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Andrew Yeh Ching Nee • Soh Khim Ong
Editors

Springer Handbook of Augmented Reality

With 526 Figures and 79 Tables

 Springer

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Foreword



I'm happy to have the honor of introducing the Springer Handbook of Augmented Reality.

Augmented Reality (AR) has been a topic of research for decades, but recent commercial interest and investments have made certain forms of AR available to hundreds of millions of users. AR generates the illusion, in real time, of 3D virtual objects appearing to exist in the real world around the user, either supplementing or modifying how users see their surroundings. Unlike Virtual Reality, which completely replaces what a user sees with a purely virtual 3D environment, AR retains the user's view of the real world and modifies or supplements that with 3D digital objects and information. AR offers a new paradigm of how people view and interact with both digital information and the reality around them. It enables new interfaces and experiences that require combining real and virtual. It can provide the experience of having "supersenses," where a person can see, hear, and otherwise sense things that were previously invisible and undetectable. The long-run potential of AR glasses is to replace smartphones as the dominant mobile computing platform. That is why companies are investing billions of dollars today to make these visions a reality.

This handbook provides a detailed introduction to the field of AR, through chapters contributed by many notable researchers and practitioners. The first two chapters set the context by describing AR itself and the history of the field. Chapters 3–8 describe key algorithms needed to build effective AR systems, including tracking, mapping, and interaction techniques. Chapters 9–12 focus on the hardware of AR systems, including optics, tracking systems, and wearable devices. Chapters 13–20 introduce many different consumer usages, including gaming, education, theatrical performances, museums, and tourism. However, the first usages that were explored for AR were enterprise usages, such as the maintenance and repair of complex equipment, medical usages, and military applications. Chapters 21–27 cover many of these enterprise usages, while Chaps. 28–31 focus on medical and health applications. Finally, many people are excited about the concept of the "metaverse," as an open, interoperable virtual 3D world that replaces the digital platforms we use today. A specific type of metaverse is a "mirror world" that is a digital twin of the real world, at 1:1 scale, where the Internet of Things

enables the real-time digitization and connection between reality and its digital twin. AR will be the interface to these mirror worlds, so it is a key technology for making this type of metaverse successful. Chapters 32–35 describe this emerging vision of the future.

I hope you find this handbook invaluable for learning about AR and in guiding your own contributions to this exciting field.

Intel Labs

Ronald Azuma

Foreword



Augmented Reality (AR) has the potential to create one of the most significant shifts in how humans and computers interact. Unlike Virtual Reality, which aims to immerse humans in a computer-generated space, AR augments human activity in the real world by seamlessly blending the digital and physical space. One of the overarching goals of Human-Computer Interaction is to make the computer invisible and for people to interact with digital content as easily as they can do with objects in the real world. AR makes this possible.

Over the last 50 years AR technology has moved from the research laboratory to the mobile phones in the pockets of billions of people and so is now widely available. AR is ideally suited for applications that have a strong spatial element, need real-time interaction, and are connected to the real world. So, there are many compelling use cases in different domains such as Engineering, Education, Entertainment and more. However, the technology still hasn't reached its full potential. For example, mobile phone-based AR doesn't provide an immersive AR view of the real world, and current head-mounted AR displays are bulky and difficult to use. Books like this are necessary to educate the next generation of people who will drive the field forward and overcome these limitations.

In terms of content, the book contains 5 sections with 35 chapters written by over a hundred authors. The first section is an overview of historical development, including a definition of what Augmented Reality is, how it is placed in context with different realities, and a history of AR technology development. The second contains chapters that outline various principles and fundamentals of AR, such as object tracking and mapping, hand pose estimation, interaction techniques, and privacy and security issues. Next is a section on hardware and peripherals, including chapters on AR displays, tracking, interaction and networking. The bulk of the book contains chapters describing a wide range of applications in the fields of Arts and Education, Engineering and Science, and Health Science. The nineteen chapters describing applications in each of these areas show the huge potential that AR has to change many aspects of our lives. Finally, the last section describes the convergence of AR with other emerging technologies of the Internet of Things and Digital Twins, both important research fields that have significant overlap with the AR space.

