Andy Beane

3D Animation
ESSENTIALS

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3D ANIMATION

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To my wife, Heather, and my boys, Ollie and Max,
thank you for all of the patience you have shown me
during all of my fretting and for picking up my slack
around the house to allow me to complete this project.

Acknowledgments

This book allowed me to write out in a formal form information I am asked about weekly as a professor at Ball State University—questions such as *What kind of jobs are there in 3D animation?* and *Where will I have to move to, to work in 3D animation?* To the prospective students and their parents who have been asking these questions, this book is for you.

I would first like to thank my fantastic wife for supporting me during the writing of this book. Also I would like to thank Mariann Barsolo for giving me the chance to write this book and for helping me through the whole process. Thanks to Candace English, my development editor, for helping me make this book understandable and worth reading. Thank you to my technical editor, Keith Reicher, for helping me keep it real and correct. I would like to thank Larry Richman for giving me a recommendation that started this whole endeavor and for giving me my start in the education world. I would also like to thank the entire Sybex production team for making this book look great. I would like to thank everyone who helped me by talking about his book and creating images for me to use. They look good.

About the Author

Andy Beane is an animation artist who has been teaching and working in the field since 2002. He currently oversees the animation major at Ball State University in Indiana and previously taught animation at the Art Institute of California–Orange County. His production experience includes a children's television show pilot with Xzault Studio, "Coming Undone" music video, and *Barnyard* from Paramount Pictures. He wrote curriculum for the Autodesk Animation Academy 2010 and is also a board member of the MG Collective, an Indiana-based motion graphics and animation community group. He has an MFA in computer animation from the Academy of Art University in San Francisco.

Contents at a Glance

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Introduction

What is 3D animation? What kind of jobs are there in the field? How does 3D animation get created? What is the future of 3D animation? These are all questions that are asked by someone who is looking to pursue 3D animation as a career or hobby and are reasons this book was written. The answers to these questions are not always easy to find and definitely not in one location, so this book can be used as a reference to answer your personal questions about the animation industry.

This book looks at the history of the computer and how its evolution has driven and continues to drive computer graphics and 3D animation, and at the same time how computer graphics have driven developments in computer hardware and software. 3D animation is an industry that borrows from many other fields, including film, art, photography, sculpting, painting, and technology. In this book, you will look at up-to-date techniques and practices related to those realms and also take a look at what is coming up in the near future.

Who Should Read This Book

This book is for anyone who is at all interested in anything related to 3D animation. For students graduating from high school (and for parents of high-school students), this book can give you insight into the industry of 3D animation and allow you to better understand basic job functions, basic terminology, and 3D animation techniques. For students already in college or undergoing some other kind of formal training, this book can give you insight into future concepts you may need to learn to make you more marketable in the 3D animation industry. Finally, for people looking to change careers, this book will teach you the basics so you can figure out what part of the industry you might be interested in breaking into.

What You Need

This book is about concepts and techniques, so you really do not need any particular program to complete this book. But if you want to jump in and try some

3D animation techniques, you can get demo versions of 3D animation software from various software companies, including the following:

Autodesk Maya, 3ds Max, Softimage, Mudbox, and MotionBuilder at `http://usa.autodesk.com/` and `http://students.autodesk.com/`

Blender at `www.blender.org`

Maxon Cinema 4D at `www.maxon.net`

NewTek LightWave 3D at `www.newtek.com/lightwave.html`

Side Effects Software Houdini at `www.sidefx.com`

Luxology modo at `www.luxology.com/modo/`

What Is Covered in This Book

You will learn the essentials of the 3D animation industry, including a history of the industry, how 3D animation projects are created, basic computer-graphics principles, basic animation, story and film theory, the core concepts of each of the job functions of a 3D artist, what hardware and software tools are available today, and what the future of 3D animation may have in store.

Chapter 1: 3D Animation Overview What is 3D animation? This question is answered in Chapter 1. This chapter also explores the different industries that utilize 3D animation in various ways. The history of 3D animation is presented, along with the history of the computer, as the two are tied together inextricably.

Chapter 2: Getting to Know the Production Pipeline Almost all 3D animation is created in a team setting, and this chapter breaks down the steps that a studio uses to create 3D animated projects. You'll learn about the preproduction, production, and postproduction stages of the production pipeline and get a high-level view of the specific jobs in each of the stages.

