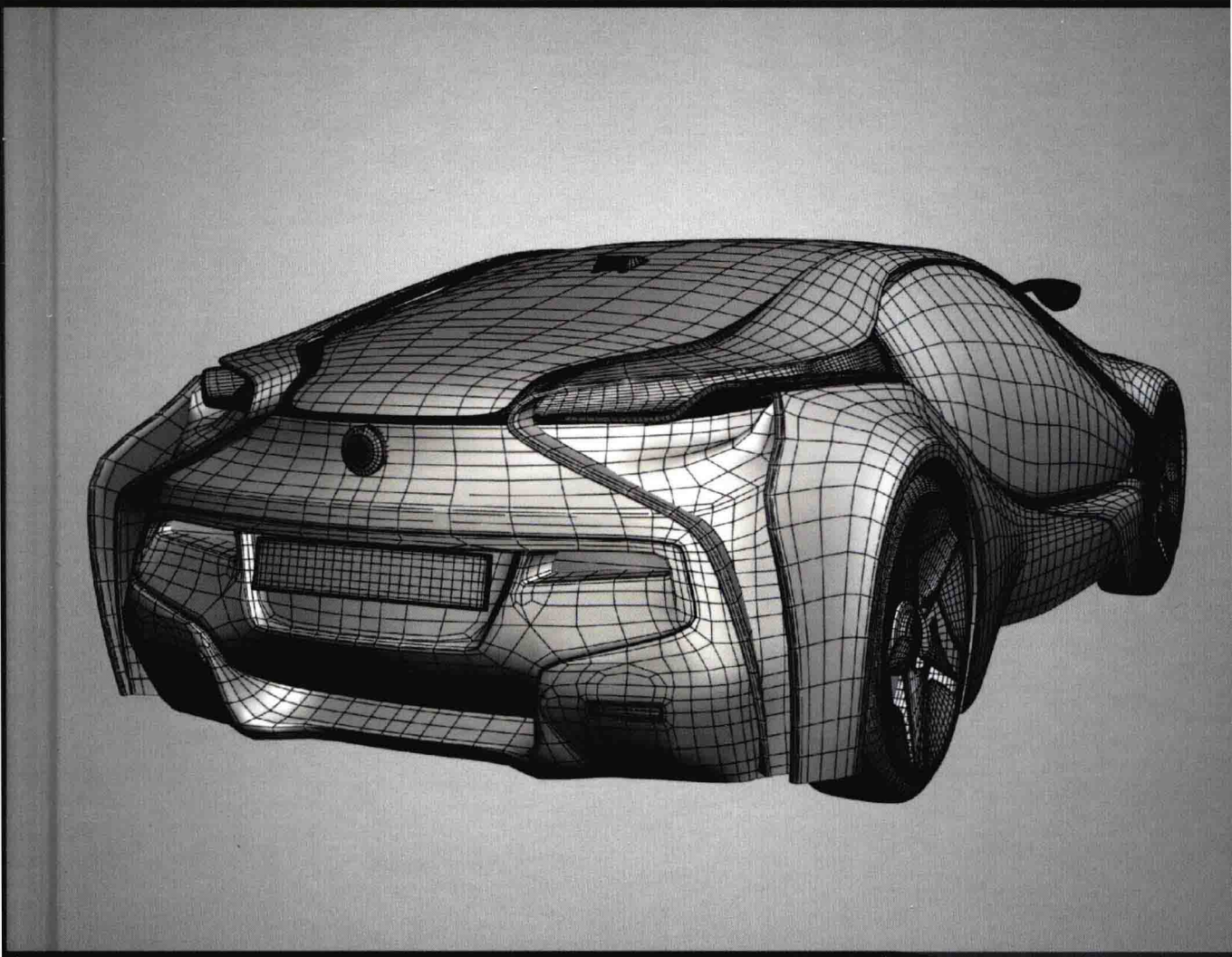
Computer Graphics
Principles and Practice



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Larsen Keller

Computer Graphics: Principles and Practice

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Larsen & Keller
www.larsen-keller.com

Computer Graphics: Principles and Practice
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ISBN: 978-1-63549-074-9 (Hardback)

Larsen & Keller
Published by Larsen and Keller Education,
5 Penn Plaza,
19th Floor,
New York, NY 10001, USA

Cataloging-in-Publication Data

Computer graphics : principles and practice / edited by Ruben Hawkins.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-63549-074-9
1. Computer graphics. 2. Computer art. 3. Computer animation.
I. Hawkins, Ruben.

