Outdoor Virtual Reality

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ABSTRACT

This paper presents our novel concept Outdoor Virtual Reality. By using outdoor augmented reality techniques we propose to build very wide area virtual reality systems, outdoor virtual reality. The concept of outdoor virtual reality is compared and contrasted to traditional definitions of augmented reality and virtual reality. We present our flexible Tinmith-evo5 software architecture as a platform to build outdoor virtual reality applications. We have constructed two outdoor virtual reality applications, a 3D visualisation tool and an outdoor game.

1 INTRODUCTION

We purpose the use of outdoor augmented reality techniques to build very wide area virtual reality systems, which we refer to as *Outdoor Virtual Reality*. A major limiting factor to current virtual reality systems is the inability to allow users to walk unimpeded over large distances (greater than 50 metres). The act of walking is a powerful cueing mechanism for humans [2]. We overcome this limiting factor by using accurate GPS tracking equipment for positioning information of the user. Head orientation is determined by 3DOF hybrid orientation sensor attached to the user's head mounted display (HMD). The position of the user's hands is determined in 3DOF relative to the user's head by a vision based tracking system.

We made a key observation while operating outdoor augmented reality applications that are not registered to the physical world: that the visual information from the physical world becomes irrelevant and merely a backdrop. The applications we are operating are very similar to a virtual reality 3D information visualisation system. In a number of cases the 3D visualisation information (say a 3D connected graph) is floating in space and the user moves around the information to gain a perspective from different viewpoints. The 3D information is placed in a virtual room or setting to provide the user with a fixed world reference to help them navigate around the 3D information. This virtual room or setting is irrelevant to the particulars of the 3D information and acts merely as backdrop. We found the outdoor setting of unregistered augmented reality information to act in the same way. In the outdoor setting, the user is able to freely walking around the information space.

Outdoor virtual reality systems provide extremely large virtual environments for the user to interact with. Imagine a user walking around a 3D information visualisation the size of a football field, with a flat fenced-in area to make it safe to operate. Any large area would work for the user; therefore the system could operate anywhere that is large and smooth enough and can receive GPS signals. This form of virtual reality does not support the tracking accuracy for applications such as medical applications [15], but it is appropriate for applications domains such as military training[3], information visualisation, and gaming [4, 13].

The remainder of this paper describes our concept of outdoor virtual reality in detail. The next section describes the concepts of augmented reality and virtual reality. This enables us to provide a more complete definition of outdoor virtual reality. Following is an overview of the platform we use for our current outdoor augmented reality and outdoor virtual reality applications. Next we describe two outdoor virtual reality applications. Finally some concluding remarks are provided.

2 AUGMENTED REALITY VERSES VIRTUAL REALITY

Augmented reality (AR) is the registration of projected computer generated images over a user's view of the physical world. With this extra information presented to the user, the physical world can be enhanced or augmented beyond the user's normal experience, and increase understanding by presenting the information spatially relative to the user. Virtual Reality (VR) operates with opaque display technology to immerse the user into a fully synthetic environment. One of the first integrated environments was by Fisher et al [7], combining tracking of the head for VR with the use of tracked pinch gloves as an input device.

Augmented reality and virtual reality share common features in that they present computer generated images for a user to experience, with information anchored to 3D locations relative to the user's display, their body, or the world [5]. Augmented reality also allows the user to see the physical world however, and so this is a fourth kind of information that the user can experience, although it is not artificially generated. A typical example of a head mounted display is shown in Figure 1, and an example augmented reality scene showing both physical and virtual worlds is shown in Figure 2. The schematic diagram in **Figure 3** depicts how an AR display system can be conceptualised, and Figure 4 depicts the conceptualisation of a VR display system.

