Leila Alem
Weidong Huang *Editors*

Recent Trends of Mobile Collaborative Augmented Reality Systems

Springer

Recent Trends of Mobile Collaborative Augmented Reality Systems

Leila Alem • Weidong Huang
Editors

Recent Trends of Mobile Collaborative Augmented Reality Systems

Springer

Editors
Leila Alem
CSIRO ICT Centre
Cnr Vimiera and Pembroke Roads
Marsfield, NSW 2122
Australia
Leila.Alem@csiro.au

Weidong Huang
CSIRO ICT Centre
Cnr Vimiera and Pembroke Roads
Marsfield, NSW 2122
Australia
Tony.Huang@csiro.au

ISBN 978-1-4419-9844-6 e-ISBN 978-1-4419-9845-3
DOI 10.1007/978-1-4419-9845-3
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011935229

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Augmented reality (AR) is a direct or indirect view of real world scenes in which physical objects are annotated with, or overlaid by computer generated digital information. The past two decades have seen a fast growing body of research and development dedicated to techniques and technologies for AR. In particular, due to the recent advances in mobile devices and networking technologies, the use of mobile collaborative augmented reality (MCAR) has expanded rapidly. Although there is still a long way for MCAR systems to become commonplace, successful applications have been developed in a range of fields, for example computer-supported collaborative learning, entertainment, tourism and collaborative architectural design. An overview of recent trends and developments in this rapidly advancing technology is needed. This book is set out to:

- Provide a historical overview of previous MCAR systems
- Present case studies of latest developments in current MCAR systems
- Cover latest technologies and system architectures used in MCAR systems

This book includes 13 chapters. The first two chapters of this book are invited contributions from established researchers in the field. The remaining chapters are extended versions of papers presented in the 2010 international workshop on mobile collaborative augmented reality (MCAR 2010). We briefly introduce these chapters as follows.

In chapter 1, Billinghurst and Thomas provide an overview of current state-of-art in MCAR. The authors first introduce a set of technologies that are required for MCAR. Then examples of recent MCAR systems are presented. The chapter finishes with an insightful look into requirements and directions of future MCAR.

In chapter 2, Perey et al. discuss the needs, approaches, issues and directions of standardization of AR related applications and services. This discussion includes guiding principles of an open AR industry, AR requirements and use cases, approaches to the AR standards challenge and content-related standards. The current state of mobile AR standards is also introduced and analysed.

In chapter 3, Yew et al. propose a system framework called SmARt World which is to support various mobile collaborative applications in indoor environments.

This system has a three-layered architecture – physical layer, middle layer and AR layer. The initial prototype has been implemented and the tests of it show that it is low-cost, user friendly and suitable for many applications.

In chapter 4, Hoang and Thomas present research directions motived by the problem of action at a distance in mobile augmented reality. The discussion is based on the authors' augmented viewport technique. Current research challenges are identified, which include the utilization of various types of remote cameras, collaboration features, better visualization of the cameras' views, precision by snapping and improved input devices.

In chapter 5, Webel et al. present a series of analytic results of interdisciplinary research. Based on previous research and experiments performed in cooperation with human factors scientists, improvement of Augmented Reality based training of skills is analysed and recommendations for the design of Augmented Reality based training systems are proposed. These recommendations include visual aids, elaborated knowledge, passive learning parts and haptic hints.

In chapter 6, Vico et al. describe a taxonomy for classifying types of applications involving mobile AR-based collaboration. The authors propose that experiences can be classified according to the type of content generated and then give examples of how current mobile AR applications would be classified. Some possible use cases of the taxonomy and future research are provided.

In chapter 7, Gu et al. describe the development of a mobile AR collaborative game called AR Fighter. The structure and features of this game's prototype are introduced. In this prototype, the authors present a concept of game playing: 2 players can play an AR game without any onlookers interfering.

