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# DYNAMIC INTERACTIVE 3D MOBILE NAVIGATION AID

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**ABSTRACT**

This paper presents the mechanism of multi-user navigation interaction in real-time as a high-priority objective in improving mobility services efficiency and effectiveness, and investigate the support of three-dimensional representation in mobile device in aiding interactive navigation in an unknown environment. The paper is based on the fact that the use of 3D representation in mobile device is more intuitive than the conventional 2D representation. Unfortunately, Mobile devices are small devices, and that is why there are mobile, as a result, 3D dataset in mobile device might overload its performance. Even though, certain techniques were seen in many research on tackling this problems, yet, when it comes to the navigation aid the predominant 3D mobile navigation system are not interactive in real-time, that is a user will not be aware of other users while on-the-go and both using mobile navigation aid in the same environment. We provide an interactive navigation techniques for finding the shortest path to a desire destination and also been able to interact with an (agent if it's another user) or (object in terms of point or destination) in real-time with the help bi-A* pathfinding algorithm and voronoi diagram. The use of bi-A* Algorithm is to establish a forward and backward search for a destination or a position of users, while the use of voronoi diagram is to establish points and region within the navigation environment. The result of our finding indicate that information in three-dimension for navigation aid in mobile device is more intuitive and experimental result shows that multi-user interaction with support of 3D representation in mobile devices helps in aiding number of user going around within an environment an been able to be aware of their movement in real-time. This approach is unique because it provides visualization of 3D representation (map) in mobile devices' which assists users to navigate interactively.

**Keywords:** *Mobile navigation, 3D representation (map), Voronoi diagram, Bi-A* Pathfinding*

## 1. INTRODUCTION

In spite of an onward increase in computing resources and wireless networking services, mobile devices have still some limitations: they typically comes with little resources compare to the bulky applications that run fast in PCs, and mostly the user interface is restricted within limited ranges. When evaluating computing resources of current PC's 3D graphics capabilities and mobile devices 3D graphics supports, a significant problem is seen with mobile 3D graphical applications support. However, in pursuit to strive for usage the of 3D graphics application in mobile devices for navigation aid from the on-set is to compressed it and make it lightweight as possible in order to deal with the limited amount of memory available and the low processing capabilities of mobile devices [6]. Although this may seems to be a solution to the problems faced by mobile device when 3D application are used, but there are other considerations which this paper is trying to addressed, for example interactivity.

Over the years new services and applications of 3D graphics techniques for visual interactive navigation have already achieved practical standards on desktops computer; while the computing resource-constrained in mobile devices result to the measure drawback of 3D graphics application implementation, yet mobile devices stand as a feasible devices that will aid navigation in simple and user friendly. The motivation for research that will yield a good technique for 3D representation in mobile device for navigation aid is considering the fact that mobile devices resources and applications are continuing getting greater in input, computing power, memory, storage, and most of the currently mobile devices were embedded with high resolution graphical hardware

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for function of displaying together with an increasing wireless networking capabilities and Global Positioning System (GPS) receiver and lot of more unimaginable advance resource that may come soon.

The interactive navigation aided mechanism with mobile device that this paper is presenting is in two parts: The first is the main primary interaction; that is interaction between the mobile device and the user while on-the-go, and the second is the secondary interaction; which is the interaction between different users in a real-time. This is perceived as the demonstration of feature mobile devices services because to our knowledge this scheme is not widely available and it's necessary. Our scheme is to combine the creation of shortest path and create dynamic interactive technique for many users to aid navigation with mobile device at the same time.

In order to get the shortest path and enable dynamic interactive navigation, Voronoi diagram and Bi-A* pathfinding has been introduced. Voronoi diagram is applied to model the work space nodes and region, and Bi-A* pathfinding algorithm, is used to get the forward and reverse shortest paths within the environment. The proposed scheme is unique for the reason that it will provides visualization of 3D map model in mobile devices' which will assists users to navigate to a target location by using the shortest path.

The remaining part of this paper is organized as follows; In section 2 we discuss about some related work, and in section 3 we provides the system structure and section 4 we discusses the proposed architectural framework of this study, While in section 5 we described the result and in section 6 we provide our experimental scenario and In section 7 we give the discussion, and finally in section 8 is the conclusion of the work.

## 2. RELETED WORK

This paper is an extension of [21] and [22], with extended focus. The initial effort of an experiment on 3D mobile devices which visualize 3D vector graphics, animation and other media data over GSM network were established by Raposo et al [16]. The possibilities of the implementations despite the mobile devices low computing resources were first seen in an attempt by Rakkolainen et al in the 3D City Info project [15], which was aimed at creating mobile interactive 3D maps, to visualize real-time GPS data with VRML worlds, unfortunately it was faced with rigorous technical limitations and had to perform the first field experiments with pre-rendered images on web pages.