Chapter 3: Understanding Digital Imaging and Video Almost all 3D animation is viewed via computer monitors, projectors, or TV screens, and all 3D animation is created on computers. So an understanding of digital imaging and video is a must. This chapter breaks down the digital image to its most basic form—the pixel—and then explores the other elements that make up a digital image.

Chapter 4: Exploring Animation, Story, and Pre-visualization All 3D animation must tell a story. This chapter presents basic 3D animation methods worked out through traditional 2D animation, basic storytelling theory, and film and pre-visualization techniques with cameras.

Chapter 5: Understanding Modeling and Texturing This is the first of three chapters that provide detailed looks at the individual job roles in the 3D modeling profession. Chapter 5 breaks down the basic principles, terminology, and techniques of modeling and texturing. When you're finished with this chapter, you'll understand what's behind polygons, NURBS, UVs, shaders, and more.

Chapter 6: Rigging and Animation This chapter digs into the specifics of the closely linked animation and rigging roles to give you a good idea of their interrelatedness and the fundamentals behind the jobs, such as deformers, inverse and forward kinematics, and keyframes.

Chapter 7: Understanding Visual Effects, Lighting, and Rendering Here you'll learn about visual effects, lighting, and rendering through discussions of particle systems, light types and options, raytracing, global illumination, and more.

Chapter 8: Hardware and Software Tools of the Trade Many tools are available to 3D animators today, including the computer, monitor, and human interface tools such as a mouse and tablet options. This chapter covers those plus storage options and solutions that make 3D animation possible with the large amount of data the files will create and files that will need to be shared by different artists at one time. This chapter also presents the software options 3D animators have so you can figure out what packages make the most sense for you to learn.

Chapter 9: Industry Trends The 3D animation industry is changing constantly, so it's important to be aware of what is on the cutting edge and what is on the horizon. Techniques and methods such as real-time rendering, motion capture, stereoscopic 3D, and point cloud data are integral to the future of the industry.

Appendix A: Answers to Review Questions This appendix presents the answers to the review questions found at the end of each chapter.

Appendix B: Gaining Insight into 3D Animation Education This appendix brings you interviews with experts in the 3D animation education field so you can glimpse some of the differences within the formal 3D animation educational system. The appendix includes interviews with the following professionals:

- Linda Sellheim, academic segment manager for primary and secondary education at Autodesk
- Larry Richman, dean of academic affairs at the Art Institute of California–Sacramento
- Steve Kolbe, assistant professor at the University of Nebraska–Lincoln

Appendix C: Learning from Industry Pros This appendix presents interviews with professionals in the 3D animation industry. Some of the differences between the hiring methods of different 3D animation fields come to light in interviews with the following people:

- Brian Phillips, executive creative director at The Basement Design + Motion
- Jim Rivers, hiring manager at Obsidian Entertainment
- Rosie Server, senior recruiter at Sony Pictures Imageworks

Sybex strives to keep you supplied with the latest tools and information you need for your work. Please check its website at `www.sybex.com/go/3danimationessentials`, where we'll post additional content and updates that supplement this book if the need arises.

CHAPTER 1

3D Animation Overview

3D animation has become a mainstay in film, television, and video games, and is becoming an integral part of other industries that may not have found it all that useful at first. Fields such as medicine, architecture, law, and even forensics now use 3D animation. To really understand 3D animation, you must look at its short history, which is tied directly to the history of the computer. Computer graphics, one of the fastest growing industries today, drives the technology and determines what computers are going to be able to do tomorrow. In this chapter, you will look at present-day 3D animation and then look back at how the past has shaped what we do today.

- **Defining 3D animation**
- **Exploring the 3D animation industry**
- **Delving into the history of 3D animation**

Defining 3D Animation

3D animation, which falls into the larger field of 3D computer graphics, is a general term describing an entire industry that utilizes 3D animation computer software and hardware in many types of productions. This book uses the term *3D animation* to refer to a wide range of 3D graphics, including static images or even real solid models printed with a 3D printer called a rapid prototyper. But animation and movement is the primary function of the 3D animation industry. 3D animation is used in three primary industries:

- Entertainment
- Scientific
- Other

Each of these industries uses 3D animation in completely different ways and for different final output, including film, video, visualizations, rapid prototyping, and many others. The term *3D animation* is still evolving, and we have not yet seen everything that it will encompass.

