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Using Mobile Code to Create Ubiquitous Augmented Reality

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Abstract. Augmented reality systems supplement reality by adding virtual objects into a real-world view. In this article, we describe a flexible mobile code approach for implementing ubiquitous, active, and mobile augmented reality systems. We will concentrate primarily on solving the problem of how to acquire the data for the virtual objects in a way that will be flexible and expandable enough to be used in ubiquitous computing. To clarify the concepts and to illustrate our current research status, we will present an example system that provides virtual user interfaces for various real-world objects. We also hope that these interfaces provide useful insights to the possibilities that our approach can provide. This article suggests that the mobile code approach offers a relatively simple solution that is flexible, scales well, and does not require the computing equipment attached to the real-world objects to be excessively complicated. We can use the same approach in applications that provide only simple descriptions of the real-world objects and in complex applications that allow the user to manipulate real-world objects via virtual user interfaces that exist only in augmented reality. Our approach also supports active augmented reality, in which the virtual objects can react to the real-world events.

Keywords: augmented reality, mobile code, ubiquitous computing, mobile computing

1. Introduction

This article describes a flexible mobile code approach that we can use to create ubiquitous and active Augmented Reality (AR) in mobile computing. We will concentrate primarily on outlining our solution to the problem of how to acquire the data used to augment the real-world and how to construct an AR system so that it will be flexible and expandable enough to be used in truly ubiquitous computing environments: environments where the computer-controlled objects are an integral part of our everyday life [40]. We will outline the hardware issues related to constructing such an AR system only briefly.

The concept *augmented reality* is used to describe a system that supplements reality by adding virtual objects into the real-world view of the AR system user. Ideally, these virtual objects appear to coexist with the real objects in the same space [2]. In other words, the user is able to see the world as a combination of both real and virtual objects. This is usually achieved by using Head-Mounted Displays (HMDs) that can even be integrated into eyeglasses [32]. Another approach is to use a hand-held device to operate as a magnifying glass [28]. The user can look through the device and inspect the combination of the real-world and annotated data.

In AR, virtual objects can be annotations that we can use to identify the real-world objects [28,34] or that help us to navigate in unfamiliar environments [28]. Likewise, virtual objects can be instructions that explain to us how we can use the real-world objects or how we should operate in exceptional situations. For example, Feiner et al. [9] describe a system that helps the user to maintain a printer. Moreover, we can also use virtual objects as avatars to implement remote communication among people in a group [3]. Finally, the virtual objects can also be Virtual User Interfaces (VUIs) that allow us to interact with the real-world objects via the user interfaces that exist only in AR, as envisioned in [26]. Augmented reality is also used for example in medical applications [35], teleoperation [23], Computer Supported Collaborative Work (CSCW) [4,28], architecture and structural engineering [39], and entertainment [25].

Current AR systems are, however, usually designed for a specific application in mind; thus the techniques they use are not suitable if applied in ubiquitous computing. In ubiquitous computing, the same AR system should be usable in applications that range from applications providing only simple descriptions of the real-world objects to complex applications allowing the user to manipulate real-world objects via virtual user interfaces that only exist in augmented reality. Simply put, the AR system should place minimal restrictions on the possible AR applications in which it could be used. For example, the AR system should support active augmented reality in which it would be possible for the virtual objects to react to external events, such as manipulation or user movement. Likewise, the virtual objects should also be able to communicate with the real-world objects in which they are attached. Naturally, the AR system should also support mobile computing.

Moreover, to be usable in ubiquitous computing, we feel that the AR system should only be required to display augmented reality by using the location of the real-world objects in its environment. In other words, the AR system should not need to identify various real-world objects, if not desired, as this may be problematic in ubiquitous computing. The AR system should also be able to use a simple technique to obtain the virtual object data. For example, the communication required to obtain the virtual object data should be local as much as possible, to enable maximal use of low-power communication devices, such as Bluetooth [12].

The approach we propose in this article relies on mobile code to implement the virtual objects in the AR system. For