There are a lot of primary interactive 3D mobile navigation system (primary interactive here, means the interaction is between the user and the mobile devices while on-the-go) with the intention of aiding navigation of users in an environment, one of the uniqueness of the system we developed is the secondary dynamic interactivity (that is the interaction of many users at the same time) and finding the shortest path within. Although, Rodrigues et al present 3D virtual tour application [17] where multiple mobile clients using M3G navigate through and interact with each other in a shared 3D space. Unfortunately the communication details between the mobile application and the central server, as well as the details of the search mechanism used for selecting an appropriate 3D scene were not presented. In VisUN project by Mantoro et al [7] Mobile 3D navigation system was design to navigate user to a static and dynamic target location/object which could navigate more than two users in a 3D walk space and at the same time showing their whereabouts on 3D projections mapped. Although in [6], the framework for the map that shows the user's location in the scene to navigate from source to the target and the target also moves to the source to meet on the same physical location and image plane, were seen as an extension of [7], the interactivity between users as explain was solely dependent on the 3D projected map, thus the approach is in-line with the approach of this paper.

In m-LOMA project by Nurminen [9] mobile 3D navigation system (3D city Map) was designed by applying temporally coherent and hierarchical view frustum culling as the measure technique, so that the entire city blocks is cull depending on the rotation and movement of the viewpoint in order to save resources. Saving resources in order not to weaken the mobile device performance was also their concern. As result, their work provides ways in which little mobile resource will be utilized in order to enhance performance. In pursuit to strive for suitable 3D graphics application in mobile devices a number of researches were carried out in 3D representation in mobile device for navigation aid [1, 10, 12, 13, 18, 19] and mostly advocate the use of compressed and lightweight 3D model for mobile devices due to the limited amount of

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memory available and the low processing capabilities support of mobile devices.

## 3. SYSTEM ARCHITECTURE

The proposed system structure is in two subdivisions as presented in Figure 1, it is provided for client server remote rendering architecture. The first subdivision is designing the 3D model and the second subdivision is the remote rendering.


*Fig. 1, Structure of the System*

The design of the 3D model was carried out through the following stages: 1) Planning, 2) Using the reference descriptions (Image and video files), 3) Initial Modeling, 4) Refinement of the Model and final smoothing. At the planning stage, we make preparation to manually design a simplified 3D model suited for mobile devices. The 3D application used for the design is Autodesk 3DsMax 2010 and the final 3D model is exported to VRML 2.0 through the VRML exporter. The reference description of the model is a layout map and video file of the area as shown in Figure 1, which is the zone A to zone D of IIUM Gombak campus, which is within the administrative and academic area of the IIUM Gombak campus [21].

The second subdivision is the remote rendering. Prior to emergence of mobile 3D hardware, the possibility of remote rendering was considered to provide the rendering services at the server side [11]. Remote rendering was described by Hesina and Schmalstieg as out-of-core rendering [5] in addition, remote rendering has been used to describe a situation where the rendering is performed remotely, and final frames sent to the clients [2, 3, 14]. 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 [11]. Quax et al. have examined this possibility from the viewpoint of encoding, where a single encoding server with a dual core 3GHz CPU could serve 25 clients [14], thus 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 [17]. Nurminen observe latencies and scalability problems in remote rendering [11]. The minimum latency is the round-trip-time of the network, and the transmission time for the payload (the image or the encoded stream fragment). Nurminen gave an example, that with a 20kB average frame size and 40kB/s network speed, the latency would be 150ms + 500ms = 650ms, without the contribution of rendering and encoding. Consequently Bao clarify that unlike streaming systems where all the frames have to be sent continuously, in remote rendering the data only need to be sent once every eight to ten frames. This method therefore significantly reduces network latency [2].

The server side handles and administers the 3D dataset. The application that makes the procedure possible is design with C++ to manage entire activities of the 3D graphical bits and pieces by responding to client navigation request. From any given location, the server prepares the 3D dataset and gets the adjoining details of the 3D dataset, the application is design in such a way that it will allow only those nodes which lie in a view region will be loaded, and nodes are search by enclosed voronoi region while the shortest pathfinding are search by square grids. If a viewpoint moves over an adjacent node the application will tend to maintain a square grid orientation of the new node so that it will be loaded to the client memory as new node and becomes the current node. At the same time, the application will remove some far nodes which are not within the field-of-view in order to free memory for the fetching of new nodes.

## 4. INTERACTIVE ARCHITECTURE

The dynamic interactive architecture of this system is based on two algorithms: the Voronoi diagram and Bi-A* pathfinding. Voronoi diagram

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generate points (nodes) and display the distances between sets of points in any dimensional space. For path planning, voronoi tends to be used in two dimensional space, where sets of points all lie within a plane is divided into cells so that each cell contains exactly one region as shown in Figure 2.

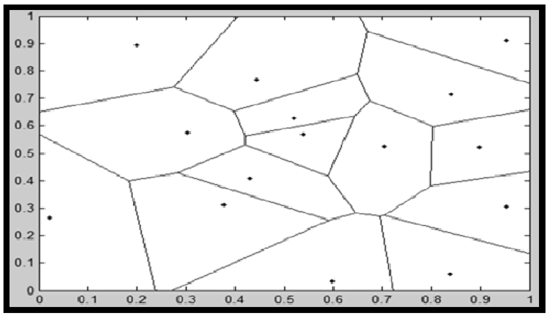

*Fig 2. Voronoi diagram*

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. If this rule is followed across the entire plane, then the boundaries of the cells, known as Voronoi edges, will represent point's equidistance from the nearest 2 sites. The point where multiple boundaries meet, called a voronoi vertex, is equidistance from its 3 nearest sites**.**

**Lemma 1.** *The number of Voronoi vertices and edges are respectively* $2(n-1)-h$ *and* $3(n-1)-h$ *respectively,* where $n$ is the number of sites and $h$ the number of sites on the convex hull of $S$ .

