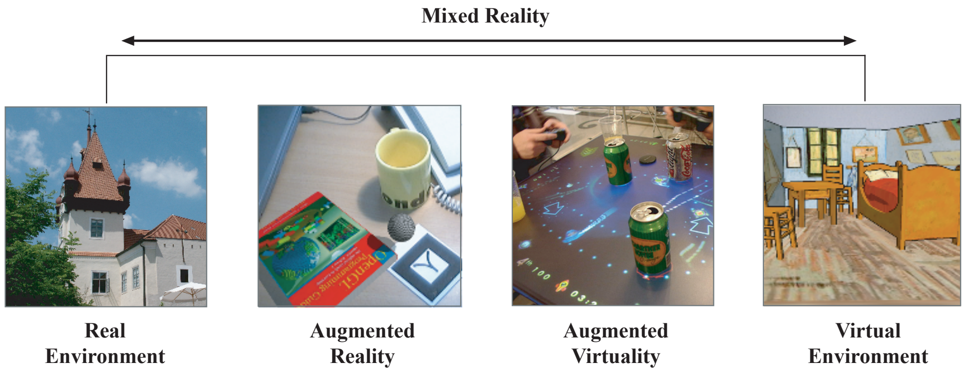
Preface

Motivation

Augmented reality (AR) research aims to develop technologies that allow the real-time fusion of computer-generated digital content with the real world. Unlike virtual reality (VR) technology, which completely immerses users inside a synthetic environment, augmented reality allows the user to see three-dimensional virtual objects superimposed upon the real world. Both AR and VR are part of a broader reality–virtuality continuum termed "mixed reality" (MR) by Milgram and Kishino (1994) (see Figure 1). In their view, a mixed reality environment is "one in which real world and virtual world objects are presented together within a single display anywhere between the extrema of the virtuality continuum."

Figure 1. Reality-virtuality continuum (Milgram & Kishino, 1994)



State of the Art

Mixed reality technology can enhance users' perception and interaction with the real world (Azuma et al., 2001), particularly through the use of augmented reality. Using Azuma's (1997) definition, an AR system has to fulfill the following three characteristics:

- It combines both the real and virtual content,
- The system is interactive and performs in real-time, and
- The virtual content is registered with the real world.

Previous research has shown that AR technology can be applied in a wide range of areas including education, medicine, engineering, military, and entertainment. For example, virtual maps can be overlaid on the real world to help people navigate through the real world, medical imagery can appear on a real patient body, and architects can see virtual buildings in place before they are built.

Analyzing the proceedings of the leading AR/MR research symposium (The International Symposium on Mixed and Augmented Reality), we can identify several significant research directions, including:

- **Tracking techniques:** How to achieve robust and accurate overlay of virtual imagery on the real world
- **Display technologies:** Head mounted, handheld, and projection displays for AR
- **Mobile augmented reality:** Using mobile computers to develop AR applications that can be used in outdoor settings
- **Interaction techniques:** Methods for interacting with AR content
- Novel **augmented reality applications**

Overview

Although the field of mixed reality has grown significantly over the last decade, there have been few published books about augmented reality, particularly the interface design aspects. *Emerging Technologies of Augmented Reality: Interfaces and Design* is written to address this need. It provides a good grounding of the main concepts of augmented reality with a particular emphasis on user interfaces and design and practical AR techniques (from tracking-algorithms to design principles for AR interfaces).

A wide range of experts from around the world have provided fully peer reviewed chapters for this book. The targeted audience is computer-literate readers who wish to gain an initial understanding of this exciting and emerging technology. This book may be used as the basis for a graduate class or as an introduction to researchers who want to explore the field of user interfaces and design techniques for augmented reality.

Book Structure and Use

This book is structured around the following four key topics:

- Technologies that support augmented reality
- Augmented reality development environments
- Interface design and evaluation of augmented reality applications
- Case studies of augmented reality applications

The first section, **Introduction to Technologies that Support Augmented Reality**, provides a concise overview of important AR technologies. These chapters examine a wide range of technologies, balanced between established and emerging new technologies. This insight provides the reader with a good grounding of the key technical concepts and challenges developers face when building AR systems. The major focus of these chapters is on tracking, display, and presentation technologies.

In **Chapter I**, mixed reality applications require accurate knowledge of the relative positions of the camera and the scene. Many technologies have tried to achieve this goal and computer vision seems to be the only one that has the potential to yield non-invasive, accurate, and low-cost solutions to this problem. In this chapter, the authors discuss some of the most promising computer vision approaches, their strengths, and their weaknesses.

