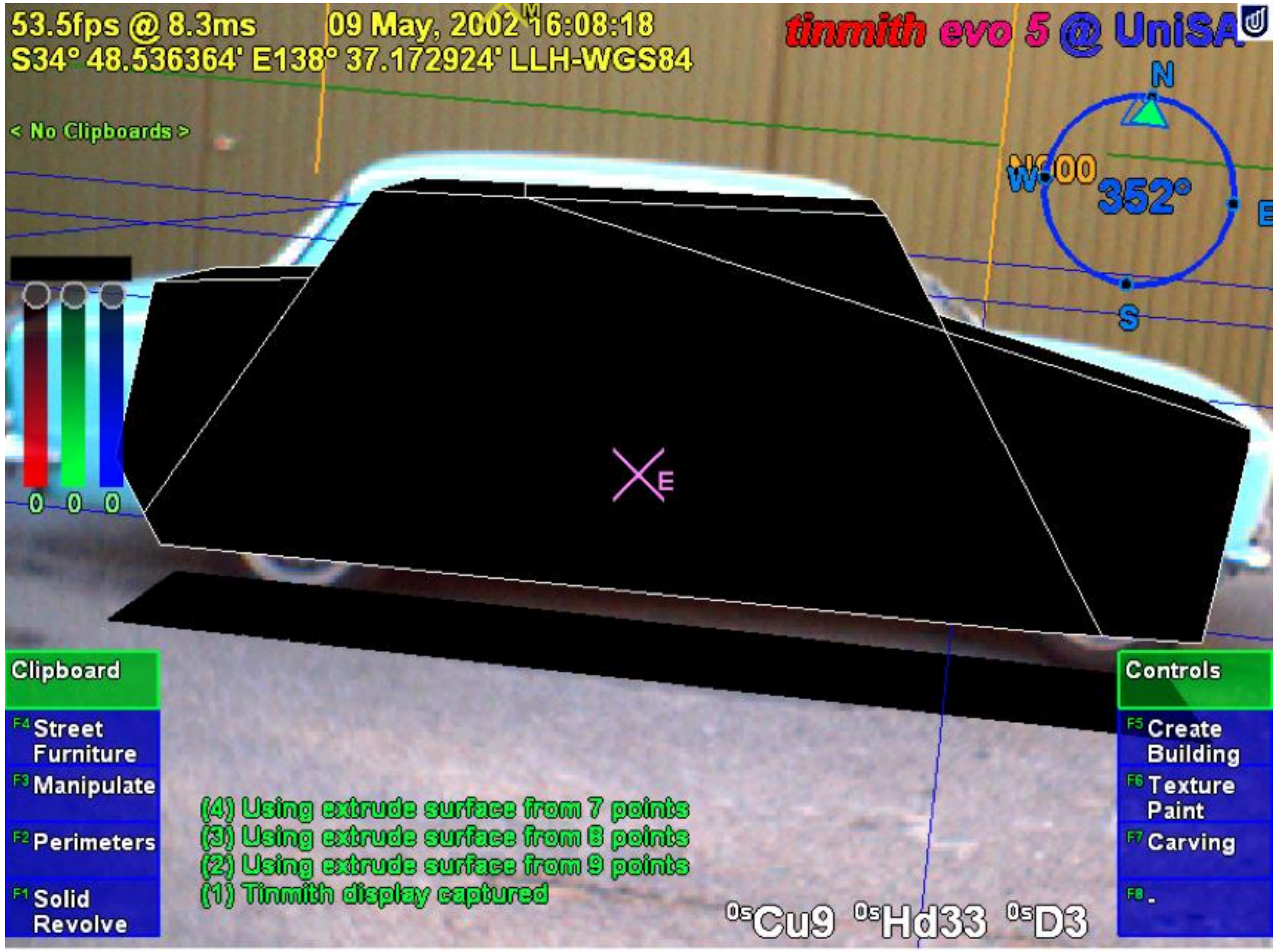
Module III
Augmented Reality Interfaces & Design

