A 3D Virtual Navigation System Integrating User Positioning and Pre-Download Mechanism

Ching-Sheng Wang, Yu-Hung Su, and Ching-Yang Hong

***Abstract*—**This paper takes the actual scene of Aletheia University campus – the Class 2 national monument, the first educational institute in northern Taiwan as an example, to present a 3D virtual navigation system which supports user positioning and pre-download mechanism. The proposed system was designed based on the principle of Voronoi Diagra) to divide the virtual scenes and its multimedia information, which combining outdoor GPS positioning and the indoor RFID location detecting function. When users carry mobile equipments such as notebook computer, UMPC, EeePC…etc., walking around the actual scenes of indoor and outdoor areas of campus, this system can automatically detect the moving path of users and pre-download the needed data so that users will have a smooth and seamless navigation without waiting.

***Keywords*—**GPS, Positioning, RFID, Virtual Navigation, Voronoi Diagram.

I. Introduction

VIRTUAL REALITY (VR) is the virtual environment established using simulations of real scenes by computers. The scenes in virtual reality can be the environment we are familiar with or the scenes we have never saw. It can also be imagined space and users can have immersive feelings with some helmet monitors or sensor gloves.

In recent years, because of rapid improvement of computer efficiency and internet transmission speed, the application of virtual reality is getting more and more popular. The most frequent applications are computer games, the navigation of virtual campus and museums, etc. However, because virtual reality is getting more and more exquisite and complicated, the finished file is getting bigger and bigger. Among them, because computer games already provide discs for users to install all the scenes into computers directly, there is not a download problem for huge data. On the other side, because virtual navigation usually need instant download to view, the huge amount of data will cause a long time download, and seriously affect the smoothness of user's navigation.

For the problems mentioned, this system applies the concept of Voronoi Diagram Division[1] to appropriately divide the scenes into independent download areas according to the distance of data points, and combine the function of indoor and outdoor positioning to actually make a virtual navigation system which supports pre-download of virtual scene and multimedia data.

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The combination of virtual navigation and user positioning is a new and practical research area. Scholars such as Tetsuro Ogi used cell phones which support GSP and photographing function to combine the photos of actual scenes shot by cell phones and virtual scenes to reinforce the navigation impression of users [2]. Shohei Koide also proposed a positioning system which combines audio navigation for visual impairments [3].

Our system further uses active RFID readers and tags to set appropriate sensor thresholds by analyzing the signal strength of each active RFID, and refer to the moving path of users to precisely detect the location of users in the real scene, and then combine 3D navigation system to show user's corresponding position in the virtual scene. Based on the positioning mechanism, system can download scenes in advance, and further remind users to visit and understand the detailed information of the surrounding artifacts more deeply.

Moreover, in order to make the presentation of virtual navigation more efficient, and clear, easier to understand, scholars such as Fan Zhang use labels to make users quickly know the name and introduction of the objects when they are in a huge virtual scene [4]. Andreas Schmeil designed a mobile virtual assistant into the campus navigation system. When user is navigating the campus, the virtual assistant will appear in user's view to remind users of related information [5]. Nazrita Ibrahim proposed a method by using mini maps and the billboards of the scenes to have users know the current position and how to get to the place they want to visit [6]. To increase the convenience of the navigation system, our system combines user's positioning mechanism and provides dynamic labels and mini maps to assist users to navigate scenes effectively.

This paper is organized as follows. Chapter 2 will introduce the construction and division method of virtual scenes, Chapter 3 is the explanation of positioning mechanism, the implementation and illustrations will be demonstrated in Chapter 4, Chapter 5 is the analysis of system experiments and results, and the last chapter is the conclusion and research directions in the future.

II. Construction and Division of Virtual Scenes

In this paper, we use 3DS MAX to establish all buildings, campus scenes and object models, and than use Quest3D to integrate all objects, building, and multimedia data into the virtual campus, which user could navigate the virtual campus freely. The completed virtual campus navigation scene is as shown in Fig. 1.

Fig. 1 Scene of virtual campus

After virtual campus scene is established, it will be divided for instant transmission and download. However, the purpose of division is not to divide the scene and design separately, but to divide it into areas for the mechanism of collision download only.

