SECTION I

Introduction

(Previous page) *Brillia* was created with GROWTH, a recursive algorithm that grows complex life forms. The software repeats simple rules that generate fantastic forms inspired by marine life. (© Yoichiro Kawaguchi.)

1.1.1 *Luxo Jr.* presents a charming view of a small curious lamp who seeks bigger challenges. This short, directed by John Lasseter, was a *tour de force* in three-dimensional computer animation because it was one of the first shorts that tried and succeeded in incorporating many of the traditional principles of animation. (© Pixar Animation Studios.)

CHAPTER 1

Animation and Visual Effects in Context

(Top: A *Fearless* blue screen shot. Image courtesy of Menfond Electronic Art & Computer Design Co. Ltd.)

QUICK INDEX

Summary

THE BRIEF HISTORICAL INFORMATION PRESENTED HERE provides readers with a simple context in which to frame technical and stylistic discussions related to three-dimensional computer animation and visual effects. A summary of events and projects that contributed to the creative and technical development of three-dimensional computer animation and digital visual effects techniques is presented in this chapter.

1.1 A Digital Creative Environment

More than ever before computers have become a part of our life, especially part of our creative, production, and professional lives. They can be found everywhere: they coordinate the flow of information in our banking transactions, they digitize our voices and filter the noise in telephone conversations, they control the fuel injection systems in our cars, and they adjust the settings in photographic and video cameras so that image quality is always optimal. Most of the jobs in the visual professions and trades today require some degree of computer competency. Much of the broadcasting, manufacturing, graphic arts, and entertainment industries have computerized their production. Likewise, many independent artists and design studios develop their work with computers and often deliver it in digital formats.

The transition to increased reliance on computer systems affects many creators and technicians. Large numbers of established visual professionals have retrained to acquire new skills, and young students are eager to learn the secrets and shortcuts. Expectations range from the sensible to the ridiculous. Those who resist the change altogether, for example, are left behind because the world of animation production is changing. Those who are overly enthusiastic often have unrealistic expectations. By finding a balance we can accept the advantages that computer technology has to offer while retaining and developing the knowledge that we inherited from traditional practitioners.

Disney Animated Features without Digital Technology

1937 *Snow White and the Seven Dwarfs*
1940 *Pinocchio*
1940 *Fantasia*
1941 *Dumbo*
1942 *Bambi*
1943 *Saludos Amigos*
1945 *The Three Caballeros*
1946 *Make Mine Music*
1947 *Fun and Fancy Free*
1948 *Melody Time*
1949 *The Adventures of Ichabod and Mr. Toad*
1950 *Cinderella*
1951 *Alice in Wonderland*
1953 *Peter Pan*
1955 *Lady and the Tramp*
1959 *Sleeping Beauty*
1961 *101 Dalmatians*
1963 *The Sword in the Stone*
1967 *The Jungle Book*
1970 *The Aristocats*
1973 *Robin Hood*
1977 *The Many Adventures of Winnie the Pooh*
1977 *The Rescuers*
1981 *The Fox and the Hound*

1.1.2 The Walt Disney Studios created the first animated color feature movie in 1937 and dominated animated feature movies for several decades. These movies were created before the advent of computer animation technology.

Much of today's creation and production of images is indeed performed with the aid of computers. Increasingly, professionals from a wide variety of visual disciplines are working with **digital information**. Some of the traditional visual practices based on drawing, painting, photography, and video techniques are merging with **digital imaging techniques**. A creative environment that used to exist as a collection of totally separate and unrelated disciplines—each with its own tools, techniques, and media—is turning into an environment where visual people use tools and techniques that cross over different media. As a result some of the traditional barriers between visual disciplines no longer have to exist. There is now, for example, great overlap between the fields of animation, graphic arts, broadcasting, and film. The creative **digital environment** has fostered this overlap because computer technology often provides more creative power to visual people. Decades ago, for example, visual professionals used to purchase tools specialized for their professions. These tools were useful for doing the work in their field, but not in others. A photographer, for example, would use a photographic camera to capture reality on film, and a traditional animator would use a pencil and light table to create animated sequences of drawings on paper. Today's photographers and animators, as well as many other creative professionals, share the computer as the tool—loaded with specialized software—to carry on each of their unique tasks.

Animation and Effects in the Predigital Days

For many of us it is difficult to imagine today that only a few decades ago all animation, effects, and entertainment in general was made, distributed, and consumed without any type of computer or digital technology. But this was the case even a few decades ago. One of the first fully three-dimensional computer animated independent shorts, John Lasseter's ***Luxo Jr.***, was released in 1986 (Fig. 1.1.1), and the first fully three-dimensional computer animated feature film, Pixar's ***Toy Story***, was released in 1995 (Fig. 12.1.1).

As we experiment with new modeling, rendering, and animation techniques it is also worthwhile to remember the innovation of many of the animation pioneers, both those who developed character cartoon animation and those who pioneered the use of experimental methods such as collage, cutouts, wax, pinhead shadow, object, and abstract painting animation. Among the former we count the New York and Hollywood animators who delivered gag after gag and amused audiences with the likes of Popeye, Woody Woodpecker, Bugs Bunny, Tom and Jerry, and Mickey Mouse. These animators include Max Fleischer, Walt Disney, Walter Lantz, Tex Avery, Friz Freleng, Chuck Jones, and the many talented animators who worked alongside them in their studios. Among the experimental animators we count the French Léopold Survage and Alexander Alexeieff; the Germans Hans Richter, Oskar Fischinger, and Lotte Reininger; the Canadian Norman McLaren; and the Americans Claire

Parker and John Whitney, Sr. The classic Disney animated movies that popularized the genre were created in the late 1930s and 1940s (Fig. 1.1.2). The well-known twelve principles of animation covered in Chapter 10 were also developed by Disney animators during the same time period, fifty years before computer animation started to be used in their animation studios (Fig. 1.1.3).

As we seek to invent new digital visual effects it is refreshing to remember that in 1939 Hollywood's Academy of Motion Picture Arts and Sciences (AMPAS) created the Special Effects category in their awards competition. Between 1964 and 1971 the category was renamed Special Visual Effects, and between 1972 and 1976 the category of visual effects was renamed as Special Achievement Award, one not necessarily given in a particular year. Since then the category has mostly been called Visual Effects. Winners between 1939 and 2003 are listed in the timelines at the end of this chapter.

If we go back a bit further, just to put three-dimensional computer animation in perspective, we find out that the first kinetoscope parlor opened in New York City in 1894, 101 years before the release of ***Toy Story***. This event was the result of the work of Thomas Alva Edison and his assistant William K. Dickinson to improve the devices for creating images in motion and, above all, the simultaneous recording of sound and motion. Edison and his assistant developed the **kinetoscope**—which means "viewing in motion" in Greek—a closed box in which 50 feet of looped film could be viewed through an opening. The few kinetoscopes equipped with earphones to hear simultaneous music were called **kinetophones**. A few years later on the other side of the Atlantic, during the 1900 Paris Exhibition, a mechanical platform gently rocked by a steam machine presented riders with panoramic views of real and imaginary scenes of the world. These panoramic rides so popular at the turn of the nineteenth century are clearly the ancestors of virtual rides and location-based entertainment. In retrospect it is clear that the kinetoscope spawned many other film viewing and projection systems that fueled the growth of the **seventh art**, cinema, and its animation cousin.

Disney Animated Features with Digital Technology

1985 *The Black Cauldron*
1986 *The Great Mouse Detective*
1988 *Oliver & Company*
1989 *The Little Mermaid*
1990 *The Rescuers Down Under*
1991 *Beauty and the Beast*
1992 *Aladdin*
1994 *The Lion King,* and *The Return of Jafar* *
1995 *Pocahontas,* and *A Goofy Movie* *
1996 *The Hunchback of Notre Dame,* and *Aladdin and the King of Thieves* *
1997 *Hercules*
1998 *Mulan*
1999 *Tarzan*
1999 *Fantasia 2000*
2000 *The Emperor's New Groove, Dinosaur*, and *The Tigger Movie* *
2001 *Atlantis: The Lost Empire*, and *Recess: School's Out**
2002 *Lilo & Stitch, Treasure Planet*, and *Return To Never Land* *
2003 *Brother Bear*, *Jungle Book 2*,* and *Piglet's Big Movie* *
2004 *Home on the Range,* and *Mulan 2* *
2005 *Chicken Little* (all-3D CG)
2007 *Meet the Robinsons* (all-3D CG)
2008 *Bolt* (all-3D CG)
2009 *The Princess and the Frog*
2010 *Rapunzel* (all-3D CG)

1.1.3 The Walt Disney Studios started using digital technology in the production of its animated features during the mid-1980s. This listing also includes (marked with an asterisk *) a few of the movies produced as "straight-to-video," mostly by the Television Animation division. Some of the straight-to-video titles also had a limited theatrical release.

1.2 The Development of the Technology

Computers, particularly their visual capabilities, are profoundly altering the way in which we create and distribute images. But the powerful computer systems that are so common today—and that everybody takes for granted—have existed for a relatively short period of time.

The ancestors of today's electronic digital computers were mechanical adding machines used to perform repetitive arithmetic calculations. Those early mechanical devices eventually evolved into machines that could be programmed each time they were used to perform different sets of instructions. In the 1940s, electric versions of these computing machines were in operation.

The early computer models were called **mainframes** because all

SIGGRAPH Computer Animation Festival Awards

Best of Show Award

1999 *Bunny*, Chris Wedge
2000 *Onimusha*, Takeshi Kaneshiro
2001 *Values*, Van Phan
2002 *The Cathedral*, Tomek Baginski
2003 *Eternal Gaze*, Sam Chen
2004 *Birthday Boy*, Sejong Park
2005 *9*, Shane Acker
2006 *One Rat Short*, Alex Weil
2007 *Ark*, Grzegorz Jonkajtys and Marcin Kobylecki
2008 *Oktapodi*, Emud Mokhberi, et al.

Jury Honors Award

1999 *Masks*, Piotr Karwas
2000 *Stationen*, Christian Swade-Meyer
2001 *F8*, Jason Wen
2002 *Le Deserteur*, Olivier Coulon, Aude Danset et al.
2003 *Tim Tom*, Romain Segaud and Christel Pougeoise
2004 *Ryan*, Chris Landreth
2005 *Fallen Art*, Tomek Baginski; and *La Migration Bigoudenn*, Eric Castaing et al.
2006 *458nm*, Jan Bitzer et al.
2007 *Dreammaker*, Leszek Plichta
2008 *Mauvais Rôle*, Alan Barbier, Camille Campion et al.

1.2.1 (Above) Recipients of the SIGGRAPH Computer Animation Best of Show Award and the Jury Honors Award.
(Opposite page) Recipients of the SIGGRAPH awards for technical research in computer graphics, including the Computer Graphics Achievement Award, and the Steven A. Coons Outstanding Creative Contributions Award.

their bulky components were housed in large steel frames. During the 1960s two types of computers were developed. **Minicomputers**, smaller and less expensive than mainframes but almost as powerful, were developed in an attempt to bring computers to a wider audience and range of applications. **Supercomputers**, usually bigger and more expensive than mainframe computers, were developed to tackle the most taxing computing projects regardless of the cost and with an emphasis on speed and performance.

Before the mid-1970s the large majority of artists found computers very uninteresting. They were too expensive and cumbersome to operate, and even the simplest tasks required extensive programming. Most models lacked monitors, printers, mice, or graphics tablets. **Microcomputers** with millions of microscopic electronic switches on a single **silicon chip** were developed in the mid-1970s. Some early models of microcomputers, such as the Apple Macintosh, the Amiga, and a variety of Intel-based PC computers, were widely embraced by visual professionals during the 1980s (Fig. 1.2.2). Many of today's powerful microcomputers are small enough to be carried in a bag or briefcase. Those that can fit in a pocket still have limited capabilities for professional image creation, but many are quite good at displaying moving images of different degrees of quality. The supermicrocomputer and the parallel computer were developed during the 1980s and had a great effect on the way visual people use computers. **Supermicrocomputers**—also called **workstations**—are microcomputers built around a powerful CPU that is customized to excel in the performance of a specific task, for example, three-dimensional computer animation. **Massively parallel computers** deal with very complex processing challenges by dividing up the tasks among a large number of smaller microprocessors. Some of these computers may have between a dozen and thousands of processors.

Computer graphics technology was developed in the early 1950s to make visible what was invisible to the human eye. Most of these early applications were related to the military, manufacturing, or the applied sciences and included, for example, flight simulators to train fighter pilots without having to fly a real plane; computer-aided design and manufacturing (CADAM) systems to allow electrical engineers to design and test electronic circuits with millions of components; and computer-aided tomography (CAT) scanners to allow physicians to peek into the human body without having to physically open it. None of the early computer graphics systems was developed for artistic work.

During the 1950s and 1960s, the early years of computer graphics technology, the computer systems and techniques for creating images were rudimentary and very limited—especially by today's standards. During that period very few artists and designers even knew that computers could be used to create images.

During the 1970s and 1980s computer technology became more practical and useful, and a significant number of visual creators started to get interested in using computers. During the 1990s a sig-

nificant drop in the prices of computer systems and an increase in their computing power occurred. This situation encouraged many visual professionals to purchase the technology and to integrate it into their daily professional practices. Professionals from all visual disciplines accepted computer technology as it became more powerful, more practical, and less expensive. Many of the major technical innovations in the area of computer animation and related applications have traditionally been presented at the **SIGGRAPH** annual conference. Sponsored by the Association for Computing Machinery's Special Interest Group in Graphics, SIGGRAPH has been the most influential professional association in the field of computer animation since the 1960s. Figure 1.2.1 lists the international computer animation projects awarded at SIGGRAPH's screenings since the inception of the awards. It also lists some of the computer science and engineering pioneers in the field of computer graphics as recognized by their peers through the SIGGRAPH awards. Some of the research papers and innovations of these technical pioneers can be found in the conference proceedings.

The computer technology necessary for creating three-dimensional imagery and animation has evolved tremendously since the first systems were developed in the 1950s. Within just a few decades the capabilities of hardware and software for creating three-dimensional environments went from simple to highly complex representations that often fool our visual perception.

A complete history of three-dimensional computer graphics technology and creative works remains to be written. However, the information presented in the rest of this chapter summarizes some of the highlights and landmarks. This summary is certainly not exhaustive, and it does not attempt to present a complete and detailed portrait of all the significant events. Instead, it provides a personal account of individual examples and a summary of the major trends.

Technical Developments: 1950s and 1960s

The decades of the 1950s and 1960s saw the development of the first interactive computer systems, which were further improved during the following decade. The field of computer graphics was so new then, and most of the technological innovations from this period did not yield spectacular visual results. These innovations were, however, fundamental in facilitating the impressive developments that would flourish 20 years later.

