Handbook of Computer Animation

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This book is dedicated to the memory of Rob Edwards

Preface

The UK's National Centre for Computer Animation (NCCA) is based at Bournemouth University and has been associated with teaching, research and consultancy in computer animation for over 15 years.

Currently, there are approximately 250 students studying computer animation on a three-year undergraduate course and three one-year postgraduate courses. The overriding philosophy behind these courses is based upon the marriage of art and science. Students come from a variety of creative and technical backgrounds and during their stay at the NCCA they are immersed in a multidisciplinary approach to computer animation.

To gain access to the undergraduate course, students must possess strong creative skills, but also the potential to cope with mathematics, programming and computer technology. During the three-year course, students develop strong animation skills, and become expert in animation systems such as Maya, Houdini, RenderMan and OpenGL. At the same time they learn to program in C, C++ and Java, and are taught a range of mathematical topics that include vectors, transforms, matrices, parametric curves and surfaces. Students also become familiar with computer architectures, operating systems, computer hardware and networks.

As one would expect, graduates from this course are in great demand by industry. This multifaceted education, together with strong problem-solving skills, make these graduates ideal candidates for a wide variety of jobs in the computer animation sector. Perhaps the most relevant role is that of a Technical Director within a special effects company.

The postgraduate courses comprise: MA 3D Computer Animation, MA Digital Effects and MSc Computer Animation. Students on these courses are exposed to the same philosophy of marrying art with science, which is manifested in the wide range of masters projects they undertake in their final semester.

Running such an ambitious range of courses requires a highly qualified academic team, which the NCCA has managed to acquire and maintain. Members of the team come from a variety of backgrounds that include computer science, computer animation, traditional animation, fine art, engineering and media production. This wealth of knowledge provides the academic framework to support the above courses and is the key to maintaining a vibrant and stimulating student environment.

Like many other computer-based disciplines, computer animation is in a constant state of flux. New techniques are constantly being developed; software products come and go; increased processor speeds transform working practices; and new GUIs improve performance and project complexity. Anyone working in such a rapidly changing subject must constantly update their knowledge and remain abreast with state-of-the-art developments. In computer animation, this means following international events such as SIGGRAPH, IMAGINA and CGI, monitoring recent research papers and books, as well as attending film festivals and watching key films. It can

also mean that personal research projects are pursued to develop an individual expertise.

Staff at the NCCA are engaged in all of the above activities. There is an active research group, which is recognized as the UK's center of excellence for computer animation. Academic staff are also engaged in a variety of personal research projects, computer animation productions and the writing of books, which brings us to this particular volume.

Two years ago, we decided to write a book on 3D computer animation. Each member of staff would contribute a chapter on their particular area of expertise. The challenges associated with such a task were threefold: the first was agreeing on the level of technical competence expected of the reader; second, maintaining a level of technical continuity across the book; and thirdly, keeping a flowing literary style across the chapters.

We agreed that the technical expertise expected of our readers would be that associated with a typical NCCA 3rd-year undergraduate or postgraduate student, and that the subjects addressed in the book would correspond to key topics associated with their academic studies. This provided the freedom to address what we believed to be central topics within computer animation, but which were not necessarily linked directly to one another. We also wanted to address the breadth of diverse subjects associated with computer animation such as computer games, special effects, curves and surfaces, and genetic algorithms. As far as we knew, no such book existed, and writing such a book presented a unique opportunity to provide the student community with a book that addressed a collection of major topics relevant to anyone studying computer animation.

The book is divided into seven chapters – each one is written by an individual member of staff. I will introduce each chapter in this preface and attempt to describe the *raison d'être* behind its inclusion and the expertise of the author. The chapters are organized in the form of a journey through the world of computer animation. We begin with computer game design and finish with rendering and shading. During our journey we stop at some very interesting points that include genetic algorithms, shooting live action, digital effects, cubic polynomial curves and surfaces, and subdivision surfaces.

Chapter 1 explores various issues associated with computer game design and is entitled *Computer and Video Game Design Issues*. It is written by Lee Uren who was a graduate of the NCCA's BA (Hons) Computer Visualization and Animation course. After graduating, Lee joined the NCCA as a Demonstrator and because of his unique knowledge of computer games joined the lecturing staff and aligned himself with the teaching of this subject. Like many other graduates of the NCCA's BA course, Lee enrolled for the MA Computer Animation and was awarded a distinction in 1999. Lee is now employed as an animator at Industrial Light & Magic, Inc. Fortunately, before Lee left, he finished the manuscript for this chapter where he traced the history of computer games and documented the rapid technological developments that occurred over the past two decades. The chapter concludes by addressing recent events such as the launch of the Playstation II and finally he gazes into the future to see what is coming in over the horizon.

Chapter 2 is entitled *Evolutionary Algorithms in Modeling and Animation* and is written by Anargyros Sarafopoulos. Anargyros was a graduate of the NCCA's undergraduate course and is now a Senior Lecturer. Anargyros lectures on computer programming and he has recently completed a PhD where he has been investigating the role of genetic algorithms in computer animation. Much of this chapter is drawn from his research and is truly state-of-the art. The chapter updates the reader's knowledge with the fundamental principles of genetics and quickly moves to the digital domain where genetic algorithms are starting to get a foothold in computer graphics and computer animation. He explains how evolutionary

algorithms can be used as an artistic meta-tool, and even though still images are used to demonstrate the technique, the potential for animation looks very promising. Anargyros' PhD supervisor at University College London was Professor Bernard Buxton, who also contributed to the chapter.

