's mobile device's request through the on-board GPS receivers. At the initiation state, the GPS data of the clients' mobile device will be read by the server. As a result, the client will send the request of 3D data-set and the server will use the GPS data of the client and send the corresponding 3D data-set of that particular location of the GPS data. Furthermore, the server will continue to follow the changes in the GPS data of the client as he navigates and keeps on sending the 3D data-set until the client logs out.

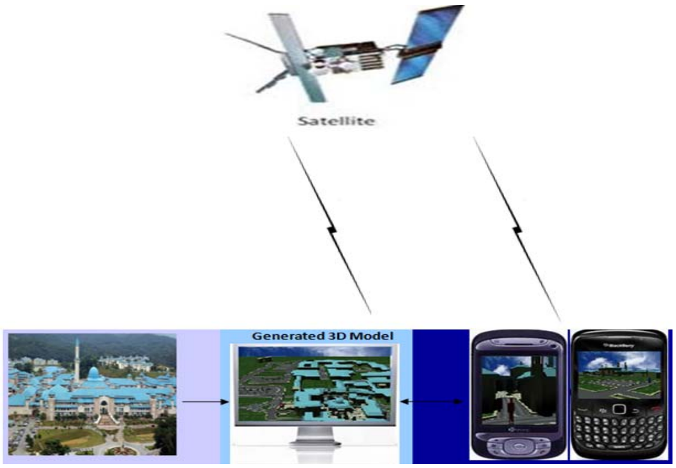

Figure 1. Structure of the System.

A. Spatial Design Orientation

The spatial design orientation is established within a specific region as shown in Fig. 4. This is because it might not be justifiable to implement multi-user real-time interactive navigation in wide, open environments. There should be a certain region that should be set in order to validate the accuracy of the design. As a result, we defined and established the specific region and locations at which the interactive navigation will take place by using the Voronoi diagram. The Voronoi diagram generates points (nodes) and displays the distances between sets of points in any dimensional space. For every point in the cell, the Euclidean distance of the point to the site within the cell must be smaller than the distance of that point to any other site in the plane. The boundaries of the cells are known as Voronoi edges, and represents points equidistance from the nearest 2 sites. The point where multiple boundaries meet is called a voronoi vertex. This is equidistance from its 3 nearest sites. The use of the voronoi diagram helps establish specific points and region, and this is proved by the following;

Lemma 1. *The Voronoi diagram V (S) has O(n) many edges and vertices. The average number of edges in the boundary of a Voronoi region is less than 6.*

Proof. By the Euler formula for planar graphs, the following relation holds for the numbers v, e, f, and c of vertices (v), edges (e), faces (f), and connected components (c).

$$v - e + f = 1 + c: \qquad (1)$$

We apply this formula to the finite Voronoi diagram. Each vertex has at least three incident edges; by adding up we obtain $e \geq 3v/2$ because each edge is counted twice. Substituting this inequality together with c = 1 and $f = n + 1$ yields

$$v \leq 2n - 2 \;\; and \;\; e \leq 3n - 3 \qquad (2)$$

Adding up the numbers of edges contained in the boundaries of all n+1 faces results in $2e \leq 6n - 6$ because each edge is again counted twice. Thus, the average number of edges in a region's boundary is bounded by

$$(6n - 6)/(n + 1) < 6 \qquad (3)$$

The same bounds apply to V (S). Given a set of two or more but a finite number of distinct points in Euclidean plane as shown in Fig. 2, there is an association of all locations in that space with the closest number(s) of the point set with respect to Euclidean distance. The result is a tessellation of the plane into a set of the regions associated with members of the point set as shown in Fig 3. Thus, this is the planar ordinary voronoi diagram generated by the point set, and the regions constituting the voronoi diagram ordinary voronoi polygons. The points are finite numbers n of points in the Euclidean plane.

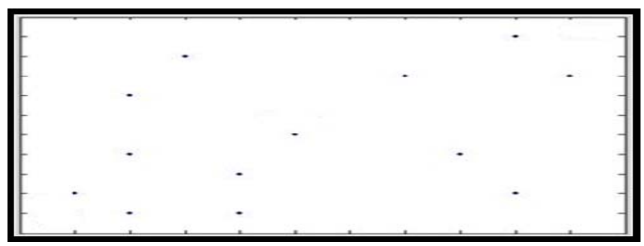

Figure 2. Design of Voronoi point (nodes)

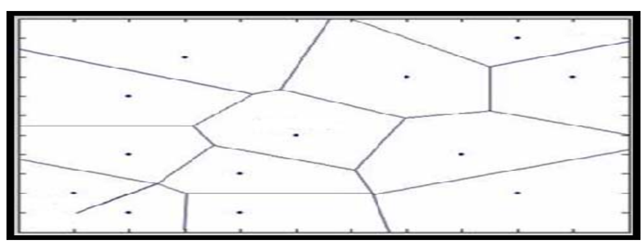

Figure 3. Design of Voronoi polygon (regions)

B. Navigation Orientation Design

The generated Voronoi Diagram that this study employs divided the entire region of the 3D model into appropriate various data points (nodes), and uses the data points to determine the shortest path through the interrelationship between the nodes, which can contribute to lessen computation time and satisfies the needs of real-time scheduling. Voronoi diagram is constructed on an entire outline of the 3D model at pre-processing stage to establish the different locations and the distances between the locations as shown in Fig. 4. This provides us with the selected points and links in the 3D model to be rendered based on the strategic nodes within the points resulting from voronoi division, and as such, only the view front within the nodes will be rendered. However, this means that each view front within the nodes ought to register its events of awareness, which is its neighboring nodes, that subsequently notifies the appropriate views every time an event occurs. Any updating in the current state of the view front must be registered as an event.