Common divisions are square division, hexagonal division, Voronoi Diagram Division, etc. We chose Voronoi Diagram Division because of square division and hexagonal division are all equal divisions, and will have a problem of cutting buildings if the division areas of virtual scenes are too small, and may have too many buildings/data in the same area if the division area is too big.

The Voronoi Diagram Division we used can effectively separate the buildings of the virtual scene and divide it into appropriate areas, because Voronoi Diagram Division treats major buildings (with more materials, surfaces, and mass of multimedia data) as various data points, and uses these data points to divide areas so that to avoid the cutting of building models.

The other advantage of Voronoi Diagram Division is that, in the same divided area, all points are closest to the building. Therefore, when users are doing navigation, they do not have to wait for the download of all files, but only to download the basic scene and they can navigate campus scene and download the data of the neighboring scenes at the same time so that to have a seamless navigation of virtual scenes.

Take the virtual navigation scenes of the Aletheia University for example, there is about 50 MB(2D texture, image and 3D building for the complete school scene, plus around 310MB of multimedia information, it is about 360MB totally. After division into different areas, the basic environment scene is about 30MB. The complete school scene can be divided into 10 blocks by Voronoi Diagram Division principle, with about 30~40MB multi-media information on average as shown in Fig. 2.

As shown in Fig. 2, Bi(i=1~10) represents 10 major buildings, Ai(i=1~10) represents the 10 divided areas, and Lij represents the lines between Ai and Aj , and x represents the coordinates of virtual scenes, then we could divide areas according to Voronoi Diagram as equation 1:

$$A_i=\{x:|B_i-x| \leqq |B_j-x|, \forall j\neq i\} \quad (1)$$

$$Min\{|L_{ij}-u|, \forall A_j \text{ closed to } A_i\} \quad (2)$$

We assume when users enter area A1, system will automatically detect the distance between users(noted by u) and L12 and L13, and decide the block it will pre-download according to the equation 2, which means it will download the information of the block closer to users (including indoor scenes, multimedia data such as images, audios, and video, etc.)

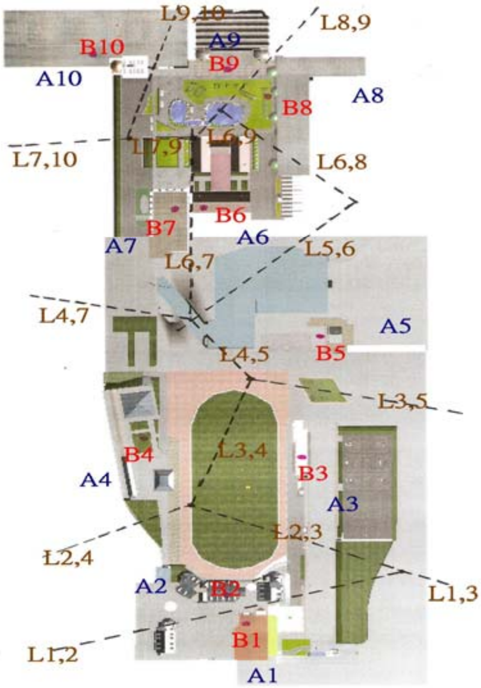

Fig. 2 Division diagram of virtual scene

III. The Positioning Mechanism

The virtual scenes of schools are not familiar to users who first use the navigation, and the whole virtual campus is so huge, therefore this system provides users the function of indoor and outdoor positioning. When users are outdoors, we use GPS to get the position of users, and when users enter into buildings, we use active RFID to get user position. By doing this, users can know their positions precisely while they are indoors or outdoors.

GPS is the abbreviation of Global Position System, and is more and more popular recently. When a user carries a GPS receiver with them, it can find out user's position using the triangle positioning principle of GPS. The signals received from GPS will immediately update the avatar location coordinated in the virtual scene corresponding to the user's actual position in the real scene. However, when users enter buildings, they can not receive the signals from GPS.

Therefore we use RFID to get indoor positioning.