T385 .C66 2017
006.6--dc23

Printed and bound in China.

For more information regarding Larsen and Keller Education and its products, please visit the publisher's website www.larsen-keller.com

Computer Graphics: Principles and Practice

Preface

The book aims to shed light on some of the unexplored aspects of computer graphics. It provides thorough insights about the uses and methods relevant in this field of study. Computer graphics is a rapidly growing field of computer science which concerns itself with the creating of pictures and movies using computers. It includes topics like vector graphics, computer vision, 3D graphics, sprite graphics, etc. Such selected concepts redefine the subject that has been presented in this book. This text is a compilation of chapters that discuss the most vital concepts in the field of computer graphics. It unfolds the innovative aspects of this field which will be crucial for the holistic understanding of the subject matter. The text is appropriate for those seeking detailed information in this area.

Given below is the chapter wise description of the book:

Chapter 1- The pictures and moving images created with computers are known as computer graphics. This area is very vast and is recent as well. The chapter on computer graphics offers an insightful focus, keeping in mind the complex subject matter.

Chapter 2- The forms of computer graphics discussed in the following section are 2D computer graphics and 3D computer graphics. 2D is the digital images produced in computers and they are mostly formed by traditional printings and drawings. 3D dimensions are graphics that use three-dimensional representations. The section elucidates the major forms of computer graphics.

Chapter 3- The main components of computer graphics are sprite, vector graphics, 3D modeling, computer vision and user interface design. Vector graphics present images in computers by using polygons. The major components of computer graphics are discussed in the following chapter.

Chapter 4- Processes and techniques are important components of any field of study. Some of the techniques explained in the chapter are volume rendering, motion capture, shader, rasterisation, feathering and visual effects. Volume rendering is a method used to exhibit a 2D projection on a 3D scalar field whereas motion capture is capturing the movement of things or humans. The aspects elucidated in this section are of vital importance, and provide a better understanding of computer graphics.

Chapter 5- Animation is the process of creating an illusion of movement with the help of drawings. Computer animation helps in this process by generating these images. Traditional animation, stop motion, skeletal animation and animation database are some of the aspects of animation that have been elaborately explained in the following section.

Chapter 6- Amira is a software used for 3D and 4D management and visualization. The other software used for computer graphics are Amira, iClone, Indigo Renderer and CityEngine. This chapter helps the reader in understanding the various computer graphics software.

Chapter 7- The applications of computer graphics discussed in the section are special effect, ambient occlusion, web design, texture mapping, molecular graphics, drug design etc. Special effects are the visual tricks used in movies or video games whereas web designing deals with the production of websites. The topics elaborated in the section will help in gaining a better perspective about the applications of computer graphics.

Chapter 8- The history of computer graphics is an important part of the subject of computer graphics. The initial use of this technology was for scientific reasons and research purposes but as this subject grew, the focus shifted to art and media. This chapter helps the readers in understanding the growth and evolution of computer graphics over a period of decades.

At the end, I would like to thank all those who dedicated their time and efforts for the successful completion of this book. I also wish to convey my gratitude towards my friends and family who supported me at every step.

Editor

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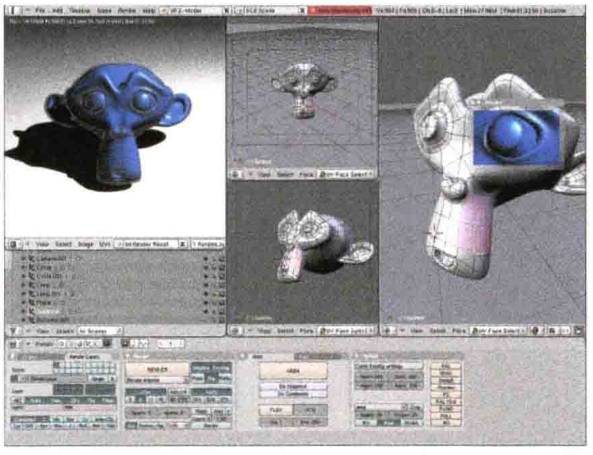
Understanding Computer Graphics

The pictures and moving images created with computers are known as computer graphics. This area is very vast and is recent as well. The chapter on computer graphics offers an insightful focus, keeping in mind the complex subject matter.

