THE ‘REALISM’ OF ALGORITHMIC HUMAN FIGURES

A Study of Selected Examples 1964 to 2001

by

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ABSTRACT

It is more than forty years since the first wireframe images of the Boeing Man revealed a stylized human pilot in a simulated pilot's cabin. Since then, it has almost become standard to include scenes in Hollywood movies which incorporate virtual human actors. A trait particularly recognizable in the games industry world-wide is the eagerness to render athletic muscular young men, and young women with hour-glass body-shapes, to traverse dangerous cyberworlds as invincible heroic figures.

Tremendous efforts in algorithmic modeling, animation and rendering are spent to produce a realistic and believable appearance of these algorithmic humans. This thesis develops two main strands of research by the interpreting a selection of examples.

Firstly, in the computer graphics context, over the forty years, it documents the development of the creation of the naturalistic appearance of images (usually called 'photorealism'). In particular, it describes and reviews the impact of key algorithms in the course of the journey of the algorithmic human figures towards 'realism'.

Secondly, taking a historical perspective, this work provides an analysis of computer graphics in relation to the concept of realism. A comparison of realistic images of human figures throughout history with their algorithmically-generated counterparts allows us to see that computer graphics has both learned from previous and contemporary art movements such as photorealism but also taken out-of-context elements, symbols and properties from these art movements with a questionable naivety. Therefore, this work also offers a critique of the justification of the use of their typical conceptualization in computer graphics.

Although the astounding technical achievements in the field of algorithmically-generated human figures are paralleled by an equally astounding disregard for the history of visual culture, from the beginning 1964 till the breakthrough 2001, in the period of the digital information processing machine, a new approach has emerged to meet the apparently incessant desire of humans to create artificial counterparts of themselves. Conversely, the theories of traditional realism have to be extended to include new problems that those active algorithmic human figures present.

Keywords:

algorithmic human figure, algorithm, realism, photorealism, 3D computer graphics, visual art, computer graphics imagery, computer animation

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1 INTRODUCTION

Fig.1.1: (left) Boethius and Pythagoras in competition.
(Source: *Gregor Reisch, Margarita philosophica.* Freiburg: Johann Schott, 1503)
Fig.1.2: (right) Deep Blue, a chess-playing program developed by IBM
against world champion Garry Kasparov in May, 1997

We treat realistic images as
a continuum and speak freely of pictures,
and of the techniques used to create them,
as being “more” or “less” realistic.

-- James Foley, Andries van Dam, Steven K. Feiner, John Hughes,
Computer Graphics: Principles and Practice, 1990, p605

1.1 Definition of Algorithmic Human Figure

Algorithmic human figures have become an important phenomenon across the world from the early beginning in 1960s. Images of these algorithmic humans appear more and more often and they are more and more realistic and believable. Currently the 'realism' of these images is discussed scholarly not only in the field of computer graphics but also in the realm of culture and visual art. Delineating where they come from, how they have been generated, and what their future holds are the aims of this thesis.

The first algorithmic human figure on the screen was produced in 1964 for the Boeing Company by William Fetter[1], in order to design an airplane cockpit so as to give the pilot the maximum freedom of movement. [see *Fig. 2.1*] The first algorithmic human figure 'Boeing Man', referred to by Fetter as the '*First Man*' [2] provided one of the most significant and iconic images in the history of early computer graphics. And at the beginning of an essay in 1982, William Fetter tried to describe the potential future aims of the algorithmic human figure:

> *There has been a long-standing need in certain computer graphics applications for human figure simulations, that as descriptions of the human body are both accurate and at the same time adaptable to different user environments.* [3]

That is firstly in the category of computer graphics; to use computer graphics applications to develop the algorithmic human figure. Secondly, there is the long-standing aim to clarify the relationship between algorithmic human figures, human beings and the real world. Algorithmic human figures should simulate real humans, and moreover make progress towards increasingly accurate simulations and to adaptation to different user environments.

However, according to the history of algorithmic human figures, in the early stages the appearance of algorithmic human figures was artificial-looking. Such figures looked like manikins with translucent and plastic-like skin. Their clothes corseted the body, their hair was always fixed tightly to the head, and they looked very different from a real human figure, with much less commercial value than a completely artificial creation.

More than forty years have passed since the first wire-frame images of the Boeing Man. Meanwhile, it has become almost standard to include scenes in Hollywood movies containing virtual human actors or 3D (three-dimensional) characters. Most of them act as either digital extras or digital stand-ins facilitating the completion

[1] William Fetter (1928-2002) was an art director who worked for Boeing. As a pioneer of computer graphics he became the first to construct a wire-frame human figure using a computer.

[2] William A. Fetter, A Progression of Human Figures Simulated by Computer Graphics, in *IEEE Computer Graphics and Applications*, Vol. 2, No. 9 (1982), p. 9

[3] Ibid.

of shots which are difficult for real human actors to perform. There are only a few realistic human figures who take the film's leading roles. These are to be found particularly in 3D CG (three-dimensional computer-generated) films, such as *Final Fantasy: The Spirits Within*[4]. At first glance the film's digital actors are so life-like that it is difficult to believe that they are totally computer-generated human figures. Some of these 'virtual actors' have been created by artists, and some have been 'cloned' directly from existing human actors. In the future, maybe more and more actors and celebrities will hope to have their heads laser-scanned in order to save their digital body data sets, to create their 'digital clones', just like those wax clones displayed in the Museum of Madame Tussauds. Hundreds of years from now these virtual actors and digital clones of celebrities may live on even after their real 'parents' have died.

The booming games industry is keen to render the images of human figures in the shape of strong muscular young men and heroines to fight their way through dangerous adventure worlds, or seductive beautiful women to be rescued by heroes.

These human figures might also be 'avatars'[5] in the virtual world. With the popularity of the Internet-based virtual world *Second Life*[6] in particular, this has become a key subject for debate. Unlike former computer games, played solely by a generation of young men, this game attracts players of every age, gender and race. Even elderly people can now design their own avatar in order to begin their new life in *Second Life* when they retire. In *Second Life*, an 'avatar' is the user's representation of him or herself in the virtual world.

In the world of entertainment, some of these human figures have become the 'virtual agents' of companies and organizations; in order to promote online businesses through websites. This is because a virtual agent interface is easy to use than a pure text-based interface. Simultaneously, school teachers are now trying to use intelligent virtual humans to help deaf and mute students to learn language with the aid of a computer. In scientific research, in the fields of biology, medicine and ergonomics for example, scientists utilize the virtual human to undertake dangerous experiments or to do things that people cannot accomplish alone. Examples include automobile crash tests and, in biological and medical research, scientists model the virtual human with not only the structure and form of the human figure but also its physiological functions, thus carrying out research of virtual operations.

Although after more than forty years, these human figures have already infiltrated and affected our everyday life in many aspects away from the original scientific research purpose, the focus of this thesis will be in the

[4] A full CG Film distributed in 2001 by Columbia, which will be discussed in Chapter 5.

[5] Originally the word 'avatar' in Hindu, especially Vishnu, means the incarnation of a Hindu deity in human or animal form.

[6] Second Life (abbreviated as SL) was launched in 2003, developed by Linden Research, Inc. (commonly referred to as Linden Lab). A downloadable client program called the Second Life Viewer enables its users, called 'Residents', to interact with each other through mobile avatars. Residents can explore, meet other 'Residents', socialize, participate in individual and group activities, and create and trade items (virtual property) and services with one another. Official website: www.secondlife.com.

field of computer graphics. The common procedure when creating images of algorithmic human figures is to undergo modeling, rendering and animation using specific 3D software, and finally, on-screen presentation. No matter what the origin and goal of such a modeling effort may be, in computer science and particularly in 3D computer graphics (three-dimensional computer graphics), we concentrate on technical aspects more than on aesthetics. In this thesis, unless an exception is made, the term computer graphics refers to 3D computer graphics.

The study of computer graphics is a sub-field of computer science, which spans a range of topics from theoretical studies of algorithms and the limits of computation to practical issues of implementing computing systems in hardware and software. Computer graphics studies the manipulation of visual and geometric information using computational techniques and focuses on the mathematical and computational foundations of image-generation and processing.[7]

In the context of computer science, algorithms can be considered as *'the stuff of computer science'* and *'the central objects of study in many, if not most, areas of the field.'*[8] Algorithms are also an important kind of objects in computer graphics. In this context, I would group the human figures discussed in this thesis under the title 'algorithmic human figures' in order to establish a basic definition, which will act as a starting point for research. The using of algorithmic human figure certainly does not deny the rationality of other names (or titles); conversely other names often correspond to different periods or research foci and areas of application. Within the process of historical development, these fragments form an integrated panorama.

Such as, the computer-generated human figure has been considered within the context that the computer is defined as a physical calculation machine invented in the 1940s and as a new media in contrast to other traditional media. But till the 1960s, computers could still only show on the screen simple dots and lines, without any color; however a few scientists and artists began to cultivate what little graphic capacity had just been revealed in the computers of the time. They believed that '*the computer [was] having an implosive effect upon the way [they] deal[t] with a variety of problems. As an extension of man's senses, computer technology [could] provide exciting new potential for the creation of art.*'[9] They described their attempts as Computer Art, stating that '*Computer Art already embraces many forms of traditional art -- there are computer-generated graphics, sculptures, films, choreography, poems, and music. All these developments stand in close relationship*'.[10] This also implied that the computer was a new media and that it was different from traditional tools for hand-crafting artwork.

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[7] Wikipedia, s.v. 'Computer Graphics', available from: www.wikipedia.com/computer graphics, accessed 28.02.2011

[8] Robert Sedgewick, *Algorithms in C++, Parts 1-4, Fundamentals, Data Structures, Sorting, and Searching*, 1998, p. 4

[9] Charles Csuri and James Shaffer, Art, Computers and Mathematics, in *AFIPS Conference Proceedings*, Fall Joint Computer Conference, Vol.33 (1968), p. 1293

[10] Herbert W. Franke, *Computer Graphics--Computer Art*, 1971, p. X

According to Frank Dietrich's discourse, the end of the first decade of computer art (1965-1975) '*was marked by economic, technological and programming advances that allowed artists more direct access to computers, high quality images and virtually unlimited color choices'*.[11] Afterwards due to the whole world pursuing high quality computer-generated images, computer art was not mentioned again for a long time. It had begun to represent low-quality pixel images and visual graphics with abstract lines. At the beginning of the 21st century, the pioneering experiments of the 1960s were brought to light and reevaluated. In addition, due to new technology including 3D printing, holographic imaging and interactive technology, many ideas from the 1960s have reappeared in spatial and interactive dynamic forms, renewing the debate of the scope of visual art and entering the contemporary art mainstream. In the 1970s and 1980s, in computer special effects, a distinction was drawn between real scenes shot using a camera and scenes modeled using a computer. The latter became known as CGIs (Computer-generated Imageries). This enhanced the computer's status as a different kind of image-making device from a camera. In addition, in music, sound generated automatically by computer became known as Computer Generated Music. Here, computers acted as a kind of intelligent machine and antithesis of the musician. At the beginning of the 1980s, computer-generated (or artificially-created) actors were given the name 'synthespians' distinguishing them from their real human counterparts.[12] The potential for competition existed between these two groups. In the 1980s, the competition was particularly fierce, reflecting the mood of hostility between the two groups.