The bi-A* pathfinding recorded the shortest path using the formula

$$F = G + H \quad (4)$$

Where F is the value for the shortest path and G is the cost or obstacle found along the path, while H is the heuristic value which is the approximate shortest distance to the target. The heuristic is very important in the sense that it determines the computational complexity of the search. Whether it was heuristically accurate or nearly accurate, it guaranteed the quickest search for the shortest path with less computational complexity. Using lower heuristic also guaranteed the search of the shortest path but with more computational complexity and using the higher heuristic will not guarantee the search of the shortest path but it will result in less computational complexity. However, when the heuristic is zero, it will guarantee the search for the shortest path but will require a higher computational complexity. In our case, we determine our heuristic by using Manhattan distance model, where a search area is in a regular square grid and shown in Fig. 5. The complexity of the function is

$$\left| h(x) - h^*(x) \right| = O\left(\left(\log h^*(x)\right)/2\right) \quad (5)$$

where x is the current user location and h^* is the optimal heuristic, the exact time/distance to get from current user location (x) to the target.

During the implementation, the entire search area is divided into a square grid. This will simplify the search area to a simple two dimensional array by adopting Manhattan distance model. Each item in the array represents one of the squares on the grid, and its status is recorded with eight arrows, four to the sides and four to the diagonals as either walkable or unwalkable. The path is found by figuring out which squares it takes to get to the destinations. The square grids are mapped on the voronoi diagram. The cost of movement from each square node to another square node going through the sides of the square is less than the cost of movement of the square node moving through the diagonal by square root of 2, or roughly 1.414 the cost of moving sides ward. During initialization, the search started in both directions and maintains the length of the shortest path.

IV. IMPLEMENTATION

An experiment was carried out in IIUM Gombak campus zone A to zone D with three participants. Their task was to use the application as a guide to navigate and meet at a specified point. The goal is to determine the shortest path, and all participants should be aware of their whereabouts before reaching the target point. The participants depend on the 3D dataset that will be rendered on-the-fly to their mobile devices from the server while they are connected to the local network of the campus. The conditions given to the participants are adopted from the navigation task presented in Downs and Stea [10] which is divided into four main stages as follows: the initial orientation, maneuvering, maintaining orientation, and recognizing the target. At the initial orientation, the entire participants render scene in their mobile devices displayed their cardinal location in the 3D data-set. At their start maneuvering and maintaining maneuvering, their navigation information was provided in longitude latitude and distances.

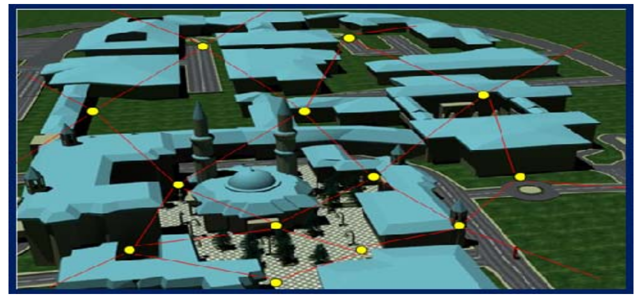

Figure 4. Voronoi diagram of the study area

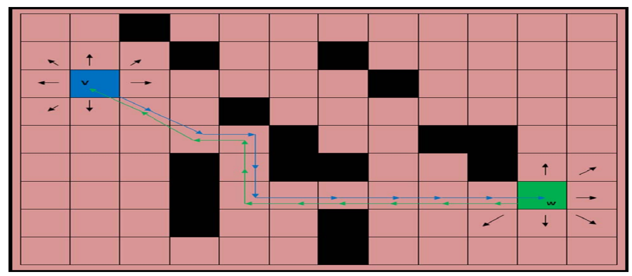

Figure 5. Manhattan gird distance model, used for search

V. RESULT

The main aim of the experiment is to test the implementation of multi-user interactive navigation in a given environment with the aid of 3D mobile devices. The areas of concentrations are the shortest path, multi-user awareness and the unforeseen drawbacks that might happen. The distances of the entire participants during the experiment to reach to the target point are; 1.23miles 0.97miles and 1.14miles respectively. Thus, in order to verify the result it was further simulated with GPS Visualizer (http://www.gpsvisualizer.com/) and gives the true values recorded during the experiment. Furthermore, the profile of the entire navigation was drawn with GPS visualization and the result is presented in Fig. 6, 7, and 8.