Computer Graphics

Computer graphics are pictures and movies created using computers – usually referring to image data created by a computer specifically with help from specialized graphical hardware and software. It is a vast and recent area in computer science.The phrase was coined by computer graphics researchers Verne Hudson and William Fetter of Boeing in 1960. It is often abbreviated as CG, though sometimes erroneously referred to as CGIcomputer-generated imagery.



A Blender 2.45 screenshot, displaying the 3D test model Suzanne.

Important topics in computer graphics include user interface design, sprite graphics, vector graphics, 3D modeling, shaders, GPU design, and computer vision, among others. The overall methodology depends heavily on the underlying sciences of geometry, optics, and physics. Computer graphics is responsible for displaying art and image data effectively and meaningfully to the user, and processing image data received from the physical world. The interaction and understanding of computers and interpretation of data has been made easier because of computer graphics. Computer graphic development has had a significant impact on many types of media and has revolutionized animation, movies, advertising, video games, and graphic design generally.

Overview

The term computer graphics has been used a broad sense to describe "almost everything on computers that is not text or sound". Typically, the term *computer graphics* refers to several different things:

- the representation and manipulation of image data by a computer
- the various technologies used to create and manipulate images
- the sub-field of computer science which studies methods for digitally synthesizing and manipulating visual content, see study of computer graphics

Computer graphics is widespread today. Computer imagery is found on television, in newspapers, for example in weather reports, or for example in all kinds of medical investigation and surgical procedures. A well-constructed graph can present complex statistics in a form that is easier to understand and interpret. In the media "such graphs are used to illustrate papers, reports, thesis", and other presentation material.

Many powerful tools have been developed to visualize data. Computer generated imagery can be categorized into several different types: two dimensional (2D), three dimensional (3D), and animated graphics. As technology has improved, 3D computer graphics have become more common, but 2D computer graphics are still widely used. Computer graphics has emerged as a sub-field of computer science which studies methods for digitally synthesizing and manipulating visual content. Over the past decade, other specialized fields have been developed like information visualization, and scientific visualization more concerned with "the visualization of three dimensional phenomena (architectural, meteorological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component".

History

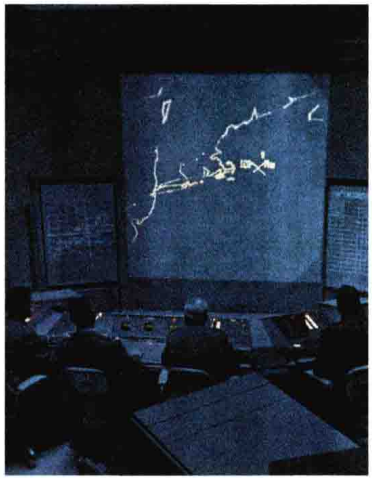
Introduction

The precursor sciences to the development of modern computer graphics were the advances in electrical engineering, electronics, and television that took place during the first half of the twentieth century. Screens could display art since the Lumiere brothers' use of mattes to create special effects for the earliest films dating from 1895, but such displays were limited and not interactive. The first cathode ray tube, the Braun tube, was invented in 1897 - it in turn would permit the oscilloscope and the military control panel - the more direct precursors of the field, as they provided the first two-dimensional electronic displays that responded to programmatic or user input. Nevertheless, computer graphics remained relatively unknown as a discipline until the 1950s and the post-World War II period - during which time, the discipline emerged from a combi-

nation of both pure university and laboratory academic research into more advanced computers and the United States military's further development of technologies like radar, advanced aviation, and rocketry developed during the war. New kinds of displays were needed to process the wealth of information resulting from such projects, leading to the development of computer graphics as a discipline.

