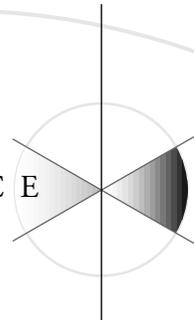


P R E F A C E



How to Use This Book

This book and its accompanying CD-ROM make up the definitive reference on the *Radiance Lighting Simulation and Rendering System*. This suite of UNIX programs was developed over the course of 10 years, under funding from the U.S. Department of Energy and the Swiss federal government, primarily by the first author, Greg Ward Larson. Although *Radiance* is now available commercially for other operating systems, the free version is still available with C source code only for UNIX, so this version is the one we focus on in this book (specifically, release 3.1). New releases will be made available from the *Radiance* Website for the foreseeable future, at radsite.lbl.gov/radiance/. There are currently no restrictions (or warranties) on the use of *Radiance* for any application, public or private, but the software itself may not be resold or distributed without a license from the Regents of the University of California, who hold the copyright. (See the notice at the end of the book or on the sleeve of the CD-ROM for details.)

What Is *Radiance*?

Radiance is a collection of fifty-odd programs that do everything from object modeling to point calculation, rendering, image processing, and display. The system was originally developed as a research tool to explore advanced rendering techniques for lighting design. It has evolved over the years into a highly sophisticated lighting visualization system, which is both challenging and rewarding to learn. *Radiance* is unique in its ability to accurately simulate light behavior in complicated environments, which means two things: correct numerical results, and renderings that are indistinguishable from photographs. There is simply no other physically based rendering system, free or otherwise, with as much power and flexibility as *Radiance*.

There are a few core *Radiance* programs that everyone will use, several others that most will use, and many more that only a few will use. These programs will be introduced in the order of most frequently to least frequently needed in Part I (Chapters 1 through 4). The most advanced users may even combine programs to create new functionality specific to their needs, and we will offer some guidance for them in Chapter 4 as well.

Users typically fall into one of the following categories:

- **Computer graphics enthusiasts**
People who want the most realistic rendering software available and/or are working with a relatively small budget.
- **Researchers**
Graduate students and professors who want source-level access to advanced techniques in rendering and global illumination, or a basis for comparison to their own rendering algorithms.
- **Designers**
Architects, illumination engineers, and other designers who need accurate tools for predicting light levels and visual appearance in novel situations and who have the time and energy to invest in a sophisticated rendering system.
- **Students**
Computer graphics and design students using *Radiance* as part of their coursework in rendering or CAD modeling.
- **Industry professionals**
Professionals working in the arts, entertainment, and litigation who need rendering tools with the latest in local and global illumination methods to obtain results of the highest quality and veracity.

Even if you do not fall into any of the above categories, if you are looking for something out of the ordinary, something that challenges your skills and your imagination, thumb through the pages of this book and glimpse some of the possibilities. The book is divided into three sections: tutorials, applications, and calculation methods. A glossary at the end of the book contains important terms and their definitions, and additional reference materials are provided on the CD-ROM.

Part I: Tutorials

The tutorial chapters were written by both authors. Greg Ward Larson wrote most of the introduction, and Rob Shakespeare, an expert in lighting design who is renowned in the worlds of stage and exterior lighting, created two scenes to introduce users to the concepts they will need for their own lighting studies in Chapters 2 and 3. In Chapter 4, Greg comes back with some simple examples and some advanced ones for users with a penchant for programming and data analysis.

Chapter 1, Introduction, provides a broad overview of lighting simulation and its relationship to rendering, and includes the general principles underlying the *Radiance* system and its design, plus a short tutorial to get the beginner started.

Chapter 2, Scene 1 Tutorial, steps through the construction of a simple cafe scene, introducing the basic concepts and programs needed for everyday rendering.

Chapter 3, Scene 2 Tutorial, demonstrates a more advanced scene, introducing physical light sources, sky simulation, indirect illumination, textures and patterns, complex surfaces, and object generators.

Chapter 4, *Radiance* Scripting Techniques, gives some examples of scripting, which can be used to manipulate scene input and simulation output.

Part II: Applications

The application chapters, 5 through 9, give specific examples and advice for lighting and daylighting analysis, roadway lighting, dramatic lighting, and animation. These chapters were solicited from and authored by experienced *Radiance* users who are experts in these areas. Readers may be interested in one or more of these chapters, depending on their specific needs.

Chapter 5, Lighting Analysis, by Charles Ehrlich, explains lighting analysis methods in detail, including data collection, luminaire modeling, computation, and visualization techniques. Ehrlich has worked with *Radiance* almost from the

beginning and has extensive experience in consulting for daylight and lighting design. His tireless enthusiasm and fertile imagination have been responsible for countless new features and program improvements.

Chapter 6, Daylight Simulation, by John Mardaljevic, explains how to accurately calculate values and render with daylight using four progressive case studies: an unobstructed overcast sky, a simple windowed office space, an office with external obstructions, and the same office under a sunny sky. A brief example of the secondary source calculation is then followed by a final case study taken from a real-life design problem involving a large atrium building. Dr. Mardaljevic has worked extensively with *Radiance* and validating its daylight simulation capabilities, and has produced some of the most impressive models ever built with the system's scripting utilities.