A 3D artist is anyone who works in the production stage of 3D animation: modeler, rigger, texturer, animator, visual effects technician, lighter, or renderer. Each of these job titles falls under the umbrella term *3D artist*, and so each job can also be referred to more specifically: 3D modeler, 3D texture artist, 3D lighter, 3D animator, and so forth. These jobs are discussed in more detail throughout this book, to give you a good idea of the role of each on a day-to-day basis.

Exploring the 3D Animation Industry

Let's take a closer look at the three primary industries using 3D animation. This section details the various opportunities of each so you can see what a person wanting to get into 3D animation could do today.

Entertainment

The entertainment industry is the most widely recognized of the three primary 3D animation industries and includes film, television, video games, and advertising—each of which has subfields within it. The entertainment industry is dedicated to creating and selling entertainment to an audience.

Film

Two primary types of films are created in the 3D animation realm: fully animated films and visual effects films. In fully animated films, all the visual elements onscreen are created in 3D animation software and rendered. Examples include *Toy Story*, *Monsters vs. Aliens*, and *Shrek*. Visual effects films are typically shot with real actors, but the backgrounds or other effects are computer generated. *Jurassic Park*, *Sky Captain and the World of Tomorrow*, and *Tron* are examples of visual effects films.

The film industry is one of the largest industries using 3D animation. These films typically take about six months to four years to complete, depending on the scale of the project. The production crew can range from 3 people to 300, again depending on the scale of the overall film.

Fully animated full-length films can take two to four years to create and have a very large crew of hundreds of employees. One studio usually completes the whole

film internally. Short films (those shorter than 40 minutes) often are created by individuals or small studios. These short films are usually done on the side or after hours as personal projects. Large studios might create a short film to test a new technique or production pipeline. These films can be completed in a few months with a large crew or may take years depending on the artists' work schedules.

Visual effects films are different from fully animated feature films in that they are shot by a regular movie crew. A visual effects supervisor helps with camera work and with collecting any other data needed for the addition of the visual effects. Then the completed shots are sent to visual effects studios to complete parts or the whole sequence of effects as needed. Today most visual effects–heavy films use one or two primary studios for most of the work to keep the effects looking consistent, but then farm out smaller shots or sequences to other studios to save time. Visual effects studios can be very large to very small, depending on the type of work they are expected to complete.

Television

3D animation is still trying to make its mark in the television industry. Creating a single 3D animated television show is quite expensive and time-consuming. Still, several of today's shows are being created with 3D software, including *South Park*, *Mickey Mouse Clubhouse*, and *Star Wars: The Clone Wars*.

A more common usage of 3D animation in television is the addition of 3D visualizations to regular shows on networks such as the Discovery Health Channel, History Channel, and Science Channel. These visualizations typically are used in educational shows to help the audience understand certain topics.

The television industry doesn't have the film industry's luxury of lots of time and lots of money. Television shows need to be made in months, not years. The budgets are tremendously smaller, and more content needs to be created in a single season. 3D animation in television shows usually does not have the overall quality of that in film, but can still be very good if a stylized final look is used in the project.

Video Games

The video game industry enables artists to use 3D software to create virtual worlds and characters that will be played in a video game engine. This industry is massively popular and is at least as profitable as the film industry. There are two primary fields in the video game industry: in-game 3D animation, which creates the actual game world that players are immersed in while playing the video game, and game cinematics, which are cinematically created cut scenes of a video game that help drive the story forward in between levels.

Video game cinematics are like mini movies between levels that allow the game developer to control the storyline of a game while the player progresses.

Low-resolution polygon modeling is covered further in Chapter 5, "Understanding Modeling and Texturing."

The in-game side of this industry is closely tied to the computer programming that makes playing the video game possible. The creation of in-game art is limited by the hardware and software that is used to play video games in real time. For example, a game destined for a console such as the Xbox 360 or PlayStation 3 requires low-resolution models in order to allow numerous characters to appear in the game at once, along with the background elements and all the props and effects. To allow for real-time rendering and game play, the modeling artist must stay within a specific polygon count for these low-resolution models. Once the 3D animation assets are created, the video game programmers will create a system enabling the asset to be placed into the game to be played.

Triple-A video game titles are games that are expected to do well commercially and typically take longer to develop.

Most game cinematics, like film, are limited today only by the budget and time needed to create the 3D animation assets and to render the final frames to be played in video. Game cinematic artists are similar to film 3D animators. They do similar work but typically in a faster timeline (although not as fast as television). Many game cinematic trailers and in-game cinematic scenes are of a very high caliber that can rival film.