Techniques of Augmented Reality

Outdoor AR systems

Traditionally, AR research has been inclined to focus on the presentation of information, which is created offline using desktop based systems. Systems such as **Feiner's** Touring Machine and the original **Tinmith** work had limited capabilities to enter information, and were mostly ocused with information presentation. The work presented in uses the intersections of projected lines from different locations to enter in vertices, and then connecting them together to form shapes. Due to the generic nature of the technique, it is possible to enter in very arbitrary shapes, as there are fewer constraints, at the cost of increased modelling time and complexity for the user.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(3) Using extrude surface from 8 points
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(1) Tinmith display captured
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Indoor modelling systems

There has been a wide range of work in the area of 3D indoor modelling using monitors and head mounted dis- plays (HMDs): Clark's surface editor [4] implemented direct manipulation of splines using a HMD and a wand; Sachs' 3-Draw performs the creation of arbitrary models using direct manipulation of a stylus and tablet; Liang's JDCAD pioneered many new techniques such as lasers and spot lights for action at a distance using 3D input devices; But- terworth's 3DM [3] developed new user interfaces for im- mersive VR modelling; Forsberg's work with apertures [8] extended Liang's spot lights to use a circular cursor on the hand projected from the head into the scene; Pierce's im- age plane techniques [20] extended Forsberg's aperture pro- jection concept to introduce a series of selection methods based on the projection of the user's hands and fingers; Mine's CHIMP [12] implemented within arms reach tech- niques based on proprioception and scaled world opera- tions; Stoakley's Worlds-In-Miniature [24] demonstrated remote manipulation using small copies of the world held within the hands; MultiGen's SmartScene is a commer- cially available application which implements many of the previously mentioned techniques.

A common trait of many of these systems is that they use direct manipulation to create new vertexes and objects within arms reach, and action at a distance for manipulation when the object is not reachable. By using scaling techniques in combination with flying, the user may manipulate small buttons in an eleva- tor, or place a large building on a street. Due to their non- exact input methods, these systems are also limited to con- ceptual modelling tasks and not precision modelling, since it is not possible to easily enter accurate data and compare the model against that of a physical object.

Physical capture techniques

In the construction and surveying domain, a number of techniques are used to capture the geometry of outdoor structures. The most basic method (although very tedious) is to physically measure the structure, and then record the dimensions and geometry on paper. This information can then be used to recreate the object as a 3D graphical model using a desktop CAD system. Brooks also discusses many current capture methods, and points out that this is still an area with a number of problems.

Debevec's Façade system allows the capture of objects using photographs of a building taken from various angles, and then processes these offline to produce 3D models. Façade is not automated and requires the manual specification of similar points between the images by the user to reconstruct geometry.

A common capture method used by surveyors is employing portable laser scanners, such as the commercially available I-SiTE or Cyrax scanners. These devices sweep a laser over a large outdoor area and capture dis- tance measurements, constructing a detailed mesh of the object.

The specifications for the I-SiTE scanner claim to measure a point every 30 cm at a distance of 100 metres, and to be able to reconstruct a large building from four different angles within one hour.

With all these techniques, to produce an absolute posi- tion model, a GPS must be used to offset some reference point in the model, and the equipment must be very care- fully setup before use, which can be time consuming. The setup and capture time is also fixed no matter what the desired model mesh complexity is, and so for simple tasks it is not possible to capture an entire building with a basic mesh in a few minutes. Most importantly, the Façade and laser scanner methods are both ineffective in environments where it is not possible to obtain perfectly clear views of the building from all angles, such as when obscured by trees, clouds, or other objects. Given these limitations, we believe that our work is a useful tool to complement these techniques.

Augmented reality working planes

While image plane techniques and our AR extensions are useful for selecting and manipulating objects at a distance, they are not useable for the placement of new objects as there is no distance information. As a result, we define a new technique known as augmented reality working planes that is based on previous interfaces used in desk- top CAD systems. AR working planes can perform a wider range of tasks than is possible with previous image plane techniques, such as construction at a distance. AR working planes are infinite in size and can be fired from the user's current location in a specified orientation, or created at an object with the surface normal matching the object or pointing toward the user. AR working planes can be created either in absolute world coordinates, or relative to the head orientation of the user. Relative AR working planes can be used to perform all operations previously performed using image planes.

