Unifying Augmented Reality and Virtual Reality User Interfaces

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Abstract

This paper presents a unified user interface technology, using 3D interaction techniques, constructive solid geometry, and a glove based menuing system, known as Tinmith-Hand, to support mobile outdoor augmented reality applications and indoor virtual reality applications. Tinmith-Hand uses similar concepts for both domains so that AR and VR applications are consistent to use. The future goal of this user interface is to allow collaboration between outdoor AR and indoor VR systems.

We use current AR and VR technology as a foundation for the user interface, and explain several new techniques that we have devised that allow us to develop applications that allow users to construct complex 3D models of objects in both indoor and outdoor settings. We demonstrate our user interface with the capture of a large house at a distance outdoors, and the creation of a simple building with street furniture at arms reach indoors.

1 Introduction

We have been investigating immersive 3D outdoor Augmented Reality (AR) architectures and applications. One area we have investigated is the collaboration between a user outdoors operating an AR application, while a second user is indoors in a Virtual Reality (VR) setting [13]. We believe a unified user interface technology between outdoor AR and indoor VR applications is desirable to facilitate the interoperability between the systems.

Previously, we have demonstrated a mobile user of an AR system interacting with outdoor 3D entities, while another user interacts with the same entities on a VR workstation situated indoors [13]. Both computer systems are in radio contact with each other to share information. The mobile system transmits its position and orientation so that the VR system can draw an avatar at the appropriate location on artificial terrain maps. Both the AR and VR users may insert objects into the virtual world; these objects would appear overlaid on the AR user's outdoor view. Using the pitch, roll, and yaw of the outdoor user's head, the presentation to the indoor user of the virtual world can be slaved to the outdoor user's direction of view. In other words, we can provide a virtual camera without transmitting the raw video data. This original system required two different sets of applications and user interfaces, one for indoors and one for outdoors. It also only transmitted entity tracker information, not the actual models themselves, and only rendered points and labels for the AR user to simplify the display.

The goal of this investigation is to support collaboration between users in an indoor VR setting, and mobile users outdoors viewing the same information with an AR interface. Imagine someone is sent to a remote location to survey the physical terrain and building features; simultaneously experts are viewing the data feed and directing the remote person's actions. The remote person is recording the surveyed information via a mobile AR computing system. The indoor experts view the model as it is being built, and therefore the experts can direct the remote users to regions of most interest by annotating the remote user's view of the world.

In this paper we present one possible user interface for the two users, Tinmith-Hand, which uses pinch gloves and thumb tracking to control a menu and a 3D modelling system. The annotation and communication aspects of the above scenario are currently being investigated. The modelling and recording aspect has been demonstrated as two applications using the Tinmith-Hand technology, Tinmith-Metro (an outdoor AR application) [15] and Tinmith-VR (an indoor VR application). Tinmith-Metro allows users to capture the designs of outdoor buildings and structures using special techniques that can be operated from a distance. Tinmith-VR is designed to model structures in the same fashion as Tinmith-Metro, but also allows for direct manipulation operations that are within arms reach. Both modellers are based around new techniques we have developed which rely on the intuitive nature of constructive solid geometry (CSG) operations. The contribution of this work is the single user interface technology to support interactive CSG modelling, as well as the way CSG is applied to capture outdoor 3D structures with AR, and create new models indoors with VR. Our work draws heavily on known good solutions to AR and VR interaction problems, and it is through the combination of these solutions that our technology has been developed.

The remainder of this section will discuss the aim of the user interface, as well as a summary of the concepts implemented. To place our work in context with that of other researchers, we provide an overview of related work that forms a foundation of our ideas. A description of our CSG technique is given, showing how buildings can be constructed from primitive objects. We describe an example showing from a user's perspective how Tinmith-Metro is used to model a building in the outdoor augmented reality mode; and a second example creating an artificial scene using the indoor Tinmith-VR application. Our novel menuing system with pinch gloves is discussed, followed by the use of thumb tracking, with image plane and 3D direct techniques for selection and manipulation of models. The overall implementation of the system is also described, listing the hardware and software components used. We conclude this paper discussing some of the problems solved, the knowledge gained from this investigation, and future research.

1.1 Aims of the user interface

Our main interactions with Tinmith-Hand are through head and hand gestures (although voice recognition is another viable option), and so we wish to keep the hands free from holding input devices if possible, allowing more natural styles of interaction. The primary user interaction for graphical object manipulation will be through the 3D tracking of the user's head and two electronic pinch gloves. The gloves operating in a pinch mode will control the menu system. The goal of the menu system is to allow the user to easily access the functionality of the application, in a logical manner, while not obscuring the user's vision or preventing other tasks. When the entire system is combined together, Tinmith-Hand is a complete user interface solution that is capable of controlling outdoor AR and indoor VR applications, including 3D modelling.