Furthermore, in this thesis I have chosen to consider the effect of realistic algorithms on both '3D characters' and '3D humans.' 3D characters are mainly distinguished from human figures in 2D cartoon animations, indicating how the computer forms these characters and makes them move. Although 3D character artists and animators use different tools than 2D artists and animators, it is easy to see the connection with traditional animation. The movements of 3D characters, like 2D cartoon characters, are controlled by animators. Although 3D animators inherit and learn many of the basic concepts of 2D animation, there is still a significant difference[13]. Moreover, in current real-time animation, much of the algorithmic figure's movement and behavior is programmed, so 3D characters are only suitable for certain applications.

The concept of digitization provides a valuable context to the latter-day development of the algorithmic human figure. As such, I have drawn on the work of *Nicholas Negroponte* in his text *Being Digital*. At the end of the 1980s and the beginning of the 1990s, *Negroponte* asserted that due to new information technology, mankind would see the arrival of a totally new way of life. Although he believed that '*every technology or gift of science had a dark side… [and that] being digital [was] no exception*', he still believed that this was

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[11] Frank Dietrich, Visual Intelligence: the First Decade of Computer Art (1965-1975), in *Leonardo* Vol. 19, No.2 (1986), p. 159

[12] Diana Walczak, Synthespianism and Anthropomorphization of Computer Graphics, available from: http://www.kurzweilai.net/synthespianism-anthropomorphization-of-computer-graphics, accessed 28.02.2011

[13] The founder of Pixar John Lasseter has published the 'Principles of traditional animation applied to 3D computer animation' in *Computer Graphics*, Vol. 21, No 4, July 1987. This paper demonstrates the importance of these principles to quality 3D computer animation.

the beginning of '*an age of optimism*' [14]. Just some years later the releasing of many publications such as *Digital Illusion*[15], *Digital Beauties*[16] signify, to some extent, the optimism of the digital technology has come to true.

I have chosen to consider the 'virtual human' chiefly in reference to the valuable contemporary scientific research taking place in the area of virtual reality. Virtual actors, virtual teachers and the inhabitants of virtual worlds, are like aliens; like mysterious unknown life-forms. In fact, whilst Virtual Reality and Reality were initially completely independent of each other, now they have begun to influence and permeate each other. Mixed Reality, Augmented Reality and Immersive Reality are all attempts to try, through different methods, to close the distance between reality and virtual reality; however, after a long period of time, this kind of space-time distance is still enormous.

Anyhow, in this thesis, I would like to define the algorithmic human figure in the context of computer graphics; they are 3D mathematical models of the human body, clothing and hair. The algorithmic human's motion and behavior can be manipulated in the same way as a puppet or controlled by a program in real-time. Ultimately, the image of the figure can be displayed on the computer screen or other state-of-the-art display equipment. But how to simulate the human figure as accurate as possible becomes one of hardest problems of computer graphics in a long time.

1.2 Realistic Algorithmic Human Figures: One of the Hardest Problems of Computer Graphics

If *'computing machinery in its form as digital media incorporates three great principles: computability, interactivity, and connectivity*,'[17] these three principles could be also appearing in the development of algorithmic human figures. That is, from 1964, when the first algorithmic human figure Boeing Man was presented, up until today, the images of the algorithmic human figure underwent the following process:

From simple line-drawn images to refined photo-realistic images;
From static postures to free movement;
From the Cartesian separation between body and mind to integration;

[14] Nicholas Negroponte, *Being Digital*, 1995

[15] Clarks Dodsworth, *Digital Illusion: Entertaining the Future with High Technology*,1997

[16] Julius Wiedemann, *Digital Beauties: 2D and 3D CG Digital Models*, 2002

[17] Frieder Nake, Paragraphs on Computer Art, Past and Present, 2010, in *Proceeding of CAT 2010 London-- CAT 2010: Ideas Before Their Time*, edited by Nick Lambert, Jeremy Gardiner and Francesca Franco (2010), p. 56

From passive adaptation to changing environments to interaction with real humans and their surrounding environments;

This development has profited much from the general development of computer science. Obeying Moore's Law[18], computer hardware performance is getting better and better. From the large machines of the 1940s and 1950s to the smaller scale and personal computers developed in the 1960s and 1970s, computers have not only become faster and smaller but also cheaper. The popularization of personal computers in the 1980s as well as the development of internet technology has made the digital information era finally take over the era of machines. In addition, from its beginnings of undertaking simple calculations, software has now become complex and powerful enough to control entire processes of work. The human-machine interface is increasingly easy-to-use. Therefore, developments in computer technology guarantee that the overall trend of the algorithmic human figure's development shows a gradual tendency towards the development of realistic simulation of the real human body, however the actual road is also wrought with twists and turns and has not been easily formed.

Firstly the specific nature of the algorithm confirms that the development of realistic algorithmic human figures will be a tortuous process.

As defined in the Encyclopedia Britannica (15th ed.), an algorithm is a *'systematic mathematical procedure that produces the answer to a question or the solution to a problem within a finite number of steps.'* Instructions are assumed to be listed explicitly, and are described as starting 'from the top' and going 'down to the bottom', an idea that is described more formally by flow of control. Therefore, an algorithm is a type of effective method to solve one kind of specified task.

The algorithm is a concept which is not bound by time or space. It has a long history. It began with calculating algorithms. The symbolic image *of Fig1.1* is depicting Arithmetica supervising a competition between Boethius, who uses the new Arabic numerals, and Pythagoras, who uses a counting board. Boethius looks very proud, he has finished, whilst poor Pythagoras still tries to find the solution. Hundreds of years later, scientists find out that algorithms are becoming *'methods for solving problems that are suitable for computer implementation.'*[19] Consequently, in May 1997, Deep Blue, a chess-playing program developed by IBM could beat world champion Garry Kasparov.[20] [*Fig 1.2*]

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[18] Moore's law describes a long-term trend in the history of computing hardware. This is that the number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years. The law is named after Intel co-founder Gordon E. Moore, who described the trend in his 1965 paper 'Cramming More Components onto Integrated Circuits' in *Electronics Magazine*.

[19] Robert Sedgewick, *Algorithms in C++, Parts 1-4, Fundamentals, Data Structures, Sorting, and Searching*, 1998, p. 3

[20] see IBM website, IBM research: Deep Blue, available from: http://www.research.ibm.com/deepblue/, accessed 28.02.2011

An algorithm is described (in a precisely defined syntax) as a finite sequence of statements or commands. Each of these statements or commands is effective. A statement or command is effective, if it can be executed in a unique and unambiguous way. The execution of the algorithm determines the result of an operation, fulfilling a given purpose. It constitutes the solution to a set of problems each one of which is identified by input parameters. The algorithm may, or may not, end in finite time.

Quality of algorithms is judged by correctness, efficiency, and aesthetics in use. Any given problem may have several algorithms to solve. A given problem may not have a 'best' algorithm, only a currently prevailing 'winner' judged on the basis of performance. '*The choice of the best algorithm for a particular task can be complicated, perhaps involving sophisticated mathematical analysis*.'[21]

Besides the storage and execution time measurements applicable to all algorithms, graphic algorithms may be evaluated according to the aesthetic quality of the visual result compared to efforts spent.

A famous example of a graphic algorithm is recursive ray-tracing. It determines the image corresponding to an arbitrarily complex 3D scene. To solve this, the scene must be projected onto the image plane, the visible parts of the scene must be determined, and for each visible part the color shade must be calculated. To determine the color of one smallest surface element in the scene, local as well as global influences by light bouncing through the scene must be considered. The principle of this algorithm was described already in the mid-1960s. But it took until around 1980, before the algorithm could be implemented such that it became realistically possible to determine images of complex scenes. It still may have taken hours or days to calculate a single image.

But any algorithm is *'the method, rather than the computer program. This method is often independent of the particular computer to be used. It is likely to be equally appropriate for a range of computers and computer languages…When we write a computer program, we are implementing a method that has been devised previously to solve a problem.'*[22]

In very general terms, computer graphics is concerned with algorithmic solutions of what the photo camera does physically. In the case of camera, light itself generates the image. In computer graphics, all that must explicitly be described. However, the scene to be rendered must not exist outside the machine. Therefore, artificial human figures became possible.

Secondly, the difficulties exist due to the specific feature of computer graphics; not only complexity, diversity but also fuzziness and multi-discipline.

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[21] Robert Sedgewick, *Algorithms in C++, Parts 1-4, Fundamentals, Data Structures, Sorting, and Searching*, 1998, p. 4

[22] Ibid.

'*Computer graphics is a complex and diversified technology*'[23], debated by Rogers in his book *Procedural Elements for Computer Graphics.* Willam Fetter, who established the field computer graphics has defined computer graphics from beginning on as that *'computer graphics is a combination of graphic art and computer methods.'*[24]

This kind of combination was in any case not easy, neither for scientists and researchers, nor for artists and designers. The difference in mindsets between these two groups presented obstacles. Herbert W. Franke described the scientific and artistic mindset as wholly contradictory stating that artists were *'illogical, intuitive and impulsive'* where as scientists were '*constrained, logical and precise.'*[25] However, there are still some pioneers, who attempted to bring together the computer's execution of algorithms and visual art, when computer graphics had almost no imaging capability at beginning. Such as the earliest known examples of algorithmic art are artworks created by Georg Nees, A. Michael Noll and Frieder Nake in the early 1960s. These works were executed by a plotter, a self-contained machine, controlled by a punch tape that was calculated by a computer. The act of creation lay in writing the program, the sequence of actions to be performed by the plotter. These experiments are included in the 60s' computer art and marked the earliest attempts at such kind of combination. In this thesis, I will focus on those who inherited the spirit of the pioneers of 1960s and continued to make such combination.

How to generate realistic algorithmic human images is one of the most difficult areas of computer graphics, and experts in the field have worked hard to solve the problems involved.

Therefore, computer graphics scientists and researchers do not only need to find the solutions for the universal difficulty of creating realistic simulations, e.g. since most display devices are 2D, 3D objects must be projected into 2D, with considerable attendant loss of information, which can sometimes create ambiguities in the image. They now also need to face the greatest area of difficulty in the research of the algorithmic human; the most complicated computer-generated creature, which is to solve the problems specifically related to simulating a real person.

It requires not only a realistic image, but moreover, the body proportions, shape, facial expression, color and skin texture, hair, motion posture and behavior of a real human. From birth, everyone has the ability to discriminate between people. This ability can be used to test whether the algorithmic figure; a man-made creature can accurately simulate a human being. Any part of the algorithmic human which is not wholly realistic will be identified by the human eye. Ed Catmull, a computer graphics pioneer and a founder of Pixar once stated: '*The human face is a unique problem. We are genetically programmed to recognize human faces. We're so*

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[23] David F. Rogers, *Procedural Elements for Computer Graphics*, 1998, p. 1-2

[24] William A. Fetter, *Computer Graphics in Communication,* 1965, p. 5

[25] Herbert W. Franke, *Computer Graphics--Computer Art*,1971, p. 104-105

good that most people aren't even aware of it while they think about it. It turns out, for instance, that if we make a perfectly symmetrical face, we see it as being wrong.' [26]

Therefore, our self-recognition ability is undergoing an unceasing process of development, not only our knowledge of our physical matter but also of the many domains of the human body still undiscovered, e.g. the behavior and psychology of the human being.

