Computer Science Workbench

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Image Synthesis

Theory and Practice

With 223 Figures
80 of them in Color

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Series Preface

Computer Science Workbench is a monograph series which will provide you with an in-depth working knowledge of current developments in computer technology. Every volume in this series will deal with a topic of importance in computer science and elaborate on how you yourself can build systems related to the main theme. You will be able to develop a variety of systems, including computer software tools, computer graphics, computer animation, database management systems, and computer-aided design and manufacturing systems. Computer Science Workbench represents an important new contribution in the field of practical computer technology.

TOSIYASU L. KUNII

To our three daughters, Mélanie, Vanessa, and Sabrina

Preface

Image Synthesis: Theory and Practice is the first book completely dedicated to the numerous techniques of image synthesis. As indicated in the title, both theoretical and practical aspects of the subject are treated in detail. Although numerous impressive computer-generated images are included in this book, the main purpose is to explain the most advanced techniques used to produce these images. The book contains a detailed description of the most important algorithms; other algorithms are summarized or simply listed. This volume is also a unique handbook of mathematical formulae for image synthesis. Algorithms are described using a pseudocode, which is something between PASCAL and structured English.

Before explaining the techniques of image rendering, four chapters survey the techniques of computer graphics which play an important role in the design of an image. In the first two chapters, the various geometric models, image and viewing transformations, and the role of virtual cameras and color systems are described. The next chapter presents the most important curves and surfaces, making a clear distinction between approximation and interpolation methods; among the most important techniques described in detail are Kochanek-Bartels interpolation splines, Bézier curves and surfaces, Coons surfaces, B-splines, and β -splines. Solid modeling techniques are also introduced in a specific chapter because of their importance in recent rendering algorithms, such as ray tracing; boundary models, constructive solid geometry and octrees are emphasized.

Each major topic in image synthesis is presented in a separate chapter. The first important problem is the detection and processing of visible surfaces; depth-buffer, scan-line, list-priority, and recursive subdivision techniques are explained in detail; several techniques specific to free-form surfaces and solids are also described. Two chapters are then dedicated to the central problem of light and illumination: In Chap. 6, basic algorithms such as Phong shading, Gouraud shading, and the Whitted illumination

model are introduced; the processing of simple transparency surfaces is also described; in the next chapter, more complex models are presented: spotlights, complex light-source descriptions, complex refraction models, and interreflection models.

As aliasing is a major problem in image rendering, the most important antialiasing techniques are described in Chap. 8. As well as classic prefiltering and supersampling techniques, specific hidden-surface algorithms with antialiasing are explained. The motion blur problem is also presented in detail.

Chapter 9 is dedicated to the problem of shadows. The most common algorithms are presented: shadow volumes, the z-buffer approach, and the polygonal-clipping approach. Techniques for producing soft shadows and penumbræ are also emphasized.

In the last few years, image rendering has been strongly influenced by ray tracing techniques. For this reason, Chaps. 10 and 11 are dedicated to this important approach. After an introduction to the basic algorithm, ray tracing algorithms for specific objects are presented, including quadrics, implicit surfaces, parametric surfaces, and surfaces defined by sweeping. Optimization techniques are explained in detail: bounding volumes, ray coherence, cone tracing, beam tracing, and methods based on space division. The problems of antialiasing and the techniques of distributed ray tracing are also discussed.

Chapter 12 discusses texturing algorithms. Texture mapping, bump mapping and solid textures are the three major kinds of texture discussed in this chapter. Several algorithms are presented for each type of texture. Other types are also explained, including ray-traced textures, syntax-based textures, and textures based on a growth model. Textures based on recursive subdivision are presented in Chap. 13 because of their relation with fractals. Chapter 13 is completely dedicated to fractals from the formal Mandelbrot theory to the recursive subdivision approaches. Other approaches are presented such as iterated function systems and ray tracing of fractals.

Natural phenomena present a particularly difficult challenge in image synthesis. For this reason, we have chosen to devote a large portion of the book to this topic. In Chap. 14, we present the main theoretical approaches to the representation of fuzzy and soft objects. In particular, we explain in detail particle systems, the use of scalar fields, volume density scattering models, and cellular automata. Chapter 15 is more applied and describes various techniques for representing terrains, mountains, water, waves, sky, clouds, fog, fire, trees, and grass.

Techniques for combining images are also explained in Chap. 16; in particular, adaptive rendering, montage and composite methods are described.

The last chapter presents the MIRALab image synthesis software: the SABRINA image synthesis system is described in detail, because most of the techniques presented in this book are available in SABRINA. An informal presentation of the INTER-MIRA specification language, used to implement SABRINA, is also included in this chapter.

Finally, a very complete bibliography on image synthesis is provided at the end of the book.

NADIA MAGNENAT-THALMANN
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