1950s

Early projects like the Whirlwind and SAGE Projects introduced the CRT as a viable display and interaction interface and introduced the light pen as an input device. Douglas T. Ross of the Whirlwind SAGE system performed a personal experiment in 1954 in which a small program he wrote captured the movement of his finger and displayed its vector (his traced name) on a display scope. One of the first interactive video games to feature recognizable, interactive graphics – *Tennis for Two* – was created for an oscilloscope by William Higinbotham to entertain visitors in 1958 at Brookhaven National Laboratory and simulated a tennis match. In 1959, Douglas T. Ross innovated again while working at MIT on transforming mathematic statements into computer generated machine tool vectors, and took the opportunity to create a display scope image of a Disney cartoon character.



SAGE Sector Control Room.

Electronics pioneer Hewlett-Packard went public in 1957 after incorporating the decade prior, and established strong ties with Stanford University through its founders, who were alumni. This began the decades-long transformation of the southern San Francisco Bay Area into the world's leading computer technology hub - now known as Silicon Valley. The field of computer graphics developed with the emergence of computer graphics hardware.

Further advances in computing led to greater advancements in interactive computer graphics. In 1959, the TX-2 computer was developed at MIT's Lincoln Laboratory. The TX-2 integrated a number of new man-machine interfaces. A light pen could be used to

draw sketches on the computer using Ivan Sutherland's revolutionary Sketchpad software. Using a light pen, Sketchpad allowed one to draw simple shapes on the computer screen, save them and even recall them later. The light pen itself had a small photoelectric cell in its tip. This cell emitted an electronic pulse whenever it was placed in front of a computer screen and the screen's electron gun fired directly at it. By simply timing the electronic pulse with the current location of the electron gun, it was easy to pinpoint exactly where the pen was on the screen at any given moment. Once that was determined, the computer could then draw a cursor at that location. Sutherland seemed to find the perfect solution for many of the graphics problems he faced. Even today, many standards of computer graphics interfaces got their start with this early Sketchpad program. One example of this is in drawing constraints. If one wants to draw a square for example, they do not have to worry about drawing four lines perfectly to form the edges of the box. One can simply specify that they want to draw a box, and then specify the location and size of the box. The software will then construct a perfect box, with the right dimensions and at the right location. Another example is that Sutherland's software modeled objects - not just a picture of objects. In other words, with a model of a car, one could change the size of the tires without affecting the rest of the car. It could stretch the body of car without deforming the tires.

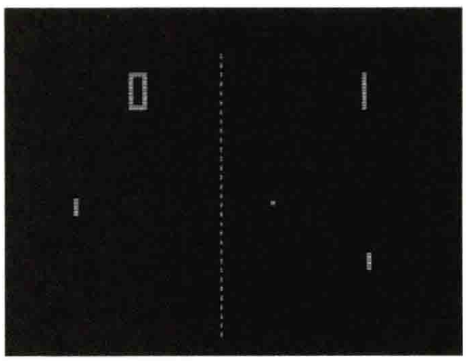
1960s

The phrase "computer graphics" itself was coined in 1960 by William Fetter, a graphic designer for Boeing. This old quote in many secondary sources comes complete with the following sentence: (*Fetter has said that the terms were actually given to him by Verne Hudson of the Wichita Division of Boeing.*) In 1961 another student at MIT, Steve Russell, created the second video game, *Spacewar*. Written for the DEC PDP-1, Spacewar was an instant success and copies started flowing to other PDP-1 owners and eventually DEC got a copy. The engineers at DEC used it as a diagnostic program on every new PDP-1 before shipping it. The sales force picked up on this quickly enough and when installing new units, would run the "world's first video game" for their new customers. (Higginbotham's *Tennis For Two* had beaten *Spacewar* by almost three years; but it was almost unknown outside of a research or academic setting.)

Spacewar running on the Computer History Museum's PDP-1

E. E. Zajac, a scientist at Bell Telephone Laboratory (BTL), created a film called "Simulation of a two-giro gravity attitude control system" in 1963. In this computer-generated film, Zajac showed how the attitude of a satellite could be altered as it orbits the Earth. He created the animation on an IBM 7090 mainframe computer. Also at BTL, Ken Knowlton, Frank Sinden and Michael Noll started working in the computer graphics field. Sinden created a film called *Force, Mass and Motion* illustrating Newton's laws of motion in operation. Around the same time, other scientists were creating computer graphics to illustrate their research. At Lawrence Radiation Laboratory, Nelson Max created the films *Flow of a Viscous Fluid* and *Propagation of Shock Waves in a Solid Form*. Boeing Aircraft created a film called *Vibration of an Aircraft*.

