

Augmented Reality 3D Interactions for Wearable Computers

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Abstract

This paper presents a set of large object manipulation techniques implemented in the Tinmith system that are optimized for an outdoor setting. The extended manipulation techniques for rotation, translation and scaling are focused on using what we determined to be the best coordinate system to operate in, and supplement the current techniques using image planes. Four 3D object manipulation techniques are presented Revolve, Xscale, Pull/Push and Gravitise.

1. Introduction

Augmented reality (AR) systems supplement the real-world environment with virtual information. Image plane techniques are well suited for wearable computer AR interactions, as they are easily implemented with wearable tracking sensor technologies [1]. This paper presents a set of action-at-a-distance techniques [2] designed to overcome a number of limitations found in the 2D nature and inherent relative coordinate systems of image plane techniques.

Our investigations into AR in an outdoor setting have ranged from collaboration [3], modeling [4], to entertainment [5]. One of our particular interests is for action-at-a-distance manipulation of large scale graphical objects, such as buildings, trees, and street furniture. Interaction commonly involves the placement of virtual objects co-located with physical objects with a specific location, orientation and scale. A unified methodology is the main approach of current AR user interfaces for the manipulation of graphical objects. These are limited to the manipulation of a single coordinate system; some examples are as follows: image plane manipulation is head relative, hand-based direct manipulation is object relative, and laser pointer is world relative.

This paper presents a number of interaction techniques that have been optimized for the best relative coordinate system for the manipulation of large virtual graphical objects (large in scale to the user) in an outdoor setting. Different proper frames of reference and manipulation techniques are required for each of the direct manipulation operations: translation, rotation, and scale, because we found that a single technique was unsuitable. This paper is innovative in grouping manipulation techniques together in proper context, in order to provide a more natural interaction for the operations on large graphical outdoor objects. Interactions with large virtual objects in an outdoor setting are generally constrained to the ground; this supports intuitive and real life object manipulations, such as rotating a physical picnic table. The following attributes state the features this collection of manipulation operations support: 1) rotations are around a normal vector to the ground, 2) scaling is performed in the object's coordinate system, 3) translations are along the ground, and 4) no operation will place any part of the graphical representation below the ground plane. These techniques have been incorporated into the Tinmith system to enhance the image plane and precise manipulation techniques. When those attributes do not hold true, the existing image plane and precise manipulation techniques are still available to the user.

The four 3D object manipulation techniques are Revolve, Xscale, Pull/Push and Gravitise. Revolve and Xscale support rotation and scaling of objects about their own coordinate axes, as opposed to the image plane technique. The Pull/Push technique extends the 2DOF (degrees of freedom) interactive translation operations to 3DOF interactive operations. Gravitise partly emulates the force of gravity by lowering floating objects and raising underground objects to ground level without changing their orientations.

This paper starts with an overview of previous work. The limitations of using image plane techniques

for the manipulation of large objects in an outdoor setting are examined. The direct manipulation techniques to overcome the discussed limitations are then presented. Finally a set of concluding remarks is given.

2. Background

Action-at-a-distance techniques allow users to interact with objects that are not within arm's reach. Lasers and spot lights are early examples of 3D action-at-a-distance techniques [6]. Apertures [7] are an extension of the spot lights techniques that employ a circular cursor on the hand projected from the head into the scene for selection. Image plane techniques [8] further extend the aperture projection concept to introduce a series of selection methods based on the projection of the user's hands and fingers onto the scene. These techniques were extended by Piekarski and Thomas [4] for direct manipulation.

Bowman's CDS [9] used object extrusion determined by intersecting points against a ground plane with a laser pointing technique. Leveraging the ground plane is a very useful technique, and this is especially true when operating on large virtual objects in an outdoor setting. Wither et al. [10] used aerial photographs to aid in the placement of AR annotations. Their approach overcomes a problem of AR user interfaces always being in a first person perspective. Although viewing the data on a static aerial photograph from a bird's eye view is not strictly AR, the method allows the user to manipulate the data from a different perspective and frame of reference.

