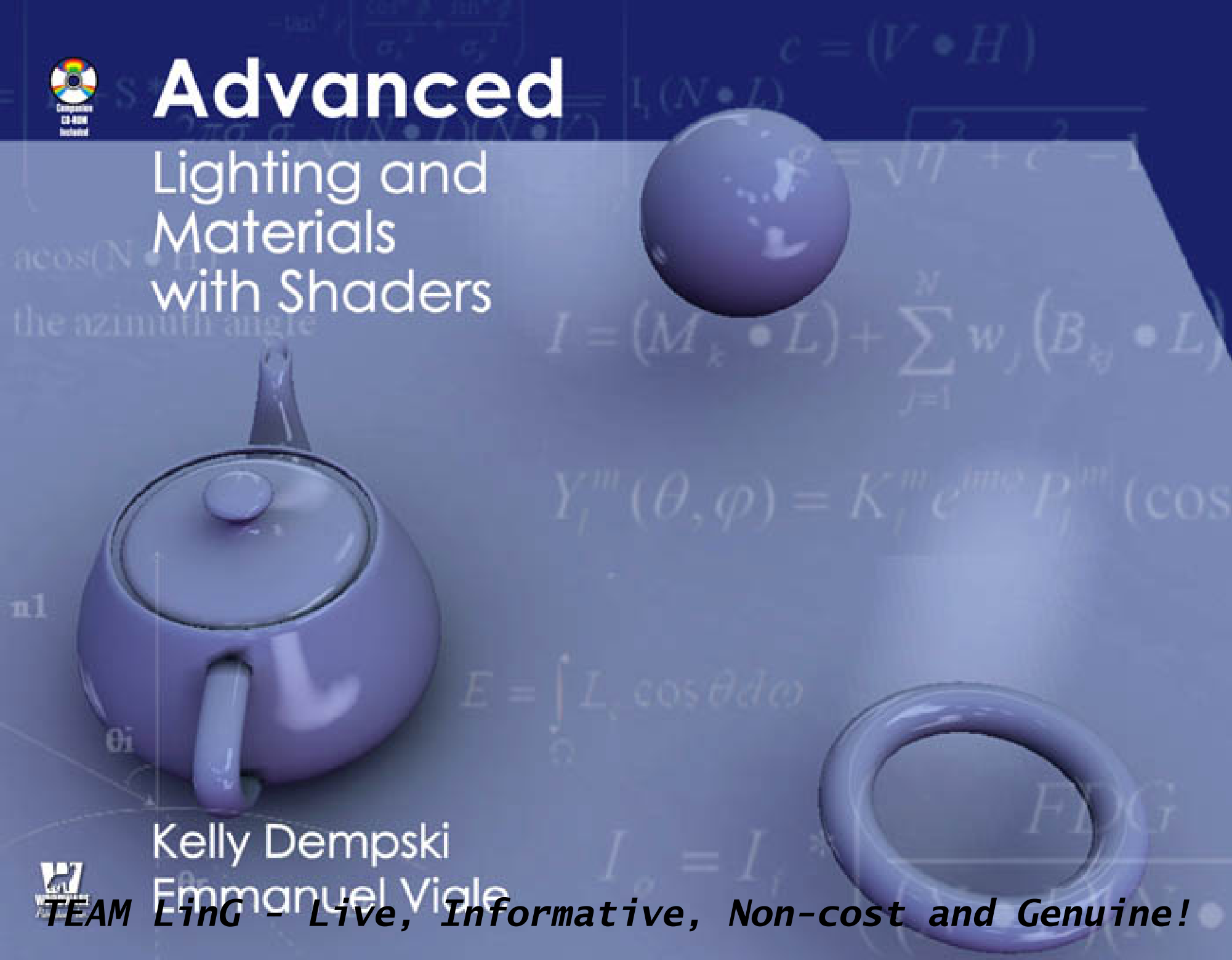

Advanced Lighting and Materials with Shaders

Kelly Dempski and Emmanuel Viale

Wordware Publishing, Inc.