The first computer to use CRT displays as output peripherals was the Whirlwind computer at the Massachusetts Institute of Technology (MIT) in the early 1950s. This system was used to display the solutions to differential equations on oscilloscope monitors. During the mid- to late-1950s the SAGE Air Defense System of the U. S. Air Force used command-and-control CRT displays on which operators could detect aircraft flying over the continental United States. The SAGE operators were also able to obtain information about the air-

ACM SIGGRAPH Awards

Computer Graphics Achievement

1983	James F. Blinn
1984	James H. Clark
1985	Loren Carpenter
1986	Turner Whitted
1987	Robert Cook
1988	Alan H. Barr
1989	John Warnock
1990	Richard Shoup and Alvy Ray Smith
1991	James T. Kajiya
1992	Henry Fuchs
1993	Pat Hanrahan
1994	Kenneth E. Torrance
1995	Kurt Akeley
1996	Marc Levoy
1997	Przemyslaw Prusinkiewicz
1998	Michael F. Cohen
1999	Tony DeRose
2000	David H. Salesin
2001	Andrew Witkin
2002	David Kirk
2003	Peter Schroder
2004	Hugues Hoppe
2005	Jos Stam
2006	Thomas W. Sederberg
2007	Greg Ward
2008	Ken Perlin

Outstanding Creative Contributions

1983	Ivan E. Sutherland
1985	Pierre Bézier
1987	Donald P. Greenberg
1989	David C. Evans
1991	Andries van Dam
1993	Ed Catmull
1995	Jose Luis Encarnação
1997	James Foley
1999	James F. Blinn
2001	Lance J. Williams
2003	Pat Hanrahan
2005	Tomoyuki Nishita
2007	Nelson Max

craft by pointing at their icons on the screen with light pens.

During the 1960s various technology-intensive organizations developed the first **computer-aided design and manufacturing (CADAM)** systems. The goal of these early CADAM systems was to make the design process more effective by offering users sophisticated design functions and to improve the organization of the manufacturing process by linking the numerical data that represents an image with other types of information, such as inventory and engineering analysis. One of the first CADAM systems was developed by General Motors, and it included various time-sharing graphic stations for designing cars. Other companies, including Boeing Aerospace, IBM, McDonnell Douglas, General Electric, and Lockheed, developed similar systems.

Early attempts to create computer-generated movies took place in several research institutions. Short pieces of animation were produced at Boeing by William Fetter and Walter Bernhart in the early 1960s. Three-dimensional drawings were plotted on paper and filmed one at a time to produce animations of an aircraft carrier landing. Fetter also modeled the human figure for ergonomic studies related to the design of cockpits. At Bell Laboratories, researchers Michael Noll and Bela Julesz produced various stereo computer animations on film to aid in the study of stereo perception. During this period some of the first animation programming languages were developed, but most of them resulted in programs that ran only in a noninteractive mode.

Only a few commercial companies were involved in computer graphics research during these two decades. Most of the technological developments during this period came out of government-funded academic research laboratories such as MIT's Lincoln Labs.

In the early 1960s, computer graphics were developed to visualize objects and situations that were too costly or just impossible to represent otherwise. Flight simulators, CADAM systems, and CAT scanners were among the pioneering computer graphics systems.

The first interactive system, called **Sketchpad**, was developed in the early 1960s by Ivan Sutherland at MIT. This system allowed users to interact with simple wireframe objects via a light pen. This system made use of several new interaction techniques and new data structures for dealing with visual information. It was an interactive design system with capabilities for the manipulation and display of two- and three-dimensional wireframe objects.

By the mid-1960s the first algorithms for removal of hidden surfaces were developed, and the systems for producing full-color surface-shaded animation in real time were improved. General Electric developed a flight simulator that animated and displayed simultaneously as many as 40 solid objects with hidden surfaces removed and in full color. The Mathematical Applications Group, Inc. (MAGI) in Elmsford, New York, was one of the first companies that offered computer-generated animation of fully rendered polygonal objects in the commercial environment. Their process was named

Timeline of Intel Processors

1971	The 4-bit 4004 with 2,300 transistors, and 108 KHz clock.
1972	The 8-bit 8008, twice as powerful as the 4004.
1974	The 8080, CPU of the Altair, first personal computer.
1978	The 8086-8088, CPU of the IBM PC.
1982	The 286, first Intel processor that runs software written for its predecessor.
1985	Intel 386, 32-bit chip with 275,000 transistors, 100 times more than the 4004.
1989	The 486, with built-in math co-processor, for graphical interfaces, 25-50 MHz.
1993	First Pentium processor.
1995	Pentium Pro, 5.5 million transistors.
1997	Pentium II, 7.5 mill. transistors and video processing MMX technology, 200-300 MHz.
1999	Celeron, value-oriented.
1999	Pentium III, 9.5 million transistors, 650 MHz to 1.2 GHz.
2000	Pentium 4 debuted with 42 million transistors, real-time 3D rendering, 1.3-1.8 GHz.
2001	Xeon, for high-performance dual-processor workstations.
2001	Itanium, first in a family of 64-bit processors.
2004	Pentium 4, Hyper-Threading technology, at 3.4 GHz.
2005	Pentium extreme Edition 840 dual-processor workstations.
2006	Energy-efficient Core 2 Duo, 291 mill. transistors and Core 2 Extreme.

1.2.2 Some of the most popular microprocessors manufactured by Intel since the early days of microcomputers.

Synthavision, and its first contracts included simulations for the military and advertising-related projects.

The early three-dimensional computer animation and imaging systems depended on costly mainframe computers that were slow by today's standards. Most of the programs would run only on a specific type of computer and display device, and were not portable to other systems. The use of computer graphic systems during the 1960s was restricted by the high cost and limitations of the hardware involved.

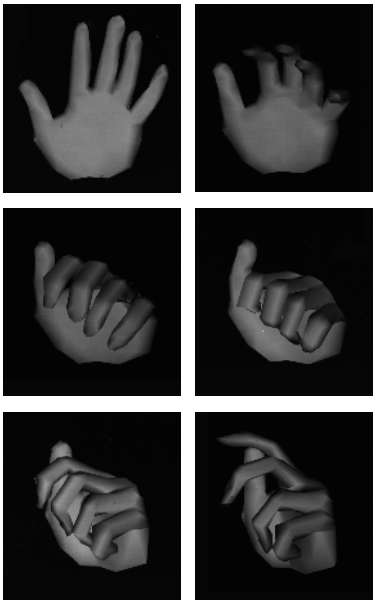
Virtually all of the graphics software from this period was developed in-house. It was not marketed, and it was minimally documented. Most programs were executed in the batch mode, and very few had any interactive features at all. Users had to input their data almost exclusively through the keyboard; other types of input peripherals that encouraged more artistic freedom were just not available. A few computer systems had graphics screens, but most had monochrome alphanumeric CRT screens or just teletype or dot matrix printers.

Technical Developments: 1970s

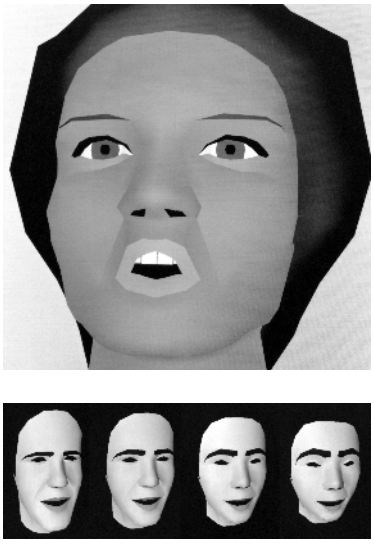
The 1970s was a significant decade for the development of computer animation and imaging technology. Many of the basic rendering techniques still in use today were formulated during the 1970s. The minicomputers that became popular during the 1970s were easier to maintain than mainframe computers, and provided significantly more power at a reduced cost. Microcomputer technology was also introduced to the consumer markets in the late part of the decade.

From the point of view of computer hardware, most of the research and production work done during this decade was based on minicomputers. The microcomputer's 8-bit computing power, memory capabilities, and output solution was insignificant when compared to their high-end counterparts (Fig. 1.2.2). But in the videogames arena the new microcomputers greatly contributed to the popularization of computer-generated graphics. A standard configuration of an early 1970s microcomputer included an 8-bit CPU without any graphics co-processors, less than 100 KB of RAM memory, a clock speed of 10 MHz, a low resolution screen with a maximum palette of 8 colors (or slightly higher if dithering was used), and a limited amount of peripheral storage.

During this decade the University of Utah became a primordial force and a center of innovation in three-dimensional computer graphics research. Under the guidance of David Evans, co-founder of Evans & Sutherland, the Department of Computer Science at the University of Utah produced a distinguished roster of Ph.D. students. Many of them developed a large number of the major technical contributions of the decade, such as the original versions of polygonal, Gouraud, and Phong shading; image and bump texture mapping; z-buffering; the subdivision and the painter's algorithms for hidden line removal; antialiasing methods; and hand and facial computer animation (Fig. 1.2.3).



1.2.3a Early example of hand animation. (Courtesy of Ed Catmull.)



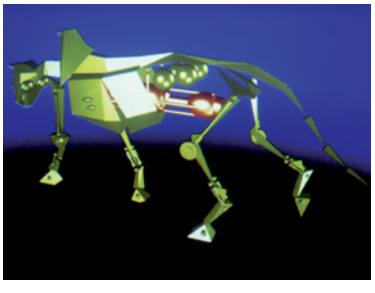
1.2.3b Early examples of face animation. A 1972 model (top) used simple expression interpolation. A later sequence used shape interpolation. (Images courtesy of Frederic Parke.)

1.2.4 Vase rendered with stochastic textures. (Image courtesy of Ken Perlin.)

Technical Developments: 1980s

It was during the 1980s when computer graphics technology leaped from being a curiosity into becoming an area of proven artistic and commercial potential. Technologically speaking, this decade started with the uneven coexistence between powerful minicomputer systems and 8-bit microcomputers. But the decade ended with a new breed of powerful 32-bit microcomputers and 64-bit RISC (reduced instruction set computer) graphics workstations at the forefront, and with minicomputers in the back seat. Silicon Graphics Inc., the company that pioneered visual workstations with its **Geometry Engine**, was started by James Clark in 1982. Commercially speaking, this decade started with a handful of companies that pioneered the production of three-dimensional computer animation and imaging. These companies included Digital Effects and MAGI on the East Coast and Robert Abel Associates and Information International, Inc. (III) on the West Coast. These companies operated exclusively with software developed in-house and with much custom-built graphics hardware. The 1980s concluded with the closing of all of the pioneer production houses—or at least of their production divisions—and with the creation of a new group of smaller, leaner, and more market-oriented firms that operated mostly with off-the-shelf hardware and with a mixture of custom and off-the-shelf software.

The bulk of the software research and development during this decade was spent in refining the modeling and shading techniques inherited from the 1970s. Ground was broken with new rendering approaches such as radiosity and procedural textures, and with the development of the first generation of solid user-friendly computer-human interfaces for three-dimensional computer animation and imaging software. The **RenderMan** shading language was released by Pixar in 1988. Some of the software companies that pioneered the high-end tools for three-dimensional computer animation and visual effects production were founded during this period. In 1981 Wavefront opened in Santa Barbara, California. In 1982 Alias opened in Toronto, Softimage in Montreal, and Mental Images in Berlin in 1986. Side Effects Software opened in Toronto in 1987.



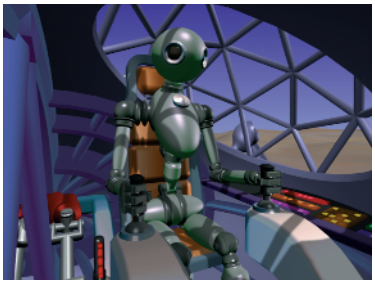
1.2.5 Developed jointly by Toyo Links and Osaka University, the muscle movement in *Bio-Sensor* was modeled with metaballs and rendered with ray tracing techniques. (Director: Takashi Fukumoto. Technical Director: Hitoshi Nishimura. © Toyo Links, 1984.)

Some of the leading academic centers in North America involved in three-dimensional graphics research during this period included Cornell University (radiosity rendering techniques), the Jet Propulsion Laboratory at the California Institute of Technology (motion dynamics), the University of California at Berkeley (spline modeling), Ohio State University (hierarchical character animation and inverse kinematics), the University of Toronto (procedural techniques), the University of Montreal (character animation and lip syncing), and New York University (procedural textures, Fig. 1.2.4). Significant original research efforts also took place at the University of Tokyo and Osaka University (modeling with blobby surfaces, Fig. 1.2.5), and the University of Hiroshima (radiosity and lighting). A few research centers and private companies invested significant resources

in the development and production of shorts that pushed computer graphics technology to its limits (Figs. 1.2.6 and 1.2.7). Government-sponsored research centers also developed pioneering simulation techniques. Figure 1.2.8 shows a landmark simulation of natural forces. Most of the three-dimensional software products that were commercially available during the first half of this decade lagged behind the exciting work done in research institutions. This was partly due to the lack of capital investors who believed in the commercial potential of the technology. It was also due to the difficulty of implementing computing-intensive techniques with off-the-shelf hardware systems that were not quite as fast as needed and perhaps a bit overpriced.

Some of the hardware research during the 1980s focused on the development of more powerful general-purpose microprocessors and special-purpose graphics processors, and techniques for the high-speed transfer of visual data. A standard midrange computer system for three-dimensional computer animation production during the 1980s, for example, consisted of a 32- or 64-bit microcomputer or supermicrocomputer with one or several graphics processors, clock speeds higher than 50 Mhz, several dozens of megabytes for RAM memory, and extensive peripheral storage.

In terms of output standards, few of the production companies at the beginning of the decade were capable of first-generation output to videotape. Most of the high-end work was output to film first and then transferred to videotape. By the end of the decade, however, video output established itself as a common output method for computer-generated animation.

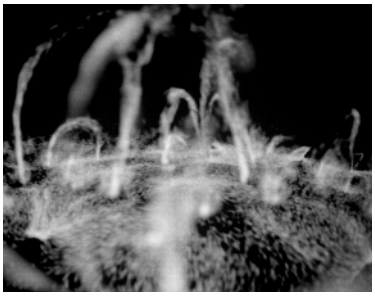


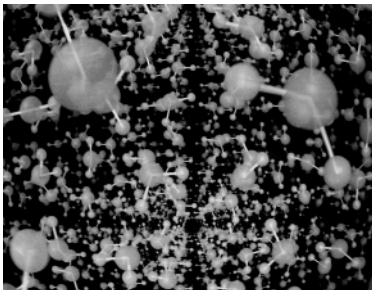
1.2.6 Mechanical ant from the 1984 trailer for *The Works*. (Design, animation, and modeling by Dick Lundin. Robot model by Ned Greene. Images courtesy of Ned Greene and NYIT Computer Graphics Lab.)