1.2 Concepts implemented

The user operates the application with the Tinmith-Hand user interface, using head movement, thumb tracking, pinch gloves, and a menu system to perform the following object manipulation tasks:

Object selection – the user can point at objects and select them, placing them into one of several clipboards.

Object transform – perform translate, rotate, and scale operations, in a variety of different ways.

Create primitives – 3D primitives can be created in the virtual world, from infinite planes as the simplest, to complex graphical models such as a water heater.

Combine primitives – previously constructed and manipulated primitives may be combined together using Constructive Solid Geometry (CSG) operations to produce higher level graphical objects.

The following components are used to implement the user interface and applications, used to construct large graphical objects outdoors:

Menu system and pinch gloves – the command interface to the system through the pinch action of our gloves. These gloves were custom built to integrate in with the rest of the system.

Four integrated pointing techniques – the system is capable of using four interchangeable pointing devices to supply input, depending on the requirements at the time and the suitability. The devices are one and two handed thumb tracking, a head orientation eye cursor, and a trackball mouse. Multiple selection buffers are used to store lists of objects in the process of being constructed.

Image plane interaction techniques – these techniques are designed to support interactions at a distance, where the objects are manipulated on a 2D plane perpendicular to the current view direction [16]. By combining pointing with image plane techniques, it is possible to manipulate objects in a 3D environment, selecting an appropriate camera angle simply by walking around in the physical world.

3D direct object manipulation – in immersive environments with objects that are within arms reach, it is possible to manipulate an object directly in the same way that is done with a physical object.

CSG operations – users intuitively understand operations such as carving and combining objects. We have leveraged this understanding by basing the interactive construction of complex real world shapes around the use of CSG operations.

2 Background

This section contains a brief overview of current AR and VR work, as well as other techniques that can be used to capture the geometry of physical models.

2.1 Previous augmented reality systems

Most AR and VR systems are oriented toward information presentation, the user wearing a HMD, moving around the world, and experiencing the artificial reality. There have been a number of systems for outdoor augmented reality such as the MARS Touring machine [5], NRL BARS system [8], previous UniSA Tinmith navigation systems [13, 22], and UniSA ARquake [21]. However, these systems only allow the user to control the presentation of the information, and not actually create new information, especially 3D models. An excellent discussion of other problems in the AR field is the survey paper in [1].

2.2 Previous VR interaction work

There are a number of concepts we have leveraged from the area of VR interaction, although most of these are focused on the manipulation of existing objects. As a result, the construction of new objects from primitive building blocks is still a fruitful area of investigation.

Our system builds on concepts from a number of researchers, including: Proprioception and the placement of objects relative to the body in [11]; Viewing and manipulation of objects using the Worlds-in-Miniature [20] and Voodoo Dolls [17] techniques; Two handed 3D interaction techniques in [7] and [23]; Selection and manipulation techniques like the GoGo arm [18] and various others covered in [2]; The WearTrack system and its variety of user interfaces in [6].

Another existing powerful modelling system is MultiGen Smart Scene [12], which allows users to construct and manipulate objects in a virtual environment using pinch gloves and direct action with objects at arms reach.

Existing VR menu systems tend to be very similar to current desktop environments, in that a tracker and button is used as a cursor to select from available options on a floating 3D toolbar or palette. Given that tracking technology has accuracy and delay problems, in some cases, using these menus can be difficult and time consuming.

2.3 Current capturing techniques

There are a number of techniques to construct large outdoor graphical models. A simple technique to model an existing building is to measure up and record the dimensions of an entire building with a tape measure, for example. This is very inefficient and time consuming because there may be inaccessible features, and the user must switch from indoors to outdoors at each iteration to modify the model and then verify its accuracy. Faster methods such as laser scanning and synthetic aperture radar [19], or multiple cameras [4], can be used to recover models, but tend to have large quantities (sometimes millions) of wasteful facets, and suffer from some features not being captured by the scans, causing ‘shadows’.

We propose our novel CSG primitive based approach as a way of interactively allowing users to build models outdoors, without the limitations of the other discussed methods. Although there are other limitations introduced with this process, they are different from the other two methods, and so the user now has an extra choice when deciding how to capture 3D models. The method is designed to capture reasonably simple objects to the accuracy of the tracking devices, and the user can create highly detailed models as they see fit, while keeping others simple if desired.

3 Tinmith-Metro for outdoor AR modelling

To better understand our user interface technology, we explain our overall CSG modelling technique and then present an example of how to construct a minimal graphical model of a physical object in both AR and VR systems.