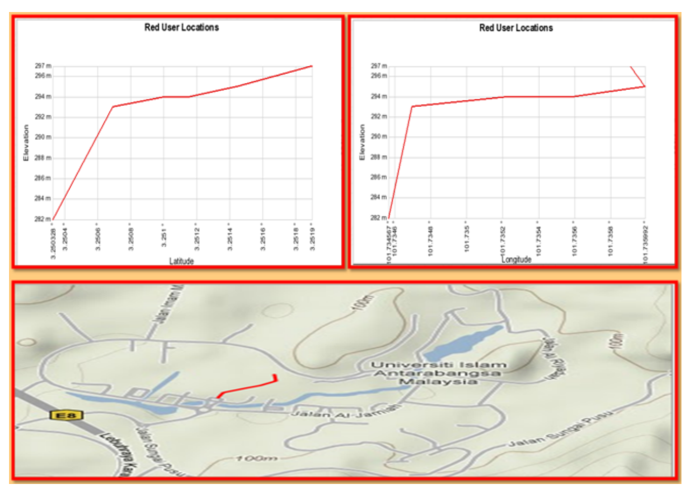

Figure 6. Navigation orientation of the first participant.

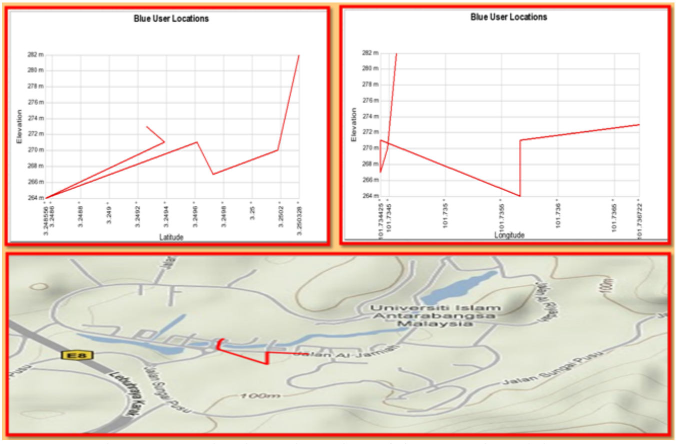

Figure 7. Navigation orientation of the second participant

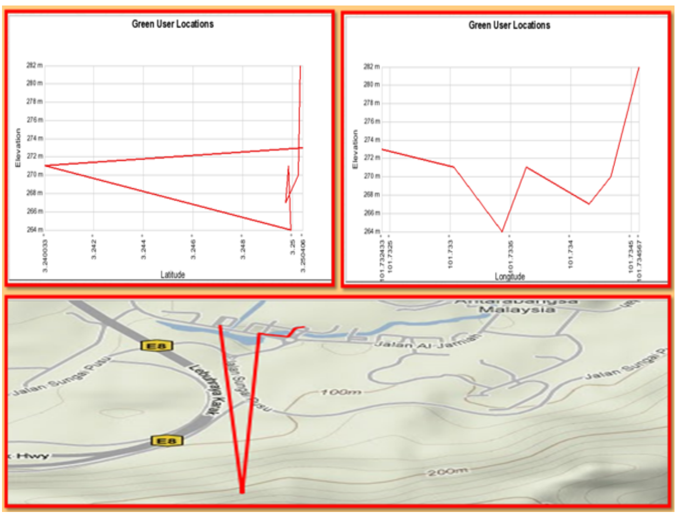

Figure 8. Navigation orientation of the third participant.

The figures show the nature of the movement of the participants in 3 quadrants. The top left quadrant indicates the back and forward movement orientation and measures in degrees of latitude as north and south respectively. The top right quadrant shows the nature of left and right movement orientation of the participants and measures in degrees of longitude as west and east respectively. The lower quadrant is the terrain map indicating the path taken from the starting point to the destinations, which is a combination of both the left and right quadrants. The participants did not report any ambiguity with the mobile devices (see Fig 9) and the application, and report that they were aware of their own and each other whereabouts as they navigate.

Figure 9. Mobile device having the 3D rendered data-set

VI. CONCLUSION

This paper presents the study of multi-User navigation within an environment with the aid of 3D mobile support. The 3D model of IIUM Gombak Campus is used for the study. The motivation of the study is based on the need for multiple users to be able to interact with each other when they were within an environment that they were not familiar with. The contributions of this study are: mapping of an environment into a set of points and regions and evaluating the shortest path within those points and regions. This led to the development of 3D model of an environment and integration of the sets of points and regions established together with the shortest pathfinding technique in order to incorporate them into mobile devices for navigation aids. The application also provides a tool for users to be aware of their own and others whereabouts while navigating within the same environment using the same system on their mobile devices at the same time. This has been proved by the experiment conducted. The results of the experiment also show that users do not face any problems while working with the application. Further study will be carried out on the battery consumptions while using the application.

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