The difference between AR and VR is that visual information from the physical world is not included in the VR display system. This combination in AR systems has two distinct parts, overlaying of the graphics on the physical world and registration of those graphics to the physical world. Azuma defines augmented reality as systems that contain the following three characteristics: combines real and virtual, interactive in real time, registered in 3D [1]. To quote Milgram and Kishino, "*… the term Augmented Reality is quite appropriate for describing the essence of computer graphic enhancement of video images of real scenes*". The vital element of AR missing from outdoor virtual reality is the registration of the virtual information to enhance the physical world. Outdoor virtual reality is a virtual reality system where the user interacts in a synthetic world overlayed but not registered to the physical world.

Interestingly outdoor virtual reality does not cleanly fit into the Milgram and Kishino's concept of a virtual reality continuum [8, 10], and can be used to perform comparisons between various forms of virtual reality by placing them onto a spectrum. At one end of the spectrum is the physical world humans experience normally, and at the other end are fully immersive virtual environments in which the stimulus is completely computer generated and artificial. AR's position on the continuum is where artificial objects (such as avatars or buildings) are added to enhance the physical world. A different position between real and virtual environments is augmented virtuality, where physical world objects (such as a scanned version of the user's body) are added into a fully immersive virtual world. As the user moves from real to virtual along the spectrum, the percentages of each vary to form a mixture, with the ends of the spectrum being completely pure. Every type of 3D environment supposedly may be placed somewhere along this spectrum to describe how it relates to other systems. Milgram and Kishino defined Extent of World Knowledge dimension for the virtual reality continuum to address the issue, "How much do we know about the world (physical and virtual) being displayed?" Outdoor virtual reality has no knowledge of the physical world but is not fully immersive; therefore outdoor virtual reality does not fit along the virtual reality continuum as it currently stands. The continuum needs to be extended to include the concept of outdoor virtual reality.

3 TINMITH AS AN OUTDOOR VIRTUAL REALITY PLATFORM

A pioneering piece of work in mobile augmented reality was the Touring Machine [6], the first example of a mobile outdoor AR system. Using technology that was small enough to be carried, a whole new area of mobile augmented reality research (both indoor and outdoor) was created. To overlay 3D models over the user's view, a mobile AR system requires a head mounted display to be combined with a device that can measure the position and orientation of the user's head. As the user moves through the physical world the display is updated by the computer in real time. The accuracy of the virtual object registered to the physical world influences the realistic fusion of the virtual objects amongst the physical world.

To implement our outdoor virtual reality applications, we use our flexible Tinmith-evo5 software architecture [12], which is a complete toolkit for the development of high performance 3D virtual environment applications. A custom backpack computer was designed to support our research, enabling a single user to carry all the necessary equipment, see Figure 6. Our current backpack is known as Tinmith-Endeavour, and is shown in Figure 1. It is based around a Pentium-III 1.2 GHz laptop with Nvidia GeForce2 graphics acceleration, mounted onto a special polycarbonate backplane. An InterSense IS-300 hybrid magnetic and gyroscopic tracker is used for orientation sensing, and a Trimble Ag132 GPS with an accuracy of 50 cm is used for position sensing. The helmet is based on a Sony Glasstron head mounted display with a FireFly 1394 camera for live video input. The backpack weighs approximately 16 kg and operates for 2 hours with a 12V battery rated at 85 Wh. We implemented Tinmith-Endeavour with as many off-the-shelf components as possible, and no effort has been made to miniaturise or lighten the design with custom built components.

Vision tracking of the gloves worn by the user was employed because the system currently already uses a camera to perform live video overlay and texture map capture for augmented reality. The ARToolKit libraries are used to obtain six degree of freedom tracking using small paper fiducial markers attached to the thumbs, see Figure 5. We use the thumbs for tracking because it is easier to hold the cursor still while pressing it against a finger, compared to finger based markers that would move during presses. Metallic pads on the gloves are used to detect finger presses and control the menu system.

4 EXAMPLE OUTDOOR VIRTUAL REALITY APPLICATIONS

We have experimented with two outdoor virtual reality applications. The first application is a 3D visualisation tool to better understand the layout of architectural designs. The second application is an outdoor game.