3.1 CSG modelling concepts

Constructive Solid Geometry allows the construction of complex 3D graphical shapes using only a small number of primitives. Solid shapes contain an inside and outside, and using set operations, it is possible to perform 3D union, intersection and difference operations (see Figure 1). By combining these operations it is possible to produce any kind of object required.

While mostly used on solid shapes, it is possible to also use infinite planes as primitives, with a front and a back face defined by the surface normal. The region of space behind the back face is defined to be 'inside' and hence if 6 planes are placed all perpendicular to each other, an intersection operation will produce a solid 3D box with a finite inside area. Concave objects (such as T, L, or donut shapes) can be produced by subtracting one object away from another.

Modelling systems tend to operate with finite objects that are directly manipulated by the user at arms reach to form the object being constructed. However, in some cases, especially when working with outdoor AR systems, it is not possible to interact directly with the object. As a result, we propose the *infinite planes technique* – the user looks in the correct direction and selects a menu option to create a plane of infinite length following the path created by firing a ray out of the eye. By walking around the object and looking along the lengths of the walls defining an object, the user can define the bounding shape for a building without having to make physical contact with it. As a result, it is possible to operate the system from large distances away and still produce solid objects that match the physical world.

3.2 Tinmith-Metro outdoor AR example

The first example is of the Tinmith-Metro application being used outdoors to capture the model of a simple house structure, with extra features such as indented windows, a sloped roof, and outdoor accessories.

System start up - The user dons the backpack computer, pinch gloves, and HMD. The HMD is then calibrated for the user's head by capturing the orientation when they gaze level to the north.

Create perimeter walls – The overall top down outline of the building must be specified to partly define the solid house object. To create the outline, the user creates infinite planes to mark each wall. Each plane is created by the following: 1) the user positions themselves to look down the edge of a building wall, at any convenient distance, 2) the user places the eye cursor along the wall edge, 3) the user selecting the menu option with the gloves to create a right facing wall, and 4) the right facing wall (an infinite plane) is added to the virtual world intersecting the eye cursor and perpendicular to the image plane. This wall cuts the entire infinite world in half, in the same way as the real wall does, with the left being inside the building, and the right being outside. By walking around the building and marking each plane, the user is carving away sections of the infinite space and defining the volume of the building. Eventually, when the user has completely circled the building, the 2D perimeter of the volume is no longer infinite. The result is an approximate 2D bounded perimeter as shown from the orbital person view in (1) of Figure 2. This figure shows some approximated finite planes that are used to give the user an idea of the locations of the planes, although internally they are stored as infinite plane equations.

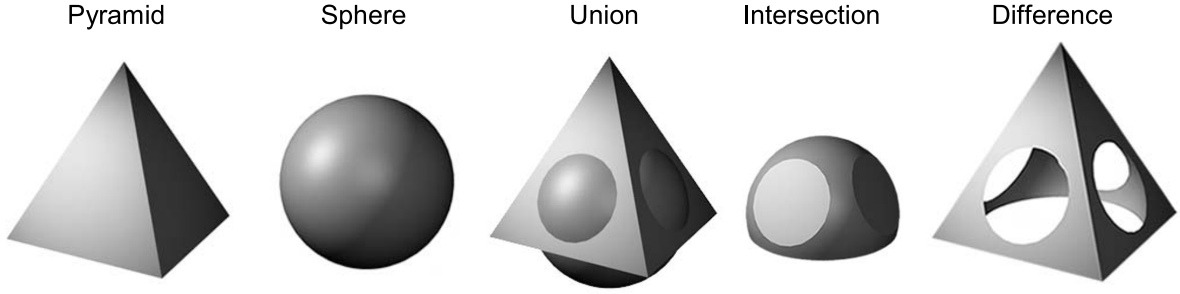

Figure 1 - CSG primitive operations example

Create floor and roof - The user then looks towards the centre of the house, and using the menu, creates a default floor infinite plane on the ground, and a flat roof infinite plane at a default height of 3 metres. At this point, the infinite planes created now form a complete solid volume in 3D, approximating a box.

Create solid box – The user selects the CSG intersect option that will create a solid object from the current planes. Whilst in the CSG mode, the modeller renders a preview of the final object, and attaches the roof plane to the cursor so that the user can interactively raise or lower it to match the physical building. The roof is the only part that is moved at this point because it was created with a default value that was not user controlled. The cursor can be controlled to move the object (using image plane techniques) using whichever input device is active. When the object is the correct shape, it is committed to a final box shape, and appears like (2) of Figure 2. Otherwise it can be deleted and started again.

