VISUAL PERCEPTION FROM A COMPUTER GRAPHICS PERSPECTIVE

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Visual Perception from a Computer Graphics Perspective

To Robert S. Thompson and Arthur M. Dunne, from whom I learned much that was important.
– WBT

To Rossana, Max-Antonio, and Ana-Magenta.
– RWF

To John, Jonas, and Isaac.
– SHC

To Derek, for showing me the value in writing books and providing me with the support to do so.
– JKS

Preface

Computer graphics produces images intended to be seen by people, yet relatively few practitioners in the field know much about the specifics of human vision. This book provides an introduction to human visual perception intended for those studying or working in the fields of computer graphics and visualization. The goal is to provide an understanding of human vision with a breadth and depth relevant to both the current state of the art in graphics and visualization and to future developments in those fields. More generally, the material presented is useful for those studying cognitive science, since it covers several topics that are not commonly included in standard perception references while offering a comprehensive overview of visual perception as a whole. Visual neuroscientists will find that the emphasis on visual performance complements studies of biological mechanisms. Finally, much of the material is relevant in motivating methods used in computer vision and image analysis. The book can be used as a text for courses at the graduate or advanced undergraduate level, as an overview of perception for those active as researchers or developers in computer graphics or related fields, and as a reference for students and researchers in vision science.

There are many excellent textbooks providing an introduction to visual perception. This book differs from those texts in several important ways:

- the book ties together image generation and the resulting perceptual phenomena, rather than having a focus only on the visual system itself;

- topics are included that are seldom, if ever, part of introductory perception texts, including the perception of material properties, illumination, the perception of pictorial space, perception and action, and spatial cognition; and
- the emphasis is on visual performance, with coverage of biological mechanisms in specific situations to aid in the understanding of issues of practical importance.

The writing of this book was inspired by William Thompson's chapter, "Visual Perception," appearing in the second edition of Peter Shirley's *Fundamentals of Computer Graphics* (2005). Some text from that chapter has found its way into the book. Further inspiration came from an ACM/SIGGRAPH meeting on Perceptually Adaptive Graphics, held at Snowbird, Utah, in May of 2001; the ACM Transactions on Applied Perception (`http://tap.acm.org`); and the annual ACM Symposia on Applied Perception in Graphics and Visualization (`http://www.apgv.org`).

About the Cover

These photos were taken at MIT by Meredith Talusen for some projects on reflectance estimation by Ron Dror, Alan Willsky, Ted Adelson and Roland Fleming. The images show two spheres with different reflectance properties: one is almost perfectly mirrored, the other has a more pearlescent appearance. Ron Dror created the database that includes these images so that he could build and test a computer vision algorithm for recognizing materials under unknown illumination conditions. This is a task that humans find effortless, even though the image of a given material can change dramatically depending on the context. It may not be immediately obvious, but the two images on the top (spheres with different reflectance properties) are actually more similar to one another—on a pixel-by-pixel basis—than the first and third images (spheres with the same reflectance properties). This is one example of the difficulties faced by the human visual system when reconstructing the world from the retinal images.

Online Resources

The web site for this book is `http://vpfacgp.cs.utah.edu/`. The site contains errata and a variety of useful information about visual perception likely to be of interest to readers.

Acknowledgments

The writing of a book such as this is a major undertaking, which would be difficult or impossible without the help and feedback we have received from many people. These include: Jonathan Bakdash, Adam Bargteil, Irving Biederman, Alex Bigelow, Bobby Bodenhiemer, Margarita Bratkova, Clifton Brooks, Joshua Bross, Susie Carlisle, Anthony Cummings, Sarah Cutler, Laura Dahl, Alexei Efros, Marc Ellens, Lisa Ferrara, Sergei Gepshtein, Michael Geuss, Jessica Hodgins, Mustafa Hussain, Ian Jensen, Alex Johnstone, David Kemker, Jasen Kennington, Dan Kersten, Ian King, James King, Rebecca Koslover, John Kowalski, Heidi Kramer, Vaidyanathan Krishnamoorthy, Brad Loos, Rachel McDonnell, James O'Brien, Andrei Ostanin, David Pilibosian, Dennis Proffitt, Kristina Rand, Brandon Rees, Erik Reinhard, Robert Shakespeare, Ari Shapiro, Lavanya Sharan, Peter Shirley, Jordan Squire, Maureen Stone, David Strayer, Margaret Tarampi, Jason Williams, and Tina Ziemek.