Besides there are also the difficulties of the complexity of the real human body and its surrounding world along with how to provide sufficient information to let the viewer understand the 3D spatial relationships surrounding the algorithmic human. Therefore, in terms of computer graphics, in comparison to modeling an object or animal, human simulation holds many particular requirements with a high degree of difficulty. In order to fulfill the aim for authentic visual realism, computer graphics researchers have a long way to go. In the past forty or fifty years, computer scientists and computer graphics scientists in particular have spent a vast amount of time researching the basic modeling, rendering and animating methods.

1.3 Algorithmic Human Figure and Realism

Furthermore, Rogers has suggested '*to begin to understand this technology, it is necessary to subdivide it into manageable parts. This can be accomplished by considering that the end product of computer graphics is a picture. The picture is the fundamental cohesive concept in computer graphics. We must therefore consider how*

Pictures are represented in Computer Graphics
Pictures are prepared for presentation
Previously prepared pictures are presented
Interaction with the picture is accomplished [27]

If the end product of computer graphics is an image, then computer graphics scientist and researcher may also face the same question as any artist do; 'What is a realistic image?', especially concerning the most difficult creation of computer graphics, the algorithmic human figure.

'Realism' has become one of the central theoretical issues in computer graphics. In the history, realism itself is a term widely debated in many disciplines, but not limited to philosophy, arts, politics, culture, social science. For the moment I don't take up the philosophical discourse, but focus on the aesthetics of realism, because

[26] Kelly Tyler, Virtual Humans, available from: http://pbs.org/wgbh/nova/specialfx2/humans.html, accessed 28.02.2011

[27] David F. Rogers, *Procedural Elements of Computer Graphics,* 1998, p. 1

the visual realism question is still at the heart of all progress in computer graphics from the beginning to this day. In the process of creating a realistic algorithmic human figure in computer graphics, it is disturbing to observe that this question and the discourse surrounding it, is still taking place on a shallow level.

Here, in the historic perspective I would like at first to investigate how, and to what a degree traditional theories and techniques of visual realism in the arts has been applied to computer graphics representation, then try to debate what's the reflection of the computer-mediated 'realism' to realism in other media.

1.3.1 Algorithmic Human Figure in the Context of Figurative Art

Firstly, when viewing the realistic on-screen image of algorithmic human figure, we could do in the same way as any figurative artwork in the history of art. Artists from different cultures and time periods throughout history have depicted the human figure in many diverse ways. The emergence and maturation of the algorithmic human can be regarded as an important extension to the development of human figurative art.

Figurative art commonly refers to art that clearly represents an image of the human figure or animal figures from the real world as its subject, the term can also be used in the more general sense of distinguishing representational art from abstract art.

Figurative art has a very long history. Prehistoric people used rock paintings to record the nature of their hunting and working lives, as well as their cultural and religious beliefs, to be left to posterity. Through preserving and copying the human figure, mankind tried to forge a link with the future world. In ancient Egyptian culture, the body was a person's home in the afterlife, without which they could be condemned to eternal wandering. By mummification of the body, they tried to preserve the body forever. In ancient China, they held a similar belief. In the tomb of Qin Shi Huang, the first Emperor,[28] tremendous terracotta armies were buried, with the purpose of assisting him to rule another empire in the afterlife.[29] The figures of the terracotta army were lifelike and life-sized. In accordance with rank, they vary in height, uniform, hairstyle and held real weapons in a range of models. For a long period of time, mankind used painting and sculpture to represent figures of kings, queens, heroes, religious leaders and Gods which were even more beautiful than real people, and were to be admired and respected. In 776BC, the first Olympic Games took place in Olympia, Greece. In Polis, the ancient

[28] Qin Shi Huang (259 BC – September 10, 210 BC), was king of the Chinese State of Qin from 247 BC to 221 BC, and then the first emperor of a unified China from 221 BCE to 210 BCE, ruling under the name the First Emperor. As the ruler of the Great Qin, he was known for the introduction of Legalism and also for unifying China.

[29] So they are also referred to as 'Qin's Armies'.

Greeks enjoyed their lives and especially, their healthy natural bodies. Ancient Greece [30] became a realm of beauty. The best known surviving sculptures, such as the Apollo Belvedere and the Venus of Milo reflect the ideal model of the living human body in all its grace and beauty. These sculptures are so vivid that we can almost feel the muscles and bones swelling and moving under the surface of the marble. There are no living bodies quite as symmetrical, well-built and beautiful as these Greek statues[31]. Alongside their creation of the great works of figure art, the ancient Greeks used their understanding of proportion to invent the architectural orders: Doric, Ionic and Corinthian. Later in ancient Roman, it was typical for Roman artists and sculptors to borrow ideas from Greek architectural sources, and to apply these to their own needs. They did the same in many fields. One of their principal requirements was good-quality, life-like portraiture. The art of the portrait flourished in Roman sculpture, where sitters demanded realistic portraits, even if these were unflattering.

Artists from different cultures all around the world depicted the human figure in many diverse ways and affected each other. For example, the culture and art of ancient Greece and Rome has not only had an immense influence on modern western society, but has also affected the art of Egypt and India of the same period. *'Egyptians still buried their dead as mummies, but instead of incorporating their likeness in the Egyptian style, they had their corpses painted by artists who knew all the tricks to incorporate the vigor and realism of Greek portraiture. There are few works of ancient art which looked as fresh and 'modern' as these.'* [32] And *'Greek and Roman art, which had taught men to visualize gods and heroes in beautiful form, also helped the Indians to create an image of their saviour. The beautiful head of the Buddha, with its expression of deep repose, was also created in the frontier region of Gandhara.'* [33] Indian Buddhism also had a great influence on Chinese art but this was limited to the sculpture of the Buddha. The Western and Oriental artistic conceptualizations of the body developed in different ways. In the art of China, the Chinese painters believe that the human figure is of no greater importance than a pine tree, a rock or a cloud. The painter used abstract lines to represent the figure paying greater attention to the figure's posture and movement than to the figure's expression.

In the same culture, based on different understandings of what constitutes a 'realistic human'. the images created in different periods are also different, So, in the West, the period after the collapse of the Roman Empire, is generally known as the Dark Ages. Much of the art work was produced for the purpose of religion.

[30] The term ancient Greece refers to the period of Greek history in Classical Antiquity, lasting from ca. 750 BC (the archaic period) to 146 BC (the Roman conquest). It is generally considered to be the seminal culture which provided the foundation of Western Civilization. Greek culture had a powerful influence on the Roman Empire, which carried a version of it to many parts of Europe.

The civilization of the ancient Greeks has been immensely influential on the language, politics, educational systems, philosophy, science, and arts, giving rise to the Renaissance in Western Europe and again resurgent during various neo-Classical revivals in 18th and 19th century Europe and the Americas.

[31] Ernst H. Gombrich, *the Story of Art*, 1995, p. 103

[32] Ibid., p. 124

[33] Ibid., p. 127

Whilst the solemnity of this work was impressive, it was never as natural, graceful or delicate as classical artwork. *'Christianity required no images of naked divinities, and new attitudes cast doubt and opprobrium on nude athletes, public bathing, and the very value of the human body. The early Christian emphasis on chastity and celibacy further devalued depictions of nakedness.'* [34] But, the coming of the Renaissance affected the manner in which people viewed and interacted with the world. Beginning with a revival of learning based on classical sources, the most significant development of the era was not a specific discovery, but rather the development of a process for discovery; the scientific method. Renaissance scholars employed the humanist method in study, and searched for realistic and human emotion in art. The development of linear perspective in painting was one of the distinguishing features of Renaissance art to former art and resulted in a wider trend towards realistic representation in the arts.

The poet Dante described Giotto di Bondone as the first painter to introduce reality into painting. He filled a comprehensible pictorial space with a person who could be imagined in real life, and who generated spatial corporality, in contrast to the flatly conceived and linearly decorated icons of the medieval period. Giotto's figures were not stylized, elongated or prescribed by Byzantine models. They were solidly 3D, had anatomy, faces and gestures based upon close observation and clothing which hung naturally, with form and weight, rather than swirling, formalized drapery. The heavily-sculptured figures occupied compressed settings with naturalistic elements, often using forced perspective devices so that they resembled stage sets.

In comparison with Greek and Roman art, designed to visualize gods and heroes in beautiful forms, the visual art following the renaissance adopted the desire to represent both human emotions and the daily life of the common person. Since the influence of the renaissance was felt in literature, philosophy, art, politics, science, religion, and other aspects of intellectual enquiry, it was also given as the dividing line between the late middle ages era and the early modern era.

Later, along with the increasing lengths and scope of exploratory voyages, as well as tremendous inventions in science and technology and the publication of Charles Darwin's *On the Origin of the Species*,[35] mankind gained unprecedented knowledge of the world and the self.

With the revolution of the whole of society and the introduction of photography, realism was not only a movement in literature, but also became a new visual art movement under the guidance of *Gustave Courbet*, a French painter in the 1850s. These Realists positioned themselves against Romanticism, a genre dominating French literature and artwork in the late 18th and early 19th centuries. In reaction to the Romantic Movement, without romantic idealization or dramatization, Realists began to render everyday characters, situations, di-

[34] Jean Sorabella, the Nude in the Middle Ages and the Renaissance, available from: http://www.metmuseum.org/toah/hd/numr/hd_numr.htm, accessed 28.02.2011

[35] Published on 24.11.1859.

lemmas, and objects in verisimilitude. *'Its aim was to give a truthful, objective and impartial representation of the real world, based on meticulous observation of contemporary life.'*[36] Realism created a desire for people to produce things that looked objectively real.

A non-trivial concept of realism was assumed. There are many successors of realism in art, Naturalism is the closest, which is *'a late 19th- and early 20th-century movement that was inspired by adaptation of the principles and methods of natural science, especially the Darwinian view of nature, to literature and art. It extended the tradition of realism, aiming at an even more faithful, unselective representation of reality, a veritable "slice of life," presented without moral judgment. '*[37]

'*Since the arrival of abstract art the term figurative has been used to refer to any form of modern art that retains strong references to the real world and particularly to the human figure.*'[38]

It appeared that after a long exploratory period, artists had already discovered the secrets to the realistic representation of the human body, namely proportion, texture and lighting and motion.

But, the artistic representation is not only characterized through an object's pure appearance and illusion but the existence of a higher and more actual realism. Examples can be found throughout the history of art. In the broadest sense, realistic representation in a work of art exists wherever something has been well-observed and depicted with accuracy. The Baroque Age saw artists move towards a reemphasis on physical aspects. The universalism and timelessness of Rubens representative work *La Ronde*, a construction of intense physical movement exemplifies this. In his brushwork, movement becomes '*a kind of generalized, eternal paradigm of violent physical action*.' [39] In comparison, impressionist artists stressed the concept of 'instantaneity' in their work and the '*instantaneity of the Impressionists is 'contemporaneity' taken to its ultimate limits*'[40]. The disordered, changeable, impermanent and unstable form of the modern period seems more in line with the characteristics of reality which people can feel today when compared with the pursuit of stability, balance and harmony of ancient times. As Baudelaire mind '*modernity is the transitory, the fugitive, the contingent*.'[41] But the question regarding realism which often arises is '*that is sacrificed a higher and more permanent for a lower, more mundane reality.*'[42] The distorted figures of Cubism, as painted by Pablo Picasso, the elongated, surrealist

[36] Linda Nochlin, *Realism*, 1971, p. 13

[37] Encyclopedia Britannica Online, s.v. 'Naturalism', available from: http://www.britannica.com, accessed 28.02.2011

[38] Tate, Glossary: Figurative, available from: http://www.tate.org.uk/collections/glossary/definition.jsp?entryId=104, accessed 28.02.2011

[39] Linda Nochlin, *Realism*, 1971, p. 30

[40] Ibid., p. 28

[41] Ibid., p. 28

[42] Ibid., p. 14

sculptures of Alberto Giacometti, and the flat, pop art paintings of Andy Warhol, though dissimilar in intent and style, are all examples of figurative art.