Figure 3 - *Previously created table being moved into its correct position using direct manipulation hand gestures*

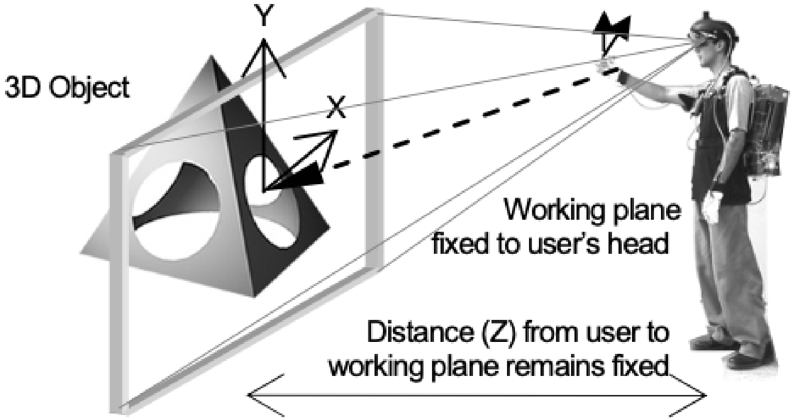

Figure 4 - *Working plane at object distance, used for 3D manipulation operations with 2D cursors*

infinite carving planes

This section describes the infinite carving planes construction at a distance technique. It is based on our original CSG with primitive objects construction technique, but the generation of more complicated 3D models is made simpler when used in conjunction with the other new techniques presented in this paper. Previously, each of the primitive objects was specified and then a CSG intersection operation was performed to produce the final volume, sometimes giving undesired results if the user made a mis- take at any point, and requiring the user to delete every- thing and start over again. With infinite carving planes, the object is now carved away iteratively and the user receives real time feedback of the infinite volume being bounded, allowing immediate undo in case of a mistake, and greatly improving ease of use.

Figure 5 shows a building (in thick black lines) and the location of the mobile AR user as they are sighting down each of the walls. When infinite carving planes mode is first started, the AR system creates an (approximately) infinite solid volume which will be used for carving. When the user is aligned with a wall, a menu option is selected, and an infinitely long vertical plane is fired from the user's head into the world. This plane divides the previous infinite solid into two parts, and the left or right portion (decided by the user from the menu) is carved away from the solid and removed. As the user sights down each wall, the solid will be reduced down to an object which is no longer infi- nite in the X and Y axes. At completion, a floor is auto- matically created at ground level, and the roof is left un- bounded for carving using other techniques, since it is not possible to sight down the roof of a very tall building. The final 3D shape is stored using absolute world coordinates and reflects the geometry of the physical building.

