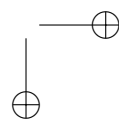
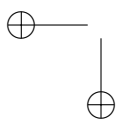
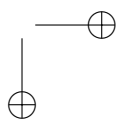
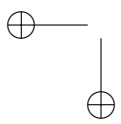
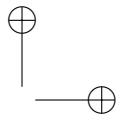
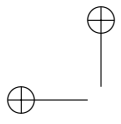
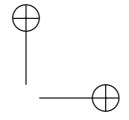
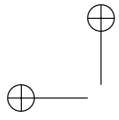


Spatial Augmented Reality







Spatial Augmented Reality

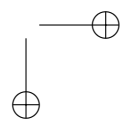
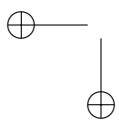
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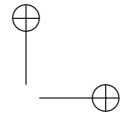
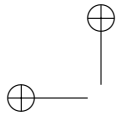
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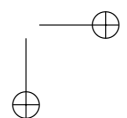
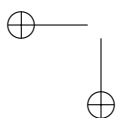
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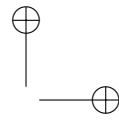
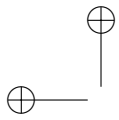
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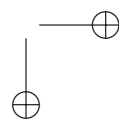
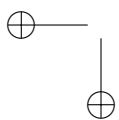


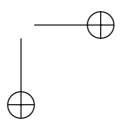
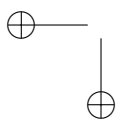
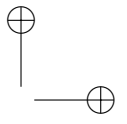
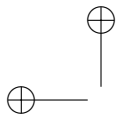
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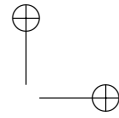
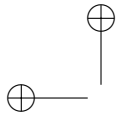
—O. B.

To my parents

—R. R.

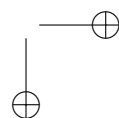
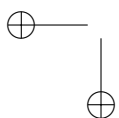


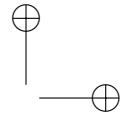
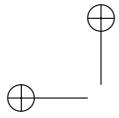




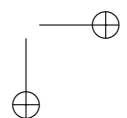
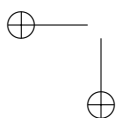
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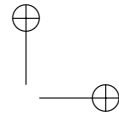
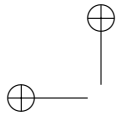
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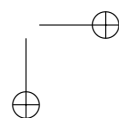
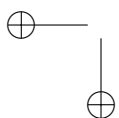


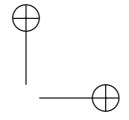
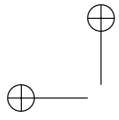
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Preface

Spatial Augmented Reality is a rapidly emerging field which concerns everyone working in digital art and media who uses any aspects of augmented reality and is interested in cutting-edge technology of display technologies and the impact of computer graphics. We believe that a rich pallet of different display technologies, mobile and non-mobile, must be considered and adapted to fit a given application so that one can choose the most efficient technology. While this broader view is common in the very established area of virtual reality, it is becoming more accepted in augmented reality which has been dominated by research involving mobile devices.

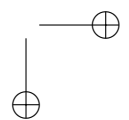
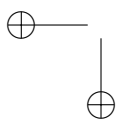
This book reflects our research efforts over several years and the material has been refined in several courses that we taught at the invitation of Eurographics and ACM SIGGRAPH.

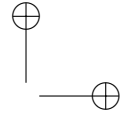
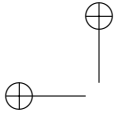
Who Should Read This Book

In order for a broad spectrum of readers—system designers, programmers, artists, etc— to profit from the book, we require no particular programming experience or mathematical background. However, a general knowledge of basic computer graphics techniques, 3D tools, and optics will be useful.

The reader will learn about techniques involving both hardware and software to implement spatial augmented reality installations. Many Cg and OpenGL code fragments, together with algorithms, formulas, drawings, and photographs will guide the interested readers who want to experiment with their own spatial augmented reality installations.

By including a number of exemplary displays examples from different environments, such as museums, edutainment settings, research projects, and industrial settings, we want to stimulate our readers to imagine novel





AR installations and to implement them. Supplementary material can be found at <http://www.spatialar.com/>.

About the Cover

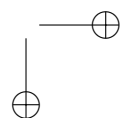
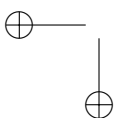
The images at the top of the front cover show a rainbow hologram of a dinosaur (*Deinonychus*) skull (found in North America). It has been augmented with reconstructed soft tissue and artificial shading and occlusion effects. The soft tissue data, provided by Lawrence M. Witmer of Ohio University, were rendered autostereoscopically. A replica of the skull was holographed by Tim Frieb at the Holowood holographic studio in Bamberg, Germany. The hologram was reconstructed by projected digital light that could be controlled and synchronized to the rendered graphics. This enabled a seamless integration of interactive graphical elements into optical holograms.

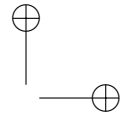
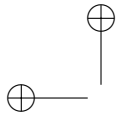
The image at the bottom show an example of Shader Lamps: an augmentation of a white wooden model of the Taj Mahal with two projectors. The wooden model was built by Linda Welch, George Spindler and Marty Spindler in the late 1970s. In 1999, at the University of North Carolina, Greg Welch spray painted the wooden model white and Kok-Lim Low scanned it with a robotic arm to create a 3D model. The wooden model is shown illuminated with images rendered with real time animation of a sunrise.

The art work on the back cover was created by Matthias Hanzlik. The sketches show early concepts of SAR prototypes. They have all been realized and are described in the book.

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The material presented in this book would not have been realized without the help and dedication of many students and colleagues. We want to thank them first of all: Gordon Wetzstein, Anselm Grundhöfer, Sebastian Knödel, Franz Coriand, Alexander Kleppe, Erich Bruns, Stefanie Zollmann, Tobias Langlotz, Mathias Möhring, Christian Lessig, Sebastian Derkau, Tim Gollub, Andreas Emmerling, Thomas Klemmer, Uwe Hahne, Paul Föckler, Christian Nitschke, Brian Ng, Kok-Lim Low, Wei-Chao Chen, Michael Brown, Aditi Majumder, Matt Cutts, Deepak Bandyopadhyay, Thomas Willwacher, Srinivas Rao, Yao Wang, and Johnny Lee.





We also want to thank all colleagues in the field who provided additional image material: Vincent Lepetit, Pascal Fua, Simon Gibson, Kiyoshi Kiyokawa, Hong Hua, Susumu Tachi, Daniel Wagner, Dieter Schmalstieg, George Stetten, Tetsuro Ogi, Barney Kaelin, Manfred Bogen, Kok-Lim Low, Claudio Pinhanez, Masahiko Inami, Eric Foxlin, Michael Schnaider, Bernd Schwald, and Chad Dyrer.

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Many thanks to Thomas Zeidler and to Alice and Klaus Peters for helping us manage the process of writing this book alongside our everyday duties.

Oliver Bimber
Weimar April 2005

Ramesh Raskar
Cambridge, MA April 2005

