APPLICATION OF AUGMENTED REALITY GIS IN ARCHITECTURE

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ABSTRACT:

Paper discusses the function and meaning of ARGIS in architecture through an instance of an aerodrome construction project. In the initial stages of the construction, it applies the advanced technology including 3S (RS, GIS and GPS) techniques, augmented reality, virtual reality and digital image processing techniques, and so on. Virtual image or other information that is created by the computer is superimposed with the surveying district which the observer stands is looking at. When the observer is moving in the district, the virtual information is changing correspondingly, just like the virtual information really exists in true environment. The observer can see the scene of aerodrome if he puts on clairvoyant HMD. If we have structural information of construction in database, AR can supply X-ray of the building just like pipeline, wire and framework in walls.

1. INTRODUCTION

1.1 Definition

Augmented reality (AR) is an important branch of virtual reality, and it's a hot spot of study in recent years. AR is that organically, in real-time and dynamically overlaying virtual images created by computers and other information on real environment which the observer sees. And when the observer moves in real environment, virtual information changes according to the movement, just like those virtual information truly exists in real world. Azuma R.T. summed up AR with three properties: combines real and virtual objects in a real environment; runs interactively, and in real time; and registers (aligns) real and virtual objects with each other (Azuma, 1997). With the help of photoelectric display technique, interactive technique, Calculator sketch technique and visualization technique, AR created virtual objects not exist in real environment. And by sensor technique AR well overlaid virtual objects on real environment.

1.2 Characteristics

Augmented reality might apply to all senses, not just sight. So far, researchers have focused on blending real and virtual images and graphics. However, AR could be extended to include sound. The user would wear headphones equipped with microphones on the outside. The headphones would add synthetic, directional 3D sound, while the external microphones would detect incoming sounds from the environment. This would give the system a chance to mask or cover up selected real sounds from the environment by generating a masking signal that exactly canceled the incoming real sound (Durlach, Mavor, 1995). AR started at 1960s, Sutherland invented head mounted display (HMD) to display 3D images. AR is not a study realm until recent years. Milgram (Milgram, Kishino, 1994) defined a reality-virtual continuum.

Real environment (RE) and virtual environment (VE) are at two sides, mixed reality (MR) is in the middle, AR is near to the real environment side. Data created by the computer can augment real environment and enhance user's comprehension about environment. Augmented Virtuality (AV) is a term created by Milgram. It means add RE images to VE, such as add texture mapping video on virtual objects. This term can increase virtual object's reality degree, decrease virtual object and real object's differences. But VE is entire virtual. In AR real object and virtual object and user environment must be seamlessly integrated together.

The most important in the feature of interactive of AR system is displaying relative information and permitting user to move discretionarily in information spaces. To portray at the same time the whole physical space in which the user walks in AR is a very speciality of GIS. The association of AR and GIS produces a characteristic, turning traditional inside static man-machine interactive mode to outdoor dynamic mode. It syncretizes the traditional GIS virtual world with the external true one to construct a imaginary-real man-made world. The earliest research on virtual reality GIS is Georgia industrial school description system (Faust, 1995).

Fig.1 Milgram's reality-virtuality continuum

Not as virtual reality system, AR technique is still at laboratory stage. At present, exploited successfully registration technique must be in controlled environment so it can capture accurate tracking result. People have gotten much progress with registration of indoor AR system, but not mature outdoor AR

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tracking project and application system. Constructing a set of applied AR system needs much preparation about survey and calibration, which restricts generalization and application of AR.

2. RELATED WORK

There has been much research in the field of AR in the past years. AR technique not only has similar application field with VR, but it is also excellent in RE augmented effect. In medical, anatomize training, exactitude instrument produce, assembly and maintain, drill, engineering design and long-distance robot etc so many fields, AR has more superiority than VR. In this paper, we mostly discuss follow aspects. Construction touring, analysis and rebuilding can be applied to aerodrome construction, inspection and renovation.