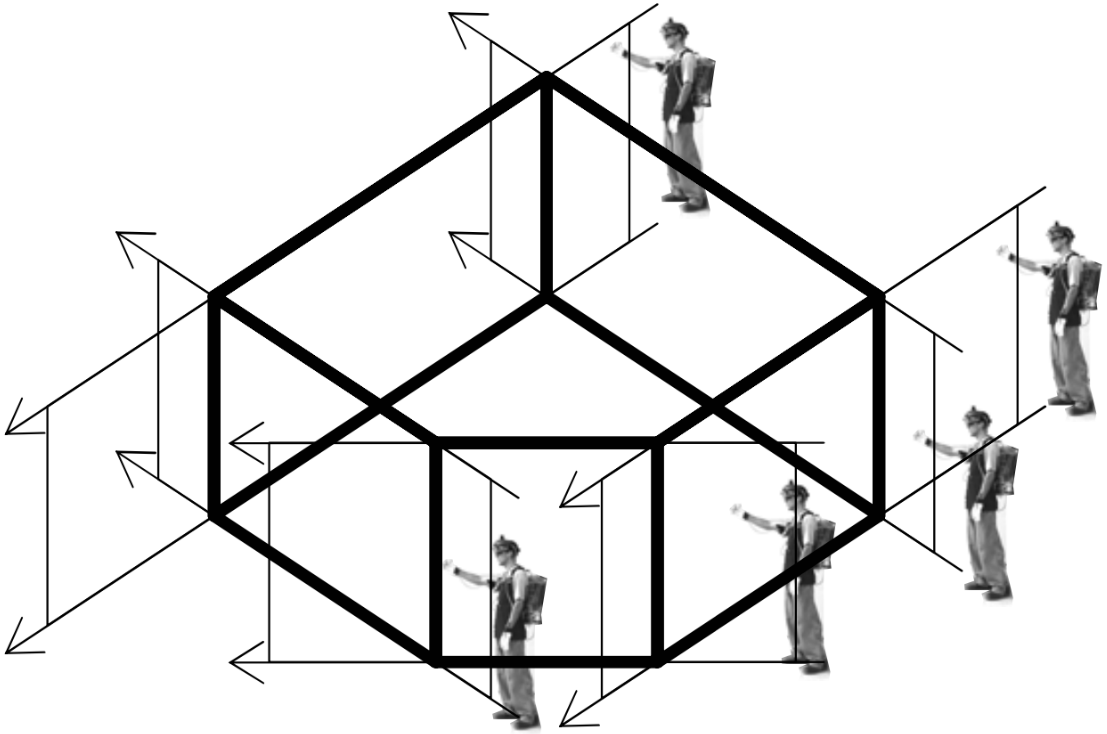

Figure 5 - *Infinite carving planes created by user to carve a solid convex shape from an infinite solid*

The repeated use of CSG to form concave objects, (**see Figure 6**) this was very time consuming, tedious, and sometimes impos- sible. By using the other techniques described in this paper, it is now possible to easily create objects such as those with zig-zag roofs, holes, and indentations, using source objects generated using infinite carving planes.

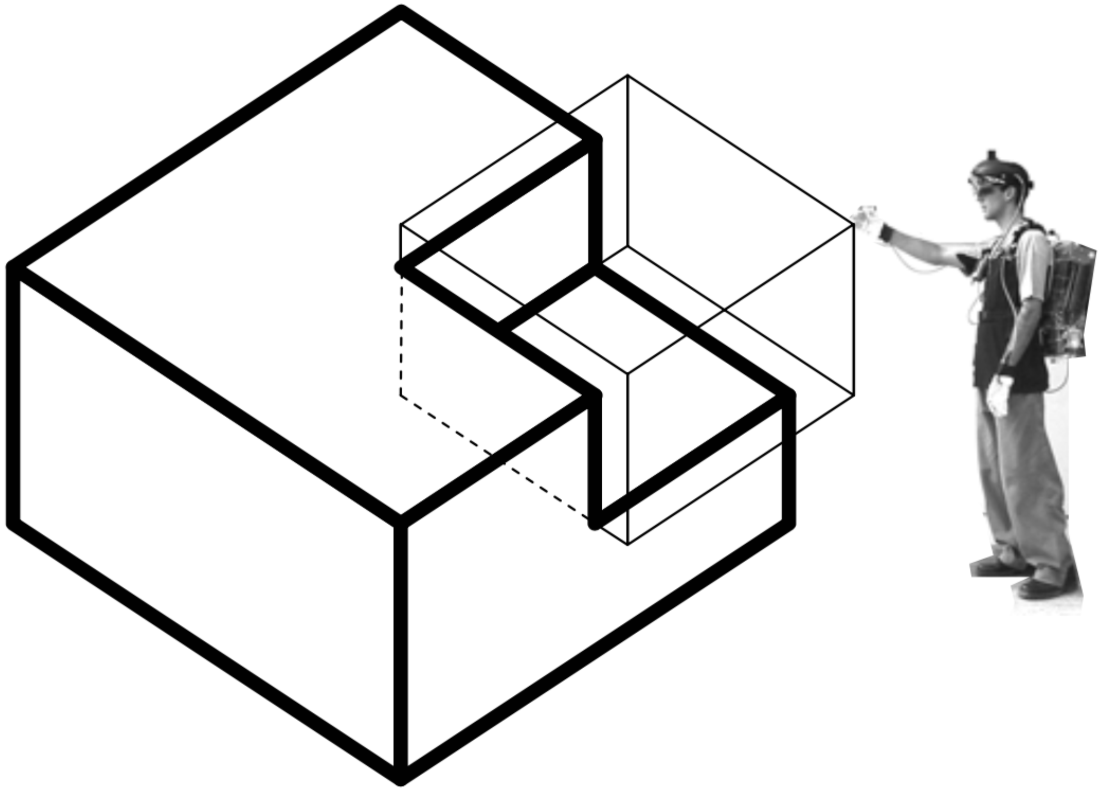

Figure 6 - *Concave objects can be interactively created by carving away other shapes with CSG*