Technical Developments: Early 1990s

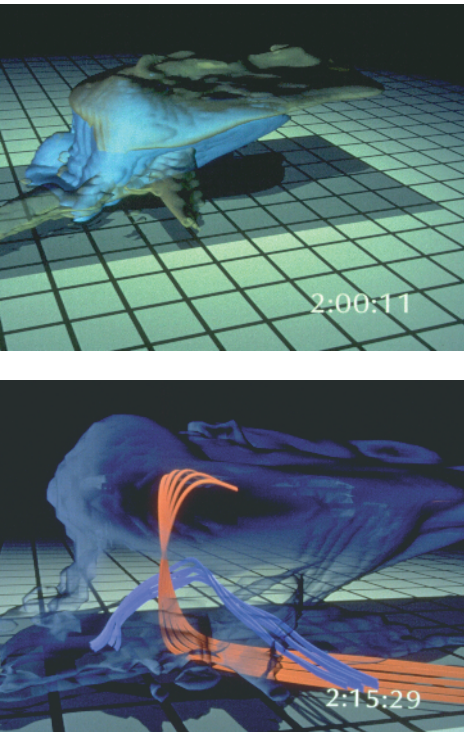
The first half of the 1990s witnessed a major move toward smaller and/or considerably more powerful computer systems. Virtually all of the low-end microcomputers currently in production are based on 32-bit microprocessors, whereas the powerful microcomputer models are centered around 64-bit CISC and RISC processors. A considerable number of models with different features were targeted at different segments of the market, especially systems with multiple processors, and computer systems were sold in a modular form. Supermicrocomputers, or workstations, kept increasing in power while decreasing in price, or remained at the same price level but with additional features.

Research and development was mostly centered around issues of efficiency, cost, and ease of use. With the midrange hardware systems being powerful enough for most creative needs, a lot of energy and time was spent in optimizing the software techniques. Taking small solid steps took precedence over making large groundbreaking advances. Computer-human interface issues also took precedence in this buyer's market. Users of three-dimensional software became increasingly sophisticated and demanding, and enjoyed new levels of creativity and computing power. Two additional trends of this period





1.2.7 *The Universe* was the world's first stereoscopic (stereo 3D) computer animation rendered and output on 70 mm 15-perf film for projection on an IMAX dome screen. It was created for the Fujitsu Pavillion at Tsukuba Science Expo '85. (© 1985 Fujitsu/Dentsu/Toyo Links/IMAX.)



1.2.8 In this simulated snapshot of a severe storm (top) the yellow-gold regions represent small cloud drops and ice particles, and the blue region represents large water drops. The surface grid lines are 10 km apart and the darkened area indicates the horizontal integration domain surface of the storm. The orange-red ribbons (bottom) represent the tracer particles in that rise through the depth of the storm in the updraft, and the blue ribbons represent tracers that eventually fall to the ground in the downdraft. The spatial resolution of the data used in the simulation was 2 km horizontally and .75 km vertically. (Image from "Study of a Numerically Modeled Severe Storm." Courtesy of the National Center for Supercomputing Applications.)

include the rebirth of the electronic game industry (and the growth in jobs, volume, and quality associated with it), as well as the fact that, overall, the computer industry became friendlier and less technical as it tried to mass-market its products to the consumer market.

Technical Developments: Late 1990s

During the second half of the 1990s the worlds of computer animation and visual effects production were impacted by the many changes and technological advances that took place in the computer hardware and software industries. Some of the more influential events include the popularization of the **Windows NT** and **Linux** computer operating systems. This trend evolved to a point where even SGI, the computer company formerly known as Silicon Graphics, Inc. and a traditional stalwart of the **UNIX** operating system, began offering NT-based computers in 1999. CPU clock speeds used for production continued to move up, with speeds of 400 and 500 MHz becoming common. Intel and its Pentium line of processors became a significant player in production environments where years earlier they had been dismissed as lightweights. Powerful graphics co-processors designed to accelerate the speed of three-dimensional computations also continued to evolve. Some ended up being bundled on PC motherboards, and others continued to be sold as add-on graphics cards. Computer networks became vital to digital production due to the popularization of rendering farms and production in multiple locations. By the end of the decade the use of company **computer intranets** for communications and file transfer and management became the standard practice at most leading centers of digital production.

Major advances in the video industry also had an impact on computer animation and visual effects production. **Digital video** became a reality in the mid-1990s, and by the end of the decade different types of productions had been realized in the new medium. Late in the decade Sony introduced a **high definition digital video** camera, and in 1999 the company announced that a 24-frame-per-second version (24P HD) was in development. In the same year the filmmaker George Lucas made statements about his plans to shoot live action with such a camera in the second *Star Wars* prequel. The success of 1999 independent films like *The Blair Witch Project* and the Danish *The Celebration* popularized the acceptance of digital video for mainstream production. These two live action films were shot on digital video (the former used only available light) and transferred to 35 mm film for theatrical release. The increasingly widespread availably of 24P HD digital video promises to simplify some production issues in the area of visual effects.

The advent of **digital movie projectors** was another significant development of the late 1990s because it pointed to the fact that one day photographic film might no longer be the dominant medium for motion pictures and animation, not only for home use but also for theatrical releases. Texas Instruments became an early

1.2.9 The 1997 computer-animated short *Geri's Game* was a technology test-bed for subdivision surfaces modeling techniques and for clothing dynamics. Rendering was done with the RenderMan shading language. (© Pixar Animation Studios.)

leader in the field of digital projectors when it introduced its first DLP model in 1998.

The great popularity and growth experienced by **computer games** and **platform games** translated into many jobs for three-dimensional computer animators, who created hundreds of real-time and prerendered games for personal computers and new game platforms such as Sony's **PlayStation**, the **Nintendo 64**, and Sega's **Dreamcast**. The arcade version of ***Virtua Fighter 3*** released by Sega in 1996 brought arcade games to a new level of polygon real-time rendering performance. But the new home console game systems continued to become more sophisticated. The game industry during the 1990s wrapped up with a great demand for computer animators and several exciting games.

In the area of software tools, there were several significant developments during the late 1990s. The modeling technique of subdivision surfaces allows users to build three-dimensional models with variable geometry resolutions throughout the model. This technique was developed at the University of Washington and then perfected at Pixar, where the 1997 award-winner ***Geri's Game*** became the test-bed for this modeling technique (Fig. 1.2.9). The technique of image-based rendering, refined at The University of California at Berkeley, facilitates the reconstruction of three-dimensional environments based on photographic references taken on location (Figs. 6.8.1–6.8.3). Nonphotorealistic rendering is used to represent three-dimensional geometry with a two-dimensional look. Applications of this approach are of great interest to technical illustrators and to

1.2.10 *Spy Kids 2* was one of the first movies to be recorded on high-definition (HD) video. (© 2002 Hybride. Images courtesy of Dimension Films.)

those looking for ways to visually integrate traditional animation and three-dimensional computer animation (Figs. 6.9.1–6.9.4). The simulation of water and gas dynamics and brittle matter also gained ground during this period (Figs. 5.5.10, 12.3.3, and 12.3.4).

Technical Developments: Early 2000s

Hardware continued its march toward smaller, faster, and cheaper. Graphics boards with powerful GPUs made hardware rendering a reality, both for professional applications and home entertainment. The game industry benefited from this increased computing power for the playback of real-time three-dimensional computer animation. Powerful home game consoles proliferated (Fig. 1.2.11). In 2000, for example, Sony introduced the **PlayStation 2**, a system built around a 128-bit processor that draws 2 million polygons per frame, which is about the geometry resolution of an average scene in the 1995 ***Toy Story*** animated feature film. Microsoft introduced the **Xbox** powered by an Nvidia graphics card capable of drawing up to 125 million polygons per second, and Nintendo introduced the **GameCube**. The competition for revenues between the computer and platform games and movie box office continued.

Processors for PCs moved to speeds closer to and beyond 2 gigahertz (GHz). Intel's Pentium 4 Processor, for example, debuted in 2000 with an initial speed of 1.5 GHz—compare that to Intel's first microprocessor, the 4004, which ran at 108 KHz! If automobile speed had increased similarly over the same period, you could now drive from San Francisco to New York in about 13 seconds. AMD introduced their 64-bit processor in 2003. 64-bit processors have attracted interest from software developers and Mental Ray is an early 64-bit renderer. In the area of operating systems, relative newcomer Linux became the dominant standard for high-end production, while **Mac OSX** gained a fair amount of attention and use because of its UNIX-like features.

High-definition video (HD) continued to develop with the successful completion of all-digital productions such as ***Star Wars: Episode II*** and ***Spy Kids 2*** (Fig. 1.2.10). Different flavors of HD cameras continued to be introduced, most notably Thompson's **Viper FilmStream** in 2002, prototypes by Olympus and JVC, as well as Sony's 1080p HD camera system, the **F950 CineAlta** with a 2/3 in. sensor and 4:4:4 full-RGB bandwidth, and the improved HDCAM-SR tape format with 4:2:2 10-bit color bandwidth. At the same time the use of digital dailies and the digital intermediate process gained converts in the worlds of movie and TV post-production. File formats for compressing and decompressing files sent via computer networks developed significantly. These formats, known as **codecs**, are especially useful for video streaming and resulted in new versions of Apple's Quicktime, Microsoft's Media Player 9, and a few others based on the MPEG-4 video compression standard (read Chapter 15 for more information on compression).

The proliferation of DVD players in the home video consumer

Game Platforms
General Specifications

Sixth Generation

Microsoft Xbox (2000)
Rendering: 125 million triangles per second (TPS)
CPU: 32-bit Pentium III, 733 MHz
GPU: Nvidia, 250 MHz
RAM: 64 MB
Storage: 6.4 GB

Nintendo GameCube (2000)
Rendering: 12 TPS
CPU: 32-bit IBM PowerPC Gekko, 485 MHz
GPU: ATI/Nintendo, 162 MHz
RAM: 43 MB
Storage: 1.5 GB

Sony PlayStation 2 (2000)
Rendering: 66 TPS
CPU: 128-bit RISC Emotion Engine, 300 MHz
GPU: 147.5 MHz
RAM: 40 MB
Storage: 4.7 GB

Seventh Generation

Microsoft Xbox 360 (2005)
Rendering: 500 million TPS
System Performance: 1 TFLOPS
CPU: 3 PowerPC-based cores 3.2 GHz
GPU: Custom ATI, 500 MHz
RAM: 512 MB of GDDR3
Storage: 20–120 GB HD

Sony PlayStation 3 (2006)
Rendering: 275 million TPS
System Performance: 2 TFLOPS
CPU: PowerPC Cell, 3.2 GHz
GPU: Custom Nvidia, 550 MHz
RAM: 256 MB XDR Main, and 256 MB GDDR3 VRAM
Storage: 20–120 GB HD

1.2.11 Specs of three popular sixth generation game platforms at time of release, and the Xbox 360 and the PlayStation 3.

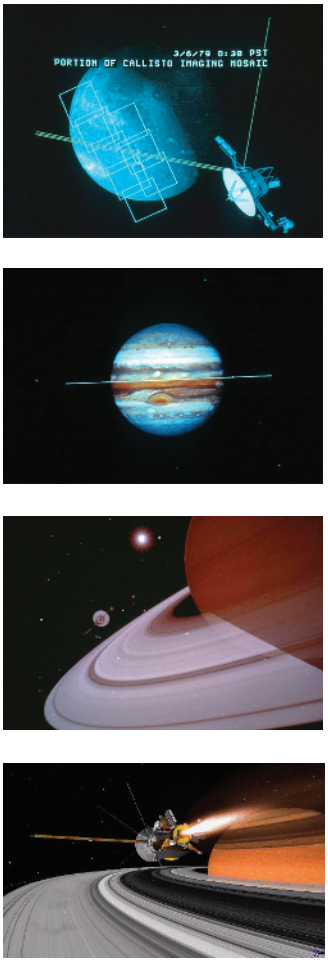
market during the early 2000s helped fuel a massive distribution of the computer-animated and visual effects "hits" of the period. A *Hollywood Reporter* survey in 2003, for example, indicated a 65 percent increase in DVD purchases between 2001 and 2002. VHS sales declined an estimated 29 percent during the same period.

Technical Developments: Late 2000s

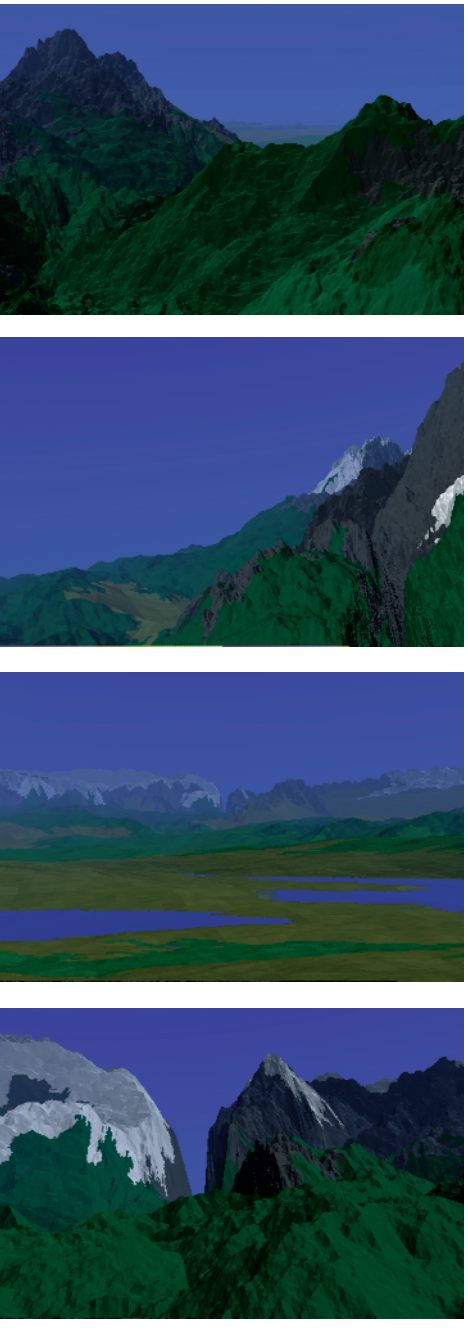
The seventh generation of game platforms was released in the middle of the decade with impressive specs. In 2005, for example, Microsoft introduced the **Xbox 360** capable of rendering 500 million triangles per second (Fig. 1.2.11). Nintendo released the **Wii** also in 2005, based on a RISC IBM PowerPC processor and an ATI Hollywood graphics card, and Sony followed up with the **PlayStation 3** in 2006. Computer and graphics cards manufacturers continued to offer faster and more powerful systems. In 2006 Nvidia graphics card manufacturer started to distribute a free version of their hardware renderer **Gelato** with native 64-bit support. Also in 2006 CPU manufacturer AMD merged with graphics card manufacturer ATI Technologies, and scheduled a new product that merges a CPU and a GPU for 2009 release. Nvidia has also announced a planned integration of a CPU and a GPU on a single chip. In 2006 Apple Computer switched to Intel CPUs for its line of Macintosh computers and servers.