2.1 Construction Touring

The first set of known AR system is Campus touring machine by Feiner of Columbia University (Feiner, 1997). This sketch (fig.2) illustrates how a MARS (mobile augmented reality system) unit could be used. Using that system, user can see certain constructions' related information in campus (department or construction's name), or certain construction in the past. The system adopts passive sensor (including compass and incline sensor) and difference GPS, but when user moves faster, system error is bigger. At present, the researchers work on overlaying some information, such as past constructions in campus, paths to certain destination, events happened in observer locus and so on, on real scene.
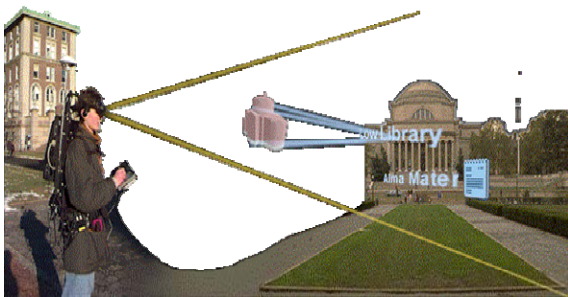

Fig.2 Prototype of Campus Touring Machine

2.2 Construction Analysis

In Rockwell Science Center, a research group registers by checking ground level contour and compare it with local geographic model. Azuma research group develop a system, including compass and three rate gyro incline sensor, use a tracking method of video based inertia mixed with optical, with a condition of already known land mark can minimize error to a few pixels (Azuma, 1999). But this system can not do real time tracking at the moment.

An outdoor AR system exploited by University of South Australia can let user see some objects exist in virtual military emluator. The system consists of notebook PC, TCM2-80 compass, Garmin GPS12XL with difference and so on. North Carolina University has done some research about tracking. They use magnetic sensor and vision tracking to develop a set of AR system (State, Gentaro, David, 1996), and got some satisfying tracking accuracy. US NRL Navy study laboratory is

developing BARS (battlefield AR system), aimed at in urban battlefield environment supplying a flat roof for commanders and soldiers to transmit 3-dimentional tactics information. The research included designing new types of user interface and new interactive method, exploiting interactive distributed 3-dimentional environment, accuracy tracking and registration system (Julier, 2000).

Fig.3 BARS shows the interior construction of a building by this system

2.3 Construction Rebuilding

Another application of AR system is letting users see characters and events in the past or in the future. When tourists visit cultural heritage, they can not see their past scene. For a modernistic tourist it is difficult to imagine past refulgence of a place. So at some historic sites there are always some actors wearing old-time habiliments performing past scene. But tourists with outdoor AR system can see redivious history created by the computer. HMD can shelter modern constructions or cenotaphs in the back, display culture heritage information at then.
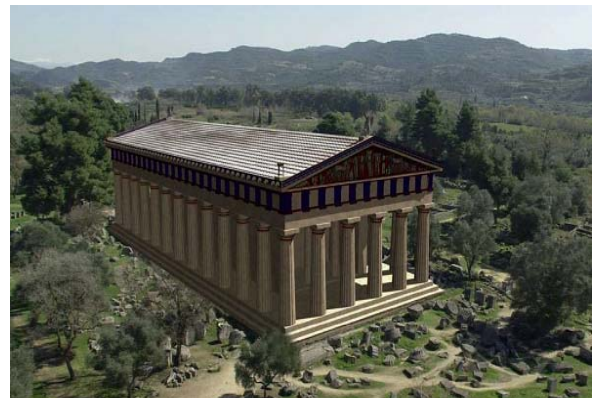

Fig.4. It is an AR scene in Archeoguide project. This project is run by many Greece research institutes and governments. The study group is working on supplying wearable AR system to visitors to rebuilding Grecian Olympia heritage information (Stricker, Daehne, Seibert, 2001). Visitors can see Grecian Olympia fane information in 2000 year before, they can better comprehend those significant events happened in these heritages.

3. CORE TECHNIQUES

In technologic investigation aspects, the most challenging problem in AR is tracking and locating of user's location and observational spot in the moving process of Outdoor AR System. Nevertheless, obvious objects based method does not adapt to outdoor natural environment, present research mainstream is inclined to picture-chasing. Considering AR and GIS technology, this paper is fixed on follow technologies.

3.1 Outdoor 3D Registration Technology

It uses close-range measurement, builds up observation point based stereo pair, and gets observation real-time location by GPS to track user's location and space transformation of his viewpoint to finish 3D registration. Including single pair fast auto-matching and comparative positioning close-range phototopography, high precision GPS data capture and auto-processing, consecutive pair speedy auto absolute positioning referencing GPS location tracking value, auto arrangement of observation point moving path.