The Tinmith system is an outdoor AR wearable computer system in the form of a belt mounted computer system, a video see-through head-mounted display, and pinch gloves input. Tinmith supports a range of 3D modeling techniques. Pinch gloves are used as input devices, with fiducial markers placed on the thumbs for cursor manipulation. The menu system is located on both left and right lower corners of the display with 10 options available at any time, each of which is mapped directly to the fingers on the corresponding pinch glove [1].

3. Limitations

Image plane techniques as implemented by Pierce et al. [8] and Piekarski and Thomas [4] have a number of limitations. Image plane techniques are 2D (x, y) in nature, and have no real ability to work with depth (z). The 2D interactions are restricted to 5DOF, two for

translate (x, y), two for scale (x, y), and one for rotate (z). The implementations to date are free hand manipulations, and therefore have the same problems with imprecision as other free hand techniques.

The Pierce et al. (original) image plane techniques were developed for virtual reality; incorporating precise 6 DOF tracking system and in some cases data glove sensors. In both the original and Tinmith versions, the user is required to keep their head very still or errant information is passed onto the interaction task.

As a means of examining the limitations and virtues of image plane techniques, we will explore a simple example task: the placement of a picnic table manipulated to be co-located with a physical one. The user first determines the physical object to model, and then selects a suitable 3D model from a menu to represent the picnic table. The user then performs the following operations on the graphical model: 1) coarse positioning, 2) rotation of the object around a normal vector to the ground to align the major axes of the graphical object, 3) perform fine placement, 4) perform coarse scaling, 5) when the graphical object is about the correct scale, fine scale manipulation is performed, and 6) iterate over these operations to achieve the desired outcome.

Using the picnic table example, the limitations and virtues with particular direct manipulation operations employing image plane techniques will now be explored. There are a number of problems in achieving step 1. A translation operation may only have movement of an object that is parallel to the image plane. This was extended to be constrained to move relative to other objects or coordinate systems with Piekarski and Thomas' AR working planes [11]. In order to change the object's position in the 3rd DOF, i.e. along the axis that is perpendicular to the head-relative AR working plane, the user has to physically move backward or forward. One disadvantage of this technique is the amount of physical walking the user performs to place an object in the required position. A second problem is that the graphical objects are not constrained to the ground plane.

Step 2 highlights a number of the problems with rotation. The image plane rotation technique has the user interact with the 2D projection of the objects on the AR working plane [11]. As a virtue, this technique employs the intuitive use of both hand cursors to specify the origin point and the rotation point. The limitation of this technique lies in the fact that the user can only rotate objects around an axis that is

perpendicular to the image plane, which does not include the vertical axis of the object (a normal vector to the ground). In step 2, the user is required to rotate the object around a normal vector from the ground, and the image plane manipulation techniques do not support this form of operation. The precise rotation commands would support this, but at the price of being unintuitive. There is a second problem when specifying the axis of rotation via the normal to the image plane. The image plane technique requires the user to exactly line up a normal vector of the image plane with the desired axis. The difficult to achieve the may cause the object to rotate about multiple axis at once.

In step 3, the current image plane techniques with precise movement commands works quite well for fine translations. This is where image plane techniques allow the user to make use of their natural ability to “line objects up”. Viewing along the axis of the object enables the user to visually inspect the final outcome while performing the translation operations. The drawback is the user must walk around the object to manipulate the different axes.

Problems with scaling are highlighted in step 4. Image plane scaling is performed with one control point and one manipulation point or relative distance between cursors. Unless perfectly aligned with the object, scaling is with at least two axes of the object, similar to the multiple axes problem with rotation. In step 5, fine-grain scaling is suitably supported via precise scaling.

4. Object manipulation techniques

Only limited implementation of image plane object manipulation including rotation, translation and scaling is supported by current Tinmith system. It has been extended with the following four 3D object manipulation techniques: Revolve, Xscale, Pull/Push and Gravitise. These operations have been constrained to be optimal for the context of manipulating large graphical objects in an outdoor setting. Designed to rely only on 2DOF input devices and a menu system, the four techniques are applicable to most AR systems.