On the digital cinematography front a variety of new high-definition cameras were introduced or improved. Many of these non-film-based cameras are increasingly used for recording commercials or live action features, particularly those with a large number of visual effects. The **Red One** camera is notable for its high resolution and its relative low price. The Red One was released in 2007 with a 24.4 x 13.7 mm 12-megapixel sensor delivering a 4096 x 2304 pixel image. Effects movie ***Jumper*** (2008), and ***Guerrilla*** and ***The Argentine*** (2008), both directed by Steven Soderbergh, were shot with the Red One (Fig. 13.12.5). In 2004 Panavision introduced the **Genesis** camera with a single 12.4-megapixel sensor and 4:4:4 color bandwidth. It was first used in 2006 to shoot effects feature ***Superman Returns***, ***Scary Movie 4***, and ***Apocalypto***, and in 2008 to record ***Asterix in the Olympic Games***. In 2007 Dalsa introduced the **Origin II** camera with a resolution of 4046 x 2048 pixels and the ability to output uncompressed 16-bit image files, yielding very wide dynamic range. The James Bond movie ***Quantum of Solace*** (2008) includes a visual effects shot captured with eight Dalsa cameras shooting simultaneously and with synchronized shutters. Arriflex introduced in 2005 its **D-20** camera featuring a 1920 x 1080 pixel resolution in 4:4:4 10-bit format. Vision Research offers the **Phantom HD** high-speed camera also capable of 2K resolution and frame rates ranging from 1 to 1000 fps at 14-bit depth per channel.

On the consumer front YouTube launched in 2005 as a video sharing website that has allowed animation and effects professionals



1.3.1 Still frames from the Voyager space mission simulations. Closest approach of Voyager 1 to Jupiter's moon Callisto (top). The field of view of the onboard narrow-angle camera is projected as a series of squares on the moon showing the planned images that were sent back to Earth. (Second-Fourth) Simulations of Voyager 2: Closest approach to Jupiter's moon Europa with texture from photographs sent back by the earlier mission; crossing of the equatorial ring plane of Jupiter; flight over the rings of Saturn, made artificially brighter for visualization purposes. (Images are courtesy of Jim Blinn, JPL/Caltech.)



1.3.2 Landscapes from *Vol Libre* created with fractal techniques. (© 1980 Loren Carpenter.)

to easily showcase their work, and has also brought a lot of animation to mainstream viewers. Google's Image Search became a useful visual research tool and in 2005 it reached 1.1 billion images indexed. Google acquired YouTube in 2006. The Blu-ray Disc became in 2008 the high-capacity de facto standard for DVD format: it can store up to 50 GB in dual layer mode.

1.3 Visual Milestones: 1960–1989

It is both refreshing and illuminating to view, enjoy, and analyze the visual works that became creative milestones in the development of three-dimensional computer animation and imaging. By analyzing these works we can learn about all the computer animation techniques and styles that have evolved into what this field is today.

Useful sources for learning more about computer animation and visual effects include the **SIGGRAPH Video Review** DVDs, issues of the ***Cinefex*** journal of visual effects, and the winners and runner-ups of the American **Academy of Motion Picture Arts and Sciences (AMPAS)** awards in the Best Visual Effects and Best Animated Feature, and Best Animated Shot categories (see listings in the timelines at the end of this chapter). Visit the **www.artof3d.com** website for links to these sources, as well as other useful computer animation resources and links.

Visual Milestones: 1960s

During most of the 1960s the computer was—in the opinion of most visual artists, critics, and spectators—too cold and technical to be involved in the creation of artistic projects. Similar prejudices about technology arose in the nineteenth century when machines were introduced on a massive scale to the industrial world. Many turn-of-the-century painters feared the new technology until they learned how to use it and became creative with it. During the 1960s the impact and influence of computers on animation and imaging can be compared to the impact photography had on the visual arts of the late nineteenth century. Miniature painters and engravers feared that the new invention would replace them, and some of them even called it the "invention of the devil." Most new technologies that prove useful eventually become everyday technologies.

As mentioned earlier, computers have been used to create images since the 1950s, but the first artistic experiments with computer-based systems did not take place until the early 1960s. Most of the early animations and images produced with computers were not created in art studios but in research laboratories, and most of them used two-dimensional techniques at first. In fact, an unlikely partnership between Bell Labs physicist Billy Klüver and artist Robert Rauschenberg resulted in the 1967 ***Experiments in Art and Technology*** in New York City. But for the most part, the majority of individuals who created the early works of computer animation came from the

1.3.3 The 1988 short *Tin Toy* presents the story of a good-hearted toy who is willing to risk it all in order to save a baby in danger. (© Pixar Animation Studios.)

fields of science and engineering, and lacked formal training in the fine arts. Nevertheless, many of them displayed a strong artistic intention and a significant degree of aesthetic consciousness.

The computer systems that were used by these pioneers were not designed primarily for artistic creation. The IBM model 360 introduced in 1963, for example, was the first family of computers centered around a Fortran-based **time-sharing** system. Compared to today's computers, systems of those years were not very interactive, if they were interactive at all. The computer-human interface of the 1960s was typically opaque, cryptic, and not self-explanatory.

Using the early computer systems to create animations and images was not easy, so many of these early creators often had to put more effort into the process of creating the works than into the form and content of the works themselves. A few early computer artists were more concerned with the development of the computer-based imaging tools than with the style of their work. But in spite of all the limitations, the pioneers made effective use of the available technology.

The early computer-generated animations and images are the products of a technology still in the stage of development. The style of these early works was defined in a major way by the limitations of the computer equipment itself, and by the lack of computer programs that were capable of rendering complex images in a variety of ways. Very often complex methods and data structures did not yield correspondingly complex images. Among the American pioneers of computer art we can mention John Whitney, Sr., and Charles Csuri whose early computer-assisted animations date, respectively, from 1961 and 1966. (Csuri's later work can be seen in Figure 6.6.3.)

1.3.4 *Knickknack* presents the hilarious misfortunes of a Casanova toy snowman who, despite the fact that he charms the opposite toy-sex, can never seem to get close to them—his bad luck is always one step ahead of him. (© Pixar Animation Studios.)

One of the earliest experiments with computer-generated character animation was ***Mr. Computer Image ABC*** created in 1962 by Lee Harrison III with the **Scanimate** system at Computer Image Corporation (the system won an Emmy Award in 1972).

In 1968 the **Motion Picture Association of America** (**MPAA**) introduced a new rating system for movies that impacted the work done by filmmakers and animators. This rating system included four categories: G (General Audiences), M (Mature Audiences), R (Restricted), and X (No one under 17). A short time later the M rating was replaced by PG (Parental Guidance). Figure 1.3.11 presents today's updated listing of ratings across the major entertainment media.

Visual Milestones: 1970s

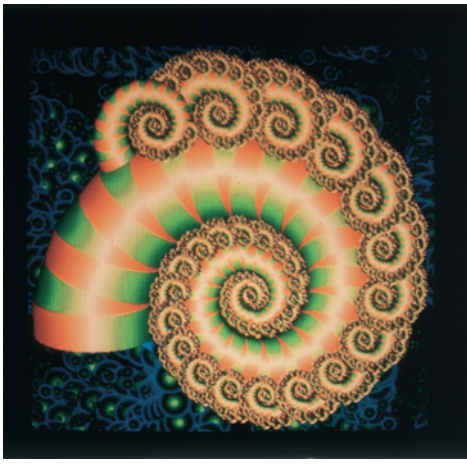
The panorama in computer art changed greatly during the 1970s because of the development of techniques for representing three-dimensional environments and because of the increased involvement of professional artists with computers. Computer-based animation and imaging systems became more interactive than what they were during the 1960s, but they were still not easy to use. Only a few of the artists who got interested in computer technology used it as their primary medium for artistic creation. In addition to their visual work, many of these early artists of three-dimensional computer animation and imaging also contributed to the technical development of their tools by collaborating in the development of software.

One of the most widely viewed works of three-dimensional com-

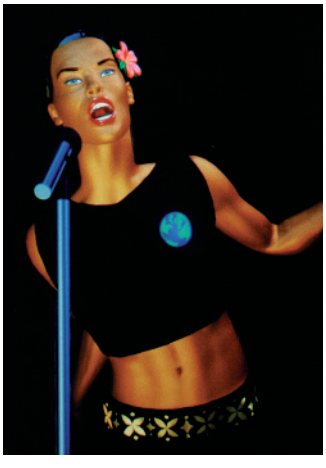
puter animation during the late 1970s was ***Voyager 2***, created by James Blinn and a team at the Jet Propulsion Laboratory (JPL) in California (Fig. 1.3.1). This work visualized the explorations of the Voyager 2 spaceship, and it is an excellent example of one of the earliest successful and extensive uses of image mapping techniques. Artist David Em, a visiting artist at JPL, created stills of fantastic planets with the same software used by scientists to render the planets of the Solar System.

Other notable examples of computer animation from this period include the 1974 animated film ***Hunger*** created by Peter Foldes under the auspices of the National Film Board of Canada. This work included striking computer-generated interpolations of key poses drawn by hand and painstakingly digitized into the computer software. ***Vol Libre***, a three-dimensional computer animation by Loren Carpenter, shows renderings of fractal mountains with great lyrical force (Fig. 1.3.2). ***The Joggler*** is an early example of a computer-animated human character attempting complex motion created at Information International Inc. (III). In 1974 The New York Institute of Technology (NYIT), in Old Westbury, New York, assembled a computer graphics research group with a notable roster of engineers and programmers. The goal was to develop computer graphics software and hardware to be used for commercial productions (Fig. 1.2.6). A few years later Industrial Light & Magic (ILM) was created to develop the visual effects for George Lucas' 1977 ***Star Wars***. This film brought visual effects to the foreground of mainstream culture, but the use of computer technology in this film was mostly limited to the computerized motion control systems used to move cameras and physical miniature models. The blue-screen compositing of the visual effects elements and plates in these films was achieved optically. In 1979 several members of the NYIT research group joined ILM with the goal of integrating computer graphics into visual effects production.

The commercial work done for advertising agencies at Digital Effects, III, MAGI, and Robert Abel and Associates is illustrative of computer animation in the late 1970s. These companies were active until the mid-1980s and then spawned other companies that continued their innovative spirit. Digital Effects was active from 1978 until the mid-1980s, III opened in 1974 and closed in 1982, MAGI was active between 1972 and 1987, and Robert Abel and Associates started in 1971 and closed in 1986.



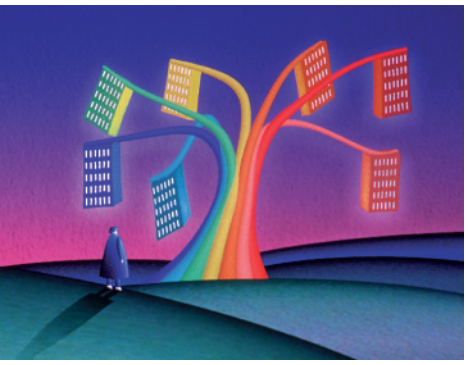
1.3.5 *Tendril* is among the first three-dimensional objects created with the recursive GROWTH algorithm. The colorful complex forms are derived from seed shapes like conch shells, tentacles, and coral. (© 1981 Yoichiro Kawaguchi.)



1.3.6 *Dozo* was the first female Synthespian™ performer created by Diana Walczak and Jeff Kleiser. She stars in their 1989 computer-generated film *Don't Touch Me*. (© 1989 Kleiser-Walczak Construction Co.)

Visual Milestones: 1980s

In the area of three-dimensional computer animation, the 1980s started with a few exceptional works and ended with a flurry of outstanding projects. This was due to many factors, such as the enhanced technology, the larger market, the maturing of the artists working in the field, and the entry into the workforce of the first art students who attended computer animation and imaging educational programs. The earliest realistic model of the full human figure from this decade is the virtual character Cindy created at III for the 1981



1.3.7 Scene based on the designs of French illustrator Jean-Michel Folon, rendered to recreate the softness of pastel colors on paper. (Images courtesy of Toyo Links, from Tokyo Gas Company 1987 campaign.)

1.3.8 *Locomotion* was one of the earliest (1988) three-dimensional computer animated shorts to use the technique of squash and stretch. (© PDI/DreamWorks.)

science fiction film ***Looker***. The 1982 Disney film ***TRON*** was the first feature film with over 20 minutes of computer animation composited optically with live action; a few of the shots required dozens of passes with filters in front of the optical printer lens. ***TRON*** combined live action with three-dimensional computer animations created by the teams at Robert Abel and Associates, III, MAGI, and Digital Effects. For all of its visual innovation, however, this film was only moderately successful at the box office. The story behind this science-fiction film centered around a videogame designer who somehow ends up inside the virtual world of his creations and has to fight the game challenges that he himself created. The topic of this film also reflected the fact that the popularity of videogames hit a peak in the early 1980s, when Atari was the leading company in this arena. A decade earlier its founder, Nolan Bushnell, had developed the table tennis game ***Pong*** (1972) that helped launch the videogame industry.

In the area of visual effects for live action film, Industrial Light & Magic (ILM) continued the excellence in visual effects started just a few years earlier with George Lucas' ***The Empire Strikes Back*** (1980) and ***Return of the Jedi*** (1983). ***Indiana Jones and the Temple of Doom*** became in 1984 their first film to have an all-digital composite shot. ***Young Sherlock Holmes*** (1985) featured a somewhat convincing jointed character made of flat stained glass-like panels with texture mapping and transparency. In ***Flight of the Navigator*** (1986) keyframes of the live action footage were scanned and used for spherical reflection mapping to simulate interactive reflections as computer-generated objects travelled through the scene; three-dimensional morphing was also used in this movie. ***The Abyss*** (1989) revolved around the first three-dimensional computer animated character that was realistic enough to blend with the live action background plates. Because of the complex calculations of reflection and refraction, the team had enough time to render the different layers in each frame only once. The different passes (diffuse, specular, refraction, highlights) were composited optically, except for a single shot (when the safety door closes and the water creature is cut in half) that was composited digitally at 8 bits with Photoshop software.

