Chapter 3.14
Real-Time 3D Design Modelling of Outdoor Structures Using Mobile Augmented Reality Systems

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ABSTRACT

This chapter presents a series of new augmented reality user interaction techniques to support the capture and creation of 3D geometry of large outdoor structures. Named construction at a distance, these techniques are based on the action at a distance concepts employed by other virtual environments researchers. These techniques address the problem of AR systems traditionally being consumers of information, rather than being used to create new content. By using information about the user's physical presence along with hand and head gestures, AR systems can be used to capture and create the geometry of objects that are orders of magnitude larger than the user, with no prior information or assistance. While existing scanning techniques can only be used to capture existing physical objects, construction at a distance also allows the creation of new models that exist only in the mind of the user. Using a single AR interface, users can enter geometry and verify its accuracy in real-time. Construction at a distance is a collection of 3D modelling techniques based on the concept of AR working planes, landmark alignment, constructive solid geometry operations, and iterative refinement to form complex shapes. This chapter presents a number of different construction at a distance techniques, and are demonstrated with examples of real objects that have been modelled in the physical world.

INTRODUCTION

Current research in AR applications has focused mainly on obtaining adequate tracking and registration and then developing simple interfaces to present display information to the user (Azuma

et al., 2001). One important problem that has not been fully addressed is the authoring of the content that is displayed to the user. Since most AR systems are being used simply as a visualisation tool, the data is prepared offline with standard editing tools and then transferred to the AR system. While ourselves (Piekarski & Thomas, 2003) and others (Baillot, Brown, & Julier, 2001) have started to investigate outdoor AR modelling, this work is very preliminary and incomplete. Brooks states that one of the still unsolved problems in VR is the creation and capture of 3D geometry (Brooks, 1999), which is also relevant for AR models. To develop content for AR systems, we have developed a number of techniques collectively termed *construction at a distance* (CAAD). These techniques use the AR system itself to capture the 3D geometry of existing structures in the physical world, and create new 3D models of virtual objects that do not yet exist. CAAD makes use of the AR working planes and landmark alignment techniques presented in a previous paper (Piekarski & Thomas, 2004), and builds higher-level operations to perform the capture and creation of 3D models. While some of these CAAD techniques have been presented previously (Piekarski et al., Thomas, 2003), in this chapter, I describe new body-relative plane techniques and expand on previous work with a discussion of how AR working planes are used in the implementation.

The introduction section in this chapter describes the advantages of these modelling techniques over other existing methods. Next, the techniques are described over three sections and how they are implemented on a mobile outdoor AR system. An overview of the user interface that supports these techniques is discussed, followed by a discussion on the use of different viewpoints to support situational awareness. The chapter is then concluded with a discussion of possibilities for collaboration, and how the accuracy of the techniques are affected by various environmental factors.

Supplement Physical Capture L imitations

The purpose of these techniques is not to replace existing object capture methods, such as image-based reconstruction (Debevec, Taylor, & Malik, 1996) or laser scanning. These techniques are highly accurate and can produce excellent results given the proper conditions. However, there are a number of limitations and CAAD provides an alternative to existing techniques in the following ways:

- A human operator is capable of accurately estimating the geometry of planar shapes, even when partially occluded by other objects in the environment. When trees occlude the edges of a building, a human can estimate the layout based on incomplete visual information and a knowledge of the volumetric properties of buildings.
- The eye is a highly accurate input device capable of aligning along the walls of buildings (Cutting & Vishton, 1995; Piekarski et al., 2004). Accurate modelling is still possible when working from a distance and direct access to the object is not available.
- Existing capture techniques (Debevec et al., 1996) have a fixed operation time no matter what the complexity of the scene is, whereas in my methods the human can judge the most appropriate level of detail. In many cases, the user wants to create only simple shapes such as boxes to represent buildings, and so these techniques are ideal for quick operations.
- Existing techniques require the object to already exist so it can be captured, whereas my methods allow the human to specify any geometry desired. My techniques allow the creation of new shapes that do not physically exist and may be used to plan future construction work.