Virtual and Augmented Reality

Virtual and Augmented Reality:

An Educational Handbook

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

List of Tables

PREFACE

What is this book about?

The purpose of this book is to explain the related concepts of mixed reality and clarify what it is and how it works. Mixed reality has in fact been part of our lives since first we started to imagine and enhance information to achieve understandable concepts and creatively expand upon our more basic thoughts. Terms and classifications have fast been established for the description of the processes of the construction of imagined worlds in conventional systems using developing technologies. We now integrate high-tech products into our lives to expand perception, thereby becoming able to see details beyond physical reality to reach a more vivid vision. The real and the virtual can be joined intimately in each field of today's world.

The widespread usage of mixed reality creates new professions and opportunities but also results in misconceptions because of the sophomoric presentation of human beings in it. In my opinion, the Reality–Virtuality Continuum of Milgram provides the best categorisation of mixed reality. This model indicates there are various shades of virtuality in the physical world that exist between the virtual and real.

Virtuality should be immersive to completely abstract users' perceptions from the perceived physical world. Although today's technologies are not sufficient to encompass perceptions entirely via virtual content to gain any desired degree of immersion, the technology is quickly approaching this level. Technological, physical, and financial challenges have not barred us from creating our artificial worlds using various digital components. Many organisations and researchers have already structured several virtual worlds. The observation of virtuality without presence is called non-immersive virtual reality. This phenomenon can be explained by the need of certain types of virtual environment to be completely structured; however, this is not the virtual reality that we mean today. The question is; which technological equipment, systems, or environments have the potential to reach a completely immersive virtual reality? This book explains the main terms and core requirements, and references suitable examples.

This book also explains the integration of virtual content into the physical world under the sub-concept of mixed reality that is augmented reality. Easy-to-understand content creation, accessibility, and the popularity of augmented reality provide large-scale samples for both users and developers. This chapter explores the capacity to develop augmented reality with emerging technologies.

I believe that these terms should be understood before using or developing virtual or augmented reality applications. Then, the reader should study the best variety of samples to ignite their imagination and structure useful applications. This book offers many examples from the fields of education, architecture, engineering, medicine, entertainment, and more. The later chapters focus on educational mixed reality applications and usage, and the potential for enhancing personal or professional learning needs.

What is this book not about?

This book is not for learning how to develop augmented or virtual reality applications with regards to graphic design and coding. I have aimed to guide readers to an understanding of related terms and techniques by which to select the proper methods and technologies during preliminary analysis with which to structure a mixed reality environment in its design phase. I hope this knowledge can be helpful throughout all stages of decision-making to suit your specific requirements.

Detailed descriptions and specialist usage of technologies and instruments are not explained in this book because the professional application of each tool would be a book unto itself. The material development for mixed reality environments is highly multidisciplinary and practice-based. Readers of this book will be able to select compatible hardware and software components to apply to their disciplines and enhance their skills. There is a wealth of online tutorials already available for each particular element by which to achieve desired outcomes.

Who is this book for?

This book is a handbook for those who wish to learn both virtual and augmented reality terms, technologies, tools, and examples. This textbook guides graduate and undergraduate students in every field, for example, computer science, education, training, medicine, or science, as mixed reality has become increasingly prevalent across all disciplines.

This book focuses on educational mixed reality applications for various disciplines. After reading this book, teachers can design and develop their particular low-cost educational materials without coding.

The conceptual structure of this book gathers fundamental terms and usages of mixed reality technologies so that researchers can find compiled knowledge from a holistic perspective.

Entrepreneurs can be inspired to plan their projects using a broad set of examples as a guide and can choose well-suited components for their projects.

This book is also useful for hobbyists because it explains mixed reality concepts from beginner to intermediate levels using simple language.

How is this book used?

This handbook adopts a sequential structure in explaining the terminology of mixed reality. Each chapter has its sub-headings according to the topic. It is possible to read each chapter separately, but readers should follow up on cross-references to better understand interrelated terms.

The first part of this book is designed to explain fundamental terms and to provide comprehension of perceived virtuality and reality. The historical background of related systems is presented chronologically with notable milestones of emerging technologies. Then, the mixed reality concept is explained in reference to Milgram's Virtuality Continuum using samples and cases to emphasise the main differences among these terms.