Create pitched roof parts - At this point, the user has created a basic box, but now needs a pitched roof. The user moves to the end of the building where there is a clear view of the angle of the roof. Using the same techniques as before, they create left and right planes on the sides of the house. The user selects one of the new planes, and activates the rotate menu. The user can rotate the plane to match the pitch angle of the roof, with either the gloves or trackball. The plane is then moved to the correct height as before, and fine adjustments may be performed using the *nudge* command from the menu to slide the object in various directions. The second plane must be aligned in the same way with the other side of the house.

Carve main object with roof - Once both roof planes are in place, the user activates the CSG engine to perform an intersection between the two roof planes and the box. The CSG engine shows a preview of the object, allowing any adjustments to be made before the operation is committed. The model is now a box shaped object with a matching pitched roof. To finish off the model, the user will now add a few extra fixtures.

Add house accessories - To add a hot water heater, (1 metre high metal drum) the user creates a cylinder primitive using the menu. The cylinder is created with default sizes that are approximately the right size. The object can now be scaled to the correct size, and then translated into the correct location. The user can add a window from a set of pre-modeled boxes. The window is created and placed in the same fashion as the water heater, except it is used as a cookie cutter and carved into the surface of the house to form indented windows. The house model is now completed, as shown in (3) of Figure 2.

3.3 Tinmith-VR for indoor VR modelling

This example demonstrates the Tinmith-VR application, which is designed to be used indoors with the same modelling techniques as the outdoor AR system. In this section, we create a simple artificial building with curved roof, and place some prefabricated street furniture

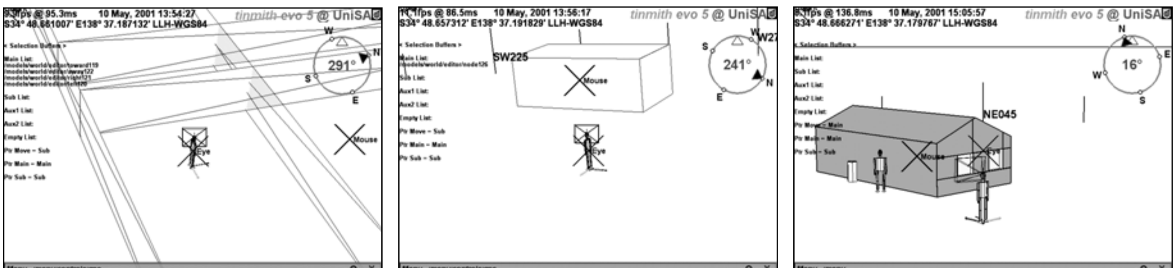

Figure 2 – Tinmith-Metro demonstrating: (1) Raw wall planes (2) Finished solid box (3) Final house model with water heater, indented windows, and avatar family

items around it.

System start up – The user dons the pinch gloves and HMD, which are then calibrated for the alignment of the user's head.

Create defining walls – Using the same CSG concepts as before, we need to define the perimeter walls of the building. Instead of walking around the building and creating walls originating from our eyes, the user creates them relative to their tracked thumbs on the pinch gloves. Walls are created, originating from the gloves, and the user moves their hands to create them at the appropriate orientations. The arched roof is created by moving the hand in a curve motion and creating planes at intervals. (1) of Figure 3 shows the roof and floor planes defining the object, arranged in a curved arch. The front and back walls have been removed for clarity.

Create solid object – The user activates the CSG intersect option, which uses the new planes to create a solid volume. The user can preview and then commit or cancel the object, making adjustments until it is satisfactory.

Add outdoor street furniture – To complete the model, the user adds some extra models such as tables, street lamps, and pine trees. These models were prefabricated in another application, but could also have been created using this system if desired. The completed model is shown in (2) of Figure 3.

3.4 Comments

The quality of the graphical objects created with our system is limited largely by the accuracy of the tracking hardware employed and by how well the user creates the primitive graphical objects.

Outdoors, using a Trimble Ag132 GPS, the accuracy is better than 50 centimetres, and so most reasonably sized structures can be modelled effectively. Errors in the IS-300 orientation sensor can cause walls to diverge, and better models are achieved when as close as possible to the building.

Indoors, the Polhemus tracker accuracy is reasonably good, and the models created tend to work well within these limits. The most difficult part is creating objects where the facets all align accurately, as positioning the thumb at the required angles can be difficult. The ability to snap objects at certain orientations and positions would be useful to help align planes accurately.