The **Genesis Effect** created in 1982 by ILM for the film ***Star Trek II: The Wrath of Kahn*** is also of historical interest because it was the first visual effects shot that was created entirely with three-dimensional computer animation techniques, the longest running sequence, and also because it is one of the earliest examples of procedural modeling and particle systems animation. ***The Last Starfighter*** was the first live action feature film to include a large amount of very realistic computer animation of highly detailed models. The basic production idea at the time was to replace the motion control cameras and the model photography with three-dimensional computer animation. The 28 minutes of computer animation for this 1985 film were animated and rendered with a Cray supercomputer at Digital Productions. To avoid aliasing artifacts most of the frames were computed at 20,000

lines of resolution and down-converted to about 1,000 lines.

Other notable works of the early and mid-1980s include ***Bio-Sensor*** created in 1984 at Osaka University and Toyo Links. This work is an impressive example of early figure locomotion and modeling with blobby surfaces (Fig. 1.2.5). The ***Brilliance*** commercial featuring a sexy female robot with convincing realistic motion was created by Abel and Associates, and also the first entirely computer-generated TV ad to be aired during a Super Bowl football game.

Also created during this period were the sublime simulations of light, fog, rain, and skies created at Hiroshima University; the intriguing non-edge simulations of clouds and smoke created by Geoffrey Gardner at Grumman Data Systems; and the first ray-traced imaging tests done by Turner Whitted at Bell Labs.

The mid-1980s also saw the rise of leading commercial production houses worldwide. In northern California, Pacific Data Images (PDI) was founded in 1980, Tippet Studios in 1983, and Pixar in 1985. In southern California, Boss Films was active from 1982 to 1997, and Digital Productions was in business from 1981 until the mid-1980s when it evolved into Whitney/Demos Productions for a few years. VIFX opened in 1984 and Rhythm & Hues Studios started in 1987. On the East Coast R/Greenberg Associates opened in New York City in 1981, the Kleiser-Walczak Construction Company was created in 1985, and Blue Sky Studios in 1987. Cranston-Csuri opened in 1981 in Columbus, Ohio, and closed in 1987, later spawning Metrolight. In 1982 Omnibus was started in Canada, and in 1986 it purchased both pioneer Robert Abel & Associates and Digital Productions before filing for bankruptcy a couple of years later. In Paris, Buff opened in 1985, Mac Guff Ligne in 1986, and Sogitec was active from 1986 to 1989 when it merged with TDI to create Ex Machina. CA Scanline opened in Münich in 1989. In Japan Toyo Links opened in 1982, the Japan Computer Graphics Lab (JCGL) was active from 1981 until it was purchased in 1988 by the videogame company Namco, and Polygon Pictures opened in 1983.

Throughout the 1980s two constants exemplify the excellence reached by three-dimensional computer animation during the decade. On one hand there was the engaging and amusing character animations by the animation team at Pixar led by John Lasseter, including ***Luxo Jr.*** (1985), ***Red's Dream*** (1987), ***Tin Toy*** (1988), and ***Knickknack*** (1989). These Pixar projects not only pushed the RenderMan shading language to its limits, but also proved that the traditional principles of character animation could be applied to computer-generated works (Figs. 1.1.1 and 1.3.3–1.3.4). On the other hand there was ***Growth***, a series of semi-abstract animations by Japanese artist-programmer Yoichiro Kawaguchi. The series portrays imaginary underwater creatures generated with procedural techniques (page 1 and Fig. 1.3.5).

The late 1980s witnessed experimentation with a wide variety of techniques ranging from the simulation of natural-looking hair growth to rigid body dynamics and modeling fabric with visible threads.

1.3.9 The character Lotta Desire from *The Little Death* had a single and continuous skin that covered her entire body, including eyes with animateable irises. This character was also one of the first to use an early version of the surface subdivision technique to raise the polygonal resolution for film output, about 5,000 polygons that were subdivided to 20,000 at rendertime. Lotta Desire also contained internal displacements, not morph targets, to achieve her facial expressions. (© 1989 Matt Elson.)

1.3.10 The hilarious *Technological Threat*, in 1988, combined three-dimensional wireframe computer animation of the environment and boss with traditional hand-drawn animation of the employees. (© 1999 Kroyer Films, Inc.)

Rating Systems Across Entertainment Media

Movies, MPAA

G	General Audiences
PG	Parental Guidance
PG-13	Parents Strongly Cautioned
R	Restricted
NC-17	No one 17 and Under

Television, TV Parental Guides

TV-Y	All Children
TV-Y7	Older Children (7+)
TV-Y7-FV	Older Children (7+), Fantasy Violence
TV-G	General Audience
TV-PG	Parental Guidance Suggested
TV-14	Parents Strongly Cautioned (14+)
TV-MA	Mature Audience Only (17+)

Video/Computer Games, ESRB

eC	Early Childhood (3+)
E	Everyone (6+)
E10+	Everyone (10+)
T	Teen (13+)
M	Mature (17+)
AO	Adults Only (18+)
RP	Rating Pending

1.3.11 Ratings across media by the Motion Picture Association of America, the TV Parental Guidelines Monitoring Board, and the Entertainment Software Ratings Board.

Stanley and Stella: Breaking the Ice, produced by Symbolics Graphics and Whitney Demo Productions in 1987, is a solid and amusing early example of flock animation. ***Don't Touch Me***, created in 1989 by the Kleiser-Walczak Construction Company, represents one of the earliest tours de force in character animation with motion capture techniques (Fig. 1.3.6). The female singer in this piece displayed more body animation and faster motion than any previous attempt; the animation was achieved by applying the motion of a live singer to the virtual character. The demo reels of design and production studios such as Rhythm & Hues and Metrolight in California, Ex Machina in Paris, Digital Pictures in London, and Toyo Links in Tokyo (Fig. 1.3.7) are representative of the commercial work of the period.

Independent short computer animations created during the late 1980s have many inspired examples. ***Burning Love*** created by Pacific Data Images in 1988 displayed an emotional quality that had not been seen in too many computer animations of the period, and it also used one of the earliest painterly treatments of three-dimensional computer rendering. ***Locomotion***, also by Pacific Data Images (1988), illustrated the story of a charming train engine that overcomes a broken bridge and, in the process, displayed great understanding of the traditional animation principles of squash and stretch (Fig. 1.3.8). ***The Little Death***, created by Matt Elson at Symbolics Graphics in 1989, applied the technique of displacement animation onto detailed models of the human figure (Fig. 1.3.9). ***Grinning Evil Death*** (McKenna and Sabiston at MIT's Media Lab) had a sassy, almost sinister sense of humor that was uncommon in computer animations of this period. ***Technological Threat***, created by William Kroyer in 1988, combines hand-drawn animation with three-dimensional computer wireframe animation to present a hilarious view of the automated office (Fig. 1.3.10).

During the second half of this decade Walt Disney Feature Animation, one of the dominant forces in traditional animation, began to experiment with three-dimensional computer animation in its animated feature films (Fig. 1.1.3). ***The Black Cauldron,*** released in 1985, was the first Disney animated feature film that used computer graphics technology in a small section of the movie to simulate a flying visible light source. ***The Great Mouse Detective*** (1986) contains a one-minute chase sequence almost at the end of the movie where the hero tries to rescue the heroine from the villain in a landscape of menacing gears that threaten to crush them as they try to evade the villain. The gears were modeled and animated with three-dimensional computer animation techniques, and then output as drawings on paper with a pen plotter. This allowed them to be integrated into the traditional production process of the time.

Many of the cityscapes in ***Oliver & Company***, a 1988 Disney release, are populated with animated three-dimensional cars. In addition, some of the car interiors are settings for conversations between hand-drawn cartoon characters, and some close-ups of car exteriors are also backdrops for shots with the canine characters that drive the film. ***The Little Mermaid*** (1989) was the last Disney animated feature

1.4.1 Animating flocks of bats in the film *Batman Returns*. The behavior of the bats is based on a flock animation computer model originally developed by Craig Reynolds in 1987. (Additional software written by Andy Kopra. *Batman Returns*™, © 1992 DC Comics. Image courtesy of VIFX.)

film to use traditional ink and paint production techniques. The very last scene in the film, where the crowds wave good-bye, was done digitally with Disney's proprietary **CAPS** software (Computer Animation Production System).

In the area of live action films, ***The Abyss*** is a 1989 feature film that crowns the decade with convincing examples of computer-generated visual effects, seamless compositing with 70 mm live action footage, and a complex production created to a great extent with off-the-shelf systems. One of the most striking moments in this film takes place when the computer-animated water creature emulates the facial expressions of the human actor who also touches the virtual creature with her hand. The first Game Developers Conference took place in 1987, and the MPAA expanded its rating system in 1984 to include a PG-13 category (Fig. 1.3.11).

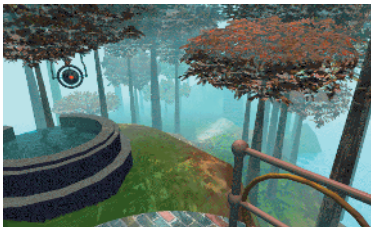
1.4 Visual Milestones: 1990–1999

Few suspected the explosion in popularity, artistic creativity, and significant revenue that computer animation and visual effects were going to play during this decade, including the beginning of a renaissance in visual effects and the creation of ***Toy Story***—the first all-three-dimensional computer animation feature.

Visual Milestones: Early 1990s

The early 1990s were characterized by refined examples of computer animation as well as a successful revival of special effects for feature films. Three-dimensional computer animation and imaging during this period became quite complex and full of varied styles and

1.4.2 The facial animation of this surprised virtual Marilyn Monroe was generated using the SMILE system, an early 1990s multilayer animation system with muscle deformation at the lower level and a high-level language to specify emotions, speech, and eye motions. (© 1991 Nadia Magnenat-Thalmann, MIRALab, University of Geneva, and Daniel Thalmann, Computer Graphics Lab, EPFL, Lausanne.)



1.4.3 *Myst* pushed the limits of realistic rendering for what was possible with 8-bit color CD-ROM computer games in the early 1990s. (Screen shot from Myst® CD-ROM computer game. Game and screen shot © 1993 Cyan, Inc®. All rights reserved.)

attitudes. Many of the projects from this period encompass an exciting body of work and a variety of styles and techniques. By the middle of the decade three-dimensional computer animation and imaging had become a mature and specialized field that finally gained a fair amount of wide recognition. Computer animators and digital artists in general were in great demand due to the increased production slate of visual effects films, animated films and television series, and computer and platform games.

The early 1990s witnessed a fair amount of company transitions in the field of commercial computer animation and visual effects. The Mill in London and Santa Barbara Studios started in 1990, and Digital Domain opened in 1993. The same year Square opened with the original goal of creating animation for both games and feature film. Sony was the first Hollywood movie studio to consider developing an in-house visual effects and computer animation facility. The result of this idea was Sony Imageworks, which opened in 1992. Later in the decade other Hollywood studios purchased independent computer animation and/or visual effects production houses. Another notable business event of this period was the agreement between Disney and Pixar to codevelop, produce, and distribute several animated feature films.

Several feature films created during the early 1990s used computer-generated visual effects extensively. ***Terminator II***, for example, is a landmark 1991 film by James Cameron with computer animation by Industrial Light & Magic. This film was the first mainstream blockbuster movie to include outstanding three-dimensional morphing effects, the first convincing simulation of natural human motion,

global reflections and even a few self-reflections when the digital actor walks through the metal bars. ***The Lawnmower Man***, a 1992 film with computer animation by Angel Studios, was the first feature film of the decade that explored the topic of virtual reality with computer animation. ***Batman Returns*** is a 1992 stylized production with effective examples of flock animation (Fig. 1.4.1). The same year ***Death Becomes Her*** used extensive digital retouching by removing the head of an actress and later tracking a shot of a talking real head onto the body. ***Jurassic Park***, a 1993 film by Steven Spielberg with computer animation by ILM, is an early example of using inverse kinematics skeletons, skin, and local deformation for each muscle. This movie was also the first example of a computer-generated human stunt double, and a great example of hyperrealistic rendering. A gigantic amount of processing was performed in a relatively short period of time. For the first time in a live action feature film, digital compositing replaced almost entirely photochemical optical compositing for the perfect integration of live action and animatronics (for the close-ups of dinosaur heads) with computer-generated images. ***The Flintstones*** (1994) is an early example of fur rendering, used for the saber tooth tiger.

Other notable examples of computer animation during the early 1990s include ***Primordial Dance*** (1991) and ***Liquid Selves*** (1992), both beautiful examples of computer animations created by Karl Sims with particle systems techniques; the irreverent and amusing ***Le Xons Crac-Crac*** and ***Baston*** created in 1991 by Ex-Nihilo and Mac Guff Ligne; William Latham's hypnotic ***Mutations*** (1991); ***Virtual Marilyn*** (1991) created with an early muscle-based facial animation system by Nadia Magnenat-Thalmann and Daniel Thalmann (Fig. 1.4.2); ***Don Quichotte,*** an ambitious keyframe animation created in 1991 by Video System; and ***Leaf Magic*** (1991), a good example of animation with motion dynamics by Alan Norton.

Some of the outstanding work for television commercials includes the 1993 ***Coca-Cola Polar Bears*** by Rhythm & Hues Studios (Fig. 1.4.4) and the 1994 ***Listerine Arrows*** by Pixar. Many ambitious and exquisite architectural visualizations were also created in the early 1990s, including ***The Seven Wonders of the World*** (1992) by Electric Images in England, ***The Ancient World Revisited I-III*** (1990–94) by Taisei Corp., and ***De Karnak a Louqsor*** (1992) by Ex Machina. In 1993 ***Myst*** set the standard for prerendered three-dimensional computer animation for computer games (Fig. 1.4.3). The early 1990s also saw great examples of broadcast-quality computer animation created entirely with off-the-shelf microcomputer systems. ***Babylon 5***, for example, is a 1993 TV series and the first mainstream example of high-end three-dimensional computer animation that was initially produced entirely on 32-bit Amiga and Macintosh microcomputers. The now ubiquitous Music Television Channel (MTV) went on air in 1981 and started its Music Video Awards program in 1984, but it wasn't until the 1990s that **music videos** came of age as a viable and original medium for cutting-edge

1.4.4 The first polar bear commercial created by Rhythm & Hues Studios was created in 1993, above. Middle and below are frames from the 1996 and 1998 editions of the commercial. (© The Coca-Cola Company. "Coca-Cola," the Coca-Cola Polar Bear design, and the "Coca-Cola" Contour Bottle are trademarks of The Coca-Cola Company.)