Figurative art has always been a common subject of art. Artists have made so many artworks, and will continue to make. Theoretically figurative art can be made in any media and in a variety of style. With the popularity of photography, a new form of media designed to produce pictures of objective reality, great changes appeared in the realm of the traditional arts. The earliest usage of the camera was also photographic portraiture and the first short video filmed a family having breakfast. It became easier for normal people to have a photograph taken to be used as a self-portrait than to commission a painting. The latter would require greater time and expense. Thus *Walter Benjamin* states through his essay; the work of art is welcoming the '*age of its mechanical reproducibility*.' [43] Later, The media theorist, *Marshall McLuhan*, who thinks in terms of generously-measured eras, stated in his 1964 book *Understanding Media*, that '*art moves from outer matching to inner making*'[44] and places photography at the beginning of the information age and the telemetric society. '*Photography was almost as decisive in making the break between mere mechanical industrialism and the graphic age of electronic man*.'[45] But actually, it was not until the invention of the computer that the information age really began. *Marshall McLuhan* lived through the beginning of computer graphics, but had not predicted the digital era and the new digital media, which bloomed following his death in the 1980s. Clearly, in the time of the digital information processing machine, a new approach to this eternal desire to represent the human figure realistically had emerged, this time without any brush or knife, but with an electric calculating machine - a computer.

1.3.2 Nalaizhuyi; 'Realism' of Algorithmic Human Figure

If we consider the place of the development of the realistic algorithmic human figure in the light of the long development of figurative art, then it is not difficult to discover that the unceasing aim since ancient times have been to recreate and representation the figure of mankind, but under the mediating of computer algorithms. The emergence and maturation of the image of algorithmic human can also be regarded as an important extension to the development of figurative art.

In this context, when in this thesis, I write about a realistic human figure, I am writing about the visual (and no other) aspects of human bodies in computer-generated images. Those images are, first of all, supposed to be

[43] Walter Benjamin, the Work of Art in the Age of Its Mechanical Reproducibility, in *Walter Benjamin: Selected Writings, vol. 4. 1938-1940*, 2003: 251-283

[44] Marshall McLuhan, *Understanding Media: The Extensions of Man*, 1964, p194

[45] Ibid., p. 190

figurative insofar as they depict a human figure in a way that strongly resembles the human body. If only based on the assumption of scientific determinism, such images could be called 'naturalistic'.

But, In this thesis, the term 'realism', not 'naturalism' or other concepts is used rather broadly to indicate the process and aims of objectively and accurately modeling, animating and rendering the algorithmic human body in the same way as previous artists in the history of figurative art.

But due to computer science's short and fast development process, many unknown and haphazard factors must be considered. Sometimes, scientists and enthusiasts do not have sufficient time for planning and naming concepts, and instead directly borrow a ready-made concept from another discipline without taking it into account seriously**.** However, this cannot be avoided in the process of development. This kind of situation occurs anywhere and anytime. 'Nalaizhuyi'[46] [grabbism] was originally critically created by the Chinese writer Lu Xun[47], when the traditional China met the modern West first time suddenly and the country was forced to open the territory at the end of the 19th century. How to deal with the modern West and the traditional heritage of ideological, political and cultural heritage became a big debate of Chinese intellectuals at that time. In this context, Lu Xun in his essay tried to advocate the first step to eclectic, pragmatic borrowing from others instead of being engrafted passively.

Concepts 'nalai' [borrowed] directly are sometimes not only obviously immature or unfitting. They may, over a period of time, also become the reason of unnecessary misunderstanding. The widely used term 'photorealism' in computer graphics may be such a case.

James Foley et al., following Margaret A. Hagen's debate in 1986, continued to discuss in their widely referenced book '*Computer Graphics : Principles and practice'* , first stated '*in what sense a picture, whether painted, photographed or computer-generated, can be said to be "realistic" is a subject undergoing much scholarly debate.*'[48] They provide an explanation in the perspective from computer graphics as follows:

> *We use the term rather broadly to refer to a picture that captures many of the effects of light interacting with real physical objects. Thus, we treat realistic images as a continuum and speak freely of pictures, and of the techniques used to create them, as being "more" or "less" realistic. At one end of the continuum are examples of what is often called* photographic realism (*or* photorealism)*. These pictures attempt to synthesize the field of light intensities that would be focused on the film plane of the cam-*

[46] First published on the newspaper *Chinese Daily* in 07.06.1934.

[47] Lu Xun (1886-1931), one of the major Chinese writers of the 20th century. He is also an editor, translator, critic, essayist and poet.

[48] James Foley et al., *Computer Graphics: Principles and practice*, 1990, p. 605

era aimed at the objects depicted. As we approach the other end of the continuum, we find images that provide successively fewer of the visual cues we shall discuss.[49]

In their book, the authors discuss most of the issues of computer graphics. But in the above statement, there is a misnomer in some way to equal the word 'photographic realism' to 'photorealism', because photographic realism is a kind of visual realism that the painter aims to produce realistic images like photography , while photorealism was an '*art movement that began in the 1960s, taking photography as its inspiration. Photo-realist painters created highly illusionistic images that referred not to nature but to the reproduced image*.' [50]

The word photorealism was coined by Louis K. Meisel in 1969 and appeared in print for the first time in 1970 in a Whitney Museum of American Art catalogue for the exhibition "Twenty-two Realists." Photorealism is the genre of painting based on using the camera and photographs to gather information and then from this information, creating a painting that appears to be as realistic as a photograph. Photo-realist artists treat the photograph as a part of reality which becomes the object of a painting.

Yet in the history of visual art, photorealism provides an extension of realism. Artists treat photographs as daily life, as part of reality. The object portrayed in photorealism is the photograph. This aim is certainly not as realistic as a photograph, but enlarges a detail. When details in the photograph are not sufficiently clear, the artist must revise this applying the same kind of clarity and reality. In this way, exhaustively realistic images in a certain sense on the contrary become a provocation to people's ordinary form of observation. The realism of photorealism is almost perfectly genuine, but the equal clarity of its details hints at its distance from reality and at the illusion beneath the reality.

At the end of the 1990s, the term 'photorealism' was widely applied in computer graphics, to define the formal aim of the period. The aim had become that computer-generated images should be completely indistinguishable from those taken by a camera. 'Photorealism' became popular and jargon in computer graphics. It became the aim of computer graphics research in the latter half decade of 20th century. From the perspective of computer graphics, 'photorealism' is used to describe a representation of reality like a photograph. However, in photorealist painting, the artists aim at creating images which are just like the reality of a photograph but, at the same time, is clearly not a photograph but an artificial construct. This aims to express the distance between art and the pursuit of reality. However, researchers and users of computer graphics used photorealism just to blur or demolish this distance. The definitions of photorealism in computer graphics and painting are thus totally contradictory. This ignores the premise of its original cultural and historical background. If we, however, think of 'photorealism' as a name for images generated with a photo camera, then the term may be used in our context also, perhaps as 'simulated photorealism' or 'quasi-' or 'pseudo-photorealism'.

[49] Ibid.

[50] Encyclopedia Britannica Online, s.v. 'Photorealism', available from: http://www.britannica.com, accessed 28.02.2011

While the very similar same situation researchers met especially at the beginning of the development of computer graphic, whatever because of computer graphics having the character of the 'combining of graphics art and computer' or 'objective and accurate representation', 'realism' of the computer graphics could be regarded as a borrowing concept from visual art by the scientist and researchers with the attitude of Nalaizhuyi.

Realism is a heavily debated concept not only in art and literature, but also in philosophy, film, international and social relationship. Actually, the visual aspects of a phenomenon are only a small cross-section of the phenomenon as Nochlin indicates:

> *The commonplace notion that Realism is 'styleless' or a transparent style, a mere simulacrum or mirror image of visual reality, is another barrier to its understanding as an historical and stylistic phenomenon. This is a gross simplification, for Realism was no more a mere mirror of reality than any other style and its relation qua style to phenomenal data – the donnée – is as complex and difficult as that of Romanticism, the Baroque or Mannerism.* [51]

The question of realism in computer-generated images especially at the beginning has certainly near to nothing to do with the historic movement and philosophy of realism. It has to do with the simulation of light as it plays a role in photography. It is algorithmic simulation of aspects of photographic imaging.

In computer graphics, an important aim is that images look deceptively close to how we perceive things. A 100% correct reflection of reality is certainly hard, even for realist painters. Nochlin's point is that despite realist painters taking an objective perspective to the greatest possible extent, in order to avoid the pitfalls of idealism and sentimentalism,

> *In painting, no matter how honest or unhackneyed the artist's vision may be, the visible world must be transformed to accommodate it to the flat surface of the canvas. The artist's perception is therefore inevitably conditioned by the physical properties of paint and linseed oil no less than by his knowledge and technique - even by his choice of brush-strokes – in conveying three-dimensional space and form on to a two-dimensional picture plane. Even in photography, which comes closer to fulfilling the demand for 'transparency', the photographer's choice of viewpoint, length of exposure, size of focal opening and so on, intervene between the object and the image printed on the paper.*[52]

Painting and photography are like this, not to mention computer graphics, and especially the simulation of human being, the most difficult issue of computer graphics, which is much more conditioned by the physical properties.

[51] Linda Nochlin, *Realism*, 1971, p13

[52] Ibid., p. 13-14

In order to give the algorithmic human figure the most accurate possible model, motion and appearance under limited conditions, computer graphics researchers have worked hard to develop a range of algorithm. At times, due to applying contemporary technology, the level of awareness of the limitations has increased, in effect signifying a state of balance; sometimes between the accuracy and speed, sometimes between the time and the efficiency, sometimes between the detail and the overall effect. The special characteristic of the algorithm determines what technological constraints and simplification, abstraction and balancing cannot be avoided.

The algorithmic human body is often a hollow 3D model of the human body, with a simplified skeleton and a skin surface without muscle, blood or flesh. As we know, an algorithmic human figure is actually one kind of numerical representation. The normal creation of an algorithmic human figure begins with elementary geometry; a point, a line, or a solid gradually forming the organic human body, rather than from the zygote. This means that these bodies are defined by mathematical functions and the accurate body shape is achieved through controlling the quantity of polygons or the parameters of curves. Whilst naturally, the human body is the entire physical structure of a human organism. Taking a cue from biology, each movable part is described as a bone. For an anatomically-correct adult human skeleton, over two hundred bones are required. The skeleton carries the weight and serves as the foundation for the body. More than six hundred muscles are attached to the skeleton with tendons, and muscles move the bones by contraction. The skeleton influences the form of the figure underneath the skin, fat, and muscles. In some parts of the body the skeleton is discernible on the surface, whilst in other areas it appears only through certain movements.