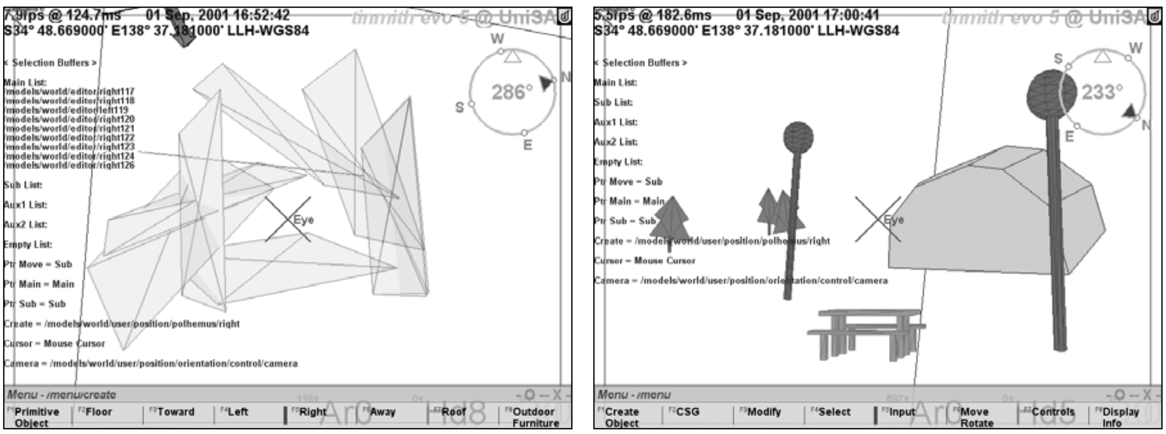

Figure 3 – Tinmith-VR demonstrating: (1) Primitive planes defining bounding volume for solid object, (2) Final solid object with curved roof and prefabricated street furniture placed nearby