Video games created for smart phones and tablets typically take a few months to develop. A large triple-A title such as *Gears of War* or *Crysis* might take 2 to 4 years to create. It is not unheard of for a game-development cycle to last 10 years, however.)

Advertising

The advertising industry is all about very short animations. Typically, only 10 seconds to 4 or 5 minutes is needed to show or describe a product or service. These short animations must be able to provide a great deal of information in this brief time span. Like film and television, 3D advertising animation can utilize an all–3D animated form or incorporate mixed-media visual effects for the final overall look.

Typical projects in this industry are television commercials, web commercials which can include print ads, and still imagery. A lesser-known side of advertising is product visualization (discussed in detail in the next section), in which the artist creates a 3D model to serve as a prototype of an actual product to show to an investor to create an interest in that product.

Advertising can have a very high level of quality but is created in a very short amount of time. Studios specializing in advertising animation are medium sized and follow a solid workflow in order to provide the fast turnaround needed for this type of animation.

Scientific

The scientific industries utilizing 3D animation include medicine, law, architecture, and product visualization. The use of 3D in these industries is not well

known, however, because the final products are aimed at a specific audience and rarely are seen by the general public.

Medicine

The medical industry uses 3D animation in many ways, from creating a visualization of a specific medical event to depicting a biological reaction. For example, you can demonstrate what happens when plaque will build up in your arteries and will block blood flow to the heart, causing a heart attack. Art has been a part of the medical industry since the beginning of modern medical practices. Many of Leonardo Da Vinci's sketchbooks, for instance, focused on human anatomy and medical processes. These drawings, shown in Figure 1.1, were used by doctors to better understand early medicine. Even today you can see posters of human anatomy on the walls of doctors' offices. So it only makes sense that the medical field would take advantage of the new art form of 3D animation.

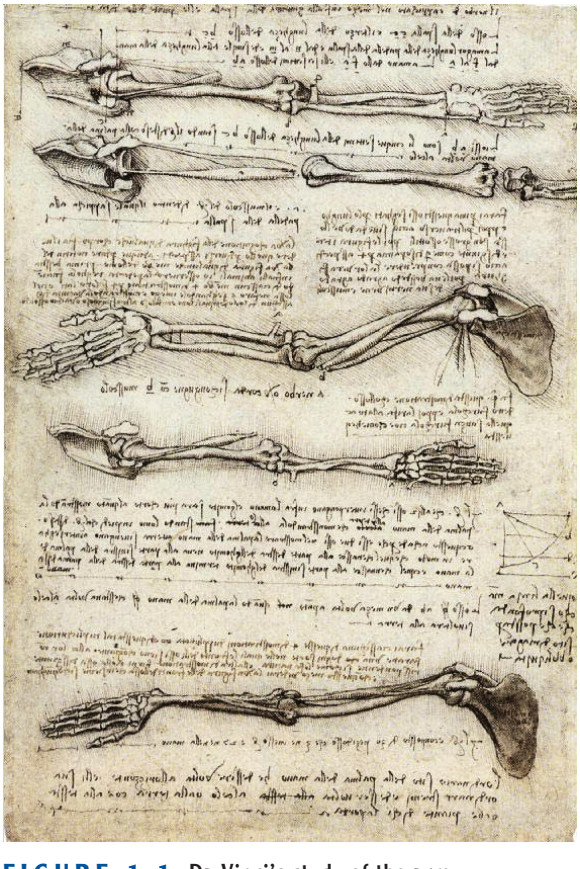


FIGURE 1.1 Da Vinci's study of the arm

The most popular medical 3D animation type is medical visualization used for education or marketing. This animation is used to educate the public and medical staff on new techniques or drugs. It is also used in marketing new medical products to investors or medical professionals, as shown in Figure 1.2. 3D animation can create a vastly rich visual guide to human and biological systems and can provide a great amount of information in a short amount of time.