1.4.5 *Moxy*, the virtual host of Cartoon Network's first original animated program, was animated with a live motion capture and motion control system. (© 1993 Cartoon Network, Inc. See Figure 12.2.6 for full credit.)

1.4.6 *Megasónicos*, also known as *Megasonikoak*, was the first 3D computer animation feature to be produced in Europe. (© 1997 BALEUKO, S.L.)

computer animation and visual effects (Figs. 1.4.14 and 1.4.15).

Motion capture systems for character animation experienced an intense development during this period. Some of these efforts included the Facetracker system developed by SimmGraphics to animate the Super Mario character; ***Moxy,*** a virtual TV host animated by Colossal Pictures for the Cartoon Network (Figs. 1.4.5 and 12.2.5); Acclaim Entertainment's optical system with up to 70 sensors for simultaneous two-person capture (Fig. 12.2.5); and a variety of commercially available motion capture hardware and software.

During the early 1990s computer animation at Walt Disney Feature Animation went from a mere novelty to a significant standard component in the digital production process. Disney's 1990 release ***The Rescuers Down Under*** was the first Disney animated feature film to be produced entirely with the first version of the CAPS software. This landmark event ended 53 years (since 1937) of inking and painting acetate cels. This film also contained a moving vehicle and a few props created with three-dimensional computer animation. ***Beauty and the Beast*** (1991) includes the memorable ballroom scene where the animated camera follows Beauty and Beast as they dance in a three-dimensional environment that included columns with marble textures and a detailed chandelier. This film was also the first animated feature film to be nominated for an Academy of Motion Picture Arts and Sciences award in the Best Picture category.

In ***Aladdin***'s magic carpet we see the first example of Disney character-driven computer animation. The magic carpet's organic surfaces and detailed texture were animated with cartoony squash and stretch and impeccable timing. The complex textures mapped on the carpet would have surely been a challenge to animate, ink, and paint with traditional production techniques. In addition the three-dimensional computer animation in this 1992 movie also included the tiger-cave head rising from the sand dunes, the lava sequence, and countless other animation effects. The computer-generated stampede of wildebeests in ***The Lion King*** (1994) is one of the most striking moments in modern feature animation. It sets up with dramatic force and visual power the terrible events that will take place before the sequence is over. The wildebeests were animated with a crowd simulation system that predated many of the crowd systems that became popular later in the decade. The wildebeests' shadows and dust were also created with a three-dimensional computer animation system, as was the fire effects animation.

Visual Milestones: Late 1990s

The second half of the 1990s exploded with productions rich in three-dimensional computer animation in the fields of live action films with special effects, animated feature films, and computer or platform games. In 1995, Pixar's ***Toy Story*** became the first feature animated film to be entirely created with three-dimensional computer animation techniques (Fig. 12.1.1). Three years later two other pro-

jects joined the competitive world of three-dimensional computer animation: DreamWorks' ***ANTZ*** (Figs. 2.7.10 and 2.7.11), and Pixar's ***A Bug's Life***. Three other animated feature films—each from a different studio—were released with wide distribution in the United States during 1998: Disney's ***Mulan***, Nickelodeon's ***Rugrats***, and DreamWorks' ***Prince of Egypt***. The animated feature ***Princess Mononoke*** by Hayao Miyazaki was released in Japan during 1997. Not only did this film present a magical view of the world, including a hovering multi-tentacled monster created with 3D computer animation and non-realistic rendering, it also set box-office and TV records. At the time this film was the highest grossing of any film in Japan, and it scored the eighth best TV viewership rating ever. ***Los Megasónicos***, also known as ***Megasonikoak*** in Basque, made history in 1997 as the first European three-dimensional computer animation feature (Fig. 1.4.6).

1.4.7 The flea from 1995's *La cité des enfants perdus*. (© Claudie Ossard. Directors: Jeunet & Caro. Visual effects: Buff.)

Not only was the volume of animation production during 1998 impressive, but also the quality and creative diversity was unparalleled in the history of animation. The 1999 animated feature film releases were equally impressive: Disney's ***Tarzan*** and ***Fantasia 2000***, Pixar's ***Toy Story 2***, Warner Bros.' ***Iron Giant***, and Paramount's ***South Park***. ***Fantasia 2000*** became the first animated feature film (over 90 minutes long) to be released exclusively for the IMAX large-screen format for the initial four-month run. ***Toy Story 2*** increased the visual complexity of the computer-generated environments and the human characters in particular; ***Iron Giant*** presented an unlikely hero that was rendered with a non-photorealistic RenderMan shader.

The activity and quality of the craft in the field of visual effects during the later part of the decade was also very high. Just consider some of the many films that featured fully computer-animated main characters with live actors: ***The Lost World: Jurassic Park*** (1993), ***Jumanji*** and ***Species*** (1995), ***Dragonheart*** (1996), ***Titanic***, ***Starship Troopers,*** and ***Mars Attacks!*** (1997), ***Mighty Joe Young***, ***Mouse Hunt,*** and ***Godzilla*** (1998), ***The Mummy*** and ***The Phantom Menace*** (1999). The decade—and the millennium—in visual effects was capped with four popular effects-oriented films: the stylish ***The Matrix***, winner of the 1999 AMPAS award for Best Visual effects, ***Stuart Little*** with its innovative combination of cartoon and realistic action (Figs. 14.3.3 and 14.3.4), the sleeper hit ***The Mummy***, and the much-heralded Star Wars prequel ***The Phantom Menace***. The visual effects for the former movie were done at Mass Illusion, the later two movies were done at Industrial Light & Magic. ***La cité des enfants perdus*** (The City of Lost Children) was a 1995 French movie with ground-breaking visual effects and ray tracing rendering done with Mental Ray software (Fig. 1.4.7). The same year ***Casino*** used Lightscape radiosity software to create realistic set extensions, ***Waterworld*** incorporated water sim-

1.4.8 Some of the main characters in Chris Landreth's *Bingo*, one of the earliest computer animations rendered in a realistic style, based on improvisational theater techniques. (© Alias|Wavefront, a division of Silicon Graphics Limited.)

1.4.9 The colors in this watercolor simulation are animated to reflect the changing time in day as well as the mood of the Fisherman. (*Fishing*, a 1999 PDI short film by David Gainey.)

1.4.10 The character in *Alien Song* meets an unexpected end while disco-dancing to Gloria Gaynor's *I Will Survive*. See Figure 8.4.4 for a related image. (© 1999 Victor Navone.)

ulated with Areté software (Fig. 5.5.10), and ***Jumanji*** rendered fur on a scale larger than ever before. ***Babe*** advanced the techniques for removing, tracking, and replacing talking animal heads. During 1996 the computer-generated creature in ***Dragonheart*** was the co-star of the movie, RenderMan shaders were used in ***Mission Impossible*** to match the look of the film stock used, and a massive dynamics simulation was used to create tornados for ***Twister***. During 1997 award-winner ***Titanic*** used computer-generated water, massive digital compositing, and motion capture to create digital extras on the deck of the ship; ***Spawn*** achieved a dramatic effect in the cloth animation by combining realistic rendering with exaggerated keyframe animation; and ***Mars Attacks!*** included amusing slapstick comedy and extensive cloth animation. In 1998 ***What Dreams May Come*** perfected camera tracking techniques to facilitate the *animated painting* look developed for the movie, and ***Mighty Joe Young*** perfected hair rendering techniques. The 1999 award-winner ***The Matrix*** used image-based rendering as well as the *frozen time* visual effect (see Chapter 13); ***Star Wars: Episode One*** had memorable spacecraft racing and battle scenes, with some of the best crowd simulation work done until then; ***Stuart Little*** brought new life to the live action movie with a computer-generated hyperrealistic cartoon character with simulated wet cloth and wet fur; and ***Fight Club*** used image-based modeling and rendering (before ***The Matrix***) with several impossible camera moves through walls.

When compared to films of previous decades the visual effects films of the late 1990s had more and more complex digital and traditional effects shots. ***Terminator II***, for example—a landmark 1991 production that redefined the use of computer animation in live action movies—had approximately 150 visual effects shots including 44 digital effects. In 1995 ***Batman Forever*** had about 250 visual effects shots. In 1997 ***Titanic*** had close to 550. In 1998 ***Armageddon*** had around 240, and ***Godzilla*** had close to 400. In 2000 ***How the Grinch Stole Christmas*** had about 600 visual effects shots with about 300 of them computer-generated, including falling and melting snow; and ***The Perfect Storm*** had around 225 shots with computer-generated virtual stunt actors, 40 of them, and 33 minutes of computer-generated waves.

Production of computer animation and visual effects for feature film during the late 1990s was mostly dominated by the companies that had established themselves as leaders during the previous ten years. The major newcomers include Foundation Imaging (1992), Blur Studios, Banned from the Ranch (both opened in 1995), and Centropolis (1996). Continuing the trend set by Sony earlier in the decade with the creation of its internal visual effects and computer animation facility, in 1996 DreamWorks purchased an interest in Pacific Data Images, Fox purchased VIFX, and Disney purchased industry pioneer Dream Quest Images. A year later Fox purchased Blue Sky Studios. Warner Digital was active from 1995 to 1997.

Some of the most polished short computer animation works

that we have ever seen were also produced during this period. This includes ***Geri's Game*** by Jan Pinkava at Pixar in 1997 (Fig. 1.2.9), ***Bunny*** by Chris Wedge at Blue Sky Studios (Figs. 7.2.4 and 10.1.1) and ***Bingo*** by Chris Landreth at Alias Research in 1998 (Figs. 1.4.8 and 4.2.7), and ***Tightrope*** by Daniel Robichaud at Digital Domain in 1999 (page 293 and Fig. 12.5.8). Not only were these shorts produced by different groups, but each had a recognizable style that made it unique. Both ***Geri's Game*** and ***Bunny*** won AMPAS awards in the Best Animated Short category. The original non-photorealistic ***Fishing*** by David Gainey and the simple walk and character study ***Alien Song*** by Victor Navone were both released in 1999 (Figs. 1.4.9 and 1.4.10).

The games industry, fueled by the new game platforms, grew tremendously. In 1998, for example, Nintendo released ***The Legend of Zelda: Ocarina of Time*** for the N64. Between its launch date of November 23 and the end of the year, Nintendo reported $150 million in sales of 2.5 million copies. As a point of reference, one of the higher-grossing movies during that year was Disney/Pixar's ***A Bug's Life***, which collected $114 million at the box office. A few games from this period with innovative character computer animation include ***Soulblade***, my personal favorite fighting game from those years, Nintendo's ***Super Mario 64***, adventure and role-playing ***Ultima Online***, strategy and wargames ***Age of Empires*** and ***Civilization***, sports games ***NHL 98*** and ***NBA Live 97***, action games ***Duke Nukem 3D*** and ***Tomb Raider***, the arcade version ***Virtua Fighter 3,*** and a few installments in the ***Final Fantasy*** series by SquareSoft (Fig. 1.4.11).

1.4.11 Two of the main characters from the *Final Fantasy* videogame. (© 1998 Square Co., Ltd. All rights reserved.)

Some of the notable three-dimensional computer animation for early **location-based entertainment**—or **LBE rides** as they are known—include ***The Volcano Mine Ride*** (1995), and ***Seafari*** and ***Race for Atlantis in Imax 3D*** created by Rhythm & Hues Studios in 1994 and 1998, respectively (Figs. 1.4.12 and 1.4.13). Arcade games got away from shooting and fighting, and experienced growth in the areas of sports simulations like skiing, snowboarding, and jet skiing.

Peter Gabriel's polished music video ***Kiss that Frog*** won Best Special Effects in the 1994 MTV Video Music Awards (Fig. 1.4.14). A couple of the more memorable commercials included the ***Dance Fever*** commercials of dancing cars created by R/Greenberg Associates for Shell Oil in 1995, and ***Virtual Andre*** created from a motion-captured Andre Agassi by Digital Domain in 1997. There

1.4.12 The future of location-based entertainment is being defined by computer-generated rides like *Seafari*, a hyperrealistic computer-generated motion ride that takes the audience on an underwater rescue mission. (© 1994 MCA/Universal. Courtesy of Rhythm & Hues Studios.)

1.4.13 View of *Race for Atlantis* projected on the curved surface where the ride takes place. (Courtesy of Forum Ride Associates.)

was also a lot of activity in the area of animated television series, with new all-computer-animated series like ***Beast Wars*** and ***Reboot*** by Mainframe Entertainment (pages 58 and 449), ***Rednecks*** by Foundation Imaging, and charming ***Rolie Polie Olie*** (premiered in 1998) by Nelvana and Paris-based Sparx. Likewise, feature-length direct-to-video releases grew significantly during the decade.

Throughout the late 1990s traditional animation production at Walt Disney Feature Animation moved closer to three-dimensional computer animation, resulting in several examples of blending tradition with innovation. The rough animation for the canoe that ***Pocahontas*** (1995) rides down the river, for example, was created with three-dimensional computer animation techniques and match-moved to other elements in the scene. The face of the wise Mother Willow character was also animated with three-dimensional computer animation. Disney's 1996 production of ***The Hunchback of Notre Dame*** showcases three-dimensional computer-generated confetti and crowds, motion blur effects, and a few props. In the final shot of the "Sanctuary!" sequence, where Quasimodo rescues Esmeralda from being burned at the stake and carries her to the top of Notre Dame, the three-dimensional model of the rosetta and its architectural details add dimensionality to the shot.

The 1997 release ***Hercules*** includes a memorable segment where the hero fights a multiple-headed Hydra monster. As he cuts some of the heads others immediately pop up in a menacing and fierce way. In addition a morphing technique was used in the opening shots of the movie to blend still paintings of clouds, columns, and other background paintings. ***Mulan*** (1998) displays a large variety of three-dimensional computer-animated props that blend seamlessly with the hand-drawn elements and hand-painted backgrounds. These props include flags, arrows, and carts. There is also a fair amount of effects animation like the smoke and fire from the flaming arrows and, of course, the Hun charge, which is somewhat reminiscent of moments of the wildebeest sequence in the 1994 blockbuster ***The Lion King***. The Hun charge sequence, however, is enhanced with a couple of low-flying traveling shots that add drama to the danger and uncertainty of the sequence. Hand-drawn two-dimensional characters as well as some background elements were applied to three-dimensional billboards in order to populate scenes in this movie. The 1999 production of ***Tarzan*** offered lush jungle environments created with Disney's proprietary software Deep Canvas to recreate 2D brushstrokes on three-dimensional geometry. Many of the procedural effects animation (including water) also add to the story. From the beginning the movie was produced keeping in mind that it would be released in theaters both as a film print and as a pioneer in the digital cinema, or D-cinema, projection technology. For that reason all the final frames in the film are 100 percent digital, including the 540 feet of rolling animated credits at the end of the movie.