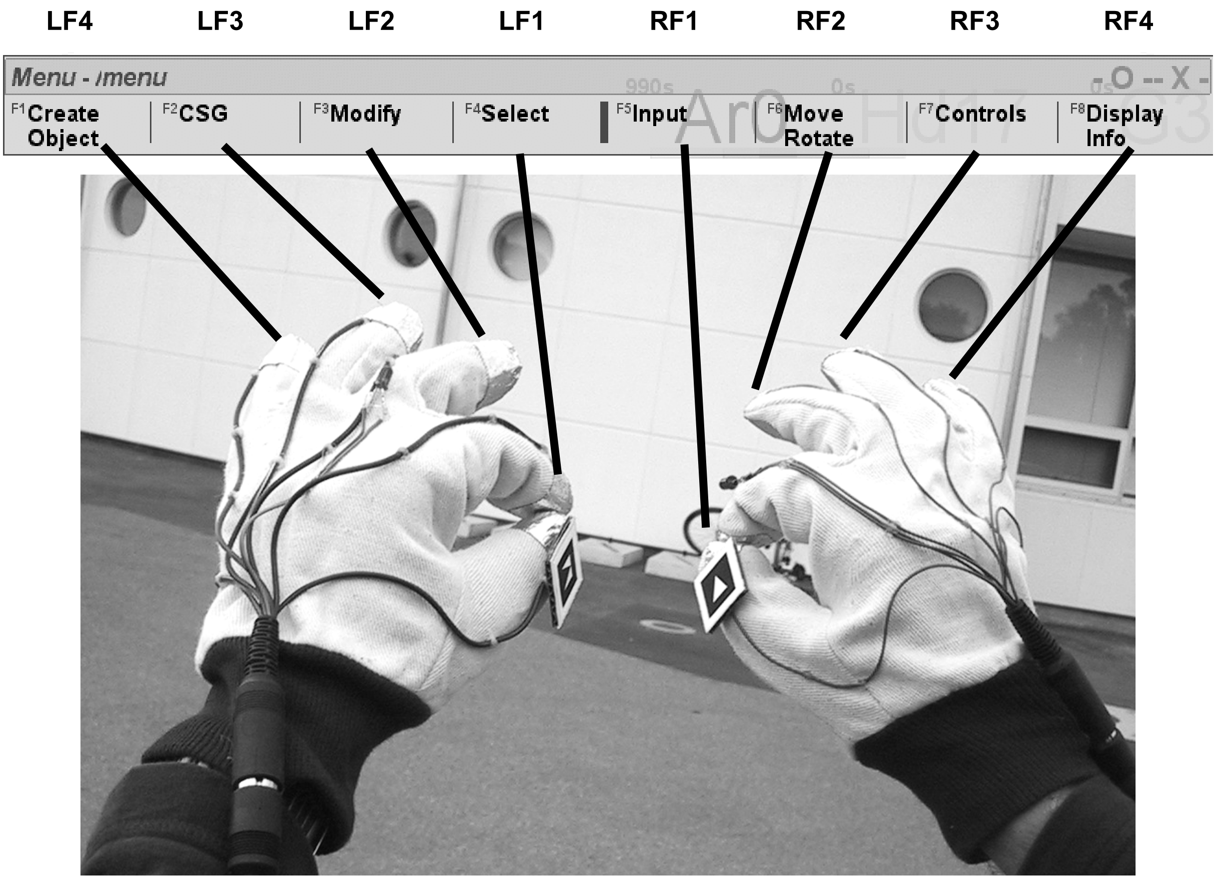

Figure 4 - Root menu node layout, with corresponding finger mappings

4 Menuing system

The menuing system of Tinmith-Hand is powerful enough to provide a user interface to a fully functional 3D modelling system, supporting object hierarchies, CSG, and editable transformations, without the use of a traditional keyboard or mouse. The menu options are presented in a transparent green dialog box at the bottom of the display, which can be repositioned if desired. Figure 4 shows the layout of menus relative to the user's fingers, and the other various screenshots show the location and transparent nature of the menu box. We used transparency to avoid visual clutter caused by menu boxes, by allowing the user to see through the menu. The menu colours and transparency are dynamically changeable.

Each menu option is assigned to a finger on the gloves. To select an option, the user touches the matching fingertip with the thumb tip. For example in Figure 4, the CSG option would be selected if the ring finger and thumb of the left hand were pressed together. By pressing any finger on the palm of the glove, the menu returns back to the top level. Menu options can perform operations or present other further menu choices for the user.

In the applications we have developed, the menus do not float in the 3D world like other VR menus such as [3, 11]. We feel that these menu options should always be visible during the graphical object creation task at all orientations, although they can be hidden if requested. One advantage is that the user does not need to move their hands to select menu options, so it is possible to be using both hands to manipulate an object and then activate an option without any movements. Another is that since the menu options are selected with finger presses, there is no problem with tracker accuracy and delay when trying to use drop down 3D cursors and menus.

The menu system described in [3] was developed at a similar time as ours for immersive VR, although was different in that it was very much like traditional pull down menus. The top-level menu items were available on one hand, and the second level options on the other hand. Using the small finger it was possible to cycle through options if there were more than three options. The menus were limited to a depth of two, and it is not scaleable to a large number of hierarchical commands. Our system is fundamentally different since there is no cycling through a small set of items, and an arbitrary depth of menus is possible.

5 Pointing and selection techniques

With Tinmith-Hand, the user has a choice of four input devices for pointing and selecting, some are 2D, like the belt mounted trackball and eye cursor, while the thumb tracking is 3D based. The user chooses whichever device is appropriate at the time for the particular control or selection task. Traditional desktop applications only use one device, or merge the devices to be all the same. All pointing and selection is currently performed using image plane techniques, since most AR work involves working at a distance.

5.1 Hand based thumb tracking

Tinmith-Hand is designed to support applications that interact with graphical objects and enter spatial information. We chose hand gestures to be the main interaction method for the user interface. As previously mentioned, a set of pinch gloves are worn by the user, and Tinmith-Hand tracks the location of user's two thumb tips.

Given the location of the thumbs, the system overlays registered 3D axes, as shown in Figure 5. At the same time, a 2D flat cursor is overlaid on top. The cursor is placed in the desired location by movement of the user's hand. When the user activates selection mode using the menu and gloves, a ray is fired into the scene from the 2D cursor, and the first object hit is selected.

Why track the thumbs? We first thought of tracking the back of the user's hand, but we quickly realised that the hands easily fill up the user's field of view when placing the cursor within the field of view of the transparent AR display. It was decided that fingers would not obscure the field of view as much and allow for finer motor control and larger movement. The ends of the index fingers were dismissed as they moved too much during the selection of the menu option with the index finger and thumb. We noticed that the thumb did not move much during a pinching gesture however. People tended to bring their fingers down to meet their thumb as opposed to bringing the thumb up to meet the fingers. As a result, we track the top of the thumb. As another option, the index finger could be tracked for one handed cursor movements, and the selection of the menus with the non-dominant hand.

5.2 Eye cursor

The eye cursor is fixed to the centre of the display, and is controlled by the user rotating their head to point to different objects in the world. We have found the eye cursor to be very useful during the construction of infinite wall planes in the outdoor AR application. The user looks down the length of a physical wall and creates a virtual one that is coplanar. Objects may also be selected with this mode, the user aims their head at the object, and the ray fired is tested for intersecting objects.

5.3 Object selection

When a user performs a pick operation on a graphical object, the system determines the closest polygon under the cursor. When a polygon is selected, the simplest object is chosen, but the user can traverse up the scene hierarchy to select more of the model if desired. Every polygon and object in the scene exists in a searchable global model hierarchy.