Chapter II introduces spatially adaptive augmented reality as an approach to dealing with the registration errors introduced by spatial uncertainty. The authors argue that if programmers are given simple estimates of registration error, they can create systems that adapt to dynamically changing amounts of spatial uncertainty, and that it is this ability to adapt to spatial uncertainty that will be the key to creating augmented reality systems that work in real-world environments.

Chapter III discusses design and principles of head mounted displays (HMDs), as well as their state-of-the-art examples, for augmented reality. After a brief history of head mounted displays, human vision system, and application examples of see-through HMDs, the author describes the design and principles for HMDs, such as typical configurations of optics, typical display elements, and major categories of HMDs. For researchers, students, and HMD developers, this chapter is a good starting point for learning the basics, state of the art technologies, and future research directions for HMDs.

Chapter IV shows how, in contrast to HMD-based systems, projector-based augmentation approaches combine the advantages of well-established spatial virtual reality with those of spatial augmented reality. Immersive, semi-immersive, and augmented visualizations can be realized in everyday environments—without the need for special projection screens and dedicated display configurations. This chapter describes projector-camera methods and multi-projector techniques that aim at correcting geometric aberrations, compensating local and global radiometric effects, and improving focus properties of images projected onto everyday surfaces.

Mobile phones are evolving into the ideal platform for portable augmented reality. In **Chapter V**, the authors describe how augmented reality applications can be developed for mobile phones and the interaction metaphors that are ideally suited for this platform.

Several sample applications are described which explore different interaction techniques. The authors also present a user study showing that moving the phone to interact with virtual content is an intuitive way to select and position virtual objects.

In **Chapter VI**, the authors describe how to compute a 2D screen-space representation that corresponds to the visible portions of the projections of 3D AR-objects on the screen. They describe in detail two visible surface determination algorithms that are used to generate these representations. They compare the performance and accuracy tradeoffs of these algorithms, and present examples of how to use our representation to satisfy visibility constraints that avoid unwanted occlusions, making it possible to label and annotate objects in 3D environments.

The second section, **Augmented Reality Development Environments**, examines frameworks, toolkits, and authoring tools that are the current state-of-the-art for the development of AR applications. As it has been stated from many disciplines, “Content is King!” For AR, this is indeed very true and these chapters provide the reader with an insight into this emerging important area. The concepts covered vary from staging complete AR experiences to modeling 3D content for AR.

AR application development is still lacking advanced authoring tools—even the simple presentation of information, which should not require any programming, is not systematically addressed by development tools. In **Chapter VII**, the authors present APRIL, the augmented presentation and interaction language. APRIL is an authoring platform for AR applications that provides concepts and techniques that are independent of specific applications or target hardware platforms, and should be suitable for raising the level of abstraction at which AR content creators can operate.

Chapter VIII presents DART, The designer’s augmented reality toolkit which is an authoring environment for rapidly prototyping augmented reality experiences. The authors summarize the most significant problems faced by designers working with AR in the real world and use DART as the example to guide a discussion of the AR design process. DART is significant because it is one of the first tools designed to allow non-programmers to rapidly develop AR applications. If AR applications are to become mainstream then there will need to be more tools like this.

Augmented reality techniques can be used to construct virtual models in an outdoor environment. **Chapter IX** presents a series of new AR user interaction techniques to support the capture and creation of 3D geometry of large outdoor structures. Current scanning technologies can be used to capture existing physical objects, while 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. This chapter presents a number of different construction-at-a-distance techniques, which are demonstrated with examples of real objects that have been modeled in the real world.

Chapter X describes the evolution of a software system specifically designed to support the creation and delivery of mixed reality experiences. The authors first describe some of the attributes required of such a system. They then present a series of MR experiences that they have developed over the last four years, with companion sections on lessons learned and lessons applied. The authors’ goals are to show the readers the unique challenges in developing an MR system for multimodal, multi-sensory experiences, and to demonstrate how developing MR applications informs the evolution of such a framework.

The next section, **Interface Design and Evaluation of Augmented Reality Applications,** describes current AR user interface technologies with a focus on the design issues. AR is an emerging technology; as such, it does not have a set of agreed design methodologies or evaluation techniques. These chapters present the opinions of experts in the areas of design and evaluation of AR technology, and provide a good starting point for the development of your next AR system.