**Proof.** A finite graph satisfies Euler's formula

$$2(n-1)-h \;\; and \;\; 3(n-1)-h \qquad (1)$$

For a convex polyhedron, where $V, E$ and $F$ are respectively the number of vertices, edges and faces of the polyhedron (graph). This can be established by a stereographic projection of the polyhedron, embedded on the surface of a sphere, into a finite graph. The Voronoi diagram of a set of $n$ sites can be transformed into a finite graph by enclosing the Voronoi diagram inside a very large circle and treating each of the $h$ (= # of convex hull vertices of the given point set) arcs that lie inside an unbounded Voronoi polygon to correspond to an edge of the graph. For this finite graph, we use the fact that $2E = 3V$ (each side of the equality counts the total degree of the graph) to deduce, using Euler's formula, that

$$V = 2(F-2) \;\; and \;\; E = 3(F-2). \qquad (2)$$

$V = h + \#$ Voronoi vertices

$E = h + \#$ Voronoi edges.

Hence the number of Voronoi vertices $= 2(F-2)-h$

and the number of Voronoi edges $= 3(F-2)-h$.

Since $F = n+1$, these counts are therefore

$$2(n-1)-h \;\; and \;\; 3(n-1)-h \;\; \text{respectively.} \qquad (3)$$

**Lemma 2.** *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, edges, faces, and connected components.

$$v - e + f = 1 + c: \qquad (4)$$

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 $e \leq 3n-3$

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

$$(6n-6)/(n+1) < 6.$$

(5)

The same bounds apply to $V(S)$.

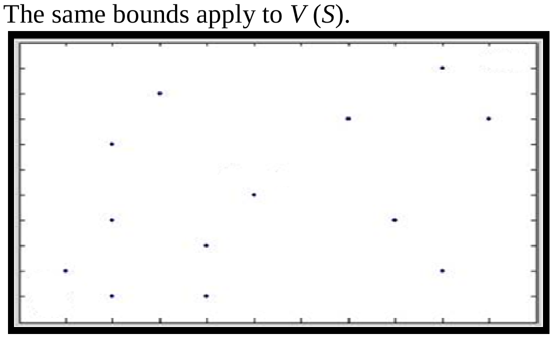
*Fig 3. Voronoi point*

Given a set of two or more but a finite number of distinct points in Euclidean plane as shown in Figure 3, 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

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a tessellation of the plane into a set of the regions associated with members of the point set as shown in Figure 4.

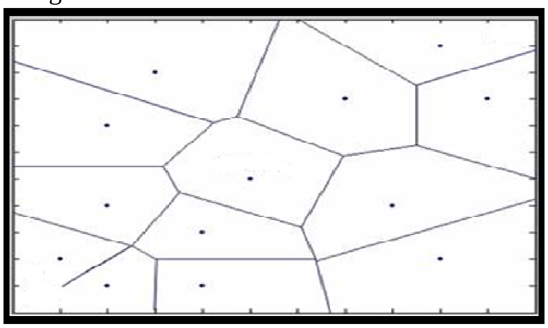

*Fig 4. Voronoi polygon*

This is the planar ordinary voronoi diagram generated by the point set, and the regions constituting the voronoi diagram ordinary voronoi polygons. Since the point are finite numbers $n$ of points in the Euclidean plane, let assume that $2n \le n < \infty$. The $n$ points are labeled by $P_1,\ldots,P_n$ with the Cartesian coordinates,

$(x_{11}, x_{12}),\ldots(x_{n1}, x_{n2})$

or location vectors $x_1,\ldots,x_n$. the $n$ points are distinct in the sense that

$x_i \ne x_j$ for $i \ne j,\ i, j \in I_n\ = \{1,\ldots,n\}$

Let $p$ be an arbitrary point in the Euclidean plane with coordinates $(x_1, x_2)$ or a location vector $x$. then the Euclidean distance between $p$ and $p_i$ is given by

$$d(p, p_i) = \|x - x_i\| = \sqrt{(x_1 - x_{i1})^2 + (x_2 - x_{i2})^2}. \quad (6)$$

If $p_i$ is the nearest point from $p$ or $p_i$ is one of the nearest points from $p$ we have the relation

$$\|x - x_i\| \le \|x - x_j\| \quad for\ j \ne i,\ i, j \in I_n$$

Let

$$P = \{p_1,\ldots,p_n\} \subset \mathbb{R}^2,\ where\ 2 < n < \infty\ and\ x_i \ne x_j \quad for\ i \ne j,\ i, j \in I_n.$$

the region given by

$$V(p_i) = \{x \mid \|x - x_i\| \le \|x - x_j\| \quad for\ j \ne i,\ i, j \in I_n\}$$

is called the planar ordinary voronoi polygon associated with $p_i$ or the voronoi polygon of $p_i$ and the set given by

$$\nu = \{V(p_1),\ldots,V(p_n)\} \qquad (7)$$

is called the planar ordinary voronoi diagram generated by $P$ or the voronoi diagram of $P$.