5.4 Selection buffers

For CSG operations, users are required to select multiple objects, operate on them independently, and then combine them together to produce a final object. One solution is to repeatedly select and deselect objects as required, but selection is tedious and error prone. As a result, rather than having the ability to select just one object and operate on it, the user operates on collections of objects in the selection buffers, which are very similar to traditional clipboards. In any particular selection buffer, the user may place multiple selected objects. The user is able to switch between selection buffers and put different objects into different buffers. CSG operations are performed between two selection buffers at a time. For example, a user may intersect all the planes in buffers A and B while translating only the planes in buffer B, the result going into A. Later, the user can place some different planes into buffer C, rotate them, and then intersect them with the previously existing result (This is how the construction of the pitched roof was performed in the example).

5.5 Camera controls

AR and VR systems are traditionally immersive, but there are situations where other camera angles are appropriate and useful. For example, when viewing a large campus model, a user may wish to view what is past the next building, or very far away – both of which are not

Figure 5 – 3D cursor mapped onto the vision tracked hand in outdoor AR scenario with Tinmith-Metro

practical with an immersive view of the world.

Tinmith-Metro and Tinmith-VR, like their predecessor [13], support a top down map, providing the user with a gods-eye view of the world, looking down onto the Earth. As the user rotates their head, the entire map rotates as well, with the user's direction being toward the top of the display.

A second useful camera control model supported is orbital mode, described in [10]. In our implementation, the orientation of the head is used to orbit around the user's avatar, showing their location compared to other objects in the world from a different angle.

6 Manipulation techniques

Tinmith-Hand supports a number of image plane techniques for manipulating (move, rotate, and scale) objects in the environment. These image plane techniques require an input cursor via one of the four input devices (one and two handed thumb tracking, eye cursor, or hand trackball) and a selection buffer to operate on. The user, via the menus, selects the desired input device and the selection buffer.

6.1 Object movement

This mode allows the user to translate an object parallel to the plane of the user's display, and is initiated via a menu selection. The cursor can be moved using the hand gloves, eye, or trackball. The system fires a ray through the cursor and intersects it against the object, calculating the Z distance, then as the cursor is moved, an appropriate translation is added to the object so that it stays under the cursor during movement. The commit option is selected to save the new position. In this mode, the object can only be moved in any direction perpendicular to the camera direction, and hence the Z distance is maintained.

6.2 Object movement nudging

Tinmith-Hand supports precise small incremental translations. In this mode, the user can slightly move an object (nudge) in any of six directions (up, down, left, right, toward, away) in increments of one metre. The user can walk around the object and refine the location from all angles until the object is satisfactory. The advantages to this mode are that we can perform movements that are finer than our outdoor tracking hardware or distance to the object will allow. Future systems will support scale and rotate nudging.

6.3 Object rotation

Rotation requires two points to be defined to calculate the rotation as an angle offset between two points. Because we are implementing image plane techniques, two user-controlled cursors are used to define a line, which then determines the angle offset. The rotation is done perpendicular to the display plane.

Two handed rotation techniques may be applied when both hand based thumb trackers are employed by the user. When the user selects this mode, the angle formed between the two cursors determines the rotation of the object.

The eye cursor by itself cannot be used in this mode, but can be used in combination with the handheld track ball. The track ball uses the eye cursor as its reference point, and so the rotation is determined between the changing track ball cursor and fixed eye.

6.4 Object scale

The object scale interaction technique is similar to the rotate mode in that two input cursors are required, with the distance between the two used to scale the object in the same X and Y directions of the image plane coordinate system. Objects could be scaled uniformly in all three dimensions by applying the scaling factor proportional to the change in distance between the two cursors.

6.5 3D direct manipulation operations

When an object is within arms reach, manipulation of objects is much easier as the user can select the object, and then rotate or translate it directly with their hands in the physical world. This technique is not generally used in the AR system, as objects such as buildings are large and physically prevent the manipulation of other features that are occluded.

7 Tinmith system

The Tinmith-Hand interface, and the Tinmith-Metro and Tinmith-VR applications are created using the Tinmith-evo5 system. This architecture is covered in [14], and Tinmith-Metro is discussed extensively in [15].

The wearable computer system as shown in Figure 6 is based on a Gateway Solo P2-450 laptop (64 mb RAM, ATI Rage OpenGL) mounted on a hiking backpack. An Intersense IS-300 hybrid tracker performs orientation sensing. Position information is gained from a Trim-