A real-life human body without a skeleton would look just like the figure with the flayed skin held up by St. Bartholomew in Michelangelo's *The Last Judgment;* a self-depiction of the artist. However, in the case of the algorithmic human body, the skeleton is mainly used in animation for movement and rarely adds structure to the body. Currently, solely for the purposes of medical research, a few companies have begun to use proprietary software capable of realistic skeletal and muscular movement. Most of the users have to use off-the-shelf software and have to rely on specific techniques to overcome these limitations. That is, the bones of algorithmic human bodies are most likely to look like simple geometric shapes. When these are rotated, they affect the polygons, splines, or NURBS meshes. Many problems are encountered during the animation process, due to the absence of muscle and fat in the algorithmic human body. These are usually found at the joints. During movement, crimping and creases, as well as unwanted protuberances, often appear. There is also a lack of muscular deformation under the skin, which makes it very difficult to create realistic human motion.[53]

If the realism in this situation could be called 'superficial realism' or 'the realism of surface', when in realistic textural representation of the skin, hair, clothes and lighting, many algorithms are designed directly with the purpose to 'trompe l'oeil', to fool our eyes . [*Fig. 1.3*]

[53] Peter Ratner, *3D Human Modeling and Animation*, 2003, p. 183

Fig. 1.3: Escaping Criticism, 1874, by Pere Borrell del Caso, oil on canvas, Collection Banco de España, Madrid

One might imagine the scene of a brick wall on a lawn for example. It would require a huge number of polygons to model the bricks and blades of grass on the lawn. In order to spare the cost of rendering these thousands of polygons, whilst maintaining the realistic appearance of the brick wall and grass, computer graphics researchers have invented texture mapping algorithms. In fact, applying this technique, the wall, the lawn and the sky can all be modeled as a rectangular solid, and created from rectangles.[54] And all the individual brick or grass is pre-painted on the texture with the software like Photoshop or Painter on a planar surface. This method can also be used in the process of realistically representing the algorithmic human body; a facial beard model requires similar techniques to those of the lawn above. 'Pseudo-realism' could even be used in this case.

Furthermore, the motion or behavior of the algorithmic human body is still limited. Manipulating the movement or behavior of the human body also requires specific algorithms. To take the online game of Second Life as an example, the avatar could decide to sit down on a sofa in either a serious or a relaxed manner by selecting one of the two pose balls attached to the sofa, entitled 'sit' and 'relax' respectively. These balls are actually two pre-written different programs. But the reality about human behavior with a sofa, could not only sit properly with a serious mien, sit respectfully, recline, or even in-between lie and sit. But here because of the limited technology and algorithms, the realism of the whole game is also a 'limited realism'. Nowadays such modes of behavior are still totally crude. Under the limitations of real-time rendering, this algorithm could not achieve realistic motion effects.

Although realism currently is used very widely for tendencies of art of any period so long as the works strive for an accurate representation of the visible world, the use of the words about all sorts of realism that appear in the literature and its derivatives in computer graphics must be also taken into account critically and ironically in the context of history and culture. Thus, in this thesis, I would prefer to still use the 'realism' but with

[54] Pascal Vuylsteker, The Quest for Visual Realism(2), lecture slides of Australian National University, 2004

quotation marks to the image of algorithmic human figures from its beginning to current in order to make an emphasis that this realism is not the same as the one in visual art.

1.4 The Evolutionary Pedigree of the Algorithmic Human Figure

1.4.1 2001: Key Boundary towards 'Realism' of Algorithmic Human Figure

The algorithmic human figure's path towards 'realism' has certainly not been one smooth road, but rather complicated and winding. There are still many links within this process which have yet to be understood. The next part of this thesis will analyze the history of the algorithmic human figures from its origins in 1964 up until the year 2001 around, within the field of computer graphics.

Since at the end of the 1990s and the beginning of the 21st century, the gradual maturity of innovations in real-time and interactive 3D computer graphics became possible. The computer imaging process and the maturation of different techniques, the renaissance of computer aesthetics, computer art, 3D animation, video games, virtual reality, mixed reality, augmented reality, and other areas of visual art began to study the production of the computer image, the game and virtual reality. The visual works produced by 3D computer graphics became the inspiration for breakthroughs in existing visual art forms. Ultimately, the result was different from other new visual art forms.

Lev Manovich in his book *The Language of New Media* describes 'realism' as the concept which '*inevitably accompanies the development and assimilation of 3D computer graphics*,' and *'the history of technological innovation and research of 3D computer graphics*' as '*a progression towards realism*'. [55] Furthermore, he defined the realism in the computer from the viewer's perspective as 'Synthetic Realism' stating:

> *The real break is the introduction of a moving synthetic image - interactive 3D computer graphics and computer animation. With these technologies, a viewer has the experience of moving around a simulated 3D space - something one cannot do with an illusionistic painting.*[56]

And at the end of 1990s, the computer animator Chris Landreth produced the short computer-animated film *Bingo* to give the audience an experience which surpassed the visual effects of real performers and raised concepts beyond photorealistic realism which he later referred to as 'psychological realism'.[57] Along with more

[55] Lev Manovich, *The Language of New Media*, 2001, p. 184

[56] Ibid.

[57] Barbara Robertson, Psychorealism: Animator Chris Landreth Creates a New Form of Documentary Film*makin*g, *Computer Graphics World*, Vol. 27, No. 7 (July 2004), p14

input, as well as the intervention and overlap with the results of mankind's latest research, the concept of 'realism' has gradually broadened and extended.

Furthermore following the advance of digital and internet technology, nanotechnology and biotechnology, we once again witness interdisciplinary cooperation in the same manner as the Renaissance. Against this background, the algorithmic human figure's development is no longer limited to the framework of computer graphics but has begun to combine with the study of medicine, biology and mechanics, sociology etc.

This thesis begins with the birth of the algorithmic human in 1964, and it stops in the year 2001. It not only marked the turn of the Millennium, but also a key boundary in the process of the algorithmic human figure's development towards 'realism'.

Firstly, two films released in 2001 brought to the attention of the world the complexities in the future development of the algorithmic human, especially the relationship between algorithmic humans and their objects of imitation. One of these films was *Final Fantasy: the Spirits Within*. This film was produced by the same team as the *Final Fantasy* game. It was a completely 3D film with an algorithmic human taking the lead role. But this film took the whole production team almost four years to make. This film was not only long-awaited by fans of the *Final Fantasy* game, but also by film developers. Prior to this time, algorithmic humans had only taken the parts of extras or small roles in films with real human actors, and the majority of algorithmic humans in completely 3D film productions had been 3D cartoon characters. Was it possible that realistic algorithmic humans could perform real human film roles? However, alongside the film showing, people's expectation regarding the simulation of real people by algorithmic humans began to decrease and they began to lose interest. In contrast, another film released in 2001 of the same name as the famous computer game, *Tomb Raiders*, revitalized belief in the algorithmic human. Many models and stars competed to take the female lead role in the film as the human version of the algorithmic human in the game. In addition, in order to make themselves closer in appearance and temperament to the Lara of the game, some competitors even underwent breast augmentation surgery. Although, the skin of Lara in the game is not nearly as realistic as that of Aki and she does not have Aki's soft compliant short hair, Lara is able to interact with real people, and to go on adventures and treasure-hunts with them. Following this release and the subsequent media-hype, the algorithmic human was no longer the animator's puppet, but could interact with real people. Lara became a star. At this time, real human figures are no longer the models of algorithmic human figures, but algorithmic human figures had become the models of real human figures.

Aside from the above examples, in 2001, *Ray Kurzweil*, an advocate of the future of science and entertainment brought his online talking algorithmic human to the TED (Technology Entertainment Design) conference[58]. Real people and algorithmic humans performed on the same stage. This formed a porous boundary between real and algorithmic humans in live performance. When online, it was only possible to see the head of Ramona, the intelligent chatter-bot, but at the TED conference, her overall potential was put on display. Thus, whether the algorithmic human could step down from the screen and interact with real people, the algorithmic human no longer passively adapted to the environment, but had already matured within the virtual environment and begun to interact with the real world. At the end of 2001, another film entitled *The Matrix*, brought about an in-depth discussion of the 'Moebius Strip'[59] between humans and algorithmic humans.

After 2001, mankind had to continue to develop a new Odyssey Tour. Thus, the history of the algorithmic human's development had already gone beyond the scope of technology to become a part of social, cultural and visual art history.

At the end of 1990s, the expectation of this advance lead to the algorithmic human becoming a hot topic. At the same time, books of digital beauties and heroes added fuel to the flames. It became a genuine possibility for ordinary people to create their ideal self. Sculptors would no longer have to live in a state of unrequited love for their sculptures of beautiful women but could interact with them.

But the releasing of the *Final Fantasy: the Spirits Within* cooled the passion not only of the public but also of scientists and researchers in pursuit of extreme 'photorealism' of algorithmic human figures. They recognized there was still a long way towards 'realism', because '*with this ability to simulate scenes of ever-increasing realism comes a new problem: depicting and visualizing these complex scenes in a way that communicated as effectively as possible.*' Thus, '*a new quest*', '*contrast with the earlier quest for realism has become known as* non-photorealism*, or NPN for short, has provoked a tremendous level of interest….*'[60] Following 2001, non-photorealistic rendering became another key point in computer graphics research. Whilst the issue of realism had been laid aside for some time, the blossoming of the online virtual world, *Second Life*, lead to a renewal of interest. In fact, in comparison with the image of *Final Fantasy: The Spirits Within*'s Aki, the image of *Second Life*'s avatars appeared very rough, much like the image of an algorithmic human figure in the 1980s. The question: *What is a realistic image?* was again proposed in the context of internet online technology. The nature of real-time realistic computer images which humans are capable of achieving came under consideration.

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[58] TED is a nonprofit organization devoted to Ideas Worth Spreading. It started out in 1984 as a conference bringing together people from three worlds: Technology, Entertainment and Design. Since then its scope has become ever broader. Official website: www.ted.com

[59] Moebius strip is a surface with only one side and only one boundary component. The Moebius strip has the mathematical property of being non-orientable. It can be realized as a ruled surface. It was discovered independently by the German mathematicians August Ferdinand Möbius and Johann Benedict Listing in 1858

[60] David Salesin, foreword for the book *Non-Photorealistic Computer Graphics: Modeing, Rendering, Animation*, written by Thomas Strothotte, Stefan Schlechtweg, 2002, p. vii

The resulting problem of these developments is that when algorithmic human figures become so realistic in form and behavior that we are difficult to distinguish them from real humans, how should we humans of flesh and blood view and treat them? In today's state of globalization either the West or fast-developing China, the phenomenon of realistic algorithmic humans, has already raised new questions in the areas of technology, aesthetics, social ethics and economics as well as arousing broad discussion across society.