A couple of refinements and additions to the ratings systems took place during this decade. In 1990 the MPAA renamed their X

1.4.14 *Kiss that Frog* is a rock video based on the music of Peter Gabriel. A rich array of shading techniques was used to portray exotic creatures in an environment that also contains live action characters. (© 1993 MEGA/ Real World. All rights reserved. Courtesy of Angel Studios, Carlsbad, California.)

rating to NC-17. In 1994 the Entertainment Software Ratings Board issued a ratings system for computer games, and a new system for rating television programs based on the existing MPAA categories was put in place in 1997 (Fig. 1.3.11).

1.5 Visual Milestones: 2000–Today

This decade witnessed a coming of age of computer animated features, where the initial fascination and novelty gave way to works that pushed the envelope on the technical, creative, and entertainment fronts. Visual effects movies also continued to become more ambitious and sophisticated: the number and complexity of VFX shots in effects-driven movies continued to increase, and incorporating high-quality VFX shots in non-effects movies became prevalent.

Visual Milestones: Early 2000s

The early years of this decade witnessed growth in the quantity of movies incorporating visual effects as well as the total number and quality of effects shots per show. The statistics of ***Star Wars: Episode II***, for example, are impressive: 2,200 visual effects shots, 10,200 visual effects elements, 5 million frames, 929 animated shots, 20 different cuts of the movie, and a crew of over 250 digital artists who completed every day of the production the equivalent of one worker-year of work. The choreography of the camera and the action is one of the most complex ever produced for a live action effects production. George Lucas, the director, also pushed to its limits the high-

MTV's Video Music Awards, Best Special Effects

1984 *Rockit*, Herbie Hancock
1985 *Don't Come Around Here No More*, Tom Petty
1986 *Take on Me*, a-Ha
1987 *Sledgehammer*, P. Gabriel
1988 *Hourglass*, Squeeze
1989 *Leave Me Alone*, Michael Jackson
1990 *Sowing the Seeds of Love*, Tears for Fears
1991 *Falling To Pieces*, Faith No More
1992 *Even Better Than the Real Thing*, U2
1993 *Steam*, Peter Gabriel
1994 *Kiss that Frog*, P. Gabriel
1995 *Love Is Strong*, Rolling Stones
1996 *Tonight, Tonight*, Smashing Pumpkins
1997 *Virtual Insanity*, Jamiroquai
1998 *Frozen*, Madonna
1999 *Special*, Garbage
2000 *All Is Full of Love*, Björk
2001 *Rock DJ*, Robbie Williams
2002 *Fell in Love with a Girl*, The White Stripes
2003 *Go With the Flow*, Queens of the Stone Age
2004 *Hey Ya!*, OutKast
2005 *Speed of Sound*, Coldplay
2006 *We Run This*, Missy Elliott
2008 *Good Life*, Kanye West with T-Pain

1.4.15 List of music videos that have won the Best Special Effects category in MTV's Video Music Awards.

definition (HD) and blue screen technologies available in 2002, proving that a feature movie can be made entirely with virtual sets, extensive previsualization, and compositing techniques. ***Spy Kids 2*** was another movie that followed with great results a smaller scale of the same production pipeline: shoot on HD taking advantage of green-screen techniques, digitize the live action, create computer-generated visual effects, composite all elements using the digital intermediate process, and output to desired media (Figs. 2.7.3 and 13.1.1).

The three installments of ***The Lord of the Rings*** (2001–2003) showcased stylized environments and creatures created with myriad effects techniques, ranging from in-camera effects to computer animation. Of special note are the eerie and emotionally convincing ***Gollum*** character (Fig. 12.2.7), the crowd animation system (Fig. 12.6.1), the superb color timing, and the fact that elements for the three episodes of this saga were shot simultaneously. The 2001 movie ***Pearl Harbor*** used massive amounts of computer-generated set extensions and props to replicate many of the ships and most of the airplanes. Billions of particles were also used to simulate the smoke and fire of bomb explosions. An effective rigid-body dynamics system was developed to make the crafts' explosions more real. Ang Lee's ***Hulk*** (2003) offered a unique combination of cartoon motion and realistic motion. The sequels ***Matrix: Reloaded*** and ***The Matrix: Revolutions*** rounded up the innovative style of the original.

Because of the increased availability of high-quality visual effects this was also a period that saw a rise in the number of feature movies with excellent and subtle supporting visual effects that do not "carry the picture" but provide important accents to the storytelling. A few examples include the rain of frogs in ***Magnolia*** and the rose petals in ***American Beauty*** (1999); the boulder plunging into the swimming pool in ***Sexy Beast*** (2000); ***Amélie***'s visible heart (2001); and in 2002 the dream sequences in ***Frida***; Lechter removing the scalp in ***Hannibal***; and Adrien Brody's head digitally composited onto the body of a piano virtuoso in Polanski's ***The Pianist***.

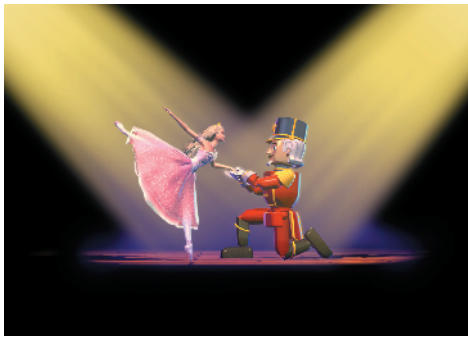
Final Fantasy marked the first attempt to create an entire animated feature movie with motion capture techniques (Figs. 5.5.13 and 9.2.4), and in spite of stunning visuals the commercial results were mixed. Warner Bros.' ***Polar Express*** (2004) was another early animated feature based on extensive motion capture. ***Synchronicity*** was one of the first independent shorts to use motion capture techniques (Fig. 1.5.1). A pair of movies featuring ***Barbie*** also made use of motion capture techniques (Figs. 1.5.2 and 12.2.8). Five years in the making, Disney's ***Dinosaur*** blended live action backgrounds with computer-generated characters. Fox's ***Ice Age*** presented a mixture of slapstick comedy and drama in a beautifully rendered saga (page v and Fig. 10.4.10). DreamWorks' ***Spirit*** made innovative use of three-dimensional computer animation techniques and "cartoon-style" non-photo-realistic rendering. Disney's ***Atlantis*** and ***Treasure Planet*** display spectacular integration of 2D and 3D animation techniques, but the latter failed to capture the interest of audiences during its initial release.

Partly because of the growth in quality and quantity in animation production the American Academy of Motion Picture Arts and Sciences (AMPAS) added a new category in 2001 for Best Animated Feature Movie in their yearly competition. DreamWorks' ***Shrek***, with its mixture of irreverent humor and unique stylized rendering, was the winner of the first award in this category (Figs. 2.2.6 and 12.4.1). Pixar's ***Monsters Inc.*** featured a green one-eyed monster, a blue-haired monster with 3 million hairs (Figs. 2.2.6 and 5.5.13), and a lovable girl, and ***The Incredibles*** featured a super-powered family animated with significant squash and stretch. DNA's ***Jimmy Neutron Boy Genius*** proved that medium-size companies could deliver good-quality three-dimensional animation with off-the-shelf software, NewTek's Lightwave, and within reasonable budgets (Fig. 1.5.4). Japanese animation master Hayao Miyazaki's ***Spirited Away*** was the 2002 winner in this category, Pixar's ***Finding Nemo*** and ***The Incredibles*** won in 2003 and 2004 (see the timetables at the end of this chapter for a listing of all nominated movies). A few years earlier the SIGGRAPH Conference also created the Best Animated Short and Jury Honors awards, which were won in 1999 by Chris Wedge's ***Bunny*** and Piotr Karwas' ***Masks***, respectively (Figs. 10.1.1 and 8.4.3); in 2000 by the cinematic opening in the ***Onimusha*** PS2 videogame (Fig. 11.3.6) and ***Stationen*** by Christian Swade-Meyer; and in 2004 by Sejong Park's ***Birthday Boy*** (Figs. 4.5.5 and 7.2.9) and Chris Landreth's Academy Award winner ***Ryan*** (Fig 10.3.4). Tomek Baginski's ***The Cathedral*** (Figs. 8.3.7 and 8.6.5) and Sam Chen's ***Eternal Gaze*** (Figs. 10.4.2 and 12.5.10) were the winners of the Best Animated Short in 2002 and 2003, respectively. In 2002 the Visual Effects Society (www.ves.org) instituted an awards program to recognize the different visual effects specialties (Figs. 1.5.3 and 13.12.3).

Computer animation and visual effects production was active and grew internationally during this period. Paris-based Duran completed memorable supporting effects for ***Amélie*** and a number of music videos including ***It's Not the End of the World*** by the Super Furry Animals, and embarked in the production of ***Immortel (ad vitam)***, an all-computer-animated feature based on the graphic novel ***La femme piège*** by comic book artist Enki Bilal (Fig 4.2.6). ***Kaena, la Prophétie*** is another French computer-animated feature completed in 2003 (Fig. 8.3.11), as well as the Danish irreverent comedy ***Terkel in Trouble*** (Fig. 9.4.6). Yimou Zhang's ***House of Flying Daggers***, Stephen Chow's ***Kung Fu Hustle***, and Timur Bekmambetov's ***Night Watch*** are examples of the increasingly ambitious and original visual effects created for non-Hollywood productions.

London-based Aardman Studios continued their relationship with DreamWorks, and newcomer Vanguard Animation struck a multi-picture distribution deal with Disney for several computer-animated features. Framestore and the Computer Film Company (CFC), also in London, merged in 2001 and created memorable TV commercials for Microsoft's Xbox and Levi's jeans (Figs. 9.8.3, 13.3.1, and 13.6.1). Hong Kong–based Menfond and Centro Pictures continued

1.5.1 *Synchronicity* by Hans Uhlig was one of the earliest independent shorts to make extensive use of motion capture. (© 2000 Bay Vista Productions.)



1.5.2 The Nutcracker and Barbie strike a pose in this scene from *Barbie in the Nutcracker*, a direct-to-video computer -animated movie that combines motion capture with keyframe techniques. (BARBIE and associated trademarks and trade dress are owned by, and used with permission from, Mattel, Inc. © 2003 Mattel, Inc. All rights reserved.)

The Visual Effects Society Award Categories

- Visual Effects in an Effects-Driven Motion Picture
- Supporting Visual Effects in a Motion Picture
- Visual Effects in a Television Miniseries, Movie, or Special
- Visual Effects in a Television Series
- Visual Effects in a Commercial
- Visual Effects in a Music Video
- Character Animation in a Live Action Motion Picture
- Character Animation in a Live Action TV Program, Music Video, or Commercial
- Character Animation in an Animated Motion Picture
- Special Effects in a Motion Picture
- Matte Painting in a Motion Picture
- Matte Painting in a TV Program, Music Video, or Commercial
- Models and Miniatures in a Motion Picture
- Models and Miniatures in a TV Program, Video, or Commercial
- Visual Effects Photography in a Motion Picture
- Effects Art Direction in a Motion Picture
- Effects Art Direction in a TV Program, Video, or Commercial
- Compositing in a Motion Picture
- Compositing in a TV Program, Music Video, or Commercial
- Performance by an Actor in an Effects Film

1.5.3 The twenty new categories that the Visual Effects Society (VES) introduced in 2002 to recognize the visual effects work from a variety of creative fields and media (winners at www.ves.org).

their innovative visual effects and computer animation work (Figs. 1.6.2, 13.1.2, and 13.7.1). In spite of increased production during these years the industry also went through a series of ups-and-downs, with significant layoffs everywhere. Fox Studios sold VIFX to Rhythm & Hues Studios, and The Walt Disney Company closed The Secret Lab, its visual effects group. In New York City R/Greenberg Associates closed its computer animation and visual effects division, and London-based Mill Film, the company that won a 2000 AMPAS award for visual effects in ***Gladiator***, closed in 2002.

The game industry continued its competition with movies as the premier form of entertainment, with multiplayer online games gaining acceptance. In 2001 ***Lara Croft Tomb Raider*** became the highest-grossing movie based on a videogame. Sony's ***EverQuest***, for example, launched in 1999 and reported hundreds of thousands of users by 2003 (Fig. 4.7.3). Other multiplayer online games launched in 2002 include Electronic Arts' ***Ultima*** and ***Majestic***, and Maxis' ***The Sims. URU: Ages Beyond Myst***, the online version of the popular game, was launched in 2003 (Fig. 4.7.4). The game platforms started to offer additional online services, and the new graphics cards for PCs fostered the development of innovative games by a wide number of developers and publishers. A few of the PC and platform games that gained critical recognition and/or economic success during 2000 include, for the PC ***Deus Ex*** by ION Storm Austin, ***The Sims*** by Maxis, ***Diablo II*** by Blizzard, and ***No One Lives Forever*** by Monolith; for the Dreamcast: ***Jet Grind Radio*** by Smilebit, ***Shenmue*** by Sega AM2, ***Samba de Amigo*** by SEGA Sonic Team, ***Seaman*** by Vivarium, and ***Crazy Taxi*** by Hitmaker; ***Spyro: Year of the Dragon*** by Insomniac for the PS2, and ***Legend of Zelda: Majora's Mask*** by Nintendo for the N64). In 2001 some of the games that received critical acclaim or public recognition include, for the PlayStation 2: ***Grand Theft Auto III*** by DMA Design-Rockstar Games, ***Jak & Daxter: The Precursor Legacy*** (Fig. 7.4.6), ***Final Fantasy X*** by Square, ***Ico*** from Sony Computer Entertainment, ***Rez*** from United Game Artists, and Konami's ***Metal Gear Solid 2: Sons of Liberty***; for the Xbox, ***Halo: Combat Evolved*** by Bungie Studios, ***Cel Damage*** from Pseudo Interactive, and ***Oddworld: Munch's Oddysee*** (Fig. 7.6.3); for the PC: ***Max Payne*** from Remedy Entertainment, and Activision's ***Return to Castle Wolfenstein***; and ***Black & White*** from Lionhead Studios for Dreamcast (Fig. 1.5.5).