The precision of RFID positioning system not only depends on the location of RFID and the quality of positioning mechanism, but even more on the selection of active and passive RFID which directly affect the design and effectiveness of the whole system. Even the indoor positioning of passive RFID tags still has space for future research to lower the positioning error, but current positioning researches mostly use RFID because passive RFID has a limit on its specification [7, 8, 9, 10, 11, 12, 13, 14].

Current active RFID positioning technology mostly adopts Signal Strength (SS), Time of Arrival (TOA), Time Difference of Arrival (TDOA) and Angle Of Arrival (AOA), etc. However, these methods usually ignore the difference of tag's signal strength. Therefore, the method proposed in this paper can set a reference of signal strength for each tag according to the environment and the individual difference of tag. When the threshold value test and setup of each tag is completed, we further use the intersection of sensor areas and refer to user's moving path to provide a RFID positioning mechanism which decreases tag numbers and increases the precision of positioning.

As shown in Fig. 3, take an environment of 6M*4M for example, we locate an active RFID tag every 2M, and give a different number to each tag (from up to down, left to right, the order is 1~12), and test the individual 2M signal threshold value of each tag, which is to set 2M as the sensor radius(R) of each tag. These intersections of sensor areas can be further divided the 6M*4M environment into dozens of independent sensor areas. Combining with user's moving path, it can be further divided into more precise sensor areas.

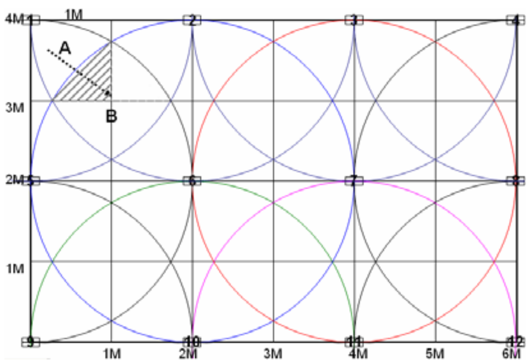

Fig. 3 schematic view of active RFID tag

For example, when a user walk to Area A, the system will sense the effective signals from tags number 1, 2 and 5, and will know that use has entered into Area A. When the user keeps walking to Area B, the system will sense the effective signals from tag 1, 2, 5 and 6 and position the user at Area B. Moreover, because the user entered Area B from Area A, the system can further position the user at the upper left area of Area B (the gray area in Fig. 3) so that to have a more precise positioning.

Fig. 4 Illustration of the RFID construction of Mackay Museum in Aletheia University

Take the actual situation of Mackay Museum Hall as an example (approximately 8M*6M), we place 20 RFID tags (as shown in Fig. 4) in appropriate locations (with 2M internal). Then we test on site and set up an appropriate signal strength threshold value for each tag as the basis of the sensor area of tags, and complete the division of RFID positioning areas based on the proposed method.

IV. System Implementation

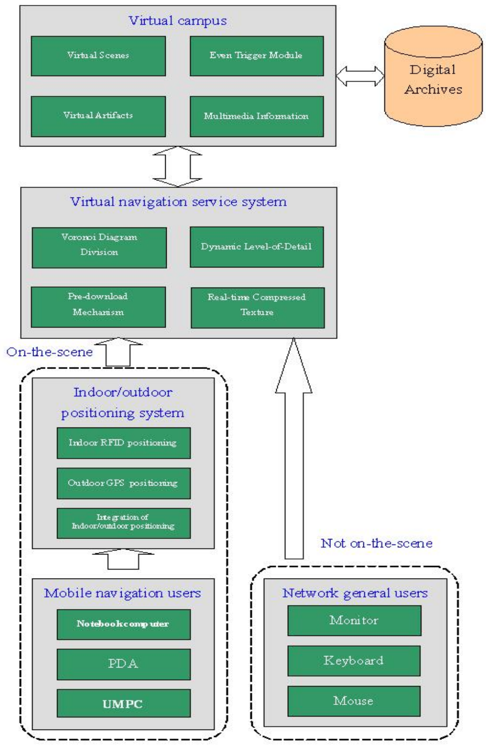

Fig. 5 System architecture

The proposed navigation system Architecture is shown as Fig. 5. The system firstly uses 3DS MAX and Quest 3D to complete the construction of virtual scenes, then classify and stores all virtual scenes and multimedia data into the digital database. Based on the mechanism of Voronoi Diagram division and collision for pre-download, users do not have wait for a long time when using navigation and can navigate the whole campus smoothly.