In recent years researchers all around the world use registration method based on video image processing and computer optical which is of strong versatility, simple equipment and low cost. The usual method is fixing one to two CCD camera to HMD. The scene in RE is taken by the camera and input into computer with digital image form. They use image analysis processing method to get tracking information, so to determine the location and direction of the camera (user's head) in environment coordinate. If the system directly analysis and identifying environment image, the operation quantity is very huge and it will bring much infection to the real time of the system. So as to reduce operation quantity we often add some characteristic sceneries or given symbols. Computers identify those given symbols and characteristic sceneries to realize fixed tracking for the camera. In computer optical based 3D registration methods, selecting characteristic sceneries and symbols and their placing mode are of importance, which will directly inflect registration accuracy and valid range. It has been one of the international hot spots of research. In our prototype of Aerodrome Building, we set up a project using several colorful plane symbols and one colorful CCD camera. This system's framework is simple. In the ordinary course of events it only needs four plane symbols to realize 3D registration. The image processing operation quantity is small, and it is easy to get the symbols' corresponding image location but not needs calculating image pair. The numerical solution procedure is liner, the difference is very small, the operating range is wide and it's real time, so it can supply real-time registration arithmetic base for general image workstation and AR system on computer.

The principle of the colorful plane symbols registration method is camera projection model. We put several colorful symbols with known world coordinates into RE, fix an accurately calibrated colorful CCD camera to the HMD. When user wearing a HMD stands in some spatial location, the camera there shoots the spatial symbol at a certain angle and distance. After inputting the video signal output from the camera to the computer, it picks up the center coordinate (screen coordinate) of the symbols from the image. AS the images are taken at different angle and distance, each colorful symbol's screen coordinate distributes differently. According to the deducing arithmetic we can get the camera's spatial coordinate location and direction relative to the symbols. When the user is moving or changing his view point, according to the change of the

inputted image, the computer can real-time ensure the HMD location and direction, so to do fixed tracking with the user.

3.2 3D Display Technology

AR stereo display needs 4 coordinate systems(fig.5), real spatial coordinate system xyz ; virtual object coordinate system $\xi\eta\varsigma$, it is used to do geometry portray to the adding virtual object; observer coordinate system $x'y'z'$, it's $o'z'$ axis is coincident with observer's line of sight; projective image coordinate system (screen coordinate system) uv , it is a 2 dimensional coordinate and straight to the projection plane of axis $o'z'$ which is also the plane the observer see. The aspect of virtual objects which need to be added in real spatial coordinate system is determined by the function that needs to be finished in system. That is the relation of virtual object coordinate system $\xi\eta\varsigma$ and real spatial coordinate system xyz is known so, 3D virtual objects geometric depiction ($\xi\eta\varsigma$) in virtual object coordinate system $\xi\eta\varsigma$ can be transformed to absolute spatial coordinate system xyz geometric depiction (xyz). After registration calculation, AR system user's head location (tx, ty, tz) and azimuth (θ, ϕ, ψ) are confirmed in real space. Then the transformative matrix B between observer coordinate system $x'y'z'$ and real spatial coordinate system xyz can be counted. So we can change 3D virtual object geometric depiction ($\xi\eta\varsigma$) in virtual object coordinate to ($x'y'z'$) in observer coordinate system, and then project virtual objects in observer coordinate system on planar coordinate system to get virtual objects depiction in AR system.
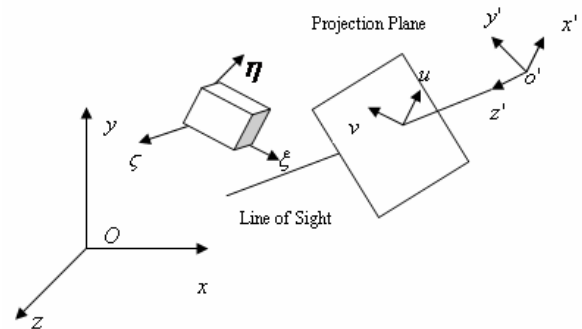

Fig.5 Registration Arithmetic of Virtual Objects Projection
People's visual system consists of left and right two relatively independent optical channels. The two eyes' fields of view are overlapped but the scenes they see are different, that is parallax. This overlapped fields of view forming human depth perception is called double eyes stereoscopy. In augmented reality system, we need to use this characteristic to supply separately different image corresponding to its light of sight to left and right eyes to realize virtual object's stereo display and augment its reality.