Orthogonal laser carving

Our new laser carving technique allows a user to mod- ify an existing shape and cut away portions to produce new highly concave shapes in an intuitive way. Figure 7 shows a detailed diagram of how the carving operation is per- formed. When the user creates the first point, the system projects a virtual laser from the head through the hand and finds the closest polygon under the cursor. This polygon is then used to create an AR working plane that is coplanar to the polygon, and all points created will be projected from the user’s hand against this plane. Each point on the AR working plane is then connected together to form a 2D concave outline, and orthogonally extruded at an infinite distance along the surface normal

This technique is first demonstrated with a simple ex- ample of modelling a building with a sloped roof, as shown in Figure 8.

The user must first model a box that is the same ground area as the building, and with a roof higher than any parts of the building (using infinite carving planes). To carve the roof, the user positions themselves in front of the building so that the entire slope is easily visi- ble. The user then indicates with the hand cursor the first point defining the roof on the left, then the peak of the roof, and then the right side of the roof. To complete the selec-tion, the user must enter points around the overall building

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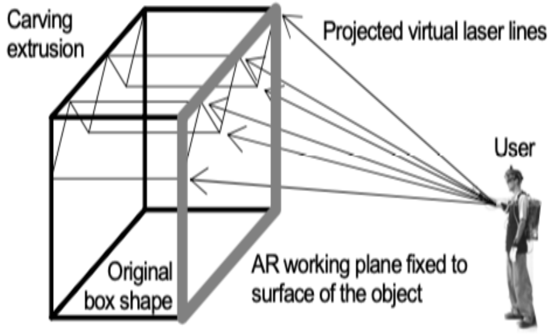

Figure 7 - *Virtual lasers perspectively projected onto an AR working plane coplanar with object, then carved orthogonally along the surface normal. This method is invariant to the user's height, position, and plane angle.*

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Figure 8 - *AR view showing building model with sloped roof registered against the physical object*

Figure 9 - *VR view of building with sloped roof, showing the overall geometry from an overhead viewpoint*

Laser colouring

Once a building has been created, it may be desirable to place windows, doors, and other annotations onto the model. While it may be possible to draw these using a texture map (which cannot be zoomed arbitrarily), or to place extra polygons outside the building to represent these (covering the original building), the building model itself is still a solid shape. If these new polygons are removed or manipulated, the original solid object remains as the changes are only superficial. A more desirable scenario is that polygons of a different colour are actually cut into the subdivided surface of an object, so that if they are deleted it is possible to see features inside the object that were previously concealed by the walls. We have named this technique laser colouring. Using the same steps as laser carving, points are created against a coplanar AR working plane to form an outline. Instead of carving away the object, it is instead subdivided and the colour of the outlined polygons is changed.

Texture map capture

Since the mobile AR computer already includes a video camera for the AR live video overlay, it is possible to pro- ject images from this camera directly on to polygon sur- faces. We call this technique texture map capture, and it allows us to easily map textures to polygons simply by looking at them.

Once the object is modelled and in the correct location, the user stands at a point where the object textures to be captured are easily visible. The capture menu option is selected and the system projects the polygon vertices onto the video overlay and maps the still image to the surface of the polygon. The user repeats this operation for each face until the object is completely textured. An example is shown in Figure 10, where a 1 metre box was modelled and then texture maps placed onto the polygon faces.

The best results for this capture are gained when the ob- ject fills as much of the HMD as possible (while still being completely visible), and is perpendicular to the user's viewing direction, such as in the laser carving example in Figure 7. Since OpenGL only supports linear texture map- ping, if the angle to the object is large (like the roof of the box in Figure 10), the image will be highly distorted as a non-linear mapping is required.