Visual Milestones: Late 2000s

The late 2000s had an abundance of visual effects blockbusters. To name a few: ***Pirates of the Caribbean*** with its innovative use of partial motion capture to animate pirate Davy Jones (2003, 2006 and 2007, Figs. 2.7.15 and 12.1.10); ***Transformers*** (2007) and its popcorn action; comicbook-inspired ***Constantine*** (2005); ***Superman Returns***, and ***X-Men: The Last Stand*** (2006); ***Spider-Man 3*** (2007); and ***The Incredible Hulk*** (2008). ***Hellboy II: The Golden Army*** and ***Iron Man*** (Fig. 2.7.7), both

also from 2008 and my personal favorites, offered creative, subtle, effective, and polished animation. The former had superb modeling craftsmanship and imaginative staging of animation, the latter had understated and elegant effects that complemented the tone and intention of the superhero storyline without calling attention to themselves.

Highly stylized animation and effects were offered in ***Sin City*** (2005), ***300*** (2007), ***Speed Racer***, and ***Wanted*** (2008). Spectacular effects and character animation were seen in sequels and remakes including ***The Chronicles of Narnia: The Lion, the Witch and the Wardrobe***, ***King Kong***, ***Star Wars: Episode III–Revenge of the Sith***; ***Mission: Impossible III*** (2006), ***TMNT*** (2007, Fig. 8.6.6), ***Indiana Jones and the Kingdom of the Crystal Skull***, and ***The Mummy: Tomb of the Dragon Emperor*** (2008). A few examples of feature movies with outstanding "invisible" supporting visual effects include the historical reconstructions in ***Memoirs of a Geisha*** (2005); the fantastic dreams and nightmares in ***The Science of Sleep*** and ***Pan's Labyrinth***, the birth scene in ***Children of Men***, and the water simulations in ***Poseidon*** (2006); the action scenes in ***The Kite Runner*** and ***The Bourne Ultimatum***, and the comedic touches in ***Blades of Glory***, (2007).

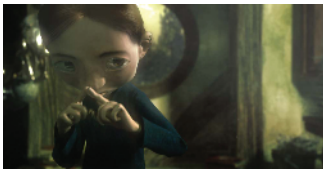
The late 2000s had memorable contributions from DreamWorks with ***Kung Fu Panda*** and ***Madagascar: Escape 2 Africa*** (2008, Figs. 10.4.13 and 12.1.8). The latter continued the unique approach to comedic squash and stretch animation initiated with ***Madagascar*** in 2005. Fox's Blue Sky continued with good-quality sequels to their ***Ice Age*** franchise, along with an interesting version of ***Horton Hears a Who!*** (2008). Sony Pictures Animation (SPA) delivered animated features produced in-house including ***Open Season*** (2006, Fig. 10.4.3) and ***Surf's Up*** (2007); ***Open Season 2*** (2009) was subcontracted to an outside production company. Sony Imageworks delivered a successful combination of motion capture and keyframe animation with ***Monster House***, nominated in 2007 for an Academy Award and directed by first-timer Gil Kenan, with a fresh animation and cinematography style (Fig. 12.2.3). ***Beowulf*** (2007) also provided solid storytelling with ambitious computer animation based on performance capture.

Pixar continued their inimitable style and track-record with my personal favorite ***Ratatouille*** (2007), stylistically different ***WALL·E*** (2008), and ***Cars*** (2006). ***Chicken Little*** (2005) was Disney's much awaited debut with an all-computer-animated feature movie. This was followed-up with ***Meet the Robinsons*** (2007) and ***Bolt*** (2008), the latter released in stereo 3D day-and-date along with the theatrical release. ***The Princess and the Frog*** (2009) is Disney's first two-dimensional animated feature produced since 2004. Interesting approaches to low-budget animated features and a respectable box-office return for some is found in independent productions ***Hoodwinked!*** (2005), ***Happily N'Ever After***, ***The Barnyard***, and ***The Wild*** (2006).

Visual effects production continued to grow internationally and became more accomplished during this period. Take, for example, the French-produced ***Empire of the Wolves***, ***Arthur and the Invisibles***, and ***Asterix in the Olympic Games***, the Chinese-produced ***The Promise***,

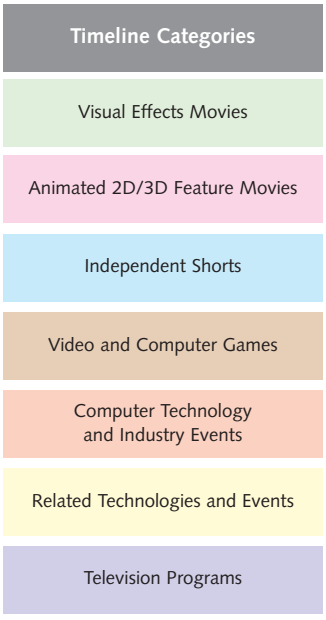
1.5.4 Jimmy Neutron and friends having a snack. (© 2003 Viacom Inc. All rights reserved. Nickelodeon, *The Adventures of Jimmy Neutron Boy Genius* and all related titles, logos and characters are trademarks of Viacom International Inc.)

1.5.5 A character in the game *Black &White*. (© Lionhead Studios.)



1.5.6 Main character in *Dreammaker* (© 2007 Filmakademie Baden-Württemberg, and Leszek Plichta.)

1.5.7 Still frame from Indian feature *Ghatothkach*. (© Copyright 2008 Shemaroo Entertainment Pvt. Ltd. All rights reserved.)



1.6.1 (Opposite page) Color coding for each of the categories in the timeline charts on the following pages. In **green** are the live action feature movies with computer-generated visual effects. In **magenta** are animated feature movies, with a focus on three-dimensional computer animation. Winners of the Academy of Motion Picture Arts and Sciences (AMPAS) awards in the categories of Best Visual Effects and Best Animated Feature are marked with an asterisk, the runners-up in each category are listed above the thin black line. Independent productions and short computer animations are in **blue** boxes. Video, computer, and platform games are in **brown**. A selection of computer technology milestones and related industry and business events are grouped under **red**. A variety of related events and technologies and facts are indicated in **yellow**. Television animated series and events are presented in **deep blue**.

Japanese ***Shinobi*** (Fig. 2.7.6), Russian ***Day Watch***, and Korean ***The Host***. Highlights of international computer-animated features include Australian 2006 Oscar-winning ***Happy Feet***, French black-and-white movies ***Renaissance*** (2006) and ***Fear(s) of the Dark*** (2007, Fig. 10.3.7), and ***Dragon Hunters*** (2008, Fig. 11.1.0), Nordic ***The Ugly Duckling and Me!*** and ***Free Jimmy*** (2006, Fig. 6.1.4), Spanish ***Donkey Xote*** (2007, Fig. 7.2.8), Japanese ***Final Fantasy VII: Advent Children***, non-photorealistic ***Tekkonkinkreet*** (2006), and well-crafted ***Appleseed Saga Ex Machina*** (2007). We can also mention ***Fly Me to the Moon,*** a Belgian production developed from start for 3D stereo projection, Indian ***Ghatothkach*** (2008, Fig. 1.5.7), and English-produced ***The Tale of Despereaux*** (2008). Highlights of independently produced animated shorts include SIGGRAPH winners ***9*** (2005) by Shane Acker scheduled to be released as a feature film in 2008, ***458nm*** by Jan Bitzer and others (Fig. 14.1.4) and Alex Weil's ***One Rat Short*** (2006); ***Ark*** by Grzegorz Jonkajtys and Marcin Kobylecki (Fig. 4.5.6) and ***Dreammaker*** by Leszek Plichta (2007, Fig. 1.5.6); and Academy Award nominees ***Oktapodi*** (2008) by Julien Bocabeille and others, and ***Even Pigeons Go to Heaven*** (2005) by BUF Compagnie (Figs. 7.3.4 and 10.3.5).

The remaining years of this decade promise to be as active as the early ones. As reported in the trade periodicals several animated and VFX feature films are in production as this book goes to press. Visual effects movies released or scheduled to be released throughout 2009 and 2010 include ***2012*** directed by Roland Emmerich, the futuristic epic ***Avatar*** directed by James Cameron, ***G.I. Joe: Rise of Cobra***, ***The Green Hornet*** directed by Stephen Chow, ***Harry Potter and the Half Blood Prince***, ***Iron Man II***, ***Kung Fu Hustle 2***, ***Prince of Persia***, ***Sin City 2***, ***Star Trek*** AKA ***Star Trek Zero***, ***Taken***, ***Terminator Salvation: The Future Begins***, ***Transformers 2: Revenge of the Fallen*** directed by Michael Bay, ***Watchmen***, ***Where the Wild Things Are*** directed by Spike Jonze, and ***X-Men Origins: Wolverine***. The working titles of a few animated projects scheduled for a 2009 or 2010 release include ***1906*** directed by Brad Bird, the much-anticipated ***Astro Boy*** being produced in Hong Kong by Imagi, ***Guardians of Ga'hoole, Hoodwinked 2: Hood vs. Evil***, from Blue Sky/Fox ***Ice Age: Dawn of the Dinosaurs***, Spanish-produced ***Planet 51***, DreamWorks' ***Shrek Goes Fourth***, ***Toy Story 3***, DreamWorks' ***Monsters vs. Aliens***, French-produced ***A Monster in Paris***, and ***Up*** co-directed by Pete Docter and Bob Peterson at Pixar.

1.6 Timeline Charts

The following timeline charts offer a chronological overview of the development of three-dimensional computer animation and related events during the last four decades of the twentieth century. The charts are limited to selected events and landmarks, and additional historical details can be found in the body of this chapter or at the website ***www.artof3d.com***. To make the information easier to read I have organized the charts in five categories, explained in Figure 1.6.1.

1890s–1950s Timeline of Animation and Visual Effects

1892…

Edison and W. Dickson develop the **35 mm** format using Eastman Kodak film stock, 1892

The Execution of Mary, Queen of Scots, 1895

Lumiere Brothers' ***Train Arriving at Station***, 1895

George Méliès ***A Trip to the Moon***, 1902

Edwin Porter's ***The Great Train Robbery***, 1903

Winsor McCay's ***Little Nemo*** is first animated short, 1911

1914…

Winsor McCay's ***Gertie The Dinosaur***, first short with live action and animation, 1914

D. W. Griffith's ***The Birth of a Nation***, 1915

Max Fleischer invents **rotoscoping**, 1915

Pathé Baby introduces **9.5 mm** film, 1922

Kodak introduces **16 mm** reversal film, 1923

First Version of ***The Thief of Bagdad***, 1924

Willis O'Brien's animates dinosaurs in ***The Lost World***, 1925

1927…

Lang's ***Metropolis,*** '26

The Jazz Singer first talkie film, 1927

Disney's ***Steamboat Willie*** is first animated cartoon with synchronized sound, 1928

The Skeleton Dance by Ub Iwerks, first Disney ***Silly Symphony***, 1929

Fleischer Brother's ***Betty Boop***, 1930

TV set patented, 1930

Frankenstein, 1931

Disney's ***Flowers and Trees*** is first color animated short, 1932

1932…

Kodak's **8 mm** film and equipment, 1932

King Kong, and ***The Invisible Man***, 1933

Fleischers' ***Popeye the Sailor*** debuts, 1933

The Bride of Frankenstein, 1935

Things to Come, 1936

Snow White and the Seven Dwarfs, first animated feature, 1937

Academy of Motion Picture Arts and Sciences creates Special Effects category, 1939

1939…

VFX Movies 1939:
The Rains Came *
Gone with the Wind
Only Angels Have Wings
The Private Lives of Elizabeth and Essex
Topper Takes a Trip
Union Pacific
The Wizard of Oz

Fleischer Brothers' ***Gulliver's Travels*** and ***Felix the Cat*** 1939

Disney's ***Pinocchio,*** and ***Fantasia,*** 1940

(* AMPAS Award Winners)

1940–41

VFX Movies 1940:
The Thief of Bagdad *
13 other finalists, incl.:
Dr. Cyclops
Invisible Man Returns
Rebecca / Typhoon
Swiss Family Robinson

VFX Movies 1941:
I Wanted Wings *
7 other finalists, incl.:
Flight Command
The Invisible Woman
The Sea Wolf
Other Movies w/VFX:
Citizen Kane

1941–42

Disney's ***Dumbo,*** 1941

Superman animated series debuts with a 9 minute episode, 1941

VFX Movies 1942:
Reap the Wild Wind *
9 other finalists, incl.:
The Black Swan
Flying Tigers
One of our Aircraft is Missing
Invisible Agent

1942–43

Disney's ***Bambi,*** 1942

Paul Terry creates **Mighty Mouse** as a **Superman** spoof, 1942

VFX Movies 1943:
Crash Dive *
5 other finalists, incl.:
Air Force
Bombardier
The North Star

Disney's ***Saludos Amigos,*** 1943

1944–45

VFX Movies 1944:
Thirty Seconds Over Tokyo *
6 other finalists, incl.:
The Adventures of Mark Twain
Secret Command

VFX Movies 1945:
Wonder Man *
Captain Eddie
Spellbound
They Were Expendable
A Thousand and One Nights

1945–47

Disney's ***The Three Caballeros,*** 1945

VFX Movies 1946:
Blithe Spirit *
A Stolen Life

VFX Movies 1947:
Green Dolphin Street *
Unconquered

Disney's ***Make Mine Music,*** 1946

Disney's ***Fun and Fancy Free,*** 1947

1948–49

VFX Movies 1948:
Portrait of Jennie *
Deep Waters

Disney's ***Melody Time,*** 1948

15-episode live action **Superman**, 1948

VFX Movies 1949:
Mighty Joe Young *
Tulsa

Disney's ***The Adventures of Ichabod and Mr. Toad,*** 1949

1950–52

VFX Movies 1950:
Destination Moon *
Samson and Delilah

VFX Movies 1951:
When Worlds Collide * (only nominee)

Disney's ***Cinderella,*** 1950

Disney's ***Alice in Wonderland,*** 1951

VFX Movies 1952:
Plymouth Adventure * (only nominee)

1953–55

VFX Movies 1953:
War of the Worlds * (only nominee)

Disney's ***Peter Pan,*** 1953

VFX Movies 1954:
20,000 Leagues Under the Sea *
Hell and High Water
Them!

Godzilla AKA ***Gojira***

1955–57

VFX Movies 1955:
The Bridges At Toko-Ri *
The Dam Busters
The Rains of Ranchipur

Disney's ***Lady and the Tramp,*** 1955

VFX Movies 1956:
The Ten Commandments *
Forbidden Planet

VFX Movies 1957:
The Enemy Below *
The Spirit of St. Louis

1958–59

VFX Movies 1958:
Tom Thumb *
Torpedo Run

Vertigo

VFX Movies 1959:
Ben Hur *
Journey to the Center of the Earth

Disney's ***Sleeping Beauty,*** 1959

Ub Iwerks improves **optical film printer** to shoot successive exposures, 1959