In chapter 8, Alem et al. present a user study of an augmented reality mobile game called Greenet. This game allows players to learn about recycling by practicing the act of recycling using a mobile phone. The study compares three different ways of playing the game and the results suggest that competitive/collaborative mobile phone based games provide a promising platform for persuasion.

In chapter 9, Gu et al. present a game called AR-Sumo. This game is a mobile collaborative augmented reality network service for educational and entertainment purposes. AR-Sumo provides a shared virtual space for multiple users to interact at the same time. It involves visualization of augmented physical phenomena on a fiducial marker and enables learners to view the physical effects of varying gravities and frictions in a 3D virtual space.

In chapter 10, Wang et al. propose a multi-user guide system for Yuanmingyuan Garden. The system integrates real environments and virtual scenes through entertainment and gaming in mobile phones. Using this system, visitors are able to tour the garden's historical sites and experience the excitements of an AR based game through various novel ways of interaction provided.

In chapter 11, Alem et al. present a gesture based mobile AR system for supporting remote collaboration called HandsOnVideo. The system is developed following a participatory design approach. It can be used for scenarios in which a remote helper guides a mobile worker in performing tasks that require the manipulation of physical objects, such as maintaining a piece of equipment and performing an assembly task.

In chapter 12, White and Feiner present a system for dynamic, abstract audio representations in mobile augmented reality called SoundSight. This system uses the Skype Internet telephony API to support wireless conferencing and provides visual representations of audio, allowing users to “see” the sounds. Initial user experience of the system indicates that visual representations of audio can help to promote presence and identify audio sources.

In chapter 13, Zhou et al. review Spatial Augmented Reality (SAR) techniques. Advantages and problems of SAR in presenting digital information to users are summarised. The authors also present a concept of portable collaborative SAR. This concept is then applied in a case study of an industrial quality assurance scenario to show its effectiveness.

In summary, the research topics presented in this book are diverse and multidisciplinary. These topics highlight recent trends and developments in MCAR. We hope that this book is useful for a professional audience composed of practitioners and researchers working in the field of augmented reality and human-computer interaction. Advanced-level students in computer science and electrical engineering focused on these topics should also find this book useful as a secondary text or reference.

We wish to express our gratitude to Professor Mark Billinghurst and Professor Bruce H. Thomas for their help and support throughout this project. We also would like to thank the members of the international editorial board for their reviews and all authors for their contributions to the book. Last but not least, we would like to thank Susan Lagerstrom-Fife and Jennifer Maurer at Springer USA for their assistance in editing this book.

Leila Alem
Weidong Huang

Contents

Contributors

Leila Alem CSIRO ICT Centre, PO Box 76, Epping NSW 1710, Australia

Peta Ashworth CESRE Division, PO Box 883, Kenmore QLD 4069, Australia

Mark Billinghurst HIT Lab NZ, University of Canterbury, Private Bag 4800 Christchurch 8140, New Zealand

Ulrich Bockholt Fraunhofer Institute for Computer Graphics Research IGD, Fraunhoferstr. 5, 64283 Darmstadt, Germany

Leanne Chang Communications and New Media Programme, Faculty of Arts & Social Sciences, Blk AS6, #03-41, 11 Computing Drive, National University of Singapore

Henry Been-Lirn Duh Department of Electrical and Computer Engineering, 21 Heng Mui Keng Terrace, #02-02-09, National University of Singapore

Steven Feiner Columbia University, 500 W. 120th St., 450 CS Building, New York, NY 10027

Timo Engelke Fraunhofer Institute for Computer Graphics Research IGD, Fraunhoferstr. 5, 64283 Darmstadt, Germany

David Furio Instituto Universitario de Automática e Informática Industrial, Universidad Politécnica de Valencia, Camino de Vera, s/n. 46022, Valencia, Spain

Nirit Gavish Technion Israel Institute of Technology, Technion City, Haifa 32000, Israel

Jian Gu KEIO-NUS CUTE center, Interactive & Digital Media Institute, 21 Heng Mui Keng Terrace, #02-02-09, National University of Singapore