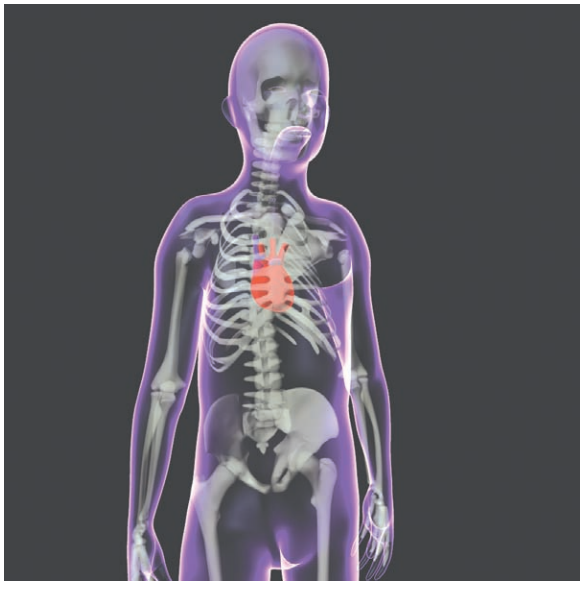


Image courtesy of and © Zachary Craw

FIGURE 1.2 Example of a medical rendering

***Motion capture*, a system of tracking human movement that can be used for medical research and the entertainment industry, is covered further in Chapter 9, "Industry Trends."**

3D animation can be used in simulations to help medical researchers predict the spread of a disease or understand which body part will fail first under great strain without actually putting a person at risk. By using motion capture, researchers can create a library of movements and then study the effects of various stresses on the human form. New probe-like technology enables researchers to track muscle strain as they watch which muscles are working the hardest during a specific movement or series of movements. The U.S. Department of Defense and professional sports have an interest in this type of data because it can help indicate how a new piece of protective equipment might be working or hindering.

One other form of medical 3D animation is tied to the video game industry. Ongoing studies are looking at how video games might be used to help heal brain injuries. These video games stimulate different areas of the brain, potentially helping the regrowth of brain tissue. These studies are very new but are

showing good results, which means that more of these types of games could be created for other healing applications.

3D animation in the medical sector is a vastly growing market that can be lucrative to an individual artist or small studio of professionals. The biggest drawback to this industry is that most people training today in 3D animation would rather work in video games or film and not for a drug company or university research project.

Law

Law animation falls into two fields: forensics and accident reconstruction and simulation. This type of animation is created to prove, disprove, or elaborate on facts in a court case, to help either the defense or prosecution. It can include pure computer physics simulations or just a hand-keyed animation of the crime scene to enable the judge or jury to move around or study the crime scene if needed. It can be used, for example, to prove that a gunman could or could not have shot someone from a specific location (see Figure 1.3) or to demonstrate a car accident scenario. These types of animations are often not allowed to be used as pure evidence but can be used to demonstrate a theory that the prosecution or defense may have on a specific case.

Forensics is a field that utilizes many different sciences to prove or disprove questions in the legal system.

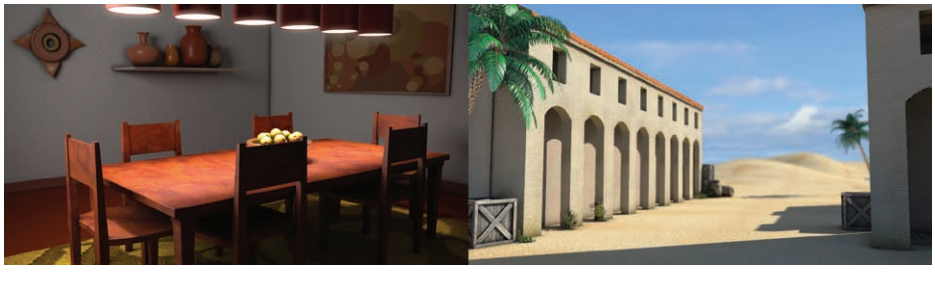
Image courtesy of and © Pat Howk

FIGURE 1.3 Forensics animation showing gunshot trajectory

Another aspect of this 3D animation field is the use of 3D laser scanning of a crime scene. This 3D laser scanning can create a perfect replica of a crime scene to be used as a reference when needed. This 3D scan can be accurate to within millimeters and therefore can be crucial to a court case or an investigation.

Architecture

Architects have been using computer-aided design (CAD) software since the 1980s to help them create better and more stable designs. Today architects use 3D software in conjunction with CAD programs not only to create models, but to test and visualize those models to see what structures would look like photorealistically before they are actually created. Software such as Autodesk AutoCAD and Autodesk Revit enable architects to test the stability of designs under certain conditions, to see whether they can withstand a specific type of natural environment or disaster. These CAD files can be converted and then rendered in software such as Autodesk 3ds Max and Autodesk Maya to enable investors and clients to see what a structure could look like from the outside and inside. This type of work is becoming more and more popular and can be a very cost-effective way to test certain material looks of a building before actually building it. You can see an example of interior and exterior architecture rendering in Figure 1.4.