Following the female lead role of the full 3D animation *Final Fantasy: The Spirits Within* and the media attention-grabbing female lead role in the 3D game, *Lara Croft*, in 2007 the algorithmic human once again became the focus of the public eye. The adult magazine *Maxim* announced their global selection of the *Hot 100*, 'the definitive list of the world's most beautiful women', among which the avatar in *Second Life* gained the 95th place. Although prior to this, there were also algorithmic humans featured in a range of magazines, most met with the same concern and reportage that we might give to anything new. However in this case, the avatar's success was not only due to her own personal charm but also because she represented millions of avatars in the virtual world. Some companies have already begun to exploit its commercial potential. *Maxim* explains its choice as,

> *Second Life is a 3D virtual world, imagined, created, and owned by its online residents. It was launched in 2003 and now boasts nearly five million inhabitants around the globe. Never taken part in the nerdfest? Isn't she reason enough?* [61]

In comparison with adults, the influence of something new on young people is deeper and more direct. Particularly today as computer games become increasingly realistic, it becomes impossible for children to differentiate between the real human world and the games world.

A shocking campus massacre has made the whole of society consider this issue. In April 1999, 17-year-old Dylan Klebold and 18-year-old Eric Harris committed the Columbine High School massacre in USA. They killed twelve students and one teacher and injured twenty-four others. These two youths were addicted to 3D action computer shooting games named *Doom* and *Quake*. Whilst shooting in the virtual world is harmless, these students began to see shooting as a normal activity and lost the ability to distinguish between the virtual and the real world. This case has usually been used as an example of the harmful effects of electronic games on young people.

The implementation of a games classification system is on the agenda. In the film industry, there is already a classification system in place to protect young viewers from violence and pornography, however in the games industry, a system of this nature has not yet been implemented. But in fact, the majority of players are young people under the age of 18. This group is especially prominent in China. Following China's implementation of

[61] See Maxim website, 2007 hot 100, available from: http://www.maxim.com/amg/girls/43960/2007-hot-100.html, accessed 28.02.2011

the One Child Policy in 1976, the first era of children without siblings began to grow up. Many students would skip class to go to the arcade to play computer games. At the beginning of the 1990s, this became a serious problem in society. Not including computer games, (the vast majority of Chinese people play computer games), the world has altogether 1.3 billion electronic games machines. The manufacturers of electronic games machines predict that electronic games will become as universal as CDs and DVDs. Aside from violence, the biggest star amongst the algorithmic humans, *Tomb Raider*'s Lara Croft and *Life and Death'*s Christie both have enormous bosoms. Aside from professional archaeologists and thugs, their inviting bodies are the chief attraction to games players. Just like in the real world, the algorithmic humans in the virtual world can become involved in pornography. For example, performances in 3D-animated pornographic films are developing to involve the online pornographic industry. When these images go beyond reality, it is difficult to discriminate between real humans and algorithmic humans. Sex and violence are usually linked. This is also the reason why many parents fear computer games.

For this reason, young people under the age of 18 are forbidden to access a lot of *Second Life*'s online content. However, certainly not all games have this discrimination and monitoring system. How to control the exposure of young people to the violence and pornography of virtual games has begun a hot discussion topic in recent years. Moreover, the most important factor is the commercial background to violence and pornography. A recent article in the *China South Weekend* newspaper has investigated the reaction and impact of China's internet games journey on Chinese people's morals behind their commercial success.

Considering that the algorithmic human has already aroused wide social attention, artists have begun to consider this issue from their own unique perspective. For example, the artist *Feng Mengbo* showcased his online interactive war game entitled *Q4U* at the *Documenta 11* Exhibition in Kassel. Through a half-ironic half-comic style he recreates an increasingly realistic virtual world, as well as the relationship between us and our online incarnations. *Feng Mengbo* transposed his own body image and his voice cheering the word 'niubi'[62] into the game *Quake*.

> *based on Quake III Arena (Id Software, Inc., 1999), one of the most popular FPS (first person shot) game today, Q4U is my latest computer artwork. compare to my last digital movie Q3 (MiniDV wide screen, 32 min, 1999), which also based on the same video game, Q4U is quite simple: no more stories. no more dialogues. only gun fires. bloods. death…this work seems very similar with the original game, except the character. the original has 32 computer-controlled gladiators (bot), they are cybronic human, reptiloid alien, gargoyle etc. Q4U has only one - a real human, that's myself, with naked torso, US army pants, and a MiniDV camcorder in my left hand. I setup the server to force all the players appear in my*

[62] Chinese slang means capable

screen only use this model, the result: the artist are anywhere, fight and kill each other. …[63]

Visitors were invited to take part in the game through the internet, but could never know who was playing the game, because the shooting and death never stopped. Artists showed the violence in a humorous way and brought forward the questions:

> *Rapidly running; fighting between humans, machines, animals, and monsters. Humans have disappeared suddenly in the air. Does the World need to be saved or to be destroyed? Everything is possible on the computer screen. Everything is too real. What we should do?* [64]

If *Feng Mengbo* exchanges his own image for *DOOM*'s computer-generated characters and monsters, the main aim is to give people a stronger sense of reality, then, when these realistic algorithmic humans are capable not only of performing operations for us but also have the ability to learn, and can be combined with different technological innovations what will they be able to do? From the first algorithmic human's appearance, different points of view have frequently arisen.

The scientist *Norman I. Badler* believes:

> *New tools and techniques such as motion capture, natural language, natural movements, evolving systems, and digital clones available to the animator will enhance all aspects of this process, whether the final product is offline special effects, interactive games, or online virtual worlds.* [65]

In his book *The Language of New Media*, *Lev Manovich* writes:

> *…we should not consider clean, skinless, too flexible, and at the same time too jerky, human figures in 3D computer animation as unrealistic, as imperfect approximations to the real thing - our bodies. They are perfectly realistic representations of a cyborg body yet to come, of a world reduced to geometry, where efficient representation via a geometric model becomes the basis of reality. The synthetic image simply represents the future. In other words,* if a traditional photograph always points to a past event, a synthetic photograph points to a future event. [66]

In contrast to the vast majority of technological optimists, when the scientist Bill Joy heard a strong argument claiming that sentient robots were a near-term possibility, he was surprised. Taking the perspective of the

[63] Shanghart Gallery, Q4U: an Artist as a QUAKER, available from: http://www.shanghartgallery.com/galleryarchive/texts/id/12, accessed 28.02.2100

[64] Exhibition Catalogue of *Documenta 11*, 2000, p. 26

[65] Norman I. Badler, Animation2000++, in *Computer Graphics and Applications* Jan/Feb 2000, p. 28-29

[66] Lev Manovich, *The Language of New Media*, 2001, p. 202-203

Theory of Evolution, the *Wired* Magazine article announcement asked: '*Why doesn't the future need us?*' and went on to argue that *'our most powerful 21st-century technologies; robotics, genetic engineering, and nanotech are threatening to make humans an endangered species.'* [67] The article aimed to raise concerns regarding the virtual world and its effects on human behavior. In the early stages of the invention of the algorithmic human, an argument of this nature was expressed in Kubrick's 1968 film *2001: A Space Odyssey* through the behavior of another lead role, HAL9000.

Yet, the provocative performance artist Stelarc is the dream spokes-person for the interactive online generation. His work focuses heavily on extending the capabilities of the human body. As such, most of his pieces are centered around his concept that *the human body is obsolete*. Stelarc's idiosyncratic performances often involve robotics or other relatively modern technology integrated with his body. He has tried to go beyond the limitations of the present human body and to challenge optimists and pessimists alike. The two perspectives of this work are extremely provocative. Stelarc's newest art work is extended for the internet. He has created an online algorithmic human copying his own body shape in order to raise the question as to whether 'the human body can be used as a direct human-machine interface on the Internet.' Using his body as a starting point, he attempts to get close to the algorithmic human. Through his work, we can recollect and feel nostalgia for the days when we had control of our bodies in cultural theory, but his work does not stop at that level but also rigorously investigates a world in which scientific research has yet to enter.

Against the background of globalization, some situations, such as the meeting of Western traditions with the rise of China, are already very common. As well as this, since entering the 21st century, the algorithmic human has seen much new development. Whilst it is not possible to provide an enumerated list within this thesis, in fact several issues have existed since the early stages of the algorithmic human's development. Through research into previous case studies of the algorithmic human from its beginnings up until the present day, this thesis aims to provide a review of the algorithmic human's development from a historical perspective, and to use a dialectic method of analysis to treat the increasingly human-like algorithmic human, this new 'species'. Furthermore, this thesis will aim to envisage the future trends and directions.

In this sense, around 2001 these originally 'realism' of computer-generated 'realistic images' is extending the implications of traditional realism not only in the visual art but also a more broader categorization. This could also be regarded as the case of the new trendy of Nalaizhuyi. This figurative term is used widely in contemporary discourse as '*conceptualise cultural borrowing not as a one-way flow from the source to the target culture, but as a two-way cultural enterprise*.' [68]

[67] Bill Joy, Why the Future Doesn't Need Us, in *Wired*, Issue 8.04, 2000

[68] Elisabeth Slavkoff, *Alternative Modernity: Contemporary Art in Shanghai*, MA thesis

1.4.2 Selected Examples 1964-2001

Yet, an overall description and examination of algorithmic human figure has been lacking. Focusing on individual cases often forms the perspective of aesthetics, fine art, sociology and other disciplines, however, research into the position and application of each individual case-study within the overall historical development as well as research into the combination of scientific, technological, artistic and cultural factors, has been relatively rare.

Ideas now current in new media are only a few of the many put forward during the founding of this field. With the emergence of this new trend, many retrospective studies have simultaneously taken place. For example, McLuhan's *Understanding Media*, a text predicting the future, has been widely discussed again long after its first publication in 1964, more than forty years ago. The author of *The Language of New Media* places new media within the history of visual and media cultures over the past few centuries, and attempts to provide a systematic and rigorous theory of new media. The book, *The New Media Reader*[69], selects important essays which relate to the origins of the important ideas of today and provide a basis for gaining a more thorough understanding of these ideas. Besides this, MoMA (The Museum of Modern Art in New York) held a special exhibition in 2005. This exhibition was entitled *Pixar: 20 Years of Animation*, and included a complete retrospective of Pixar films, showing the acceptance of 3D computer-animation by the contemporary art mainstream. The digital aesthetic, which was an area of experimentation in computer graphics' early years has since seen new development with the advance of the latest 3D printer technology. This retrospective along with the work of current artists has been presented in many museums.

The understanding of the beginning and foundation could be the source of the next big innovation. This thesis aims to research the origins and course of development of these on-screen human figures. It will aim to find a new field of vision and perspective from which to research these figures and to grasp the possibilities for their future.

I will move beyond the constraints of dealing with the technical difficulties of creating photo-realistic visual simulations. A representative sequence of individual results will be selected and presented in detail that together stand for the entire phenomenon. Each of the selected cases represents at least one particular step towards increased so-called 'realism'. Through the interpretation of selected observations as examples, this thesis develops two main strands of research discussed above. Firstly, it documents the development of photorealistic 'realism' in the computer graphics context over the past forty years, where the photorealistic image denotes an image on the computer screen with the naturalistic appearance of a photograph. Secondly, taking a historical perspective, it provides a thorough analysis of computer graphics in relation to the concept of 'realism'.

[69] Noah Wardrip-Fruin and Nick Montfort (ed.), *The New Media Reader*, 2003

Finally, this thesis aims to look beyond the superficial specific phenomenon of the algorithmic human figures and to study them in their entirety and to emphasize their fundamental common features. Namely, in the process of producing these algorithmic human images, there are issues which have been solved and which have yet to be solved, as well as methods by which to solve some of these issues and further research needed in order to develop further methods. The aim here is to grasp their development framework and future tendencies, to go beyond the technical, functional and aesthetic requirements, and to overcome the recognized limitations imposed by certain restrictions in the development process.