Yuan Xun Gu Department of Electrical and Computer Engineering, 21 Heng Mui Keng Terrace, #02-02-09, National University of Singapore

Thuong N. Hoang Wearable Computer Lab, School of Computer and Information Science, University of South Australia, Mawson Lakes Campus, 1 Mawson Lakes Boulevard, Mawson Lakes, SA 5010, Australia

Weidong Huang CSIRO ICT Centre, PO Box 76, Epping NSW 1710, Australia

Xia Jia ZTE Corporation, Nanjing, 518057, China

Carmen Juan Instituto Universitario de Automática e Informática Industrial, Universidad Politécnica de Valencia, Camino de Vera, s/n. 46022, Valencia, Spain

Shintaro Kitazawa KEIO-NUS CUTE center, Interactive & Digital Media Institute, 21 Heng Mui Keng Terrace, #02-02-09, National University of Singapore

Ivan Lee School of Computer and Information Science, University of South Australia, Australia

Nai Li Communications and New Media Programme, Faculty of Arts & Social Sciences, Blk AS6, #03-41, 11 Computing Drive, National University of Singapore

Yue Liu School of Optics and Electronics, Beijing Institute of Technology, Beijing, 100081, China

Roland Menassa GM Michigan, North America

A.Y.C. Nee Department of Mechanical Engineering, Augmented Reality Lab, National University of Singapore, EA 02-08, National University of Singapore, 117576, Singapore

S.K. Ong Department of Mechanical Engineering, Augmented Reality Lab, National University of Singapore, EA 02-08, National University of Singapore, 117576, Singapore

Christine Perey Spime Wrangler, PEREY Research & Consulting

Carl Reed Open Geospatial Consortium

Joaquín Salvachúa Rodríguez Departamento de Ingeniería de Sistemas Telemáticos, Escuela Técnica Superior de Ingenieros de Telecomunicación, Universidad Politécnica de Madrid, Avenida Complutense 30, "Ciudad Universitaria", 28040, Madrid, Spain

Andrew Sansome GM Holden Ltd, Victoria, Australia

Franco Tecchia PERCRO Laboratory - Scuola Superiore Sant'Anna, Viale R. Piaggio 34, 56025 Pontedera (Pisa), Italy

Bruce H. Thomas Wearable Computer Lab, School of Computer and Information Science, University of South Australia, Mawson Lakes Campus, 1 Mawson Lakes Boulevard, Mawson Lakes, SA 5010, Australia

Iván Martínez Toro Departamento de Ingeniería de Sistemas Telemáticos, Escuela Técnica Superior de Ingenieros de Telecomunicación, Universidad Politécnica de Madrid, Avenida Complutense 30, "Ciudad Universitaria", 28040, Madrid, Spain

Daniel Gallego Vico Departamento de Ingeniería de Sistemas Telemáticos, Escuela Técnica Superior de Ingenieros de Telecomunicación, Universidad Politécnica de Madrid, Avenida Complutense 30, "Ciudad Universitaria", 28040, Madrid, Spain

Yongtian Wang School of Optics and Electronics, Beijing Institute of Technology, Beijing 100081, China

Sabine Webel Fraunhofer Institute for Computer Graphics Research IGD, Fraunhoferstr. 5, 64283 Darmstadt, Germany

Sean White Columbia University & Nokia Research Center, 2400 Broadway, Suite D500, Santa Monica, CA 90404

Jian Yang School of Optics and Electronics, Beijing Institute of Technology, Beijing 100081, China

A.W.W. Yew Department of Mechanical Engineering, Augmented Reality Lab, National University of Singapore, EA 02-08, National University of Singapore, 117576, Singapore

Liangliang Zhai School of Optics and Electronics, Beijing Institute of Technology, Beijing 100081, China

Zhipeng Zhong School of Optics and Electronics, Beijing Institute of Technology, Beijing 100081, China

Jianlong Zhou School of Computer and Information Science, University of South Australia, Australia

Mobile Collaborative Augmented Reality

Mark Billinghurst and Bruce H. Thomas

Abstract This chapter provides an overview of the concept of Mobile Collaborative Augmented Reality (MCAR). An introduction to augmented reality is firstly provided which gives an insight into the requirements of mobile augmented reality (some-times referred to as handheld augmented reality). A set of current MCAR systems are examined to provide context of the current state of the research. The chapter finishes with a look into the requirements and future of MCAR.