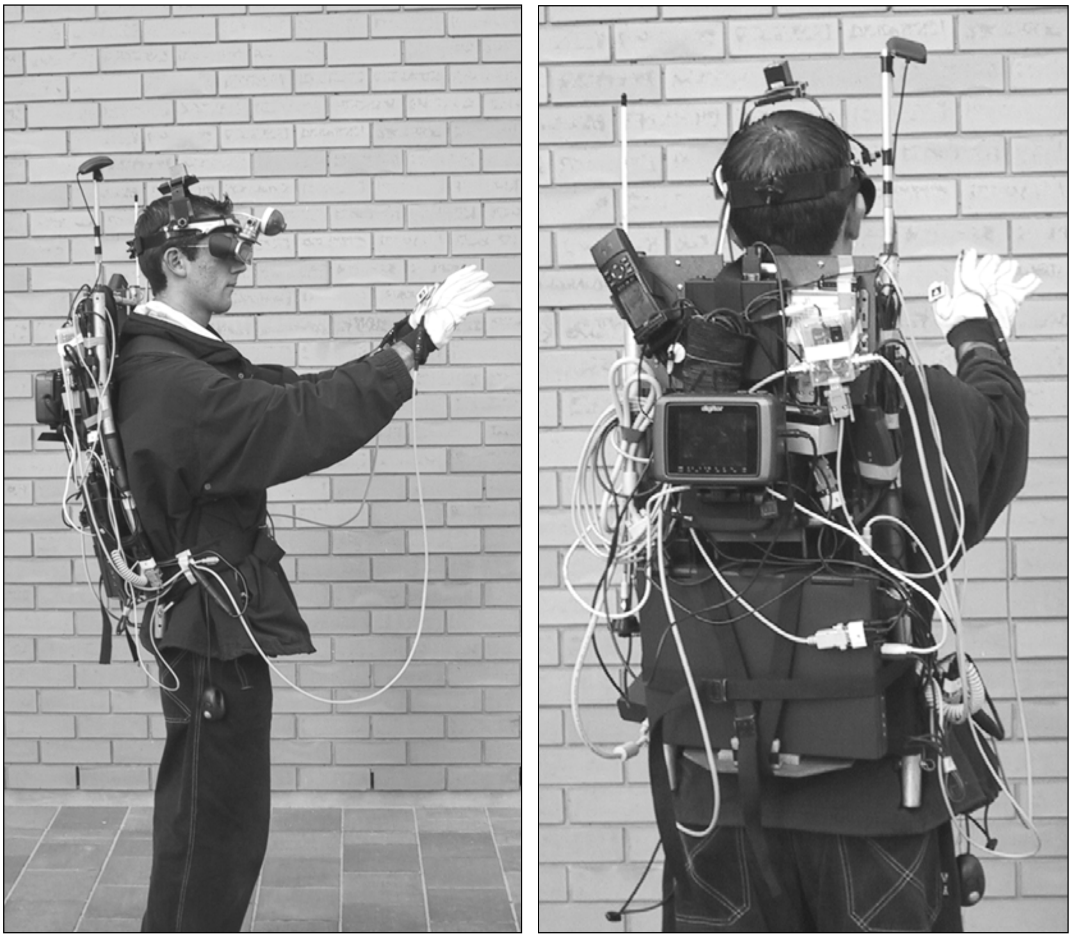

Figure 6 – Mobile outdoor augmented reality Tinmith backpack computer

ble Ag132 GPS, with an accuracy of 50 centimetres. The display is a Sony Glasstron PLM-700e monocular SVGA display. A USB video camera is used to provide images for the thumb tracking system. Custom made pinch gloves (shown in Figure 4), are combined with the target tracking and used as the main input device. Fiducial markers placed on the thumbs are processed using the ARtoolkit software library [9], providing reasonable quality 6DOF tracking.

The indoor configuration uses the same hardware as above, except a Polhemus 6DOF magnetic tracker was used for both the head and thumbs, removing the need for the GPS, IS-300, and video processing hardware. The operating range of the system was restricted to that of the magnetic field of the fixed tracking hardware.

The laptop runs RedHat Linux 7.0 with kernel 2.4 as its operating system, including the standard GNU development environment. XFree86 v3.3.6 is used for graphics, as it does hardware accelerated OpenGL using Utah-GLX. The performance of the older ATI Rage chipset is adequate for our current needs, as the system has low rendering requirements.

8 Conclusion

This paper has introduced the Tinmith-Hand AR/VR unified user interface, based on the flexible Tinmith-evo5 software system. Using our modelling techniques, based on CSG, tracked input gloves, image plane techniques, and a menu control system, it is possible to build applications that can be used to construct complex 3D models of objects in both indoor and outdoor settings.

As part of this work, we intend to explore various other 3D interaction techniques, and other solid modelling concepts. Physical land features such as rivers and roads are currently not simple to create, and other 3D techniques for action at a distance would be useful in improving the selection and manipulation of objects. Finally, the main purpose of this work is to form a foundation that can be used to extend the AR/VR integration work performed in [13], producing a system which allows collaborative modelling between users in both outdoor AR and indoor VR environments.

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