Preface

Overview

This book surveys computer algorithms and programming techniques for specifying and generating motion for graphical objects, that is, *computer animation*. It is primarily concerned with three-dimensional (3D) computer animation. The main audience is advanced undergraduate or beginning graduate students in Computer Science. Computer graphics programmers who want to learn the basics of computer animation programming and artists who use software packages to generate computer animation (*digital animators*) who want to better understand the underlying computational issues of animation software will also benefit from this book.

It should come as no surprise to anyone reading this book that activity in Computer Animation has exploded in recent years - as a research area, as an academic field of study, as a career, and even as a hobby. Feature length films are now often stored digitally and incorporate digital special effects (often referred to as *computer generated imagery* and abbreviated *CGI*). As listed by the Internet Movie Database (imdb.com) [1] as of March 2012, all of the top 10 U.S. films (All-Time U.S. Box Office) depend on extensive use of CGI. Computer animated films have become top box office attractions - according to the same movie database, 2 of the top 10 feature length films are computer animations (*Shrek 2* and *Toy Story 3*) with a third having a significant computer animation component (*Avatar*). Recent *Technical Achievement* and *Scientific and Engineering* awards from the Motion Picture Academy of Arts and Sciences have been for digital image technology including render queue management, facial motion retargeting, tools to review digital effects, and efficient rendering of volumetric effects, just to name a few [2]. And, of course, the computer game industry has exploded. The Entertainment Software Association estimate that, in 2010, consumers spent $25.1 billion on video games, hardware and accessories [3].

Computer animation is more accessible that ever. Desktop, high-quality, computer animation is now possible because of sophisticated off-the-shelf animation software, cheap CPU cycles, and cheap storage coupled with digital video recording. Many technical programs and computer science departments now offer courses in computer animation and the proliferating artistic programs train digital artists in the use of off-the-shelf animation software. There are now major technical conferences and journals that archive developments in computer animation and video game algorithms and techniques.

This book addresses practical issues, provides accessible techniques, and offers straightforward implementations. Purely theoretical discussions have been avoided except to point out avenues of current and future research. In some cases, programming examples are complete working code segments—in C, which can be copied, compiled, and run to produce basic examples of the algorithms discussed; other programming examples are C-like pseudocode that can be translated into working code. C was chosen because it forms the common basis for languages such as C++ and Java, and it lends itself to illustrating the step-by-step nature of algorithms. The Appendixes cover basic material that the reader may find useful as a refresher as well as specific algorithms for use in implementations.

This text is not intended for animators using off-the-shelf animation software (except to the extent that it might help in understanding the underlying computations required for a particular

technique). It does not attempt to cover the theory of computer animation, address the aesthetics of computer animation, or discuss the artistic issues involved in designing animations. It does not detail the production issues in the actual commercial enterprise of producing a finished piece of animation. And, finally, it does not address the issue of *computer-assisted animation,* which, for our purposes, is taken to mean the computerization of conventional hand-drawn techniques; for the most part, that area has its own set of separate issues [4] [5]. The book does concentrate on full 3D computer animation and identifies the useful algorithms and techniques that animators and programmers can use to move objects in interesting ways. While 3D techniques are the emphasis, 2D is not completely ignored.

The fundamental objective of computer animation programming is to select techniques and design tools that are expressive enough for animators to specify what they intend, yet at the same time are powerful enough to relieve animators from specifying any details they are not interested in. Obviously, no one tool is going to be right for every animator, for every animation, or even for every scene in a single animation. The appropriateness of a particular animation tool depends on the effect desired and the control required by the animator. An artistic piece of animation will usually require tools different from those required by an animation that simulates reality or educates a patient. In this spirit, alternative approaches are presented whenever possible.

Organization of the Book

This book presents background information in the first couple of chapters. Techniques that directly specify motion (*kinematic* - not based on underlying forces) are presented in the next 4 chapters followed by 2 chapters that cover force-based (*dynamics*) animation. Character animation is then covered in 3 chapters. The last chapter covers special geometric models. Appendices provide extensive support material. More detail about the chapters is given below.

Chapter 1 discusses general issues related to animation, including motion perception, the heritage of conventional animation paying particular attention to its technological innovations, overviews of animation production and computer animation production, and a snapshot of the ever-evolving history of computer animation. These provide a broad perspective of the art and craft that is animation.

Chapter 2 presents background material and reviews the basics of computer graphics necessary for animation. It reviews computational issues in computer graphics to ensure a solid background in the techniques that are important in understanding the remainder of the book. This includes a review of the rendering pipeline and a discussion of the ordering of transformations to reduce round-off errors that can creep into a series of calculations as one builds on another. A detailed section on quaternion representation of orientation is presented in this chapter as well. If the reader is well versed in computer graphics, this chapter may be skimmed to pick up relevant terminology or skipped altogether.

Chapters 3 and 4 cover interpolation. Chapter 3 presents the fundamentals. It introduces time-space curves, arc-length parameterization of a curve, and speed control along a curve. Interpolation of orientation with an emphasis on using quaternions is then covered. Various ways to work with paths are then presented. Chapter 4 presents animation techniques based on interpolation including key frame interpolation, animation languages, shape deformation, and shape interpolation including morphing.

Chapters 5 and 6 are primarily concerned with kinematic control of articulated figures. Chapter 5 is concerned with kinematics of linked appendages. It covers both forward and inverse kinematics. Chapter 6 covers the basics of motion capture (*mocap*). First, the basic technology is reviewed. Then the chapter discusses how the images are processed to reconstruct articulated figure kinematics, including some techniques to modify the resultant mocap data.

Chapters 7 and 8 cover animation that is more concerned with simulating real-world (e.g. physics-based) processes. Chapter 7 covers physics-based animation as well as mass-spring-damper systems, particle systems, rigid body dynamics, and enforcing constraints. It has an additional section on ways to model cloth. Chapter 8 covers the modeling and animation of fluids. It first covers models that handle specific macro-features of fluids and then covers computational fluid dynamics (CFD) as it relates to computer animation.

Chapters 9 through 11cover animation concerned with people and other critters. Chapter 9 covers human figure animation: modeling, reaching, walking, clothing, and hair. Chapter 10 covers facial animation: facial modeling, expressions, and lip-sync animation. Chapter 11 covers behavioral animation including flocking, predator–prey models, intelligent behavior and crowd behavior.

Finally, Chapter 12 covers a few special models that are useful to animation: implicit surfaces, L-systems, and subdivision surfaces.

Appendix A presents rendering issues often involved in producing images for computer animation: double buffering, compositing, computing motion blur, drop shadows, and billboarding. It assumes a general knowledge of the use of frame buffers, how a z-buffer display algorithm works, and aliasing.

Appendix B is a collection of relevant material from a variety of disciplines. It contains a survey of interpolation and approximation techniques, vector algebra and matrices, quaternion conversion code, the first principles of physics, several useful numeric techniques, optimization, and attributes of film, video, and image formats, and a few other topics.

The Web page associated with the book, containing images, code, and figures can be found at *textbooks.elsevier.com/9780125320009*.

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