Chapter 3 is written by Professor Mitch Mitchell, who is a Visiting Professor at the NCCA. Mitch was a cameraman and founding video effects supervisor at the BBC before going freelance. He later joined The Moving Picture Company in London and as Director of Special Effects developed new techniques and technologies as well as supervising visual effects on many commercials and broadcast programs. Freelance again he has worked as visual effects supervisor on amongst others the BBC's award winning promotional film *Next Generations*, the Orange car chase commercial "Hold Up", a 10 h mini-series *The Tenth Kingdom* and is currently completing effects and editing of a TV movie as well as writing a Media Manual on effects. Throughout his career he has written about and spoken at many conferences on new technologies in motion picture and television production and has lectured extensively to students on effects photography. In his chapter *Shooting Live Action for Combination with Computer Animation* Mitch shares with the reader a wealth of practical knowledge acquired from a professional life devoted to special effects.

Chapter 4 is called *Elements of Digital Effects* and is written by Steve Hubbard. Steve completed both the BA (Hons) Communication and Media Production, and MA Computer Visualization and Animation courses at Bournemouth University, before staging a ten-year journey into computer animation and digital effects production. He then returned to the NCCA in 2001 to communicate his discoveries and experiences to a new generation of prospective digital effects practitioners, by running the NCCA's MA Digital Effects course.

Whilst in industry, he worked on commercials, simulator ride films, cinema titles, feature films and documentary series. These included the BBC's landmark series *The Human Body* and *The Planets* and Channel 4's *What Happened to the Hindenburg*? Largely freelance, he worked at many London companies such as Lost in Space, Cell Animation, Cinesite and The Mill. He was also a founder of three computer animation companies.

Steve's chapter takes over from the previous chapter by explaining the techniques of compositing live action with synthetic images. The chapter begins by defining what is meant by digital effects, continues with a brief history of analogue and digital effects, and then explains the terminology and techniques associated with modern compositing systems.

Chapter 5 is written by Professor Peter Comninos who founded the NCCA in 1989. Peter's knowledge of computer animation is deep, as it is broad. Prior to coming to Bournemouth University in 1987 he was working at Teesside University where he had developed his CGAL computer animation system, which was the result of his PhD research. CGAL was the central software system at the NCCA for several years, and many students acquired an understanding of computer animation using CGAL before securing key jobs in industry. Apart from directing the research programme at the NCCA, Peter also teaches Advanced Animation Systems and Mathematics on the NCCA's undergraduate course and on the MSc Computer Animation course. He is one of the few people in the world who have developed a complete computer animation system single-handed, and although this could have been an exciting topic for the book, he decided to write about another subject with which he is an authority: *Cubic Polynomial Curves and Surfaces*. This chapter takes the reader into the mathematical world of curves and surfaces, and although this is the first chapter to introduce mathematics, the reader will find that he has made every attempt to communicate some fundamental mathematical ideas in a clear and simple manner.

Chapter 6 – *Smooth Surface Representation over Irregular Meshes* – follows on from the previous chapter by exploring the subject of subdivision surfaces. The author is Professor Jian Zhang who joined the NCCA in 1996, and is now Professor of Computer Graphics. Professor Zhang has published a number of papers in computer graphics, computer animation and surface modeling, and he is responsible for the research projects of the NCCA. One of his research interests is in the modeling of surfaces of irregular topology. Such surfaces have become increasingly important and widely used in computer animation, as they complement the ordinary parametric surfaces where they are generally restricted to have a quadrilateral topology. In this chapter he introduces three such surface modeling methods: Cutmall–Clark subdivision surfaces, Doo–Sabin subdivision surfaces and loop triangular patch-based spline surfaces. Although there are a number of other modeling methods, which are equally capable to handling irregular topology, these three methods are widely used in animation applications. For each method, he introduces both the theoretical background and the algorithms. This will help the reader both understand the principles and be able to implement these methods.

Chapter 7 concludes the book with *Rendering and Shading*. This chapter is written by Dr Ian Stephenson who joined the NCCA in 1997. Ian's PhD research work was in *Massively Parallel Computer Architectures*. He has worked in industry and before pursuing an academic career he was a systems programmer at Cambridge Animation Systems where he was working on the *Animo* system. At the NCCA he teaches on a variety of technical subjects that include Operating Systems Techniques, Computer Architecture and RenderMan.

Ian takes a system's approach to rendering by considering the implementation of a simple renderer, and showing how the stages interact with one another. The RenderMan standard is used as the basis of the discussion, which allows real practical problems to be considered rather than imaginary ones. The chapter begins by considering some of RenderMan's features and then explores in greater detail the concepts of shading engines. The chapter concludes by looking at more advanced features such as spectral colors, motion blur, deferred shading and occlusion culling.

We wish to thank staff and students at the NCCA for their support during the writing of this book and their permission to use their images. On behalf of the above authors, I hope that you will find the book useful, interesting to read, and that you will discover something new that will increase your understanding of computer animation.

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