The generated Voronoi Diagram that this research employ divide 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 satisfied the needs of real-time scheduling. First, voronoi diagram is constructed on entire outline of the 3D model at pre-processing stage to establish the different location and the distances between the location for our experiment as shown in Figure 5 in order to mapped out the 3D scene, 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.

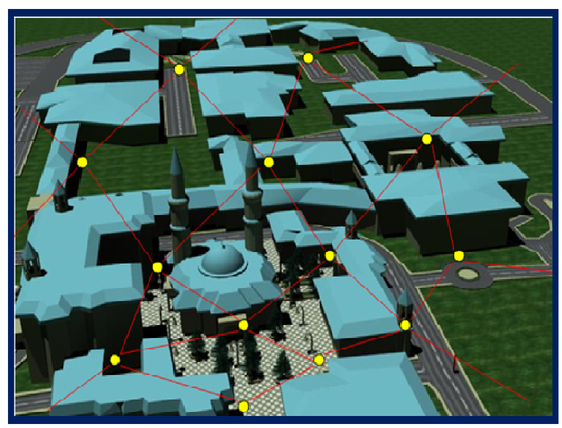

*Fig 5. Voronoi diagram of the study area*

Voronoi diagram application is found in many areas such as; Epidemiology, models for predictive forest fires and it is also used in derivations of the capacity of a wireless network. It is also used to calculate the rainfall of an area based on a series of point measurements. It is applied in computer graphics to procedurally generate some kinds of organic looking textures and used to determine clear routes considering if points are obstacles then the edges of the graph will be the routes furthest from it. YE Yuan-yuan first uses voronoi diagram to construct all the possible routes and then uses graph clipping method to find out the routes that satisfied the constrains [20].

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Path finding with the Bi-directional A* pathfinding algorithm alternates between running the forward and reverse version of Dijkstra's algorithm. This provides simultaneous bi-directional forward and the reverse search respectively. Bi-directional A* path-finding algorithm search from source to the target and in the same time the target also moves to the source as shown in Figure 7. The searching process will stop when the two directions search meet each other in a 3D walk-space. In most cases, the complexity of the bi-directional A* algorithm will be the heuristic function h that can be defined as the following [6]:

$$| h(x) - h^*(x) | = O((\log h^*(x))/2) \qquad (8)$$

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.

The heuristic can be used to control A*'s forward search behavior and consequently apply to the reverse search. This is possible when the following conditions are applied:

5 At one extreme, if *h(n)* is 0, then only *g(n)* plays a role, and A* turns into Dijkstra's algorithm, which is guaranteed to find a shortest path.

5 If *h(n)* is always lower than (or equal to) the cost of moving from n to the goal, then A* is guaranteed to find a shortest path. The lower *h(n)* is, the more node A* expands, making it slower.

5 If *h(n)* is exactly equal to the cost of moving from n to the goal, then A* will only follow the best path and never expand anything else, making it very fast. Although there are no standard that can make this happen in all cases, but it is possible to make it exact in some special cases. It's nice to know that given perfect information, A* will behave perfectly.

5 If *h(n)* is sometimes greater than the cost of moving from n to the goal, then A* is not guaranteed to find a shortest path, but it can run faster.

5 At the other extreme, if *h(n)* is very high relative to *g(n)*, then only *h(n)* plays a role, and A* turns into Best-First-Search.

The use of voronoi diagram enables the project to determine suitable heuristic for the best path based on assumption 3 above, in order to make it very fast. Even though it's not up to the exact measurement, but it get closer to the precise measurement considering the true distances. The voronoi vertexes are the established points which this research assigns for users, while the voronoi edges are taken to be the heuristic distances and finally the voronoi regions are the area covered with structures, like buildings and un-walk-able areas as shown in Figure 6. As a result this research 3D application was design considering this setting.

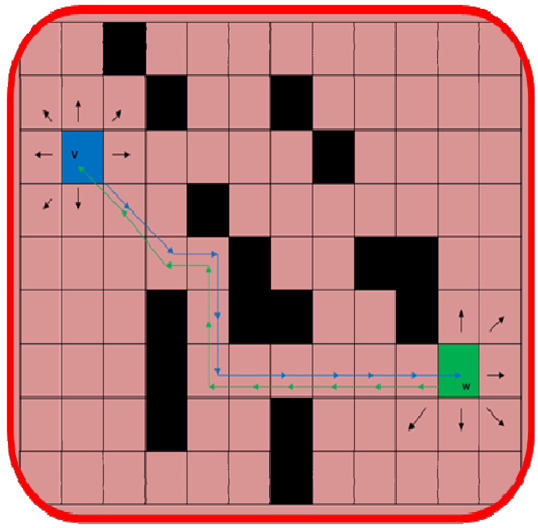


*Fig 6. Bi-A* Pathfinding search process*

The Bi-A* algorithm works as shown in Figure 6, there are two users, user blue (*v*) and user green (*w*). The algorithm will ensure that User blue moves to user green's location and at the same time, user green moves to user blue's location. The entire search area is divided into a square grid; this will simplify the search area to a simple two dimensional array. 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 from green to blue and vice versa. 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 maintains the length of the shortest path, until both meet. The algorithm terminates when all the targets are reachable from all directions meet. The experimental results which were carried out in IIUM Gombak campus is presented in the next section.

