Applications of Mixed Reality

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Introduction

This thesis gives an overview of the author's scientific work in previous years. It reflects the author's ambition to develop applications of mixed reality which are beneficial to society as a whole or to specific groups of people. Providing and deploying high-end mixed reality hardware and software applications to multiple users and larger target groups finally raises questions of scalability, robustness, design and affordability of the technology involved. They trigger scientific questions and developments in return. All of these aspects will be touched in this work.

The first part of the introduction defines the scientific domain and various problems therein followed by a discussion of the author's contribution in this area. The individual publications that constitute the remainder of the thesis are briefly discussed and put in context.

Definitions

Since the area "Applications of Mixed Reality" – chosen as the title of this thesis – is very broad it is important to establish common terms in the beginning.

In order to classify virtual reality (VR) research Milgram and Kishino [1] published a taxonomy 15 years ago. Although the field widened and diversified over the years their work still provides a rough framework which helps to classify any work done in this area. We refer to the virtual continuum (Figure 1) as discussed in Milgram and Kishino's paper. The virtual continuum represents a continuous set of (infinite) possibilities between real environments and fully virtual environments (VEs). All environments within that range (except the extremes of fully real and virtual environments) are considered mixed realities.

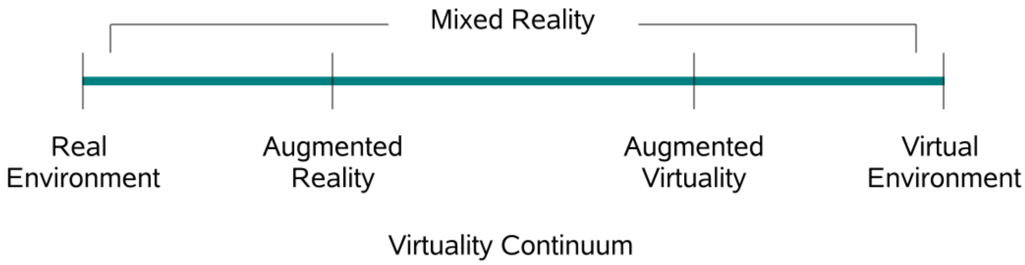

Figure 1: The Virtuality Continuum

Further on the authors specify and classify hardware and software environments within the virtual continuum and define six classes of "hybrid display environments". In a second paper [2] they add a seventh class. Nevertheless given the broad range of

virtual reality hardware and setup variations available today it is neither always clear nor easy to identify into which category a specific setup falls.
Related to Milgram's taxonomy many applications presented in this thesis belong to class 6 (defined in [1]) which states

> "6. Completely graphic but partially immersive environments (e.g. large screen displays) in which real physical objects in the user's environment play a role in (or interfere with) the computer generated scene, such as in reaching in and "grabbing" something with one's own hand […]."

They mention further

> "We note in addition that Class 6 displays go beyond Classes 1, 2, 4 and 5, in including directly viewed real-world objects also. As discussed below, the experience of viewing one's own *real* hand directly in front of one's self, for example, is quite distinct from viewing an image of the same real hand on a monitor, and the associated perceptual issues (not discussed in this paper) are also rather different. Finally, an interesting alternative solution to the terminology problem posed by Class 6 as well as composite Class 5 AR/AV displays might be the term *"Hybrid Reality"* (HR), as a way of encompassing the concept of blending many types of distinct display media."

Milgram and Kishino described three additional dimensions that distinguish different mixed reality systems: Extent of world knowledge (i.e. degree of knowledge of the real world by the application), reproduction fidelity (visual quality) and extent of Presence metaphor. Presence in short can be defined as a subjective phenomenon of the sensation of being in a virtual environment [3, 4]. It is the most researched dimension of the three and of high importance when designing new applications [5]. Different concepts and interpretations of presence have been discussed [5]. Whereas some applications require full presence of users others might require shared and equal awareness of the real and virtual e.g. in educational applications where teachers are outside the VE guiding students. With different Mixed Reality (MR) setups these variations can be achieved while maintaining a high level of presence in all cases. Appropriate and corresponding examples of application areas and target groups will be mentioned later.

Our work fulfills as well Azuma's definition of Augmented Reality (AR) [6], who defines AR as systems that have the following three characteristics:
1) Combine real and virtual
2) Interactive in real time
3) Registered in 3-D
The presented research covers a wide range of environments which are always interactive in real time but fulfill items 1 and 3 to varying degrees. The variety of systems is better encompassed by the term Mixed Reality or even Hybrid Reality – the latter term was not in use after Milgram and Kishino coined it.

System Architecture

A wide variety of MR hardware and software setups are imaginable and have been built in the past. However all share a common general system architecture. The five key elements of an MR system [7] comprise input and output devices whose spatial position and orientation might be tracked, a computing platform with a powerful

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