Chapter 1
A Client/Server Architecture for Augmented Assembly on Mobile Phones

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ABSTRACT

In this chapter, the authors present a client/server augmented reality (AR) system for viewing complex assembly models on mobile phones. Complex model information is located on a PC, which takes care of all of the heavy AR tracking and rendering computation. A camera phone is used as a client to show this information, augmented on still images as an animated view. The mobile phone interface also supports correct masking of the assembly pieces as they come together, as well as a graphics only viewing mode intended for better understanding of the assembly process. In addition to describing the mobile augmented assembly system, the authors present results from two pilot user studies evaluating elements of the user interface.

INTRODUCTION

In order to remain competitive, today's industry is employing a growing number of product variations with shorter and shorter life cycles, requiring efficient ways to handle the production planning and processing. Industrial assembly line workers face more and more complex tasks and an increasing memory load is posed by the new production needs. Experienced workers may be able to handle several product variants at the same time, but new workers require training and guidance to handle the work tasks. Related activities such as maintenance and repair also require a lot of know-how of complex products.

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Guidance in assembly tasks is commonly provided by using printed blueprints or other documents. However, these are mainly two dimensional images or text while the real assembly task is three dimensional, making the relationship between parts hard to understand. Computer based technologies have been developed such as electronic guides, multimedia training material and interactive documents. However, these typically require the user to turn away from the assembly task to study a computer screen separate from the workspace.

In our research we explore how augmented reality (AR) technology can be used to provide more intuitive guides to assist with assembly, repair and training tasks. With AR technology, synthetic objects can be merged with the user's view of the real world so that the user can perform the assembly task without needing to look at a separate screen. The virtual objects appear in the correct position so that AR enables the creation of realistic looking 3D animated assembly "manuals."

Other researchers have developed prototype AR systems for supporting assembly tasks. These are typically based on head mounted displays (HMDs) connected to desktop or wearable computers. However, wearable computers are relatively expensive, they have a short battery life, and taking them into a harsh industrial environment is not always possible. Head mounted displays can also be bulky, have safety issues, and many workers are reluctant to wear them.

To overcome these disadvantages, we are interested in developing a reliable mobile phone based AR assembly system. Today's mobile phones have fast processors, significant memory, 3D CAD computer graphics support, and high resolution displays. They contain various accessories that can be used for developing mobile AR applications such as good quality cameras, connectivity by Bluetooth, WLAN and GPRS, and various additional sensors e.g. gyrometers. Mobile phones are widely available, they are unobtrusive, robust, and have relatively long battery life.

In this article we present the augmented reality assembly system we developed for mobile phones. We first review related work, and then describe our prototype system based on a mobile phone client and PC server architecture. Next we provide results from two user studies identifying strengths and weaknesses of the system. In the final sections, we provide directions for future work and conclusions.

BACKGROUND

Several other research groups have explored the use of AR for assisting with real world assembly tasks. One of the earliest of these efforts was the augmenting of wire bundle harness at Boeing (Caudell & Mizell, 1992), using wearable PCs with head mounted displays attached. With this interface, Boeing engineers were able to superimpose virtual images over the real world showing which real wires should be bundled together. Later, researchers developed AR assisted assembly applications for putting a lock into a car door (Reiners et al., 1998), for guided assembly application (Sharma & Molineros, 1997), and assembly of architectural structures (Webster et al., 1996), among others. In most cases, these AR assembly interfaces were based around desktop computers and the user needed to wear a head mounted display to view the AR content.

User studies have been conducted to compare performance with traditional AR assembly interfaces to using manuals or other computer based technology. For example, Tang et al. (2003) compared the effectiveness of using (1) a see-through HMD based AR, or (2) a printed manual, or (3) computer aided instruction (CAI) on a monitor, or (4) CAI in a see-through HMD with non-spatially registered information for an assembly task. In this case, the task was to complete a complex toy brick assembly task that had 56 steps. They found that subjects completed assembly in all three computer aided conditions (1,3,4) significantly

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