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## 5. RESULT

The experiment carried out to determine the efficient interactive navigation among users based on client server implementation and GPS signal over network transmission was found to be proficient, the details of the result was presented in the scenario feedback. However, the datasets transfer with the lightweight 3D model designed with least level of details improves the rendering speed and does not affect the download time as was observed during the experiment and the details are also provided in the scenario feedback. The scene is remotely rendered in sequences to the mobile clients and the frame rate was sufficient for conducting the navigation within the environment. Users in a 3D walk-space are able to navigate dynamically by means of the shortest paths to meet at a certain point and at the same time sees their whereabouts in 3D projection mapped on the their mobile devices' screen.

## 6. EXPERIMENTAL SCENARIO AND RESULT

The experiment is represented in a scenario for two-way direction of users navigation in the following: there are three users involved, user blue (will only view the bottom left as the front view and the bottom right as the embedded 3D map in the same screen of mobile devices'), user green (will only view the top left quadrant as the front view and the bottom right as the embedded 3D map in the same screen of mobile devices') and user red (will only view the top left quadrant as the front view and the bottom right as the embedded 3D map in the same screen of mobile devices') and the server side will have the entire view of all the 4 quadrants as shown in Figure 7 and 8. All the users are in different position within the environment as was establish using the voronoi algorithm and they are required to meet face to face in a single location. Each user being aware of his/her position will also sees his/her current front view together with the current location of each other (as dot color) in 3D projection mapped on the same mobile devices' screen as shown in Figure 8. The heuristic distances were determined by the voronoi edges and the search orientation was carried out using the square grids. The square grids is lay in the bottom layer of the 3D outline, while the voronoi diagram is in the middle layer of the 3D outline and finally the entire 3D model is in the top layer and the whole layers were mapped together using C++ . The applications are installed on each mobile device and the simple user interface was design for rendering and end rendering.

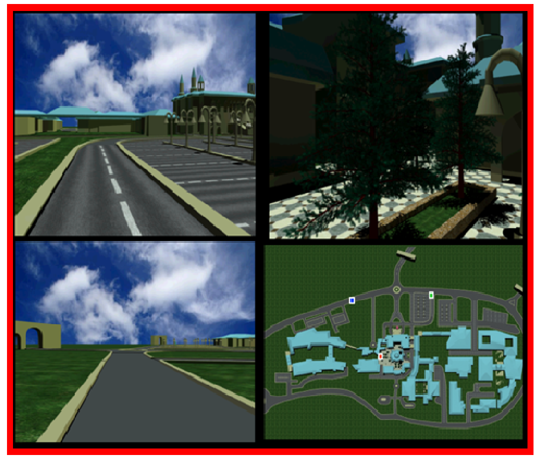

*Fig 7. Bi-A*Pathfinding Navigation Scenario*

The users invokes rendering for navigation to view their view-front and 3D projected map in order to see themselves with their changing position as they move around by "pressing send push button of their mobile devices" to send request to the server for 3D view and projected 3D map. While users end the navigation by "pressing the end push button of their mobile device. The server sends the rendered 3D dataset using the local host on VRML 2.0 and the users' mobile devices' also received the rendered 3D dataset under the local host with the VRML 2.0. The interconnection between the clients and server is represented in Figure 8.

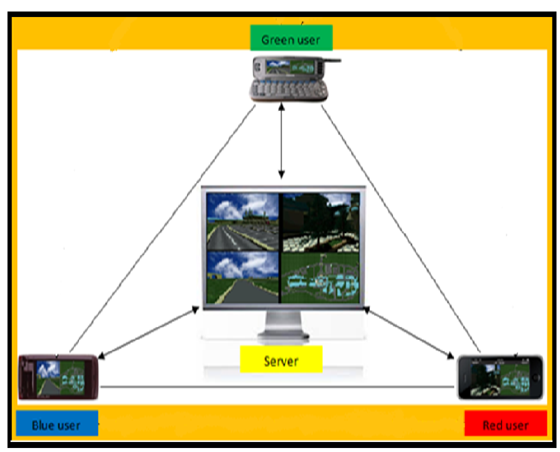


*Fig 8. Navigation Interaction of the users' platform*

The navigation orientations is subject to the users nature of movement, when there are moving

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straight ahead either to the north or south the latitude coordinates changes at each steps and if the orientation of the movement is east or west the longitude coordinates changes as well. However to avoid objectivity, users all the three users where asked to walk freely based on their natural orientations of movement, as such we are able to tracked the longitude, latitude and altitude changes on the users navigation orientations.