The second chapter focuses on virtual reality definitions and terminology to reveal the nuances and developments during its history thus far. The types and features are explained, along with a description of immersive and non-immersive virtual reality. The chapter introduces emerging hardware requirements, head-mounted display technologies, and systems with detailed specifications and functionalities. Fundamental software components are explained, such as 3D modelling, 360° video production, and game engines. This section lists the benefits and disadvantages of virtual reality applications, along with sample studies and applications from several fields.

Augmented reality terms, definitions, benefits, and disadvantages are explained in chapter three. The interfaces and interactions of augmented reality have various forms as a result of the combining of physical and virtual components. The chapter explains tracking and sensor technologies and interface types and features, along with their software and hardware requirements. The reader will learn how a diverse range of industries applies augmented reality applications and studies across disciplines.

The fourth chapter focuses on mixed reality applications and studies within the education discipline from preschool to high school. The chapter introduces mixed reality applications and potential usage areas for in-service and professional training. Lastly, instructional design and 3D interactive design requirements and methods are discussed to provide an independent learning pathway for readers.

The final chapter includes one of my immersive virtual reality applications as a bonus example. A scientific background might help in reading about this experiential research. Ultimately, in sharing these interests and insights it is my hope that readers are inspired to investigate the design features of an immersive virtual reality application of their own.

The specific contribution of this book

Mixed reality contains multiple disciplines, terms, and professions, such as optics, mechanics, programming, designing, and engineering. Though it is possible to find specific books regarding exclusive components of mixed reality, this book presents the fundamentals of mixed reality in order to explain the differences and relationships among related concepts. This book is organised to facilitate and clarify mixed reality terms, systems, and applications from beginner to intermediate level for those interested in the field.

Numerous pictures and diagrams are provided to help visualise concepts and stimulate the imagination. Both virtual and augmented realities have many intangible systems and even interfaces, which can make it hard to understand or conceptualise relationships among them. In such instances, comparison tables are used to identify the main differences concerning features of related hardware and software components.

The purpose of this book is to provide useful material to facilitate technology and software selection processes for mixed reality environments using adequate interfaces and designs. Aiding the understanding of emerging technologies and capabilities is an essential element of this book. I hope to encourage teachers, lecturers, and academics to design and implement their own applications inside or outside of the classroom to facilitate their learning processes.

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Lastly, my sincere thanks go to my precious family and especially my dear mom and dad. I am lucky to have you.

Chapter One

What is MR?

1.1 Introduction

MR, which stands for Mixed Reality, is an inclusive term that encompasses Virtual Reality, Augmented Reality, Augmented Virtuality, and variants of all these concepts. If we want to understand what MR is, we should first understand what reality is.

The five primary senses – sight, hearing, smell, taste, and touch – structure the individuals' perception of reality. They help us to comprehend the physical components of this world as sense perceptions stimulate the related neurological fields of the human brain via the nervous system. This process occurs so fast that human beings do not have time to perceive it.

Every individual has their unique mental models to interpret the perceived reality, and these models persist over a long period in the form of personal experiences and memories. The current science indicates that human beings can perceive less than 5% of the universe. The remaining 95% consists of 27% dark matter and 68% dark energy (NASA 2019). If we use the potential of all our senses, our brains can still only perceive less than 5% of the universe. This meagre perceived ratio constitutes our reality!

The human brain structures every concept within the limitations of the individuals' perceptions. Some studies in cognitive psychology have focused on imagery that indicates the dual coding process of the brain, wherein relational pathways link sight and memory. An example is the linking of a face to a name. fMRI-based imagery research shows that when someone focuses on a particular memory, their active brain areas are the same as if they were truly experiencing the event at that time. This fantastic investigation concerning hidden brain mechanisms opens up the possibility for us to control our perceptions. Virtuality gains a different meaning for the experiencing of reality in a divergent way.

What is the virtual? Virtuality can be expressed as an essence that is not formally recognised. Supplementary materials and devices are used to reflect virtual components. We become able to identify rendered virtual outputs via complementary technologies. Every individual can interpret the virtual output differently, just like with physical reality. Virtuality not only provides duplication of the physical reality, but it also offers us an imaginative vision to see what is beyond it. Thus we can perceive enhanced virtual representations of concepts, phenomena, systems, and mechanisms. Both tangible and intangible environments can be designed and developed in virtuality.