Also sometime in the early 1960s, automobiles would also provide a boost through the early work of Pierre Bézier at Renault, who used Paul de Casteljau's curves - now called Bézier curves after Bézier's work in the field - to develop 3d modeling techniques for Renault car bodies. These curves would form the foundation for much curve-modeling work in the field, as curves - unlike polygons - are mathematically complex entities to draw and model well.



Pong arcade version

It was not long before major corporations started taking an interest in computer graphics. TRW, Lockheed-Georgia, General Electric and Sperry Rand are among the many companies that were getting started in computer graphics by the mid-1960s. IBM was quick to respond to this interest by releasing the IBM 2250 graphics terminal, the first commercially available graphics computer. Ralph Baer, a supervising engineer at Sanders Associates, came up with a home video game in 1966 that was later licensed to Magnavox and called the Odyssey. While very simplistic, and requiring fairly inexpensive electronic parts, it allowed the player to move points of light around on a screen. It was the first consumer computer graphics product. David C. Evans was director of engineering at Bendix Corporation's computer division from 1953 to 1962, after which he worked for the next five years as a visiting professor at Berkeley. There he continued his interest in computers and how they interfaced with people. In 1966, the University of Utah recruited Evans to form a computer science program, and computer graphics quickly became his primary interest. This new department would become the world's primary research center for computer graphics.

Also in 1966, Ivan Sutherland continued to innovate at MIT when he invented the first computer controlled head-mounted display (HMD). Called the Sword of Damocles because of the hardware required for support, it displayed two separate wireframe images, one for each eye. This allowed the viewer to see the computer scene in stereoscopic 3D. After receiving his Ph.D. from MIT, Sutherland became Director of Information Processing at ARPA (Advanced Research Projects Agency), and later became a professor at Harvard. In 1967 Sutherland was recruited by Evans to join the computer science program at the University of Utah. There he perfected his HMD. Twenty years later, NASA would re-discover his techniques in their virtual reality research. At Utah, Sutherland and Evans were highly sought after consultants by large companies but they were frustrated at the lack of graphics hardware available at the time so they started formulating a plan to start their own company. In 1969, the ACM initiated A Special Interest Group on Graphics (SIGGRAPH) which organizes conferences, graphics standards, and publications within the field of computer graphics. In 1973, the first annual SIGGRAPH conference was held, which has become one of the focuses of the organization. SIGGRAPH has grown in size and importance as the field of computer graphics has expanded over time.

1970s

The Utah teapot by Martin Newell and its static renders became emblematic of CGI development during the 1970s.

Many of the most important early breakthroughs in the transformation of graphics from utilitarian to realistic occurred at the University of Utah in the 1970s, which had hired Ivan Sutherland away from MIT. Sutherland's graphics class would contribute a number of significant pioneers to the field, including a student by the name of Edwin Catmull - a later founder of Pixar. Because of David C. Evans' and Sutherland's presence, UU was gaining quite a reputation as the place to be for computer graphics research so Catmull went there to learn 3D animation. Catmull had just come from The Boeing Company and had been working on his degree in physics. Growing up on Disney, Catmull loved animation yet quickly discovered that he did not have the talent for drawing. Now Catmull (along with many others) saw computers as the natural progression of animation and they wanted to be part of the revolution. The first animation that Catmull saw was his own. He created an animation of his hand opening and closing. It became one of his goals

to produce a feature-length motion picture using computer graphics. In the same class, Fred Parke created an animation of his wife's face.