Specifically, the following content of this thesis comprises five sections. Basically each section uses one or two representative case studies, and each of these selected case-studies represents an important process in the move towards a so-called 'realism'.

i) The second chapter takes the Boeing Man as a case study. The 1960s aerospace industry's developments lead to the first algorithmic human's production. The Boeing Man, provided one of the most significant and iconic images in the history of early computer graphics. At this time, the necessary condition of the Boeing Man's final appearance was the invention of an algorithm to facilitate data-to-picture conversion. The algorithmic human was one of the earliest images to be converted from data to pictorial form. Computer-generated images greatly encouraged the attempts of contemporary visual artists, and computer artists very quickly came forward. The Boeing Man is the first of the few images generated using a computer. Although this form only comprised simple lines, it is still the first attempt made in computer art. In the research of the ergonomics of the human and machine, and modeling of the Boeing Man's form, the method of anthropometrics was applied to gain body proportions. In future, manufacturing, building, fashion and design industries have universally-followed the form of the algorithmic human involved in this method. This algorithmic human which applied research into aeroplane design ergonomics was not only the first algorithmic human but also witness to the birth of computer graphics and at the same time, the clear target of the development of a realistic algorithmic human.

ii) Following the 1960s' Boeing Man, no new integrated algorithmic human was presented until the 1980s. The third chapter introduces the first algorithmic figure with a preliminary realistic feel and a body mass, named Adam Powers, along with his impact on the whole film industry. In 1981, Adam Powers was displayed in public for the first time at the electronic theatre of SIGGRAPH. This is one of the 1980s' most impressive events. With the exception of the face, which was stiff and puppet-like, the performance of Adam Powers exceeded the expectation of the audience to the computer generated animation. This achievement came from the research and creation of hiding, shading and mapping algorithms in the field of computer graphics. In addition, Adam Powers became another breakthrough for the algorithmic human as his form and movement came directly from a real juggler. Adam Powers' movement applied a traditional 2D animation technique called rotoscoping, which was the tracing over the real juggler's live-action film movement frame by frame to the algorithmic human Adam Powers. The sequence of these realistic images began directly to influence the development of films and TV. This opened the prologue to the development of the algorithmic human in the film industry.

iii) Although in the 1980s, the algorithmic human began to feature widely in the music video, even in TV dramas, but on the road to becoming a performer, the largest obstacles were the richness of facial expressions and body movement. These were the necessary requirements to becoming a fine actor. Therefore, in the 1980s, methods such as the study of anatomy and dynamics were used as sources of reference, and sculpture, film and animation methods were developed and tested to solve the problem of the algorithmic human's development. The fourth chapter will consider this development using the twisting body of the female singer, Dozo. She stood on a platform, singing, in the music video, as a representative case. Whilst Dozo certainly provides a striking image of a woman, of greater importance is Dozo's facial expression whilst she sings, as well as her body movement, which has attained the basic quality of the artist. This case study represents the progress of the algorithmic human in modeling the expression and movement of the real human in the 1980s, as well as the commercial value brought by realistic computer graphics.

iv) Geri and Dave, the algorithmic humans who became Dozo's successors are subject to thorough discussion as typical case studies. They are used to discuss how the detailing of the model makes progress and moves closer to the image of the real human in the 1990s, as well as the algorithmic human's popularization with a mass audience. The development of computer technology and computer graphics lead to a significant improvement in the algorithmic human's realism. However, with regard to the modeling and creation of the algorithmic human's attachments like hair and clothing, developers met great obstacles. Many of the contradictions between the in-depth detail and the computer performance limitations lead to problems for the algorithmic human on the road to a photo-realistic appearance which was difficult to overcome. But through the modeling and animation of the algorithmic human, Geri, computer graphics experts were able to certify the effectiveness of one algorithm, 'subdivision'. *Dave*, who appeared at almost the same time as *Geri*, is an algorithmic version of a real actor. Placing these two versions in juxtaposition, the algorithmic actor, on certain levels, aims to achieve a more realistic expression. This challenge reached a climax with the main role of the algorithmic human Aki Ross in *Final Fantasy: The Spirits Within*.

v) Human figure simulation not only makes the algorithmic human look like a real person, but also signifies the social nature of the real human as well as the interaction between them and their environment, where the environment includes other real and algorithmic humans. Attempts to develop this interaction began very early, but it was not until the 1990s that successful interactions in real-time began to take place. The sixth chapter uses the algorithmic human Lara Croft as an example to discuss in depth the real-time interactive relationship of the algorithmic human and the human at the end of the

1990s and the beginning of the 21st century. In addition, the final chapter will discuss a chatterbot named Ramona as another real-time interactive case study and consider in-depth elements of the algorithmic human's development in real-time interaction aside from simulating the outer form, behavior and movement of real humans. These include how the language and thought of the real human is simulated in an algorithmic human and the improvement this leads to in exchange and interaction with real humans. Thus, on the road to 'realism', the algorithmic human has not only aesthetic targets but also further expansion of the meaning of reality. The algorithmic human has also entered the social and cultural arena.

Every case study in the history of the development of the algorithmic human acts as a cross-sectional analysis.

> *Important though it may be, fidelity to visual reality was only one aspect of the Realist enterprise, and it would be erroneous to base our conception of so complex a movement on only one of its features; verisimilitude. To understand Realism as a stylistic attitude within its period， we must turn to some of the Realists' other aspirations and achievements.*[70]

The following aspects of every case study are analyzed:

i) The background technological development in the history of the algorithmic human; the key developments in computer technology, computer graphics and algorithms which ensure the birth of the algorithmic human;

ii) Basic information relating to the specific case study: gender, appearance, body, character, and the original motivation of the creator of the algorithmic human figure;

iii) A comparison between the specific case study and previous case studies considering problems in the realistic appearance and the final decision leading to the progress of this case study towards the realist appearance;

iv) At the same time as investigating the algorithmic human's solutions, investigating whether there are solutions to this problem to be considered to be found in other visual art forms incorporating a discussion of the influences of other visual art forms as well as contemporary society and historical development.

This thesis researches the algorithmic human figures from a historical angle. It is a cross-disciplinary study between computer graphics and art history. Taking a historical perspective on the development of digital media is of key importance. In this thesis, however, I want to provide a new perspective which surpasses comput-

[70] Linda Nochlin, *Realism*,1971, p. 22-23

er graphics and goes beyond the confines of dealing with the tremendous technical difficulties of creating visual simulations that look as if they were photographic pictures taken from living humans. I want to put into a historic perspective the apparently incessant desire of humans to create artificial counterparts of themselves. Clearly, in times of the digital information processing machine, a new approach to this eternal desire has emerged.

2 MODELING THE BOEING MAN: SKETCHING THE IDEAL

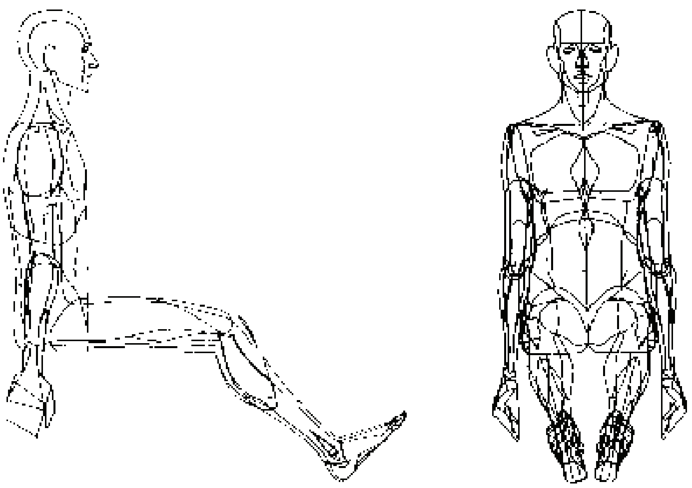

Fig. 2.1: An image of Boeing Man's sitting posture from the side-view and front.
(Source: William A. Fetter, A Progression of Human Figures Simulated by Computer Graphics, *Computer Graphics* Vol. 2, No. 9 (1982), p. 9)

There has been a long-standing need in certain computer graphics applications for human figure simulations, that as descriptions of the human body are both accurate and at the same time adaptable to different user environments.

-- William A. Fetter,
A Progression of Human Figures Simulated by Computer Graphics,
in *IEEE Computer Graphics and Applications*, Vol. 2, No. 9 (1982), p. 9

2.1 1960s: Budding of Computer Graphics

2.1.1 Background to the Origins of Computer Graphics

Before the creation of the first algorithmic human figure, the Boeing Man, William Fetter used the term 'computer graphics' for what he was doing at the Boeing Company. Later in his book *Computer Graphics in Communication*, he wrote: '*Computer Graphics is a combination of graphic art and computer methods. It is simple, fast, and economical in converting large amounts of engineering or scientific data into pictures'* .[71] This happed almost twenty years after the invention of the computer.

The majority of the first generation of electronic computers was built to help computing in the 2nd World War's military campaigns. The most famous one was ENIAC (Electrical Numerical Integrator and Computer). It was built by *John William Mauchly*, at the Moore School of the University of Pennsylvania and was completed in 1946. It was originally intended to compute the copious calculations required by ballistic missiles in the war.

This intention spurred the development of a general-purpose electronic computer. However, until the mid-1950s, most of these first generation vacuum tube-based mainframe computers were enormously big and expensive. ENIAC, for example, weighed over thirty tons. It comprised thirty separate units, plus a power supply and forced-air cooling. Its 19,000 vacuum tubes, 1,500 relays, and hundreds of thousands of resistors, capacitors, and inductors consumed almost 200 kilowatts of electrical power. Besides, the first generation mainframe computers used machine language, the lowest-level programming language understood by computers, to perform operations. They could only solve one problem at a time. The input was based on punched cards and paper tape and the output was displayed on printouts. Few specialist scientists and engineers could manipulate the machine.

At almost the same time, *Vannevar Bush* published his prediction paper *As We May Think* [72]. *Bush* argued that as humans turned from war, scientific efforts should shift from increasing physical abilities to making all previously collected human knowledge more accessible. He predicted for the near future voice interaction, wearable information devices, and wireless data connections. And his idea of the Memex, a 'future device for individual use . . . a sort of mechanized private file and library' in the shape of a desk, which was seen decades later as a pioneering concept for the World Wide Web.

However, with the exception of a small number of pioneers, scientists could never have imagined that within just fifty years, such a huge calculation machine would bring such impact and influence to the world.

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[71] William A. Fetter, *Computer Graphics in Communication,* 1965, p. 5

[72] Vannevar Bush, As We May Think, in *New Media Reader* (2003): 37-49

Later in the 1950s, two inventions were introduced which significantly improved computer technology.

The first integrated chip was developed by Robert Noyce of Fairchild Semiconductor Company and Jack Kilby of Texas Instruments Company. The first microchip was demonstrated on 12th September, 1958. The invention of the integrated circuit allowed the placement of many transistors into a small area. This advance enabled machines to become smaller and more economical to build and maintain.

