Precise Manipulation at a Distance in Wearable Outdoor Augmented Reality

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Abstract

In this paper we present our research directions on the issue of precise manipulation and modeling interactions for outdoor augmented reality. We also discuss the related issues of action at a distance techniques and the relationship between virtual and physical objects. Techniques for action at a distance are limited by the accuracy of the sensors, as well as the efficiency of tracking solution. We examine possible solutions for precise interactions including symbolic entry of data, grid snapping, and alignment operations. Grid snapping and relative snapping are also discussed as ways to improve precision.

Keywords: User Interaction, Direct Manipulation, Outdoor AR.

Index Terms: H.5.2 [Information Interfaces and Presentation]: Graphical User Interfaces—Input Devices and Strategies; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

1 Introduction

Our investigation into augmented reality has focused on outdoor AR on wearable computer. Tinmith wearable computer system is the main platform for our research, employing video see-through head-mounted display with belt-mounted computer.

We are motivated to find solutions to the question of “How to perform precise interactions in outdoor AR?” Successful solutions are beneficial to AR modeling in the creation and modification of high-fidelity and accurate models using AR, without the need for desktop-based CAD applications. Precise interactions also help to fine-tune the virtual part of AR via translation, scale, and rotation operations. For example, the user could scale a virtual building model to an exact size as specified in a building plan. We have recently been successful at precise manipulation of outdoor model refinements, using a handheld 3DOF orientation tracked single-point laser rangefinder [1].

Other issues arising from the main problem of precise manipulation include techniques for interaction at a distance in outdoor AR and relationship between the virtual and the real world. In an outdoor environment, it is common that manipulation tasks are generally out of arms reach, due to the inherently large scope of the environment and the size of outdoor models, such as buildings or street furniture. Research efforts in action at a distance interactions have been mainly limited in virtual reality, which does not directly apply to augmented reality, considering that physical world imposes more constraints on AR than VR.

Unlike desktop-based CAD applications, precise operations, such as affine transformation or modeling tasks, are not fully supported in outdoor AR, due to various restrictions on input devices and sensors noise. Further challenge is posed by the lack of suitable and robust coordinate systems for the combination of the virtual and physical environment. Such a coordinate system would assist in correctly register the virtual world against the real one.

1.1 Precise Manipulation

Precise manipulation allows a user to transform a graphical object at a much higher level of accuracy to that of free hand manipulation. Without robust hand tracking, free hand manipulation is prone to errors and imprecision.

1.1.1 Symbolic entry of the data

Desktop-based CAD applications use menus, dialogs, or toolbars to allow user to input exact measurement data via keyboard. Text entry in wearable computer could either be a forearm mounted keyboard [2], gesture-based hand input [3], or speech recognition [4]. Even though forearm keyboard is preferred over virtual keyboard [2], it requires the use of both hands. Gesture-based approach and speech recognition while walking suffer a higher error rate than pen-based solution [3, 4].

1.1.2 Snapping to a grid

Snapping the objects to an axis-aligned grid eliminates errors due to trackers noise or free hand operations. Grid snapping is a common feature for most 2D desktop-based CAD modeling system. Precision is also achievable for 3D grid snapping [5]. However, the operations can only be as precise as the grid is small. This leads to another problem of how to precisely resize the grid resolution.

1.1.3 Alignment operations

Instead of attaching to vertices of the grid in grid snapping, virtual objects could be aligned with one another or with other physical objects, via vertices, edges, and facets. Such alignment requires correct registration of virtual object to the real world. Depending on the task at hand, the virtual object could be either registered using a world coordinate system, or attached relatively to the physical objects.

1.2 Action-at-a-distance

It is well known action-at-a-distance suffers from tracker noise. A number of solutions have been examined for indoor VR systems, such as worlds in miniature [6], voodoo dolls [7], scaled manipulation [8] and scale world zoom [9]. Although a number of worlds in miniature interfaces have been developed for indoor and outdoor AR [10], these have focused on the relationship within the virtual domain only.