4.1 3D Information Visualisation

Many common technologies that are normally used for indoor virtual environments are not appropriate for outdoor virtual reality. This also affects the user interfaces that can be used, as many usually require accurate tracking or desktop input devices. We have designed a hands free user interface based on pinch gloves that combines command entry and 3D manipulation. The fingers on each hand are mapped to the commands presented on the blue menu strips to the left and right of the display. By pinching the finger against the thumb the appropriate option is selected from a hierarchical menu structure. The menu is used to represent all the commands available to the user, and many commands do not require any other inputs. We have developed an application for the user to place down prefabricated virtual objects anchored to a reference point of the user's choosing. As the user moves around, these objects appear in the user's view relative to the reference point. These objects can also be selected and manipulated (translated, scaled, rotated, grouped, carved, coloured, textured, or labelled) using the cursors on the user's thumbs. These virtual graphical objects may be viewed and manipulated at a different physical location by specifying a new reference points appropriate to the new physical location. Future work is to extend this visualisation to traditional 3D information visualisation system such as InVision [11].

As an example, a user walks outside to an empty piece of land, and creates a building that they would like to preview and perhaps construct in the future. The user rapidly constructs a model to what they would like [14], and then visualises it to see the final result, as depicted in Figure 2. The first step is to create the perimeter of the building shape by walking around the building site and placing down markers at the desired locations forming an outline. Next, the outline is extruded upwards so that it can be carved. The user then carves the contour of the building that includes a large hole through the centre of the building. After the overall roof structure is created, the object is lifted into the air using hand gestures. At this point, the trees, tables, and avatar people are created using street furniture placement of prefabricated models, and the supporting columns for the building are created. The building is then lowered onto the supporting columns with visual inspection. At this point, the user performs further carving. The user can now walk around the object to preview it from different angles, seeing how big it is, how it feels to walk around it, and determine if this the desired design.

4.2 Outdoor Gaming

Quake is a first-person shoot ' em up game, with the user interface based around a single, first person perspective screen. We built an outdoor AR version of the Quake, ARQuake, is to bring the intuitive nature of VR/AR interfaces into an outdoor game[16]. ARQuake is a first-person perspective application with the following attributes: 1) The application is situated in the physical world. 2) The point of view, which the application shows to the user, is completely determined by the position and orientation of the user' s head. 3) Relevant information is displayed as augmented reality via a head-mounted see-through display. 4) The user is mobile and able to walk through the information space. 5) The user interface additionally requires only a simple hand-held button device. The game may be played in one of two modes, outdoor augmented reality or outdoor virtual reality.

In the original Quake, certain actions are performed by the user being in a close proximity to a location in a Quake level. We have retained most of those actions. Virtual Quake doors open when the user attempts to walk through them. Users pick up objects as in the original Quake by walking over them. Standing in or moving through predetermined locations triggers traps. Actions that are not easily reflected in the physical world are removed from the game, such as secret and locked doors. The tracking of the user' s position and orientation of the user' s head handles the majority of the interaction. The only other interactions for the user to perform are to shoot or change the current weapon. We employ a two-button (thumb button and index finger button) toy gun as a physical input device for these actions. The thumb button is used to change weapons, and the index finger button fires the current weapon. The direction the weapon fires is the centre of the current view of the HMD.

In the outdoor augmented reality mode, the physical world is modelled as a Quake 3D graphical model. The AR information (monsters, weapons, objects of interest) is displayed in spatial context with the physical world. The Quake model of the physical world (walls, ceiling, floors) is not shown to the user: the see-through display allows the user to see the actual wall, ceilings and floors which ARQuake need only model internally. Coincidence of the actual and virtual structures is key to the outdoor augmented reality version of the game; the AR application models the existing physical outdoor structures, and so omission of their rendered image from the display becomes in effect one of our rendering techniques.