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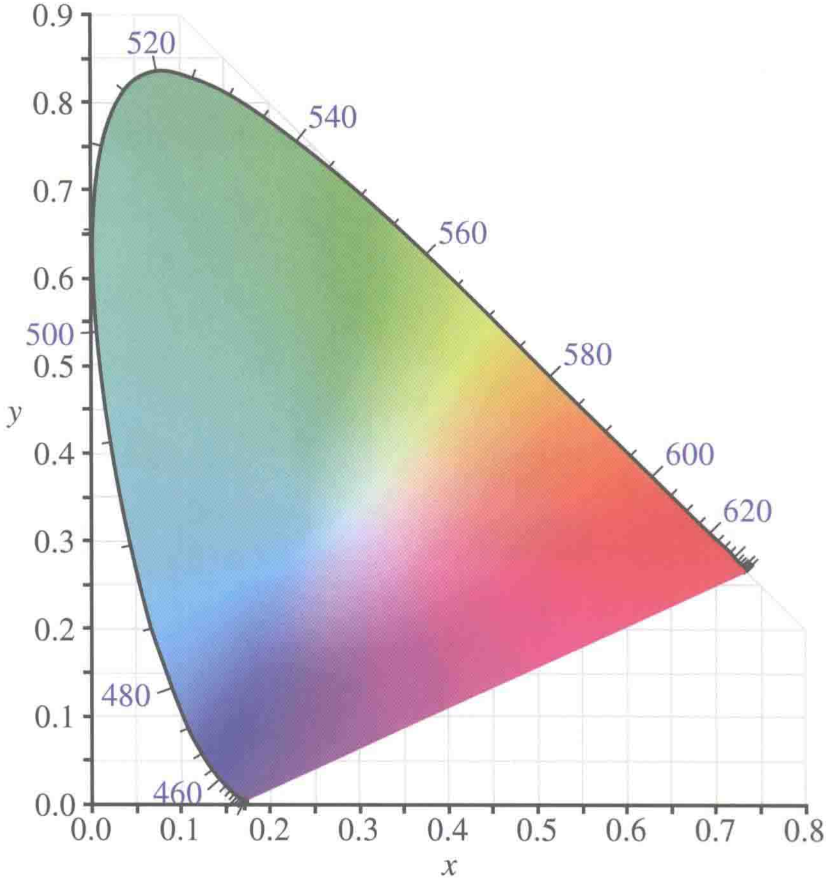

Plate IV

CIE x, y color space. The outer curved boundary shows the x, y values for pure spectral colors, with the wavelength shown in nanometers. (From the Wikimedia Commons.)

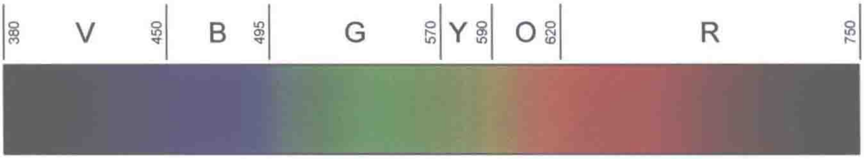

Plate I

The visible spectrum, with wavelengths indicated in nanometers. (From the Wikimedia Commons.)

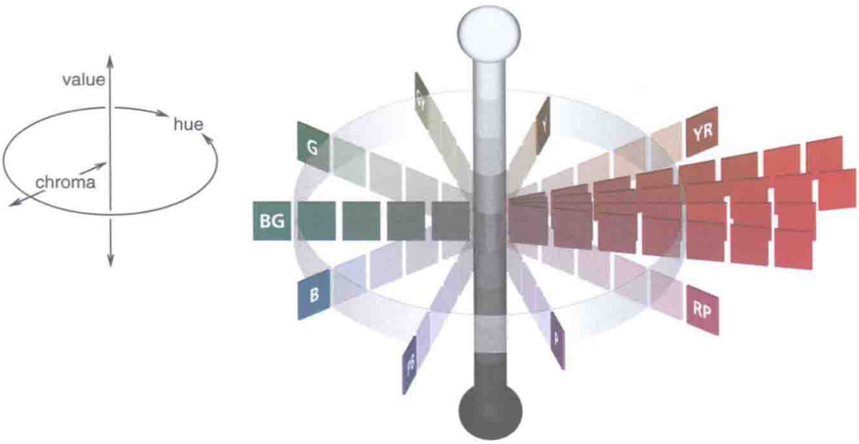

Plate II

The Munsell color system, which represents apparent color in terms of *value*, *hue*, and *chroma*, using a cylindrical coordinate system. (Figure on right courtesy of X-Rite, Inc.)