1 Introduction

Augmented Reality (AR) is a technology that allows interactive three-dimensional virtual imagery to be overlaid on the real world. First developed over forty years ago [1], applications of Augmented Reality have been employed in many domains such as education [2], engineering [3] and entertainment [4]. For example, mechanics are able to see virtual instructions appearing over real engines giving step by step maintenance instructions [5], and gamers can see virtual monsters appearing over real playing cards and fighting with each other when they are placed side by side [6]. Azuma provides a detailed review of current and past AR technology [7, 8].

Figure 1 shows a typical AR interface, in this case the user's view through a head mounted display (HMD) while looking down a street. The physical world is the building in the background, and a virtual road, street lamps, and houses appear overlaid on the real world in front of it. This particular AR application lets the user enhance the landscape outside their building with the addition of a virtual road, houses and a set of street lamps that can be walked around. The virtual objects are

M. Billinghurst (✉)
HIT Lab NZ, University of Canterbury, Private Bag 4800 Christchurch, 8140, New Zealand
e-mail: mark.billinghurst@canterbury.ac.nz

L. Alem and W. Huang (eds.), *Recent Trends of Mobile Collaborative Augmented Reality Systems*, DOI 10.1007/978-1-4419-9845-3_1,

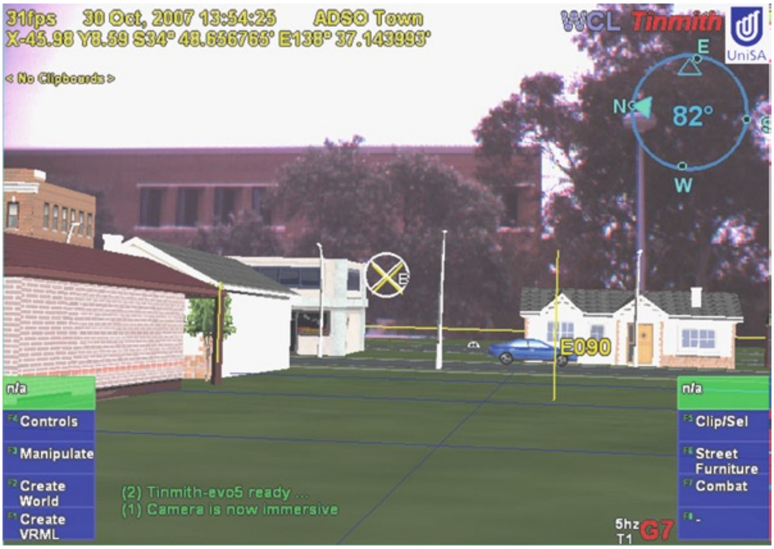

Fig. 1 Users view of the Real World

Fig. 2 Tinmith Hardware

registered to the physical world and appear at – or standards based - content, platforms or viewing applications. It is a field of technology silos and, consequently fragmented markets.

For mobile collaborative AR, the needs for standards are compounded by the fact that the content of shared interest must travel over a communications "bridge" which is, itself, established between end points between and through servers, client devices and across networks. The more interoperable the components of the end-to-end system are, the less the fixed locations in it. The Tinmith [9] AR wearable computing hardware is an example system that supports this form of AR, see Figure 2.