In the outdoor virtual reality mode, the physical world is not modelled, see Figure 7. The game may be played on any open flat piece of ground. The game designer uses the same Quake graphical modelling tools to build the game levels. Once the system is up and running, the user moves through the level by physically walking and changes view by looking around. The user views the game and the physical world through the HMD. The bottom portion of the screen is a status bar containing information about armour, health, ammunition and weapon type. The majority of the screen is reserved for the AR images of monsters and game objects. Because the user's movemen t is limited to physical walking speeds, monsters are designed to be relatively easy to destroy and do not inflict extreme damage on the user with their first attack. The monsters' skin colour and texture are changed to make them easier to see and distinguish from the physical world.

We have implemented Quake worlds that have visual effects that into three major categories: Outdoor Virtual Reality, Augmented Virtuality [9], Augmented Reality. The Outdoor Virtual Reality mode of operation is presented as Quake levels being modelled without reference to the physical world. The user is able to move around the physical world, but would not use any cues of the physical world for navigation. The may be played in any large flat outdoor area. We have demonstrated this form of the game in many locations around the world. The Augmented Reality mode only renders the game's pieces and monsters as described before, but has knowledge of the physical world for effects such as occlusion of monsters behind physical walls. The Augmented Virtuality mode places large walls and surfaces in the game, but the physical world is also viewed alongside these. An example of this Augmented Virtuality a gun turret placed on top of a physical building.

5 Conclusion

In this paper we define our original concept Outdoor Virtual Reality. The definition of outdoor virtual reality is placed in context of Milgram and Kishino's concept of a virtual reality continuum. We have show by using existing outdoor augmented reality techniques a very wide area virtual reality system can be built. We presented the Tinmith-evo5 software architecture as a platform to build outdoor virtual reality applications. We have constructed two outdoor virtual reality applications. The first application is a 3D visualisation tool to better understand the layout of architectural designs. The second application is an outdoor game, as version of ARQuake.

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Figure 1. Tinmith augmented reality platform with ARQuake extension

Figure 2. Example of augmented reality with computer generated furniture

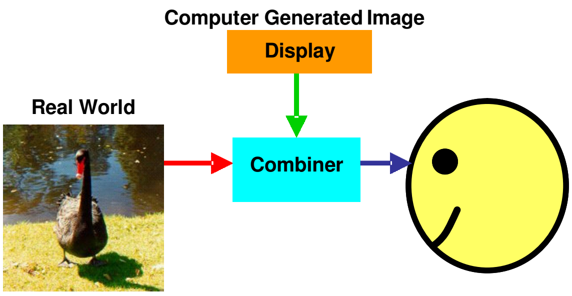

Figure 3. Schematic for AR displays

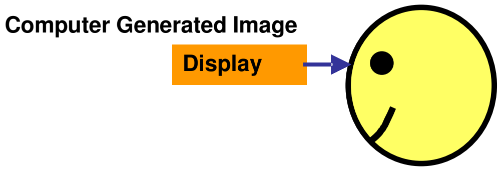

Figure 4. Schematic for VR displays

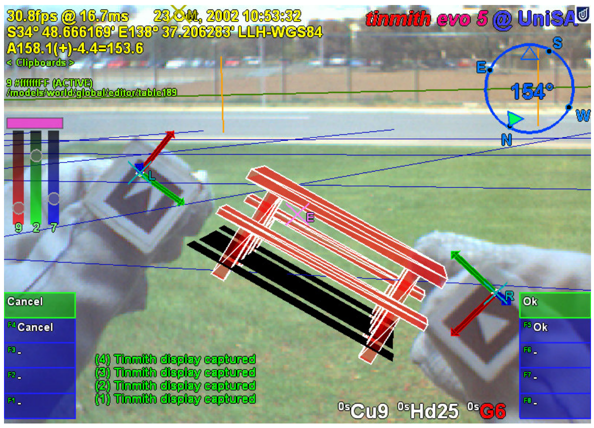

Figure 5. ARToolkit markers on the user' s thumbs

Figure 6. Tinmith- Endeavour backpack system

Figure 7. Outdoor virtual reality Quake

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