4.1. Rotation techniques

The Revolve technique allows the user to rotate an object about one of its own coordinate axes, X, Y or Z as specified in the scene graph. The Tinmith menu shall display three options of X, Y or Z, upon selection of the object. The default axis is Z that is normal to

the ground plane, see Figure 1, considering that most large graphical objects we have dealt with are a representation of physical objects, and have a natural up orientation. The most common rotation is around an axis normal to the ground plane, which is not possible with the image plane metaphor. The X and Y axes are included for completeness.

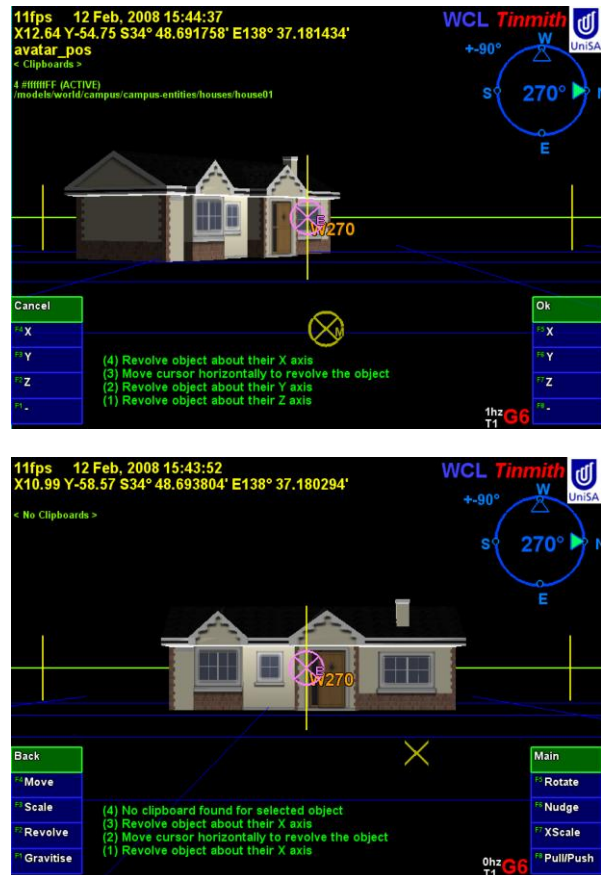


Figure 1. Before (top) and after (bottom) Revolve in the Z axis

The user moves the hand cursor horizontally in order to rotate the selected object about the selected axis. The menu options are available on both the left and the right hand menu, catering for left or right handed users. This approach, however, is limited to being a one-handed operation, without the ability to choose the control point of rotation. Although the use of two hands for object manipulation has been shown to improve performance [12], we experienced discomfort after long periods of activity. We believe this is due to the user having to hold both hands in front of the camera. The main interaction of the

Revolve technique is performed only with the dominant hand in view of the camera, while menu selection of X, Y or Z axes is supported by the non-dominant hand, out of camera view. Over long periods of interaction, user's weariness is reduced.

The user is able apply successive rotations to the object. This makes accurate rotation of any axis of the object and thereby any orientation achievable, by subsequently applying different rotations.

4.2. Scaling techniques

The Xscale technique supports scaling along the axes of the object's coordinate system. The default is to scale all three axes at once, as this has been the most common mode of operation. The three scaling axes are locked together to maintain aspect ratios, as in image editors. Objects are constrained to being above the ground during scaling operation. The user operates the Xscale technique in the same fashion as the Revolve.

