# Chapter 2.16
# Lessons Learned in Designing Ubiquitous Augmented Reality User Interfaces

**Christian Sandor**
*Technische Universität München, Germany*

**Gudrun Klinker**
*Technische Universität München, Germany*

## INTRODUCTION

In recent years, a number of prototypical demonstrators have shown that augmented reality has the potential to improve manual work processes as much as desktop computers and office tools have improved administrative work (Azuma et al., 2001; Ong & Nee, 2004). Yet, it seems that the "classical concept" of augmented reality is not enough (see also http://www.ismar05.org/IAR). Stakeholders in industry and medicine are reluctant to adopt it wholeheartedly due to current limitations of head-mounted display technology and due to the overall dangers involved in overwhelming a user's view of the real world with virtual information. It is more likely that moderate amounts of augmented reality will be integrated into a more general interaction environment with many displays and devices, involving tangible, immersive, wearable, and hybrid concepts of ubiquitous and wearable computing. We call this emerging paradigm ubiquitous augmented reality (UAR) (MacWilliams, 2005; Sandor, 2005; Sandor & Klinker, 2005).

It is not yet clear which UAR-based human-computer interaction techniques will be most suitable for users to simultaneously work within an environment that combines real and virtual elements. Their success is influenced by a large number of design parameters. The overall design space is vast and difficult to understand.

In Munich, we have worked on a number of applications for manufacturing, medicine, architecture, exterior construction, sports, and entertainment (a complete list of projects can be found at http://ar.in.tum.de/Chair/ProjectsOverview). Although many of these projects were designed in the short-term context of one semester student courses or theses, they provided insight into different aspects of design options, illustrating trade-offs for a number of design parameters. In this chapter, we propose a systematic approach toward identifying, exploring, and selecting design parameters at the example of three of our projects, PAARTI (Echtler et al., 2003), FataMorgana (Klinker et al., 2002), and a monitoring tool (Kulas, Sandor, & Klinker, 2004).

Using a systematic approach of enumerating and exploring a defined space of design options is useful, yet not always feasible. In many cases, the dimensionality of the design space is not known a-priori but rather has to be determined as part of the design process. To cover the variety of aspects involved in finding an acceptable solution for a given application scenario, experts with diverse backgrounds (computer science, sensing and display technologies, human factors, psychology, and the application domain) have to collaborate. Due to the highly immersive nature of UAR-based user interfaces, it is difficult for these experts to evaluate the impact of various design options without trying them. Authoring tools and an interactively configurable framework are needed to help experts quickly set up approximate demonstrators of novel concepts, similar to "back-of-the-envelope" calculations and sketches. We have explored how to provide such first-step support to teams of user interface designers (Sandor, 2005). In this chapter, we report on lessons learned on generating authoring tools and a framework for immersive user interfaces for UAR scenarios.

By reading this chapter, readers should understand the rationale and the concepts for defining a scheme of different classes of design considerations that need to be taken into account when designing UAR-based interfaces. Readers should see how, for classes with finite numbers of design considerations, systematic approaches can be used to analyze such design options. For less well-defined application scenarios, the chapter presents authoring tools and a framework for exploring interaction concepts. Finally, a report on lessons learned from implementing such tools and from discussing them within expert teams of user interface designers is intended to provide an indication of progress made thus far and next steps to be taken.

## BACKGROUND

In this section, we provide an overview of the current use of UAR-related interaction techniques and general approaches toward systematizing the exploration of design options.

### User Interface Techniques for Ubiquitous Augmented Reality

User interfaces in UAR are inspired by related fields, such as virtual reality (VR) (Bowman, Kruijff, LaViola, & Poupyrev, 2004), attentive user interfaces (AUIs) (Vertegaal, 2003), and tangible user interfaces (TUIs) (Ishii & Ullmer, 1997). Several interaction techniques for VR have been adapted to UAR: for example the World-in-Miniature (Bell, Höllerer, & Feiner, 2002), pinch gloves for system control (Piekarski, 2002), and a flexible pointer to grasp virtual objects that are beyond arm's reach (Olwal & Feiner, 2003). The core idea of TUIs is to use everyday items as input and output simultaneously. This idea has also been applied to UAR (Kato, Billinghurst, Poupyrev, Tetsutani, & Tachibana, 2001; Klinker, Stricker, & Reiners, 1999; MacWilliams et al., 2003). Ideas from AUIs have been used in UAR interfaces by using head tracking (Olwal, Benko, & Feiner, 2003) and eye tracking (Novak, Sandor, & Klinker, 2004).