Scale world zoom is not appropriate for AR because the AR information is registered to the physical world. The use of scale world zoom would break the one-to-one relationship between the virtual and physical worlds. Because people can not physical scale up, the virtual information would have virtual scale down.

Outdoor augmented reality has inherent problems with action-at-a-distance due to the quality of the sensors for 6DOF tracking.

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While indoor tracking can obtain millimeter tracking accuracy, outdoor tracking is left to GPS or vision based sensing systems. At the very best this would be 2-3 centimeter accuracy. While orientation sensors themselves are quite accurate, the act of physical walking adversely affects the accuracy of these sensors. A good solution for the relative tracking of a user’s hands for wearable outdoor augmented reality systems is still an open research question. The tracking of a user’s hand is a key technology for many of the action-at-a-distance VR solutions.

2 RELATIONSHIP BETWEEN VIRTUAL AND PHYSICAL OBJECTS

In order to perform precise manipulation, a coordinate system or reference framework for virtual models is required. While outside, virtual objects can be relative to some world coordination systems, such as GPS, or these virtual objects can be relative to a physical object, such as a building.

2.1 World Coordinate Relationships

The use of placing objects with some world coordinate system by itself places the virtual object in some absolute position and orientation. This form of a coordinate system makes for a quite straightforward implementation and a unified coordinate system. Employed by itself, it can only support an open loop tracking framework to specify the relationship between virtual and physical objects.

GPS is commonly used as the world coordinate system for virtual objects in AR. Physical objects inherently have a set of associated GPS coordinates. By embedding GPS coordinates into virtual objects, outdoor AR system is able to correctly position the virtual object into the physical world. Thus the relationship between virtual and physical objects is specified, within the unified Global Position System. GPS tracking of user position is required in combination with this world coordinate system.

2.2 Relative Relationships

The position and orientation of virtual objects can be specified via a relationship between each of them. Using the world coordinate of the physical and a transformation from that object, the position and orientation of a virtual object can be specified. For example a particular window can be augmented with a set of highlighting surrounding it. The location of the augmentation is specified by its relationship to the building. This relationship can be an offset from the physical structure. This enables the user to view the virtual object from different view points.

3 SNAPPING AND CONSTRAINED MANIPULATION IN OUTDOOR AR

Snapping is a common approach to precise manipulation, and 3D grid snapping has been shown to improve precision [5]. However, is grid snapping applicable in an outdoor AR environment? The challenge of suitable input devices still remains, as well as interaction techniques for snapping operations at a distance. The appropriate visualization for snapping operation also requires further consideration. Rendering of a 3D grid provide obvious indication to the user that grid snapping is effective, but might be obtrusive for immersive AR. Mechanism for determining suitable grid size requires further research. A solution could be suggested to snap objects along its own coordinate axes, instead of a global grid. The pixels representing the objects could be used as snapping points.

Snapping in outdoor AR could leverage the physical world, which is a unique feature of AR systems, as opposed to VR. Instead of being snapped to a grid structure, virtual objects could also be relatively attached or constrained to physical objects, by vertices, edges or facets. An example of such relative constraints include a virtual door being attached to a wall of a physical building, or a virtual fence running parallel at a fixed distance to the walls of a physical building. Relative snapping could also be used between virtual objects. For example, a virtual gate could be fixed onto the virtual fence in the previous example. This technique could also be referred to as constrained manipulation.

The techniques of specifying such relative relationships between virtual and physical objects are open for further research. Baillot et al. [11] presents the techniques of creating points in space as an intersection between a virtual ray and another ray, or a plane/surface. Using a laser rangefinder, Wither et al. [12] proposes techniques to affix virtual annotations to physical buildings, with correct orientation. A hybrid solution could be proposed, in which a virtual replica of the physical object is registered at the exact location of its real world counterpart, using world coordinate system, so that other virtual objects could be positioned relative to the virtual replica.

Snapping in outdoor AR, whether grid snapping or relative snapping with physical objects, assists in precise manipulation of virtual objects. By applying snapping constraints on virtual objects, manipulation errors caused by tracker devices or caused by free hand movement could be eliminated.

REFERENCE