Images courtesy of © Justin Canul and Zachary Craw

FIGURE 1.4 Example of indoor and outdoor rendering for architecture

Product Visualization

One last scientific area is product design and product rendering visualization. This is similar to architectural rendering in that products can be designed and tested in 3D software and then rendered to show investors. After the design is drawn up, a 3D artist will create a 3D model of the product in 3D design software to test its construction. Then a visualization animation will be created to show how the product will work and how it is assembled if needed. This type of visualization helps investors have a better grasp of what they may be investing in and can be used for commercial purposes as well, for presales.

Other

The 3D animation industry is in its infancy, and the technology that is driving this art form is changing on a yearly basis. This rapid pace of change necessitates the "other" category because some fields are so new that they do not fit into established mainstream categories. A trio of these new 3D animation fields are art, augmented reality, and projection mapping.

Using 3D animation in *art* is just what it sounds like: the creation of 3D elements incorporated in a final product to be shown in a gallery or other art-exhibition venue. This could include still imagery to be framed and posted on the gallery walls or a 3D statue created in 3D software and then rapid-prototyped and placed into the gallery as sculpture. Typically today 3D art animation is video installations that will use animated forms in a non-story-based structure. Sculpture might utilize moving 3D animations to enhance the piece. These types of 3D animations are typically not character- or story-based, but simply moving forms projected onto the sculptures.

Augmented reality might be considered by some as an advertising form of 3D animation, but because it is so new, it is premature to lump it into a certain field. In augmented reality, a user looks at the real world and sees 3D elements added to it. Typically, we would look through a webcam and use a *marker* (usually an image) to lock the position of the 3D elements though the camera as seen in Figure 1.5. Other viewing devices today are head-mounted with a see-through visor that add the 3D elements to the visual real world. There are also handheld augmented-reality devices and tracking with the use of GPS to add visuals to this reality.

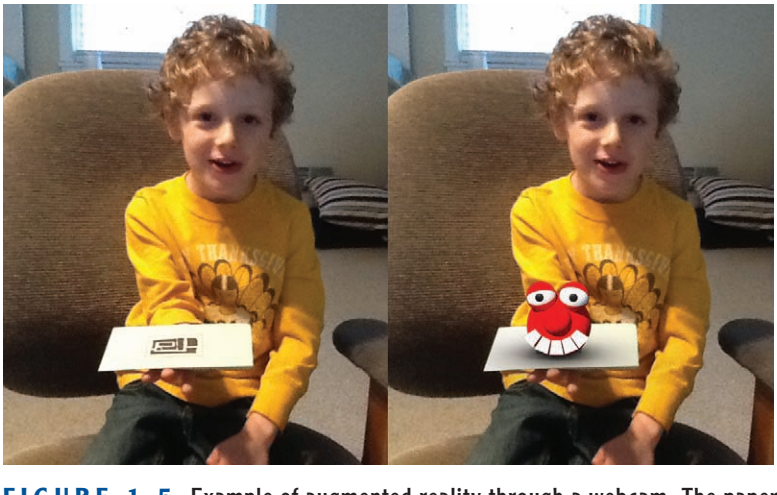


FIGURE 1.5 Example of augmented reality through a webcam. The paper the boy is holding has a marker that will allow the software to know where to place the image.

Projection mapping is a new technique that can make any surface, typically large buildings, into a video display. This technique uses projectors to project onto a building a 3D animation displaying new and exciting effects such as destruction of the building or lighting on that surface. This technique has been used to create many interesting effects, and it should become a mainstay in 3D animation in the future.

The History of 3D Animation

It is exciting to be part of the 3D animation industry today. Unlike drawing, painting, and other traditional art forms that have been practiced for centuries, 3D animation is still in its infancy. New ideas and techniques are created every year. To really understand the history of the art form, you must look at the technology behind it. 3D animation would not exist without computers, and many of the breakthroughs in computers have been directly driven by the 3D animation industry.