After the initial navigation orientation, all the clients login in to the local host using the IP address and provide their user name and ID, then they all press the "send push button of their mobile device" the rendering started instantly and they did not observed any delay. In addition their whereabouts in the projected 3D map was seen by all of them, their viewpoint changes are also being seen in the server that locates the corresponding view node and updates the client data according to the associated potential visibility sets of the 3D scene. Each mobile user navigation information where determine at six different voronoi nodes established from their starting nodes to the meeting point. As all the users constantly moves and maneuvers the environment they also sees the movement of the color dots in the projected 3D map in the same mobile devices' screen.

## 6.1 Red User Navigation Information

The parameters of the navigation orientation scenario recorded for Red users in this experiment are in the same way with the Blue and Green users respectively. Navigation task is divided into four main stages [4], which are: the Initial orientation, maneuvering, maintaining orientation, and recognizing the target, during the experiment of this work, the navigation task follow this stage [4], However, the observations were made on all the users based on this navigation orientations and the orientation of each step along the paths were traced and recorded. when the red user moves, it's found out that each change in the orientation of movement either to the north, south, east, or west is traced by latitude (see figure 10) and longitude (see figure 11) respectively and all other users sees the red dot moving. The red dot represented by the red user on the 3D projected map as shown in Figure 9, thus the elevation along the path was also recorded.


*Fig 9, Red user's view and projected 3D map*

The rendering speed required was sufficient for navigation and the network speed (download rate) was also reliable, all the results of the entire navigation from the starting point to the destination are represented in Table 1. The red user navigation orientations recorded along the paths followed to the meeting point is the combinations of the left, right, forward and backward orientation and are represented in Figure 12, this was determined by GPS profile visualizers, while the combination of the latitude changes is presented in Figure 10 and the combination of longitude changes is presented in Figure 11 these form the paths taking from the starting point to the destination.

Table 1, Navigation Information of User Red

| Paths | | GPS Location: Longitude and Latitude | Decimal Longitude and Latitude | Altitude (ft) | Data, Download rate (kbps) | Rendering rate(fps) |
|---|---|---|---|---|---|---|
| No. | Description | | | | | |
| 1 | Starting point | 3°15'06.84"N, 101°44'09.29"E | 3.2519N 101.735914E | 297 | 13 - 70 | 20 – 25 |
| 2 | Initial orientation | 3°15'06.81"N, 101°44'09.29"E | 3.251892N 101.735914E | 297 | 13 – 110 | 30 – 38 |
| 3 | Early Maneuvering | 3°15'05.20"N, 101°44'09.57"E | 3.251444N 101.735992E | 295 | 13 – 400 | 30 – 40 |
| 4 | Maneuvering | 3°15'04.14"N, 101°44'08.12"E | 3.25115N 101.735589E | 294 | 13 – 550 | 30 – 40 |
| 5 | Maintaining orientation | 3°15'03.60"N, 101°44'06.81"E | 3.251N 101.735225E | 294 | 13 – 450 | 30 – 40 |
| 6 | Recognizing the target | 3°15'02.49"N, 101°44'04.91"E | 3.250692N 101.734697E | 293 | 13 – 500 | 30 – 40 |
| 7 | At the target. | 3°15'01.18"N, 101°44'04.44"E | 3.250328N 101.734567E | 282 | 13 - 500 | 30 - 40 |

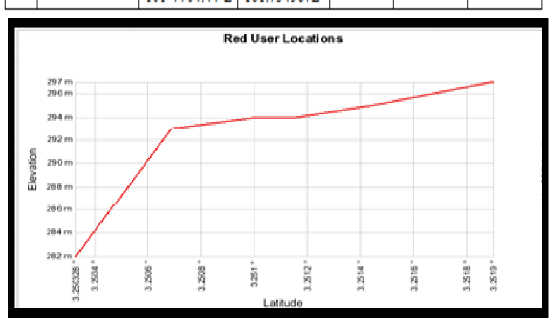


*Fig. 10, Navigation orientation of Red user as he*

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*move north or south from the starting point in degrees of latitude.*

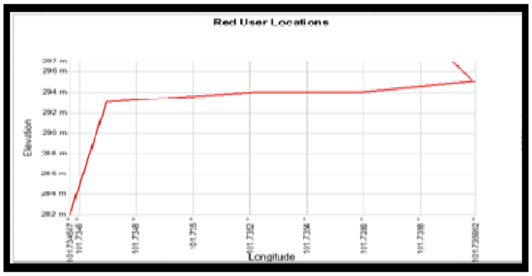


*Fig 11. Navigation orientation of Red user as he move east or west from the starting point in degrees of longitude.*


*Fig 12. Navigation orientation of Red user*

## 6.2 Blue User Navigation Information

The navigation task of User blue is the same with that of user red, therefore all the explanation of user red also apply to user blue. However, the result obtained is not the same with user blue. All the results of the entire navigation from the starting point to the destination are represented in Table 2.


*Fig 13. Blue user's view and projected 3D map*

The Blue user shortest path is represented in Figure 16, it's the combination of the latitude changes in Figure 14 and longitude changes in Figure 15 that form the paths taking from the starting point to the destination.