Plate III

Which color is closer in appearance to red: green or violet?

Plate V

An example of natural camouflage. (See Figure 8.6.)

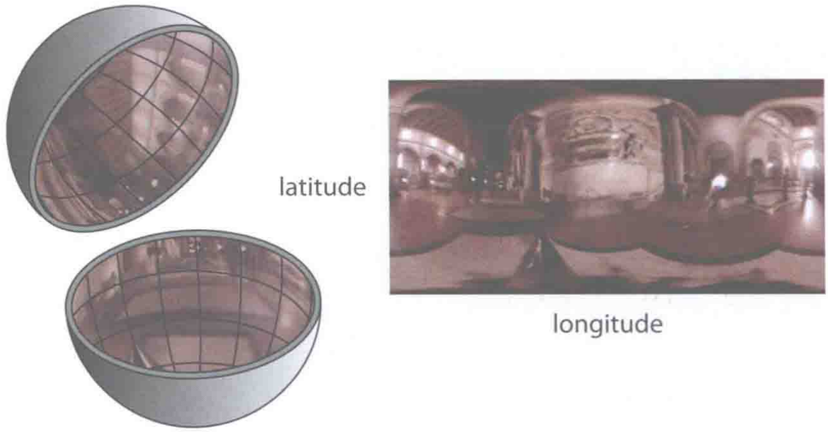

Plate VI

A light probe captures the light arriving from every direction on the sphere surrounding a point in the real world. To visualize this, we can project it into two dimensions, here using the Lambert cylindrical equal-area projection.(Light probe image from Debevec, 1998; reproduced by permission from Paul Debevec). (See Figure 9.9.)

Plate VII

On the left, the Cornell Box is rendered with only direct illumination; on the right, a full global illumination rendering is shown. Interreflections have a substantial effect on the appearance of the scene. (See Figure 9.16.)

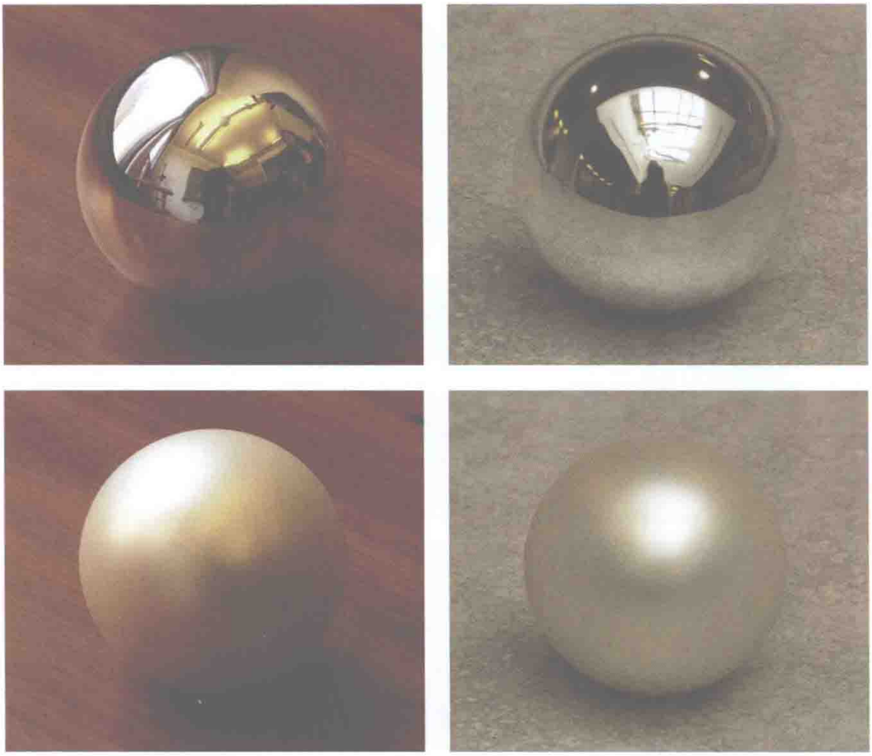

Plate VIII

Photographs of two spheres in two different contexts. We easily identify the spheres across changes in the illumination, and easily distinguish between the two spheres. (From Fleming et al., 2003.) (See Figure 10.2.)