Figure 10 - *VR view of cube model showing 3D geometry along with captured textures to improve detail*

Surface of revolution

When working outdoors, many objects do not fit against approximations like boxes or polygons, and contain many curved features. In an attempt to capture objects such as trees, we have used surface of revolution techniques (as used in many desktop CAD systems) to capture their shapes more accurately than is possible using infinite carv- ing planes. This method is completely self-contained and is not dependent on models being supplied from other tech- niques. This technique also demonstrates another scenario where AR working planes can be used to create objects that are not possible with existing action at a distance tech- niques.

To create a tree (with a reasonably symmetrical shape), the user sights toward the central trunk or axis of the tree, and fires an AR working plane from the body. The user then walks to a point approximately 90 degrees around the tree so that the normal of the AR working plane is now pointing towards them. Using techniques similar to those in laser carving, the user projects points onto the AR working plane to outline the tree, as shown in **Figure 11.**

The user next creates either one or two points to indicate the axis of rotation for the tree, and the system then generates a pre- view of the final object. Once the user is satisfied with the model, it is solidified and placed into the virtual world.

For modelling regular objects such as pine trees, which are highly symmetrical about the trunk, this technique works well. For trees that grow with deformities and other abnormal features, the models will not match very well. To better approximate these forms of physical objects, laser carving may be applied to refine the surface of revolution graphical object until the user is satisfied with the shape.

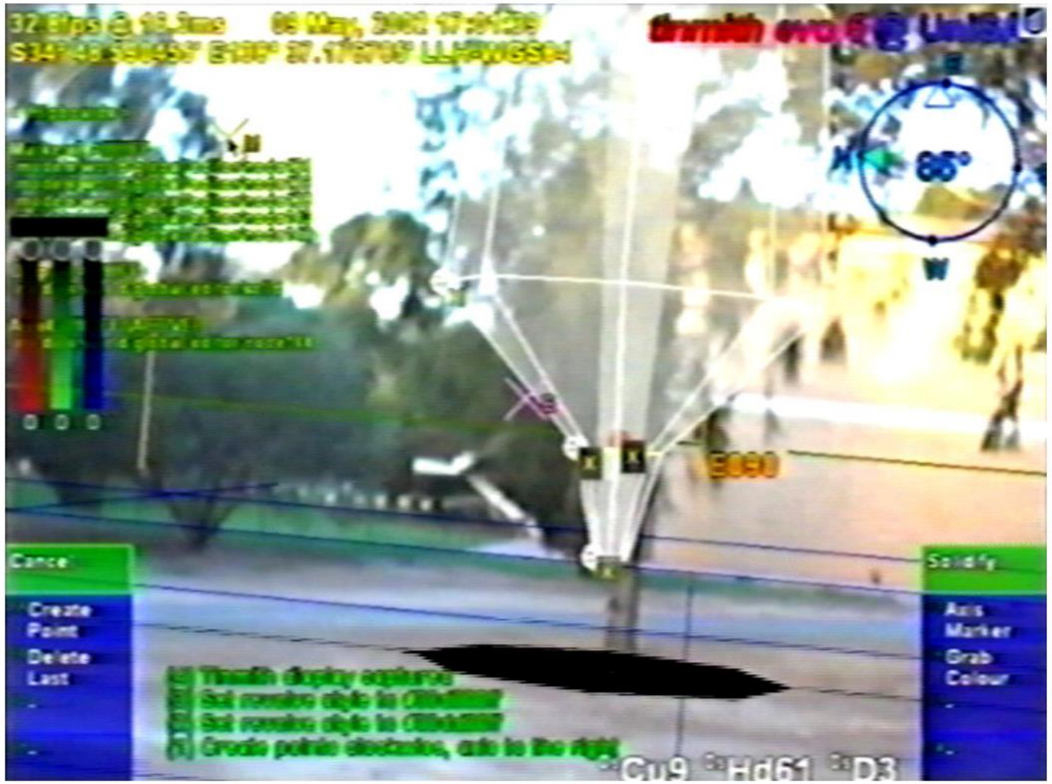

Figure 11 - *AR view of surface of revolution tree with marker points projected onto an AR working plane*

Module III

Revision