Table 2, Navigation information of User Blue

| Paths | | Location: Longitude and Latitude | Decimal Longitude and Latitude | Altitude (ft) | Data, Download rate (kbps) | Rendering rate(fps) |
|---|---|---|---|---|---|---|
| No, | Description | | | | | |
| 1 | Starting point | 3°14'57.18"N, 101°44'12.20"E | 3.249264N 101.736722E | 273 | 13 - 70 | 20 – 25 |
| 2 | Initial orientation | 3°14'57.08"N, 101°44'11.64"E | 3.249389N 101.735667E | 271 | 13 – 110 | 30 – 38 |
| 3 | Early Maneuvering | 3°14'54.80"N, 101°44'08.40"E | 3.248556N 101.735667E | 264 | 13 – 260 | 30 – 40 |
| 4 | Maneuvering | 3°14'58.63"N, 101°44'05.88"E | 3.249619N 101.734425E | 271 | 13 – 400 | 30 – 40 |
| 5 | Maintaining orientation | 3°14'59.03"N, 101°44'03.93"E | 3.249731N 101.734425E | 267 | 13 – 550 | 30 – 40 |
| 6 | Recognizing the target | 3°15'00.66"N, 101°44'04.16"E | 3.250183N 101.734489E | 270 | 13 – 500 | 30 – 40 |
| 7 | At the target. | 3°15'01.18"N, 101°44'04.44"E | 3.250328N 101.734567E | 282 | 13 - 500 | 30 - 40 |

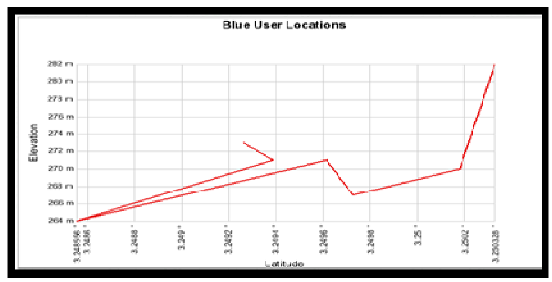


*Fig. 14, Navigation orientation of Blue user as he move north or south from the starting point in degrees of latitutude.*

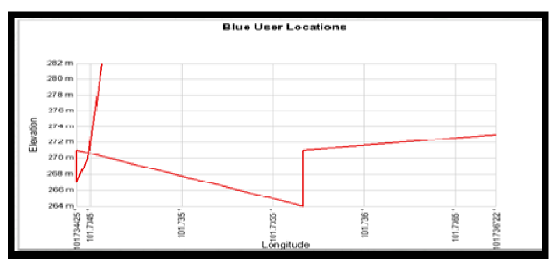


*Fig. 15, Navigation orientation of Blue user as he move east or west from the starting point in degrees of longitude.*

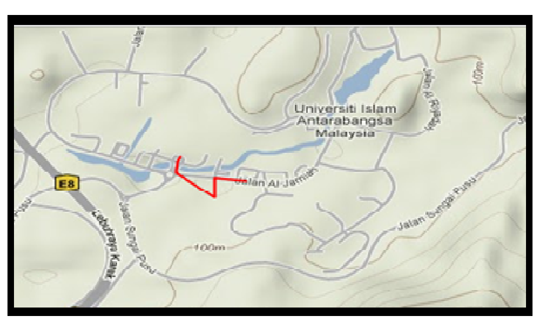


*Fig 16. Navigation orientation of Blue user*

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### 6.3 Green User Navigation Information

The navigation task of Green user is the same with the other users, therefore all the explanation of the other users also apply to Green user.


*Fig 17. Green user's view and projected 3D map*

However, the result obtained is not the same with the others. All the results of the entire navigation from the starting point to the destination are represented in Table 3. The Green users' shortest path is represented in Figure 20, it's the combination of the latitude changes in Figure 18 and longitude changes in Figure 19 which form the paths taking from the starting point to the destination.

Table 3. Navigation information of Green User

| Paths No, | Description | Location: Longitude and Latitude | Decimal Longitude and Latitude | Altitude (ft) | Data, Download rate (kbps) | Rendering rate(fps) |
|---|---|---|---|---|---|---|
| 1 | Starting point | 3⁰15'01.46"N, 101⁰43'56.76"E | 3.250406N 101.732433E | 273 | 13 - 70 | 20 – 25 |
| 2 | Initial orientation | 3⁰15'00.12"N, 101⁰43'58.92"E | 3.240033N 101.733033E | 271 | 13 – 110 | 30 – 38 |
| 3 | Early Maneuvering | 3⁰14'59.82"N, 101⁰44'00.35"E | 3.24995N 101.733431E | 264 | 13 – 260 | 30 – 40 |
| 4 | Maneuvering | 3⁰14'59.48"N, 101⁰44'01.08"E | 3.249856N 101.733633E | 271 | 13 – 400 | 30 – 40 |
| 5 | Maintaining orientation | 3⁰14'59.05"N, 101⁰44'02.95"E | 3.249736N 101.734153E | 267 | 13 – 550 | 30 – 40 |
| 6 | Recognizing the target | 3⁰15'00.86"N, 101⁰44'03.61"E | 3.250239N 101.734336E | 270 | 13 – 500 | 30 – 40 |
| 7 | At the target. | 3⁰15'01.18"N, 101⁰44'04.44"E | 3.250328N 101.734567E | 282 | 13 - 500 | 30 - 40 |