Early Computers

Some believe the first mechanical computer was the Z1, designed by Konrad Zuse in 1938. Figure 1.6 shows a replica in the German Museum of Technology. The other computer that is often said to be the first is the Colossus in 1943. Shown in Figure 1.7, this computer was used to help British code breakers decipher German messages. Neither of these resembles today's computers in appearance or behavior, but they put in perspective how young the 3D animation industry is, given that the tool required for this art form was invented only about 70 years ago.

FIGURE 1.6 Replica of the Z1 computer in the German Museum of Technology

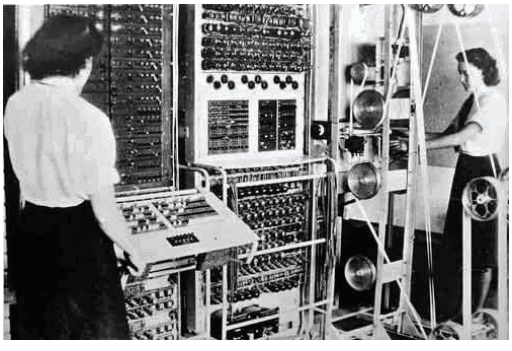


FIGURE 1.7 Colossus computer used to break coded messages in WWII

Not until the late 1950s did John Whitney Sr. use a computer to create art and the opening title sequence of the Alfred Hitchcock film *Vertigo*. Whitney used a handwriting recognition tablet (created by Tom Dimond) in collaboration with Saul Bass.

1960s: The Dawn of Computer Animation

The 1960s is when the beginnings of computer graphics and computer animation were created. This decade is when we saw the computer evolve from a strictly calculating device into a tool that allowed for creation and change. This is in the idea of hardware with user interaction devices and software that allowed for changes in real time.

William Fetter is credited with creating the term *computer graphics (CG)* in 1960. He is often thought of as the father of 3D animation because of his work at Boeing, where he used computers to create 3D models of objects and even of a human body that came to be known as the Boeing Man.

In 1962, computer programmer Steve Russell and a team from the Massachusetts Institute of Technology (MIT) created one of the first video games, *Spacewar*. In this two-player game, two spaceships try to destroy each other while also trying to not collide with a sun.

The amazing part of these first achievements in CG is that these computers had no graphical user interface, which is something we take for granted today. Instead, users would face only a blank screen and a blinking cursor and would have to understand the system and memory to access any information.

In 1963, Ivan Sutherland created a computer drawing program called Sketchpad that employed a light pen to draw simple shapes. This system paved the way for many of today's drawing and painting programs to be perfected as drawing

constraints enabled the creation of straight lines and perfect circles. The light pen used for Sutherland's system was one of the first human input devices into computers beyond that of a keyboard, switches, and dials. This system is also considered the first graphic interface for computers.

The computer mouse is one of the tools we all take for granted, but it was not invented until 1963. The original mouse, invented by Douglas Engelbart, was a block of wood with two wheels on the bottom, one facing vertically and one horizontally. The turning of the wheels controlled a pointer onscreen. Think about how you would have to interface with a computer today without a mouse.

1970s: The Building Blocks of 3D Animation

In the 1970s we saw the computer become smaller and faster, and the idea of 3D virtual surfaces was also being invented. Many of the basics of 3D animation we still use today like shaders and rendering were invented at this time. Also the first glimpse of 3D animation in film was witnessed.

In 1971, the microprocessor was developed, which allowed for the electronics of a computer to be miniaturized down to a single chip. Many of the building blocks of basic 3D animation were invented during this decade.

Researchers at the University of Utah created an algorithm enabling hidden surfaces to be rendered as 3D surfaces onscreen. Up to this point, the only thing a technician could do was draw wireframe lines, resulting in flat shading of polygons that made an object look faceted and blocky. But in 1971 Henri Gouraud created *Gouraud shading*, which allowed for the faceted polygon surface to render and look smooth. Figure 1.8 shows a comparison of flat shading and Gouraud shading.

Ed Catmull, while finishing his time at the University of Utah, created texture mapping in 1974 that allowed these early 3D graphics to achieve realism not seen to date. Catmull went on to create advancements in anti-aliasing and z-buffering and become the president of Pixar Animation Studios and Walt Disney Animation Studio.

In 1975, Martin Newell created the Utah teapot, or Newell teapot, to test rendering algorithms. That model is still used today, and some software programs have a Create Teapot button in honor of Newell and as an inside joke about the shape and its effect on the industry. The teapot was considered ideal at the time to test rendering because it has a round shape, a handle, and a spout to cast a shadow on itself (see Figure 1.9).