The short history of computer technologies has resulted in a dazzling revolution for visualisation, interaction, data transfer, and usage. The game industry has built Virtual Worlds (VWs), and visualisation has become essential to reaching a broad audience. The visualisation power of computer technologies has been so pervasive that even mobile phones are expected to feature a high-quality computer display. With current technological improvements, VWs have transformed from 2D to 3D and from single-player to multiplayer, and new sub-concepts have been defined to increase perceptions that support virtual technologies. Today, goggles and various other wearable technologies have become much more effective at visualising virtuality, allowing us to experience and interact with high-fidelity VWs.

The research shows that MR developments have touched our lives profoundly, and its spreading is inevitable. According to Gartner's hype cycle for emerging technologies (Gartner 2018), MR has now left the 'peak of inflated expectation' stage, and it has entered the 'trough of disillusionment' stage.

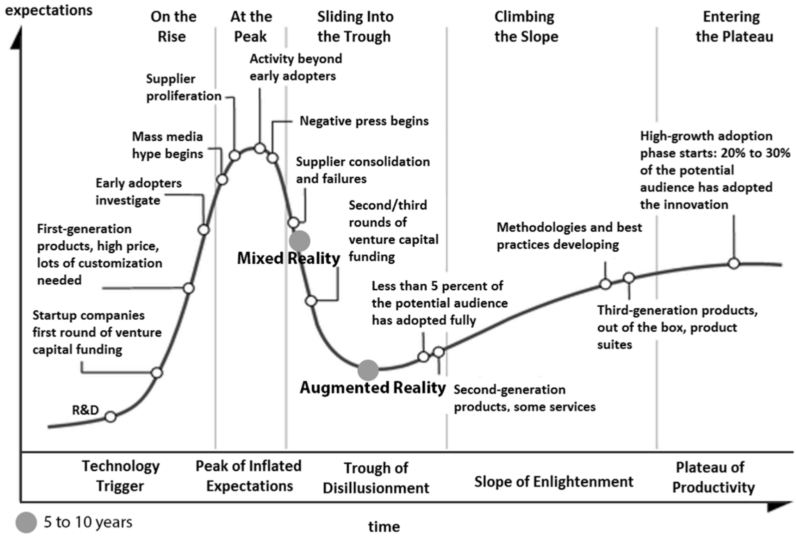


Fig. 1-1. Hype cycle of emerging technologies adapted from Gartner (2018)

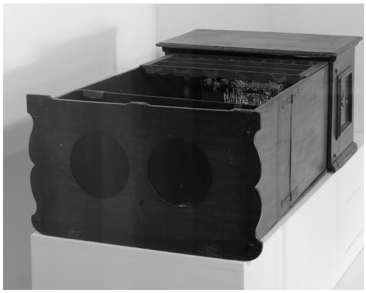
The three main reasons for disillusionment, in this case, are (1) the difficulty of 3D interface design, (2) the massive adaptation problem of VR because of convenience and control, and (3) increasing interest in AR through smartphone competition. Cheaper goggles and sensor technologies, 3D laser scanners, and 360° videos may be emerging solutions for working around these limitations. Gartner's prediction indicates that 5 to 10 years will be necessary to reach the 'plateau of productivity' stage, although we might require more time to reach fully immersive VEs as readily accessible as our smartphones.

1.2 A history of MR technologies

Authors have different ideas about the initial philosophical background of MR technologies. According to Sherman and Craig (2018), cave paintings were the ancient reflection of VR because they are virtual manifestations of physical objects.

One of the first attempts to reflect virtual living images was pioneered by Herman Casler (Casler 1901) with a motion picture device called a Mutoscope. A series of static photographic images appeared animated when played back in a rolling drum. The Peep Box, another similar device, was portable and released for handheld users. The Zoogyroscope type of device was used to display moving objects, and several similar optical devices were introduced, pioneering the way and enabling the future film industry.