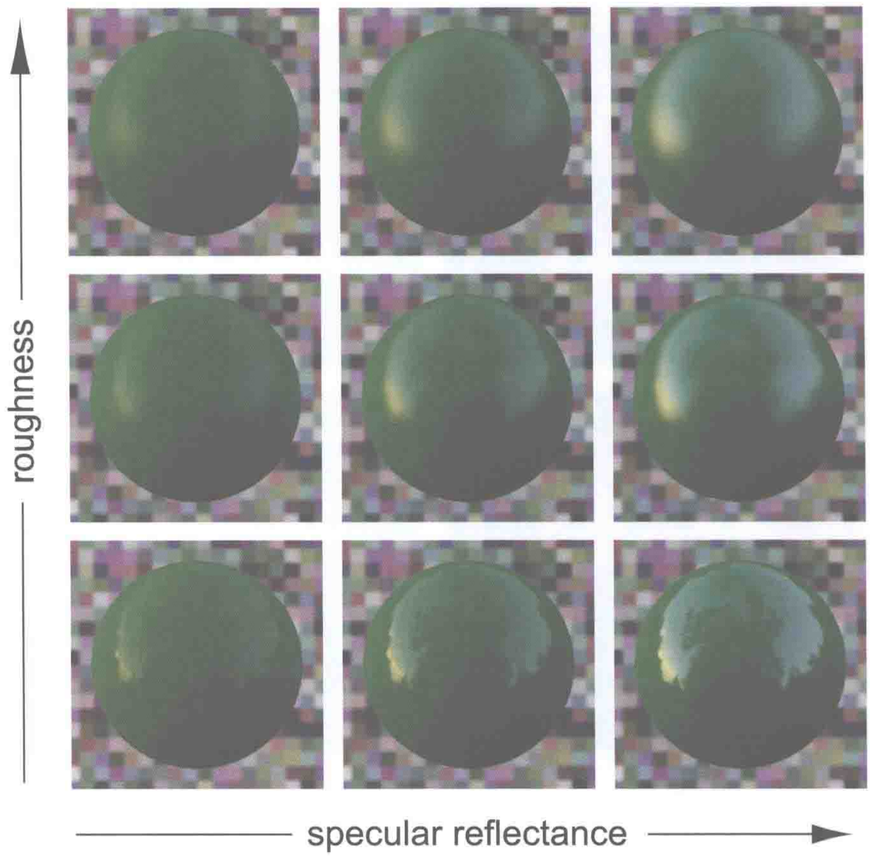

Plate IX

Renderings of a sphere with different parameters of the Ward reflectance model. By varying the parameters, a wide range of different surface appearances can be simulated. (From Fleming et al., 2003.) (See Figure 10.4.)

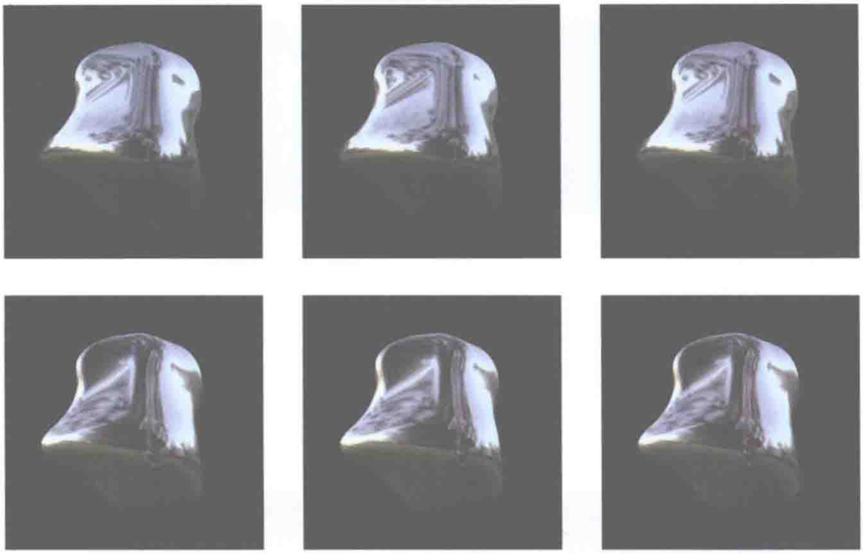

Plate X

A stereoscopic version of Hartung and Kersten's (2003) sticky reflections effect. In each row, the stereopairs formed by the left and middle images are for cross fusion, while the stereopairs formed by the middle and right images are for uncrossed fusion. Having fused the two images, the top object should appear lustrous like a metallic surface, while for the lower object, the reflections should slowly appear more like patterns painted onto the surface. (See Figure 10.12.)