Chapter 7, Roadway Lighting, by Erich Phillips, describes roadway lighting applications, standards for roadway lighting, photometric data, visualization techniques, and human perception metrics. Dr. Phillips is an expert in roadway lighting and accident reconstruction, and has used *Radiance* in his work for over six years.

Chapter 8, Dramatic Lighting, by Rob Shakespeare, features lighting applications for theater and exterior structures. Examples are taken from stage productions, nighttime lighting of high-rise buildings, and bridges.

Chapter 9, Animation, by Peter Apian-Bennewitz, looks specifically at animation, describing techniques for view path generation, network process farming, and file management. Dr. Apian-Bennewitz is also an expert in advanced daylighting systems, and has developed methods for measuring and simulating transparent insulation materials and redirecting windows. His experience with animation also includes other rendering tools, such as Rayshade, and he has produced a number of animations on single- and parallel-processor networks.

Part III: Calculation Methods

The calculation methods chapters, 10 through 15, provide details of how the local and global illumination calculations in *Radiance* work, and are recommended reading for researchers, for those who wish to gain a deeper understanding of the system, and for users who wish to obtain the best results. These chapters were written by Greg Ward Larson, who developed most of the algorithms described.

Chapter 10, Deterministic and Stochastic Ray Tracing, is a basic introduction to the calculation techniques and principles employed in *Radiance*.

Chapter 11, Direct Calculation, provides a detailed explanation of the methods used to calculate direct contributions from light sources, including virtual sources resulting from specular reflections.

Chapter 12, Indirect Calculation, describes the methods used to calculate specular, directional diffuse, and diffuse scattering and interreflection among surfaces.

Chapter 13, Secondary Light Sources, describes special methods used for handling very bright indirect sources of illumination, such as windows, skylights, and reflective light fixtures.

Chapter 14, Single-Scatter Participating Media (Mist), describes a new calculation of light-scattering participating media.

Chapter 15, Parallel Rendering Computations, describes methods for parallel computations on multiprocessor machines and workstation networks. Parallel processing may be used for large single-frame images or animated sequences.

Acknowledgments

During a collaborative research project involving the late Gary Gaiser and myself, we discovered the exciting visualization work of Peter Ngai, who, in turn, introduced me to Greg Ward Larson and *Radiance* in 1989. Those first *Radiance* pictures incited a vision that drives much of my work today. Though *Radiance* was being developed for illumination engineering audiences, there was clearly a place for this brilliant set of tools in all walks of the lighting art. With the gracious support of Indiana University, especially Prof. R. Keith Michael (then Chairperson of the Department of Theatre and Drama), Dean Mort Lowengrub from the College of Arts and Science, Assoc. Dean Jeff Alberts from the University Graduate School, and the staff of the Center for Innovative Computer Applications, the Theatre Computer Visualization Center (TCVC) was born in 1992 to advance lighting visualization in the arts. It is through the resources of TCVC that I learned to integrate *Radiance* into the core of my own theater and architectural lighting design process, which has resulted in my facilitating the use of photoaccurate visualization in the instruction and practice of all aspects of lighting design.

My major reason for joining Greg in the writing of this book was to entice and guide others to the wonderful benefits of using *Radiance*. Without the encouragement and editing skills of Marie Shakespeare, this task would have been far too arduous. As she progressed along the *Radiance* learning curve herself, she continually asked, “Why isn’t there a book to help me out when you are not around to answer my questions?” Well here it is at last! Thanks to Cindy Larson for being the first to tackle the writing of a comprehensive *Radiance* tutorial. Her work provided

excellent insights that helped me to structure Chapters 2 and 3. Thanks also to Ian Ashdown for his careful and detailed critiques of the manuscript and to our publisher for providing such excellent and friendly advice and support.

Rob Shakespeare

A comprehensive list of those who have helped in the development and exploration of *Radiance* would fill a chapter, so instead I'm going to offer general thanks and appreciation to everyone who has ever used the software and written to me about it. You were my inspiration these long years to continue my efforts. (Well, that and the neat pictures.) What started as a bootleg project under the guidance of Francis Rubinstein grew into a sizeable collection of tools I'd be lost without. Besides Francis, I would like to thank Bob Clear for always being there to answer my questions, Sam Berman and Rudy Verderber for supporting my initial work, and Jean-Louis Scartezzini and Steve Selkowitz for their more recent support. In addition to the U.S. Dept. of Energy, who funded the initial development, the Swiss government, the Dept. of Naval Research, and the Federal Aviation Administration have made important funding contributions to further *Radiance* development. For handling legal issues and *Radiance* licensing, I am grateful to Martha Luehrmann, Kristin Weissman, and Viviana Wolinsky.

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A few names are conspicuously absent from the above list, and those are the people who have contributed as coauthors on this book. Since their names are on the title page, I will forgo listing them again here, but these individuals have been very active with *Radiance* for a long time, and that is why I invited them to share the pain of writing a book. You have each earned my undying respect and gratitude. For invaluable help on the Website and in preparing the CD-ROM, I would like to thank Rachel Chadwell, Danny Fuller, Patrick Sibenaler, and Veronika

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Greg Ward Larson