4. SYSTEM OVERVIEW

Nowadays country economy is increasing with a high speed, and air transportation becomes the most imminently needed vehicle. So aerodrome building has become an important indicator of measuring a region's economic development. In pre-construction of the aerodrome such as site selection, geological environment and entironment estimation, adopting which technique is very important, this will directly reflect the project evolvement and expenditure. In the aerodrome building, construction's patrol and maintenance can be done by AR system. Bringing AR technique into aerodrome building will most enrich the theories, techniques and methods of aerodrome building, supply earth surface image data comparing with traditional techniques. It opens up people's observation view and thinking space, supplies scientific foundation to the project's decision-makers and operators.

4.1 Prototype of outdoor ARGIS

We use AR basic function library of ARToolKit to build a prototype system. This system can make image 3D registration and displaying function. The figure below is simulating outdoor registration effect.

Fig.6 Desktop Image Registration

Mobile client creates output information based on data sent by server. The experiment is augmenting a 3D tetrahedron billboard onto roof of a building. The length of side is 3.5m, the building lies in Wuhan University. The virtual billboard centre coordinate is N30°31.753´ E114°21.098´, altitude is defined 8.3m. In actual 3D image registration, virtual object will be deflective as a fact of hardware precision.

Fig.7 Outdoor Registration of a virtual Object

4.2 Aerodrome building AR system

Our AR system prototype basic framework is fig.6. It is composed of following parts: capturing virtual scene, capturing virtual objects registration information, virtual objects database, 3D image switching and romancing, virtual and real image fusion, display equipment and so on. First of all, the system need to capture real environment image, then capture virtual object's registration information, that is add virtual objects accurately to real scene to get needed location and attitude data. Secondly the computer uses the registration information to switch coordinates of virtual objects and romance. Then overlay them to real scene to realize fusion of virtual and real. Last, show the fusion augmented image information to the user by the display equipment.
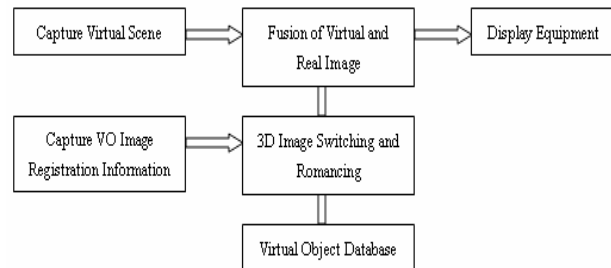

Fig.8 Basic Framework of AR system

The implementation course integrates technologies in former frame including following steps: ①real time acquirement of the feature point of image serial key frame ②real time optimized matching of the feature point of adjacent key frame image ③ real time calculation of outer camera parameters and self rectification inner parameters ④viewpoint aspect and attitude data calculation as well as calculation of true geographic coordinates conformation and matching.

For outdoor system with setting calibration, the calculation and matching of feature point are relatively easy, so at present, applied system use the method of manual setting reference symbol. For outdoor system without setting calibration, getting feature points and matching are one of core problems. Real environment is complex and multiform, generally speaking, feature points picked up from the image data per frame vary very much. So steady-going and nice matching outcomes need

mass calculation, but it also infects the system's real time function. At present research about this is still a global difficult problem.

The technique of using projection geometry method to reconstruct 3D objects from image serials has got much improvement and can well reconstruct some simple exterior entity. The technique of real-time capturing the observer point's spatial location based on image serials has been primarily settled. The problem is that research on 3D objects reconstruction is mainly about object's spatial shape complicity and accuracy but ignores real-time capturing observer point's location. In existed image serials based reconstruction of 3D objects techniques, extracting the symbols is totally based on image characteristics. A few symbols of high dependability must be extracted by complex matching and iterative computation. So at the moment with the existed techniques, we can not realize hand-free reference symbols outdoor real-time 3D registration.

The authors have done some pilot research about this. We selected a construction of characteristic shape as study object. As its surface and shape can be fast and exactly extracted from the video flow, we can calculate the observer point's spatial location by the variety of the characteristic in the video flow.
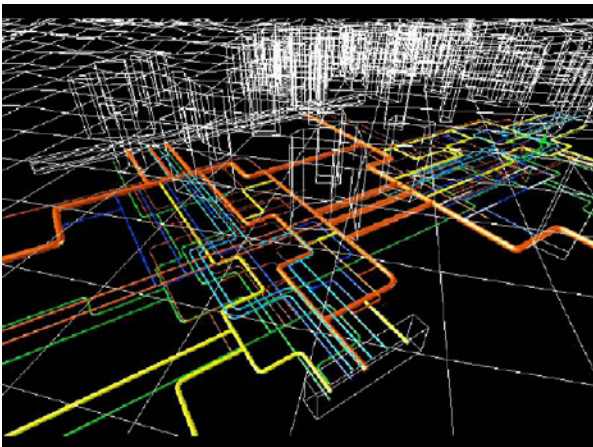