Library of Congress Cataloging-in-Publication Data

Dempski, Kelly.
Advanced lighting and materials with shaders / by Kelly Dempski and Emmanuel Viale.
p. cm.
Includes bibliographical references and index.
ISBN 1-55622-292-0 (pbk., companion cd-rom)
1. Computer graphics. 2. Light—Computer simulation. I. Viale, Emmanuel. II. Title.
T385.D467 2004
006.6'9—dc22 2004018415

2320 Los Rios Boulevard
Plano, Texas 75074

Printed in the United States of America

ISBN 1-55622-292-0

10 9 8 7 6 5 4 3 2 1
0409

All inquiries for volume purchases of this book should be addressed to Wordware Publishing, Inc., at the above address. Telephone inquiries may be made by calling:

(972) 423-0090

In memory of Helen Gaede
KD

To Alexandre, Nicolas, and Valérie
EV

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Foreword

The description of surface appearance is at the core of image synthesis, and creating convincing images with the computer remains to date a complex process, requiring advanced specialized skills. In reality, appearance is controlled by the complex interplay of light (electromagnetic radiation coming from various sources) and the materials composing the objects in the scene, with complex scattering effects taking place all along the path of light.

The physical laws governing this process have long been known at the scale of the light wavelength; yet in order to create a computational model that can be used by a computer, a discrete model is required, and the vast body of research conducted in computer graphics in the last three decades has aimed at providing simplified models for the calculation of lighting effects.

Nowadays computers are equipped with powerful graphics units specialized in massively parallel computations at the vertex or pixel level. The complex calculations needed for proper appearance rendering therefore become affordable in real-time applications, provided they can be incorporated in small programs called shaders. This book therefore provides a very timely contribution by demonstrating in detail how to create these shaders for advanced lighting.

The authors have chosen an ambitious and rigorous path by first presenting the physics and detailed lighting equations. Their discussion of lighting effects, advanced rendering algorithms such as raytracing and radiosity, and material descriptions will be useful to anyone first approaching computer graphics applications.

The remainder of the book provides ample detail on how to incorporate the most advanced lighting effects in shaders. The authors went as far as covering recent advances such as "precomputed radiance transfer" techniques, in which the objects can be illuminated in real time from all directions.

The combination of the theoretical presentation of the underlying concepts and the practical implementation methods for direct usage make this book a complete and self-contained manual. I very much enjoyed reading it and I am certain that it will prove a valuable resource for a great many professionals in the gaming or special effects industry.

Francois Sillion
Grenoble, France

Acknowledgments

Every book of this kind includes the knowledge and expertise of many people, both directly and indirectly involved with the book itself. First, we are indebted to the people who developed the theory and techniques that are described here. Their work is referenced at the end of each chapter and we encourage readers to use those sources to explore further. Of the people who worked directly with the book, we would like to thank Jason Mitchell, Scott Thompson, Wes Beckwith, and Jim Hill. Their help and suggestions were excellent.

We would also like to thank our families and colleagues. Their support is invaluable when working on a book like this.

Introduction

The Importance of Light

When you take a careful look at the real world around you, you begin to realize that most of the detail you see is the result of subtle lighting effects. Areas of light and shadow define the furrowed bark of trees. An elderly face can appear wiser simply because of the depth of its creases. Before a storm, ordinary sunlight takes on an ominous tone, and objects appear less defined. The same room can look very different when it is lit by a television or by candlelight. Each of these examples is an instance where your perception of reality is affected by very subtle changes in the way light interacts with the objects around you. Your eyes and brain are tuned to look for those subtle cues. Therefore, if your goal is to recreate reality (or to create a new reality), you must include as many of those effects as possible.

However, most game development books dramatically understate the importance of lighting and the interactions between light and physical materials. This is largely the result of the fact that, until very recently, consumer graphics hardware was not capable of rendering complex lighting effects in real time. This is changing, and game programmers are finding that they have the power to render complex effects that more closely approximate reality. In the past, the ability to render complex scenes was limited to the raw performance of the hardware. Performance will always be a concern, but complexity is now also dependent on the ability to use the capabilities of the hardware effectively.

With the correct algorithms and approaches, graphics hardware is capable of reproducing the subtle differences between elements of the virtual environment. These subtleties are the key to realism. Now characters need not be limited to simple textured models. They can be comprised of complex materials such as matte cloth, gleaming shields, and smooth skin. This level of realism is now possible, but it requires a deeper understanding of the underlying theory of how light interacts with matter.