Figure 1 shows that a major benefit of AR is the viewing of information that is location based and registered to physical objects. Basic AR systems provide information about the physical world, and let users view that information in any setting. For example, a classic use is to visualize a proposed architectural structure in the context of existing buildings or at a particular physical location. The ability to walk in and around the virtual structure lets users experience its size, shape, and feel in a first-person perspective and fosters a more emotional engagement.

Recently, mobile phones have become as powerful as the desktop computers from a decade earlier, and so mobile augmented reality has become possible. Modern smart phones combine fast CPUs with graphics hardware, large screens, high resolution cameras and sensors such as GPS, compass and gyroscopes. This makes them an ideal platform for Augmented Reality. Henrysson [10], Wagner [11] and others have shown how computer vision based AR applications can be delivered on mobile phones, while commercial systems such as Layar[1], Wikitude[2], and Junaio[3] use GPS and compass sensor data to support outdoor AR experiences.

Phones also have powerful communication hardware, both cellular and wireless networking, and can be used for collaboration. So, for the first time, consumers have in their hands hardware that can provide a collaborative AR experience [12]. A Mobile Collaborative Augmented Reality (MCAR) application is one that allows several people to share an AR experience using their mobile devices [13]. The AR content could be shared among face to face or remote users, and at the same time (synchronous collaboration) or at different times (asynchronous collaboration).

1.1 Core Mobile AR Technology

In order to deliver a MCAR experience there are several core pieces of technology that must be used, including:

- ***Mobile Processor***: Central Processing Unit (CPU) for processing user input, video images and running any application simulations.
- ***Graphics Hardware***: Graphical Processing Unit (GPU) system for generating virtual images.
- ***Camera***: Camera hardware for capturing live video images, to be used for AR tracking and/or for overlaying virtual imagery onto the video images.
- ***Display Hardware***: Either a handheld, head mounted, or projected display used to combine virtual images with images of the real world, creating the AR view.

[1] http://www.layar.com/

[2] http://www.wikitude.org/

[3] http://argon.junaio.com/

- ***Networking***: Wireless or cellular networking support that will allow the mobile device to connect to remote data sources.
- ***Sensor Hardware (optional)***: Additional GPS, compass or gyroscopic sensors that can be used to specify the user's position or orientation in the real world.

Using this technology and the associated software modules, the position and orientation of the user's viewpoint can be determined, and a virtual image created and overlaid on the user's view of the real world. As users change their viewpoint, the AR system updates their virtual world view accordingly. Thus, the basic AR process is:

1. Build a virtual world with a coordinate system identical to the real world.
2. Determine the position and orientation of the user's viewpoint.
3. Place the virtual graphics camera in that position and orientation.
4. Render an image of the physical world on the user's display.
5. Combine the virtual graphical overlay over the physical-world image.

1.2 Content of the Chapter

Although the hardware is readily available, there are a number of research and technical challenges that must be addressed before shared AR experiences are commonplace. In this chapter we provide an overview of MCAR systems with a particular focus on the history leading up the current systems, the typical technology used, and the important areas for future research. Later chapters in the book address specific topics in MCAR in more detail.

2 Mobile AR with Head Mounted Displays

The earliest mobile AR systems were based around head mounted displays rather than hand held mobile phones. Head Mounted Displays (HMDs) [14] were invented by Ivan Sutherland in the first AR system developed in 1965 [1]. Sutherland employed a physical optical system to combine the real world visual information with the virtual information. Currently the use of a digital camera to capture the visual information of the physical world allows the combination of both forms of visual information via the capabilities of modern graphics cards [15]. Using a HMD in conjunction with a head-position sensor and connected to a wearable computer, a user is able to see a large portable panoramic virtual information space surrounding them. A person can simply turn their head left, right, up, or down to reveal more information around them [16].

Figure 3 shows a conceptual image of a user within a wearable virtual information space, surrounded by pages of information. The combination of a head tracking sensor and HMD allows for the information to be presented in any direction from the user. However, a person's normal Field-of-View (FOV) is about 200