Fig.9 Constructions in AR x-ray system

Fig.10 3D aerodrome in AR system

4.3 Related AR systems

Recent advances in computer interface design, and the ever increasing power and miniaturization of computer hardware, have combined to make the use of augmented reality possible in demonstration testbeds for building construction, maintenance and renovation. In the spirit of the first see-through head-mounted display developed by Sutherland (Sutherland, 1968), we and other researchers (Robinett, 1992) (Caudell, Mizell, 1992) (Bajura, Neumann, 1995) use the term augmented reality to refer to enrichment of the real world with a complementary virtual world. The augmented reality systems we are developing employ a see-through head-worn display that overlays graphics and sound on a person's naturally occurring sight and hearing. By tracking users and objects in space, these systems provide users with visual information that is tied to the physical environment. Unlike most virtual realities, whose virtual worlds replace the real world, augmented reality systems enhance the real world by superposing information onto it. The spatial tracking capabilities of our augmented reality systems distinguish them from the heads-up displays featured in some wearable computer systems (Quinn, 1993) (Smailagic, Siewiorek, 1994).

As part of a program aimed at developing a variety of high-performance user interfaces, we have developed a testbed augmented reality system that addresses space frame construction (Webster, 1996). Space frames are typically made from a large number of components of similar size and shape (typically cylindrical struts and spherical nodes). Although the exterior dimensions of all the members may be identical, the forces they carry, and therefore their inner diameters, vary with their position in the structure. Consequently it is relatively easy to assemble pieces in the wrong position-which if undetected could lead to structural failure. Our augmented reality construction system is designed to guide workers through the assembly of a space frame structure, to ensure that each member is properly placed and fastened.

5. CONCLUSIONS AND FUTURE WORK

From the former analysis we can see that outdoor AR system design and execution is a difficult problem but also a challenge. If we did not make abundant preparation work can get accurate tracking outdoor or in uncontrollable environment, we can reduce operation complexity in AR system and extend the application of AR system. Our ultimate goal is that under any conditions and environments we can get accurate and reliable tracking and registration. As the equipment is limited, the environment is hard to change and the operation range is so wide, to construct a set of applied outdoor AR system is difficult. Researches about this have been explored and the results can be used to reduce the burden in debugging the system and object's structure. New-style outdoor tracking technology can upgrade AR system overall performance and can alter laboratory equipment based AR system to portable system. It will supply wearable computer with a man-machine interactive means.

As outdoor AR system must supply user with real-time object information of his location and surrounding, GIS is the base of AR system. Considering that real world is a 3-dimensional space at least and the territory of user is usually large scale environment so as to need a large amount of 3D information, GIS as the base of AR system should be 3D GIS. Man-machine

interface is very important for any information system. GIS is a digital portrayal of external geographic world. Although 3D GIS presents us a visual 3D virtual world, the real interactivity is only limited to plane display cannot let observer in a virtual environment. Outdoor AR technology offered a good way to solve the problem.

We believe that the work described in this paper demonstrates the potential of augmented reality's x-ray vision and instructional guidance capabilities for improving architectural construction, inspection, and renovation. Future augmented reality x-ray vision systems may enable maintenance workers to avoid hidden features such as buried infrastructure, electrical wiring, and structural elements as they make changes to buildings and outdoor environments. This promises to both speed up maintenance and renovation operations, and to reduce the amount of accidental damage that they currently cause. Future versions of augmented reality instructional systems may guide construction workers through the assembly of actual buildings and help to improve the quality of their work. Inspectors with augmented reality interfaces may be similarly guided through their jobs-allowing them to work without reference to conventional printed construction drawings and ensuring that every item which needs to be checked is in fact inspected. The potential impact of augmented reality on architecture and structural engineering will increase as the technology is tied to other emerging technologies. For example, the addition of knowledge-based expert systems (Feiner, Mckeown, 1991) (Myers, Snyder, Chirca, 1992) to the core augmented reality technology described here could yield systems capable of training workers at actual construction sites while they work to assemble a real building. Such systems could guide inexperienced users through complex construction operations. The continued evolution and integration of these and other technologies will yield systems that improve both the efficiency and the quality of building construction, maintenance and renovation.

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