4.3. Translation techniques

We have two solutions for the coarse movement of objects, Pull/Push for movements normal to the image plane and Gravitise for objects not remaining on the ground plane. A precise movement (nudge command in Tinmith) performs an individual exact movement command in one direction (up/down, left/right, back/forth). Each movement is a selectable fixed distance, requiring a single trigger of the menu system for every instance of movement for the object. The Pull/Push technique is an enhancement of the image plane move technique with a "fishing reel" technique allowing virtual objects to be translated towards and away the users [2]. This technique inherits the positives of image plane movement operations, including: intuitive control by the movement of the cursor on the screen, and head-relative. For example the user may move an object by turning their head, and perform a Pull or Push at the same time to move the object closer or further away. The rate of incremental movement is the frames per second of the graphical updates while the Pull or Push menu is active. If the increment is +2 the object will be pushed away from the user at the rate of 2m each per increment. Likewise, if the increment amount is -2, object will be moving closer at the rate of 2m. The increment and rate amount are under user control via the menu. If the increment is 0, there is not translation towards or away, and the operation is the same as the image plane movement.

During object manipulation, the user may place an object into either a 'floating' above or 'sinking' underground state, thus rendering an unrealistic situation. This is true for translate, scale, and rotate operations. Tinmith employs virtual shadows to indicate the virtual object is above or below the ground plane. When portions of an object are below the ground plane, this technique may not provide proper cueing. Gravity is a common technique [13] to allow objects to settle onto surfaces. We implemented Gravitise, a snap like technique, to quickly correct such an unreal situation. A user is able to lower a floating object or raise an underground object, so that the lowest point of the object is always at ground level. The object will still keep its orientation before it is raised or lowered, as real gravity has not been implemented. The user selects the required object while executing the Gravitise menu option in order to raise or lower the object to the ground plane.

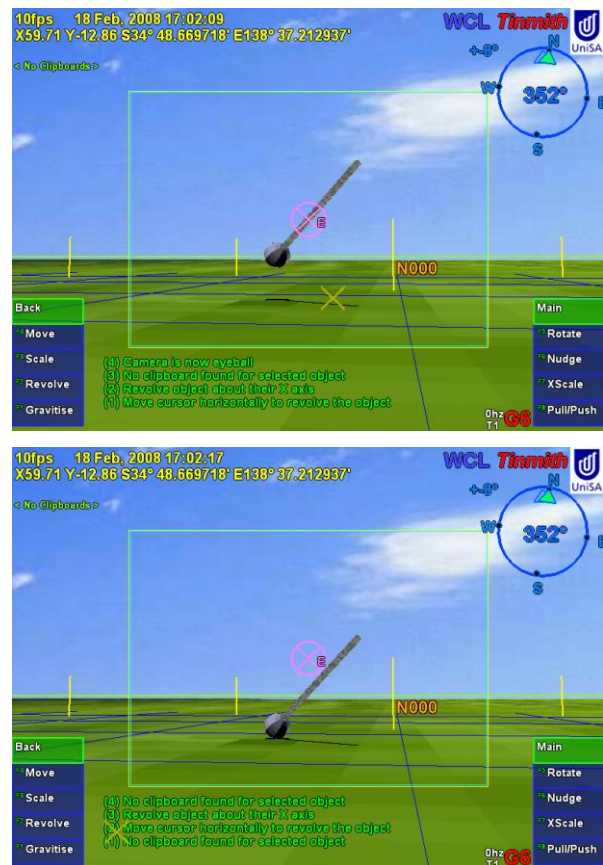


Figure 2. Before (top) and after (bottom) a Gravitise operation

5. Conclusion

We have investigated four new manipulation techniques to augment current image plane techniques to perform more natural 3D direct manipulation techniques in an AR environment. These operations are generally constrained to the ground, with the follow attributes, 1) rotations are about a normal vector to the ground, 2) scaling is about the object's coordinate system, 3) translations are along the ground, and 4) no operation will place any part of the graphical below the ground plane. The four 3D object manipulation techniques are Revolve, Xscale, Pull/Push and Gravitise. Although these techniques are not new, their application in the proper coordinate system allows a more natural interaction for the user over image plane techniques.

6. Acknowledgements

We would like to thank Wayne Piekarski and Ben Avery for all their help with understanding the inner workings of Tinmith. We would also like to thank the WCL with proofreading the paper for us.

7. References

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