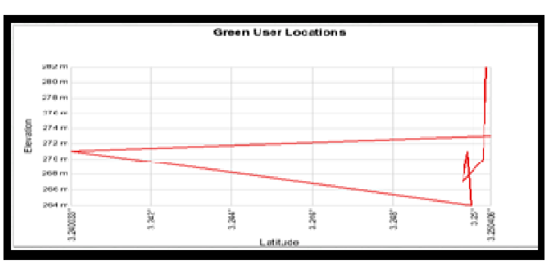


*Fig. 18, Navigation orientation of Green user as he move north or south from the starting point in degress of latitude.*

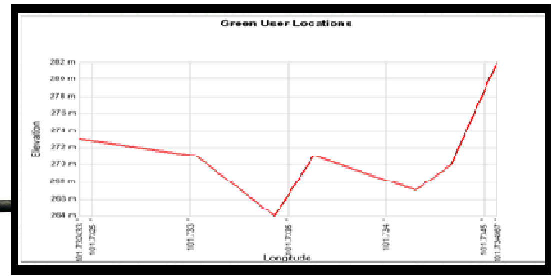


*Fig. 19, Navigation orientation of Green user as he move east or west from the starting point in degrees of longitude.*

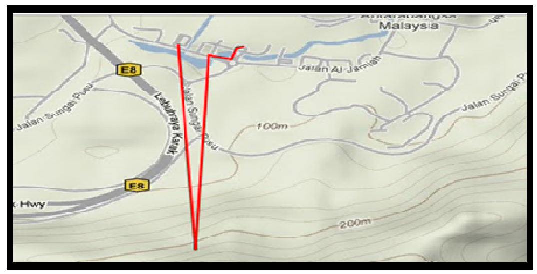


*Fig. 20, Navigation orientation of Green user*

The initial navigation orientation for all the users sees their view points and the locations of the each other in the projected 3D map. As all the users constantly moves and manoeuvres the environment based on the shortest path distance, so also they sees the movement of the colour dots in the projected 3D map in the same mobile devices' screen and at the same time their value of the GPS coordinates changes and the rendering is highly sufficient with good visible scene. The Navigation information of all the users under the experiment was obtained.

## 7. DISCUSSION

Based on the experiment carried-out in this study, it's understood that the efficiency of navigation system would only be possible when a number of experiments are accomplished. However, the user interface use for the experiment is of traditional 3D browsers which provide simple navigation tools that allow the user to modify the scene parameters such as orientation, position and focus. Using these tools, it is frequent that, after some movements as observed, the user might need to reorient himself for new task, when interacting with a 3D world model in mobile device. As observed one of the first requirements are being able to navigate in the world in order to easily access and explore information to allow for judicious decision making for solving eventual

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problems which reflect the important of being there. The thought about the basic navigation scheme does not necessarily requires a lot user's experience since the system will aid movements in a user friendly way and provide an important spatial knowledge for the users environment with a comprehensible perception of his location. The scenario revealed two important points; 1) navigation schemes are more perceptive to the 3D scene and user's tasks when projected 3D map is provided in the same mobile device's screen with the view-front. 2) Navigation is tightly bound to the visual metaphor used and the way the user moves in the virtual world is determined by the metaphor that the same world is based upon.

The red, blue, and green users in the experiment navigations' adapt to the concept of metaphor-aware navigation. Although the way users navigate in a 3D world is intimately related to the task that need to accomplished, that's reaching to a destination as quickly as possible. The remote rendering rate and the data download to the mobile devices' of the three users from the starting point of the experiment to initial orientation and early maneuvering were increasing until when the users recognized the target, at that point users do not make any requires since the target has been reached.

## 8. CONCLUSION

The dynamic interactive mobile device visualization and navigation using 3D Maps of a 3D workspaces environment has already been done and more upcoming bits and pieces are still being updated. This paper discusses the problem of interactive navigation and visualization optimization techniques for mobile 3D application. There are three motivating factors for this study: 1) Mobile devices resources enhancement over the years in computing power, memory, storage, and equipped with graphical hardware for function of displaying. 2) An increasing wireless networking capabilities for mobile device. 3) Global Positioning System (GPS) receiver in most of the mobile devices. This offers the opportunity for the success of research like ours.

The paper uses 3D maps model of IIUM Gombak Campus (within zone A to zone D), the available internet bandwidth in the campus and finally user's studies and field experiments as methodology for validating the algorithms used. The experimental result confirmed that navigation schemes are more perceptive to the 3D scene and user's tasks when projected 3D map is provided in the same mobile device's screen with the view-front and Navigation is tightly bound to the visual metaphor used. The rendering rate and the data download to the mobile devices' of the 3D scene were sufficient for navigation use. Finally, shortest paths have been found for all the users to follow and to meet at their meeting point.

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