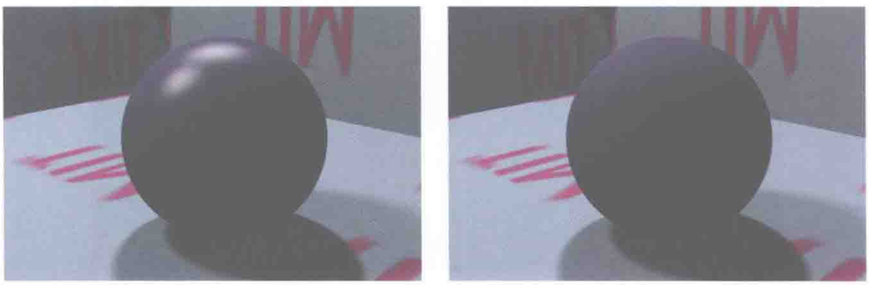

Plate XI

The highlights in the image are highly localized, and yet the impression of glossiness spreads across the entire surface. When when the highlights are removed, the object appears matte. (From Adelson, 2001.) (See Figure 10.15.)

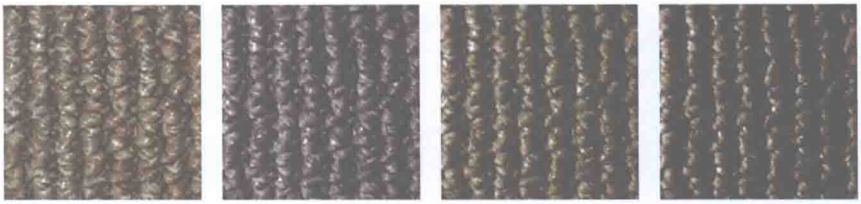

Plate XII

Examples of a BTF with different lighting conditions. The appearance of the material changes depending on the lighting and viewpoint, much like a BRDF. (Images from the Bonn BTF database by Reinhard Klein and colleagues, `http://btf.cs.uni-bonn.de/download.html`, Müller et al., 2005.) (See Figure 10.23.)

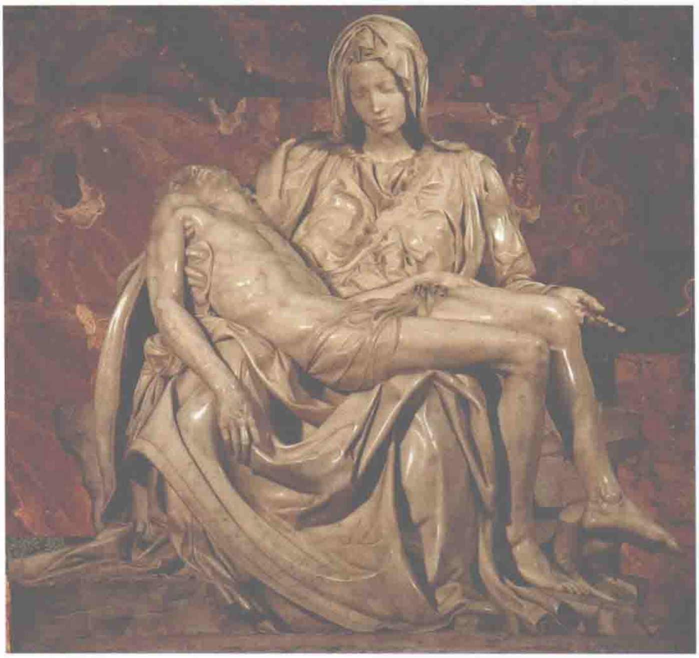

Plate XIII

La Pietà by Michelangelo. Solid marble can be made to connote different materials depending on the shape of the surface. (Image © 2005 Stanislav Traykov; reproduced with permission from the author.) (See Figure 10.24.)

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