Mutoscope



Peep Box

Fig. 1-2. Antique visualisation devices

The first television was released in the 1940s by engineers and industrialists and was then rapidly adopted for general usage (Biocca 1992). Researchers during this time had no reference to VR or VE concepts because they did not yet exist. However, they were still defining the essentials of VR (Mazuryk and Gervautz 1996). In the 1960s, these terms started to indicate a variety of concepts and sub-concepts which were to evolve as the technologies and functionalities continued to develop.

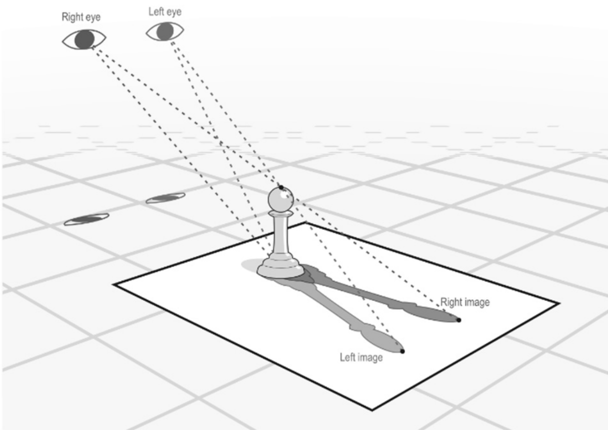


Fig. 1-3. One early 3D illustration technique

A computer scientist named Jaron Lanier initiated the concept of VR in 1989, based on a study of Ivan Sutherland (Schroeder 1993, Ma and Choi 2007). The pioneer of MR systems was the filmmaker Morton Heilig (Heilig 1962), who developed the first multi-modal theatre cabinet for a motorcycle experience and patented his product in 1962. He called this product, which presented a stereoscopic 3D object, the Sensorama. The Sensorama simulator augmented the virtual film environment using vibration, wind, and scent (Mazuryk and Gervautz 1996). The Sensorama simulator was the first AR system.

Fig. 1-4. Sensoroma

Then, the core abilities of VR were defined by MIT PhD student Ivan Sutherland for artificial worlds: interactive graphics, force feedback, sound, smell, and taste (Sutherland 1965). He designed the Scratchpad software in 1963 in order to provide human-computer interaction, and this significant leap in computer visualisation laid a foundation for future AR possibilities. The subsequent research of Sutherland presented a simple but innovative device for VR experiences using a head tracking system; the world met with the first head-mounted display (HMD) in 1968 (Sutherland 1968).

Fig. 1-5. Sword of Damocles

Military and scientific initiatives increased the development of VR technologies, and in the same years, VR started to become well-known for pilot training and NASA simulations. The 'grandfather of VR', Thomas Furless, developed the first flight simulator for the US army in 1968 (Robert Banino 2016). Then, in the mid-60s, VR technologies started to be used in universities for developing new technologies and research. This effort included early pioneering work to investigate brain perception systems and to use VR as a supporting tool in other ways within the cognitive psychology field.

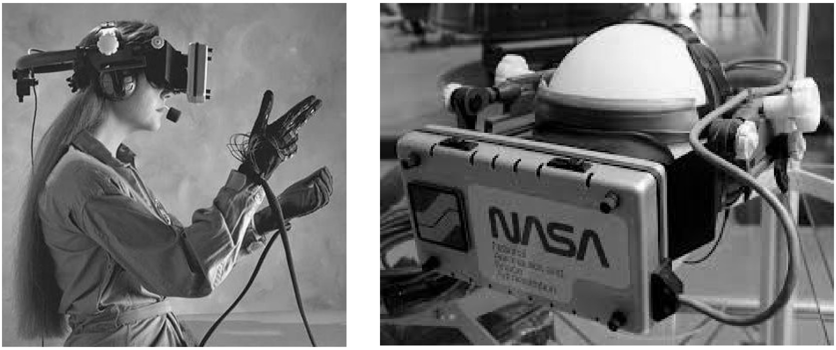


Fig. 1-6. NASA's first HMD prototype

Later investigations concerning wearable technologies, optical devices, tracking systems, and sensors have structured the fundamentals of today's AR and VR technologies. The MIT research lab focused on hand tracking systems, and in the 1970s, they released the Polhemus 3. The system featured a space tracking sensor which employed data from users' real hand positions to structure human-computer interaction. This idea stimulated more research into position tracking systems such as optical tracking, marker systems, silhouette analysis, magnetic tracking, and acoustic tracking. The tracking studies and the desire to interact with VWs via physical hand motions resulted in glove-based input systems. Daniel Sandin and Thomas Defandi developed the Sayra Glove using light emitters and photocells. The inspiration for this technology originated from Richard Sayra, whose glove system transferred the finger movements of users using an electric signal. The motion-capture-based MIT LED glove was developed in the early 1980s, and in 1983 the digital data entry glove was designed by Gary Grimes as an aid for the deaf (Robert Banino 2016, Sturman and Zeltzer 1994, Sherman and Craig 2018).