Moreover, this system even supports with the technology of Dynamic Level-of-Detail and Real-time Compressed Texture, that when users is far away from buildings or objects, the 3D model and 2D image will be presented simply to increase the efficiency and save the computer resource, while users are close to buildings, the 3D model and 2D image will be presented completely to show the detail of scenes and objects.

Fig. 6 is an illustration of virtual navigation by the propose system. When users carry mobile equipment such as notebook computers, and walk in real scenes, the system will continuously detect and record the moving path of users and automatically update user's location in the virtual scene. Right side at the bottom is the mini map of the whole scene. When users are walking outdoors, using GPS can precisely get the user's location as the red spot shown in the mini map.

Fig. 6 Illustration of virtual navigation (outdoors)

When users enter buildings, there is no satellite signal. Therefore, we use active RFID to develop the positioning function indoors. The location of users in the real scene can be immediately updated in the mini map (as shown on the upper left side of Fig. 7), too. Moreover, based on the positioning function, if users are close to the historical relics, system will actively trigger the related information and make visitors understand the related information deeply (as shown on the upper right side of Fig. 7).

Fig. 7 illustration of virtual navigation (indoors)

V. Experiments and Results

The equipment of this system includes SONY SZ36 notebook computer (CPU:1.83GHz, Video card: GeForce Go 7400, RAM:1.5G), GPS, RFID reader & tag. With the internet transmission speed of 2/10Mbps, the time to download the basic scene before navigation is about 80/16 seconds, the time to download other divided buildings and multimedia information is between 80~120/16~24 seconds (as shown in Table I).

TABLE I
NAVIGATION WAITING TIME

	Data Size	Download Time(2Mb/Sec)	Download Time(10Mb/Sec.)
Before division (whole scene+ multimedia data)	360M	1440sec.	288sec.
After division (basic scene)	30M	120sec.	24sec.
After division (each building + multimedia data)	30~40M	120~160 sec.	24~32 sec.

Therefore, if users walk at the campus with a normal walking speed, or stay in the same area over 120 seconds, then user will almost feel no delay at the area intersections of virtual scenes. If users walk faster even run and enter buildings immediately, then they also only need to wait few seconds to get the detailed indoor scenes and multimedia information.

There is another experiment on whether positioning function has any effect on users. There are totally 10 people (5 males and 5 females) in this experiment. All of them have never been to Aletheia University and the equipment each person uses is the same. There are two experiments according to whether they turn on the positioning function. For the first one, we provide a complete function (including positioning mini maps, pre-downloading mechanism, dynamic labels, etc. as shown in the Fig. 8); for the second time, we turn off the functions mentioned above and let users to navigate the campus on their own. Users in these two experiments had to pass tests to gather in front of a certain building or to look up for certain historical relic information in one of the buildings, etc.

The experimental result shows that when users enter the campus they are not familiar with and turn on the functions mentioned above, they can not only know their location precisely, but also can pre-download the related information of buildings during walking. And when they are indoors, the system can automatically provide related information of surrounding historical relics to users. Therefore, no matter the time to search for objects or the waiting time for download is

Fig. 8 Illustration of navigation with dynamic labels

improved by a lot amount. This experiment proved that the user positioning and pre-downloading mechanism we proposed has a significant effect on navigation.

VI. Conclusion and Future Work

We have successfully developed a virtual navigation system which integrated the indoor/outdoor positioning mechanism using GPS and active RGID, and have proposed the division function based on Voronoi Diagram and pre-download mechanism for virtual scenes and multimedia information. Users can not only know their location clearly but also shorten the waiting time to have a smooth navigation. Moreover, the proposed system can actively provides related information surround users for detailed navigation. The positioning function supporting virtual reality technology developed by the system is with practical value and not only can apply to campus, but also can be widely applied to museums or art galleries, etc. In the future, we plan to combine the function of user interaction to develop a more interesting virtual navigation system.

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