As the UU computer graphics laboratory was attracting people from all over, John Warnock was one of those early pioneers; he would later found Adobe Systems and create a revolution in the publishing world with his PostScript page description language, and Adobe would go on later to create the industry standard photo editing software in Adobe Photoshop and the movie industry's special effects standard in Adobe After Effects. Tom Stockham led the image processing group at UU which worked closely with the computer graphics lab. Jim Clark was also there; he would later found Silicon Graphics. The first major advance in 3D computer graphics was created at UU by these early pioneers, the hidden-surface algorithm. In order to draw a representation of a 3D object on the screen, the computer must determine which surfaces are "behind" the object from the viewer's perspective, and thus should be "hidden" when the computer creates (or renders) the image. The 3D Core Graphics System (or Core) was the first graphical standard to be developed. A group of 25 experts of the ACM Special Interest Group SIGGRAPH developed this "conceptual framework". The specifications were published in 1977, and it became a foundation for many future developments in the field.

Also in the 1970s, Henri Gouraud, Jim Blinn and Bui Tuong Phong contributed to the foundations of shading in CGI via the development of the Gouraud shading and Blinn-Phong shading models, allowing graphics to move beyond a "flat" look to a look more accurately portraying depth. Jim Blinn also innovated further in 1978 by introducing bump mapping, a technique for simulating uneven surfaces, and the predecessor to many more advanced kinds of mapping used today.

The modern videogame arcade as is known today was birthed in the 1970s, with the first arcade games using real-time 2D sprite graphics. *Pong* in 1972 was one of the first hit arcade cabinet games. *Speed Race* in 1974 featured sprites moving along a vertically scrolling road. *Gun Fight* in 1975 featured human-looking sprite character graphics, while *Space Invaders* in 1978 featured a large number of sprites on screen; both used an Intel 8080 microprocessor and Fujitsu MB14241 video shifter to accelerate the drawing of sprite graphics.

1980s

The 1980s began to see the modernization and commercialization of computer graphics. As the home computer proliferated, a subject which had previously been an academics-only discipline was adopted by a much larger audience, and the number of computer graphics developers increased significantly.

In the early 1980s, the availability of bit-slice and 16-bit microprocessors started to revolutionise high-resolution computer graphics terminals which now increasingly became intelligent, semi-standalone and standalone workstations. Graphics and application processing

were increasingly migrated to the intelligence in the workstation, rather than continuing to rely on central mainframe and mini-computers. Typical of the early move to high resolution computer graphics intelligent workstations for the computer-aided engineering market were the Orca 1000, 2000 and 3000 workstations, developed by Orcatech of Ottawa, a spin-off from Bell-Northern Research, and led by David Pearson, an early workstation pioneer. The Orca 3000 was based on Motorola 68000 and AMD bit-slice processors and had Unix as its operating system. It was targeted squarely at the sophisticated end of the design engineering sector. Artists and graphic designers began to see the personal computer, particularly the Commodore Amiga and Macintosh, as a serious design tool, one that could save time and draw more accurately than other methods. The Macintosh remains a highly popular tool for computer graphics among graphic design studios and businesses. Modern computers, dating from the 1980s, often use graphical user interfaces (GUI) to present data and information with symbols, icons and pictures, rather than text. Graphics are one of the five key elements of multimedia technology.

Dire Straits' 1985 music video for their hit song Money For Nothing - the "I Want My MTV" song – became known as an early example of fully three-dimensional, animated computer-generated imagery.

Japan's Osaka University developed the LINKS-1 Computer Graphics System, a supercomputer that used up to 257 Zilog Z8001 microprocessors, in 1982, for the purpose of rendering realistic 3D computer graphics. According to the Information Processing Society of Japan: "The core of 3D image rendering is calculating the luminance of each pixel making up a rendered surface from the given viewpoint, light source, and object position. The LINKS-1 system was developed to realize an image rendering methodology in which each pixel could be parallel processed independently using ray tracing. By developing a new software methodology specifically for high-speed image rendering, LINKS-1 was able to rapidly render highly realistic images. It was used to create the world's first 3D planetarium-like video of the entire heavens that was made completely with computer graphics. The video was presented at the Fujitsu pavilion at the 1985 International Exposition in Tsukuba." The LINKS-1 was the world's most powerful computer, as of 1984.

The continuing popularity of Star Wars and other science fiction franchises were relevant in cinematic CGI at this time, as Lucasfilm and Industrial Light & Magic became