The DataGlove was released in 1987 and patented in 1991 by the team of Thomas Zimmerman and Jaron Lanier. The glove provided tactile feedback thanks to magnetic flux sensors. Nintendo introduced the Power Glove, an idea inspired by DataGlove and an early example of low-cost gloves that entered into the game industry. The CyberGlove was developed in the 1990s by Stanford University, and glove technologies started to become more portable and ergonomic. The CyberGlove had 22 sensors and could detect movements of less than one degree (Sturman and Zeltzer 1994, Robert Banino 2016, Zimmerman et al. 1987, Zimmerman and Lanier 1991).

In this short historical account, we can see that there was some attempt to initiate wide-scale usage of VR. However, no company could release a successful VR product to end-users in the market during this era, and even the most enthusiastic attempts failed. In 1983, for example, the Atari Shock was unsuccessful. Another attempt that came from Nintendo was the Virtual Boy, but this pioneering goggles-based system could not spread through the world. It only briefly survived and then disappeared in Japan. The main reason for this collapse was that the weak head tracking caused cybersickness (Robert Banino 2016).

All these technological improvements reshaped the definition of MR, and new concepts were derived from their increasing interactivity. AR was a term coined by Thomas Caudell in 1990 (Ma and Choi 2007), and AR became a research field in the late 1990s (Van Krevelen and Poelman 2007). It has to be emphasised that the first HMD of Ivan Sutherland was the starting point for AR (Ma and Choi 2007). After the AR term gained currency, the Boeing Corporation developed an experimental AR system to help workers put together wiring harnesses (Van Krevelen and Poelman 2007).

Developments in mobile and computer technologies were based on the various emerging types of AR systems. The first 3D MARS was developed as a system that could introduce people to a university campus 'using a head-tracked, see-through, head-worn, 3D display, and an untracked, opaque, hand-held, 2D display with stylus and trackpad' (Feiner et al. 1997). This prototype of the campus information system included a massive backpack computer, cables for the interactive component, a connected long aerial antenna for location tracking, and a hand display for system interaction. This device, albeit bulky, was still a true pioneer.

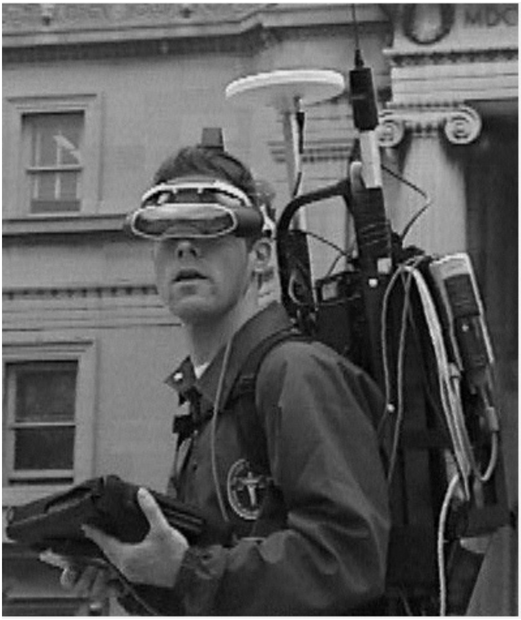


Fig. 1-7. A prototype of the campus information system (Höllerer et al. 1999)

At the beginning of the 2000s, the development and integration of GPS-based systems into mobile technologies (Loomis et al. 1994) led to the widespread adoption of portable AR systems in pocket-size devices.

1.3 Where does the MR concept come from?

The definition of the 'computer-mediated real' and the meaning of VW are usually confused (Sherman and Craig 2018). As seen in the historical account given earlier, there were no references to these terms until the 90s. All the technological improvements had