Ubiquitous augmented reality (UAR) is an emerging human-computer interaction technique, arising from the convergence of augmented reality and ubiquitous computing. In UAR, visualizations can augment the real world with digital information, and interaction with the digital content can follow a tangible metaphor. Both the visualization and interaction should adapt according to the user's context and are distributed on a possibly changing set of devices. Current research problems for user interfaces in UAR are software infrastructures, authoring tools, and a supporting design process. The authors in **Chapter XI** present case studies of how they have used a systematic design space analysis to carefully narrow the amount of available design options. The next step is to use interactive, possibly immersive tools to support interdisciplinary brainstorming sessions and several tools for UAR are presented.

The main goal of **Chapter XII** is to give characteristics, evaluation methodologies, and research examples of collaborative augmented reality systems from a perspective of human-to-human communication. Starting with a classification of conventional and 3D collaborative systems, the author discusses design considerations of collaborative AR systems from a perspective of human communication. Moreover, he presents different evaluation methodologies of human communication behaviors and shows a variety of collaborative AR systems with regard to display devices used. will be a good starting point for learning about existing collaborative AR systems; their advantages and limitations. This chapter will also contribute to the selection of appropriate hardware configurations and software designs of a collaborative AR system for given conditions.

Chapter XIII describes the design of interaction methods for tangible augmented reality applications. First, the authors describe the general concept of a tangible augmented reality interface and review its various successful applications, focusing on their interaction designs. Next, they classify and consolidate these interaction methods into common tasks and interaction schemes. Finally, they present general design guidelines for interaction methods in tangible AR applications. The principles presented in this chapter will help developers design interaction methods for tangible AR applications in a more structured and efficient way, and bring tangible AR interfaces into more widespread use.

The final section, **Case Studies of Augmented Reality Applications**, provides an explanation of AR through one or more closely related real case studies. Through the examination of a number of successful AR experiences, these chapters answer the question, "What makes AR work?" The case studies cover a range of applications from industrial to entertainment, and provide the reader with a rich understand of the process of developing successful AR environments.

Chapter XIV explains and illustrates the different types of industrial augmented reality (IAR) applications and shows how they can be classified according to their purpose and degree of maturity. The information presented here provides valuable insights into the underlying principles and issues associated with bringing Augmented Reality applications from the laboratory and into an industrial context.

Augmented reality typically fuses computer graphics onto images or direct views of a scene. In **Chapter XV**, an alternative augmentation approach is described as a real scene that is captured as video imagery from one or more cameras, and these images are inserted into a corresponding 3D scene model or virtual environment. This arrangement is termed an augmented virtual environment (AVE) and it produces a powerful visualization of the dynamic activities observed by cameras. This chapter describes the AVE concept and the major technologies needed to realize such systems. AVEs could be used in security and command and control type applications to create an intuitive way to monitor remote environments.

Chapter XVI explores how mixed reality (MR) allows the magic of virtuality to escape the confines of the computer and enter our lives to potentially change the way we play, work, train, learn, and even shop. Case studies demonstrate how emerging functional capabilities will depend upon new artistic conventions to spark the imagination, enhance human experience, and lead to subsequent commercial success.

In **Chapter XVII** the author explores the applications of mixed reality technology for future social and physical entertainment systems. A variety of case studies show the very broad and significant impacts of mixed reality technology on human interactivity with regards to entertainment. The MR entertainment systems described incorporate different technologies ranging from the current mainstream ones such as GPS tracking, Bluetooth, and RFID tags to pioneering researches of vision based tracking, augmented reality, tangible interaction techniques, and 3D live mixed reality capture system.

Entertainment systems are one of the more successful uses of augmented reality technologies in real world applications. **Chapter XVIII** provides insights into the future directions of the use of augmented reality with gaming applications. This chapter explores a number of advances in technologies that may enhance augmented reality gaming. The features for both indoor and outdoor augmented reality are examined in context of their desired attributes for the gaming community. A set of concept games for outdoor augmented reality are presented to highlight novel features of this technology.

As can be seen within the four key focus areas, a number of different topics have been presented. Augmented reality encompasses many aspects so it is impossible to cover all of the research and development activity occurring in one book. This book is intended to support readers with different interests in augmented reality and to give them the foundation that will enable them to design the next generation of AR applications. It is not a traditional textbook that should be read from front to back, rather the reader can pick and choose the topics of interest and use the material presented here as a springboard to further their knowledge in this fast growing field.

As editors is it our hope that this work will be the first of a number of books in the field that will help capture the existing knowledge and train new researchers in this exciting area.

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