Many of the chapters are written by leading researchers in AR, and taken together the material provides an ideal introduction to the field. The book is suitable for people unfamiliar with AR who want to quickly understand the basics, or those already working in the field who want to refresh and fill in the gaps of some of their knowledge. Most importantly, the content provides a snapshot of the current state of the art for AR and a research roadmap for the future. It will be an excellent resource for students, researchers, and developers in this space and for all those interested in the major trends in AR.

Finally, I want to congratulate the editors of this work and all of the chapter authors. In a fast-moving field like Augmented Reality, it can be extremely challenging to create a book that will be relevant in the years after it has been published. What they have achieved is outstanding and should be on the bookshelf of anyone seriously interested in the field. I can't wait to see what the readers of this book will create and how the future of Augmented Reality will develop as a result.

Empathic Computing Lab
University of South Australia
October 2021

Prof. Mark Billinghurst

Foreword



More than 20 years have passed since the first scholarly compilations were published about Augmented Reality (AR). Each collection marked a waterline that summarized the state of the art at the time and an updated view of the research horizon. The editors of this compilation deserve credit for selecting authors and chapters that span the current state-of-the-art achievements in AR, with each chapter serving as both an introduction and a reference for deeper study. The field is now mature enough for the opening section to summarize a significant history for a new generation of readers and researchers. The technical section presents in-depth details for a wide range of key topics, including new directions for tracking with machine learning and neural networks. The depth and breadth of the application sections are both surprising and inspiring. Several applications, such as Digital Twins, are fresh new additions to the scope of AR research. This book truly marks a new waterline for its time.

My personal history with AR began over 40 years ago. My recent research focus is on other topics, so I approach this book with a fresh perspective. While I glanced away, the ingenuity of AR researchers produced new technologies, algorithms, and system advances in the key areas of tracking, displays, and interaction. These long-standing challenge areas set the pace of progress in the field. The diversity of applications is a pleasant surprise to me. Applications provide the motivating forces for both the economic and cerebral resources focused on AR. Readers should appreciate and be inspired by the creative and challenging efforts described herein. Overall, the book leaves me personally excited and optimistic about the current state and the future of augmented reality.

Computer Science Department at the
University of Southern California
October 2021

Prof. Ulrich Neumann

Preface

Due to the rapid advancement and pervasive applications of AR technologies in various fields, Mr. Anthony Doyle mooted publishing an AR handbook, akin to many other Springer handbooks which are premium products within Springer's portfolio. Anthony made a trip to Singapore to discuss this project in mid-2018. The editors accepted the invitation and embarked on this immensely challenging project. After much discussion and planning, the call for chapters started in July 2019. It is not exactly an open call as the editors searched through AR publications in the recent years and identified potential contributors in the various fields with minimal overlapping.

The project, unfortunately, met with much delay due the worldwide onset of COVID-19. To be exact, it was like close to 2 years behind the original target. Along the way, some authors gave up and others struggled to meet timeline to wrap up their chapters. Completed chapters were rigorously reviewed and revised to meet the high standard expected of the Springer Handbook Series.

In its final form, the AR Handbook consists of 35 chapters classified into 4 categories, viz., Principles and Fundamentals, Hardware and Peripherals, Applications, and Convergence with Emerging Technologies. There are 119 contributing authors from various organizations in different countries. Many authors are trailblazers in AR research and have focused on applications in specialized fields with seminal findings. It is indeed most encouraging to see the large fraternity of AR researchers under one book cover.

It will be impossible to summarize all the contributions in one or two paragraphs, but the editors are most fortunate and honored to have received forewords from pre-eminent forerunners of AR research and technologies Ronald Azuma, Mark Billinghurst, and Ulrich Newmann. Their insights shed great lights and further illumine the handbook.

The editors sincerely hope this handbook can add to the collection of the AR community. As AR technology is continuously evolving, it is expected that newer editions of the handbook will be prepared periodically to update this exciting technology.

The editors would like to acknowledge the great assistance provided by Springer during the preparation and production of this handbook, viz., Anthony Doyle, Judith Hinterberg, Kate Emery, Heather King, and Ursula Barth.

National University of Singapore
December 2022

Andrew Yeh Ching Nee
Soh Khim Ong

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