Regarding the development of programming languages, in the early 1950s, Grace Murray Hopper invented the concept of a compiler. This allowed computers to move from cryptic binary machine language to symbolic, or assembly, languages, which allowed programmers to specify instructions in words. High-level programming languages were developed with this concept, such as early versions of COBOL and FORTRAN.

The computers in the 1950s became simpler, faster and more economical than ENIAC. In the 1960s, computer science became a recognized discipline and from the mid-1960s onwards, its rate of development accelerated. Operating systems also saw significant developments; Fred Brooks at IBM designed System/360, a line of different computers with a uniform architecture and instruction set. 1964 saw the marketing of the first functional Minicomputer, Digital Equipment Corporation's 12-bit PDP-8, and the creation of the programming language BASIC.

Besides the development of computer technology, the key motivation underlying the development of computer graphics was to render what was invisible to the human eye, visible, and hence 'to convert large quantities of engineering or scientific data into pictures'[73]. The algorithmically modeled human figure was one of the earliest images to be converted from data to picture form.

The first computer to use CRT[74] displays as output channels 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 CRT monitors. This was not the first digital computer, but it was the first computer capable of displaying real time text and graphics on a large oscilloscope screen.

Throughout the latter half of the decade up until June 30th, 1959, Whirlwind ran in a support role for SAGE. The SAGE Air Defense System of the U.S. Air Force used this system with the CRT displays on which operators could detect aircraft flying over the continent. The SAGE operators' ability to obtain information about the

[73] William A. Fetter, A Progression of Human Figures Simulated by Computer Graphics, in *IEEE Computer Graphics and Applications*, Vol. 2, No. 9 (1982), p. 9

[74] The Cathode Ray Tube (CRT) is a vacuum tube containing an electron gun (a source of electrons) and a fluorescent screen, with internal or external means to accelerate and deflect the electron beam, used to create images in the form of light emitted from the fluorescent screen. The image may represent electrical waveforms (oscilloscope), pictures (television, computer monitor), radar targets and others.

aircraft by pointing at their icons on the screen implied the beginning of a period of interactive computer graphics.

The first interactive drawing program, called Sketchpad, was developed in 1962 by Ivan Sutherland at MIT[75]. This system enabled users to interact with simple wire-frame objects by manipulating 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-dimensional wire-frame objects.

The majority of technological developments were the result of government-funded academic research laboratories such as MIT's Lincoln Labs. During the 1950s and 1960s, relatively few commercial companies were involved in computer graphics research. Apart from certain big companies such as Boeing and General Motors, these were produced in large volume for semi-commercial, semi-military purposes. Flight simulations, Computer Aided Design and Manufacture (CADAM) systems, and Computerized Axial Tomography (CAT) scanners were among the pioneering computer graphics systems.

2.1.2 Initial Applications of Computer Graphics in CADAM

During the 1960s, CADAM systems were developed by various technology-intensive organizations.

One of the first CADAM systems was developed by General Motors. Other companies, including Boeing Aerospace, IBM, McDonnell Douglas, General Electric, and Lockheed, developed similar systems.

In the case of the Boeing Man, the computer system William Fetter used at the Boeing Aerospace was the IBM 7094, which was described as a '*large-scale scientific*' computer, which featured '*outstanding price/performance and expanded computing power*', allowing him to produce an extremely realistic human body model by the standards of contemporary technology. The IBM 7094 offered substantial increases in internal operating speeds and functional capacities and had 1.4 to 2.4 times the internal processing speed.[76] Furthermore, the combination of input/output improvements along with advanced programming systems reduced job time significantly for users. The programs which Fetter used were 'Subject Checkout and Manoeuver Simulation programs'.[77]

[75] Ivan Sutherland, *Sketchpad: A Man-Machine Graphical Communication System*, 1963

[76] See IBM website, IBM Archiv:7094 Data Processing System, available from: http://www-03.ibm.com/ibm/history/exhibits/mainframe/mainframe_PP7094.html, accessed 28.02.2011

[77] William A. Fetter, *Computer Graphics in Communication,* 1965, p. 50

The goal of these early CADAM systems like the system used by the Boeing Co. was to increase the effectiveness of the design process by offering users sophisticated design functions and improved manufacturing process organization through the linking of numerical data representing an image with other types of information, such as inventory and engineering analysis. In his book *Computer Graphics in Communication*, William Fetter described the superiority of CADAM systems to colour photography and mock-up methods in design:

Weighing the benefits of colour photography he stated that they provide 'a higher degree of realism plus credibility'. Disadvantages included 'the technical problems of controlling and recording precise angles, attitudes, dimensions, [and] safety problems… associated with [the] location [of] the camera exactly at the pilot's eye point.' There was also the problem of 'using only existing airplanes or expensive modifications of an aeroplane whose characteristics… differ from a proposed design.'[78]

Fetter admitted that mock-ups were capable of a realistic representation of the cockpit, however described them as 'relatively inflexible' with regard to designing and implementing 'rapid design changes' and also 'limited in the number of landing conditions that could be shown.'[79]

In contrast, he posited that computer graphics 'provided… accurate, economical representation[s]' and '[verifiable] maneuver data'. This allowed the introduction of 'variable flight paths', allowing the plotting and computer simulation of any flight landing to a military specification.[80] Another benefit Fetter noted was the reduction of 'the process of transposing orthographic views into true perspective illustrations… to a translation of the points of reference from orthographic drawings to punched cards which are fed into a computer.' He posited that this process 'provided [the engineer] with any desired projection or view of the object as a finished drawing'. This, he reasoned, gave the engineer greater freedom 'to select …projection types or views from one set of data describing a three-dimensional object. Pictures from this system [could then] be used in still, stereo, and motion-picture presentations'.[81]

Furthermore, with the aid of mechanical analogue plotting systems, Fetter and his colleagues did the experiment work to make animated films for visualizing pilot and cockpit configurations in aircraft design. Regarding output, Fetter utilized 'Automatic Drawing tests… made on Orthomat.' For the production run, the SC 4020 was employed and the image was 'placed directly onto 35-mm motion-picture film.'[82] Three-dimensional drawings were plotted on paper and filmed one at a time to produce animations of an aircraft-carrier landing.

[78] Ibid., p. 50

[79] Ibid., p. 50

[80] Ibid., p. 50

[81] Ibid., p. 5

[82] Ibid., p. 63.

The method was used to make stop-motion animation[83], an animation technique which creates the impression of movement in static objects. This is also one of the earliest computer-generated films.

William Fetter gave a further explanation of computer graphics:

> *Perhaps the best way to define computer graphics is to find out what it is not. It is not a machine. It is not a computer, nor a group of computer programs. It is not the know-how of a graphics design, a programmer, a writer, a motion picture specialist, or a reproduction specialist. Computer graphics is all of these - a consciously managed and documented technology directed toward communicating information accurately and descriptively.* [84]

Hence, Fetter's invention sparked the development of a range of computer-graphics techniques and processes applicable across the communications and entertainment industries.

2.2 Boeing Man vs. Vitruvius Man: Accurate Proportioning of the Human Model

2.2.1 Human Model in the Field of Ergonomics

The algorithmic human figure was one of the earliest images to be converted from data to picture form. William Fetter used his creation of the Boeing man in ergonomics applications.

The updated definition of ergonomics is given by the International Ergonomics Association as follows:

> *Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.* [85]

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[83] Stop motion is an animation technique which makes static objects appear to be moving. Stop motion requires a camera. It works by shooting a single frame, stopping the camera to move the object a little bit, and then shooting another frame. When the film runs continuously for more than 15 frames per second, the illusion of fluid motion is created and the objects appear to move by themselves. This is similar to the animation of cartoons, but with real objects instead of drawings.

[84] William A. Fetter, *Computer Graphics in Communication,* 1965, p. 5

[85] See International Ergonomics Association website, What is Ergonomics?, available from: http://iea.cc/, accessed 28.02.2011

But ergonomics can be traced back to Ancient Greece. The 5th-century BC Hellenic civilization was already in the habit of using ergonomic principles to design their tools, work processes, and workplaces. Later, the 19th century concept of 'Scientific Management' proposed methods to find the best way to execute given tasks. In the early 20th century, the School of 'Time and Motion Studies' proposed to improve efficiency by eliminating unnecessary steps and actions. The Second World War marked the development of new and complex machines and weaponry, which made new demands on operators' cognition. The decision-making, attention, situational awareness and hand-eye coordination of the machine's operator became critical in the success or failure of a task. For example, it was observed that fully functional aircraft, flown by the best-trained pilots, still crashed reflecting the inevitability of human error. In 1943, Alphonse Chapanis, a lieutenant in the U.S. Army, showed that this so-called 'pilot error' could be significantly reduced if the illogical and therefore confusing arrangement of controls in the aero-plane cockpit could be replaced with logical and easily-differentiated controls. [86]

In the decades following the war, ergonomics has continued to flourish and diversify with the recovering and rebuilding of the economy and society. The development of applications related to the improvement of quality of life gradually began to overwhelm mere functionality of everyday products. Product designs aimed not only to satisfy the function but also the safety, comfort, ease of use, aesthetics, balance of productivity and performance of products. Ergonomics developed into a recognizable, thoroughly-researched discipline.

The increased interest/ emphasis on the human figure model in ergonomic applications was related to the 1960s' Space Age, where new human-factor issues were introduced including weightlessness and extreme G-forces. These issues raised questions relating to how far environments in space could be tolerated and their likely effects on the mind and body.

Boeing Man was the production of this background. '*These figures were moved down the aisles of simulated commercial aircraft to predict passenger movement. This first stage culminated in the production of the 'First Man,' …*' and the model of this '*First Man*' was '*composed of seven movable segments that could be articulated at the pelvis, neck, shoulders, and elbows to approximate various pilot motions.'*[87] [*Fig 2.2*].

[86] Wikipedia, s.v. 'Ergonomics', available from: http://en.wikipedia.org/wiki/Ergonomics, accessed 28.02.2100

[87] William A. Fetter, A Progression of Human Figures Simulated by Computer Graphics, in *IEEE Computer Graphics and Applications*, Vol. 2, No. 9 (1982), p. 9

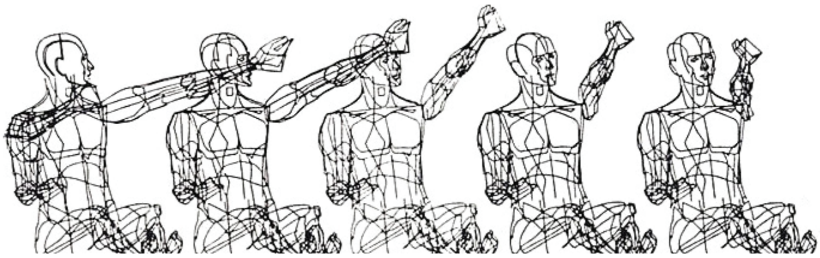

Fig. 2.2: Series movement of Boeing Man,1964.
(Source: Boeing Image Archive)

In this case, with the media of computer, 'movable' Boeing Man provides a more definitive, tangible landmark in the evolution of ergonomic concepts and applications relating to both the minimization of 'pilot error' and the improvement of aero-plane product design. Contemporary, ergonomics draws on many disciplines in its study of human beings and their environments, including anthropometry, biomechanics, mechanical engineering, industrial engineering, industrial design, architecture design, kinesiology, physiology and psychology, Hence the Boeing man model made a significant contribution to each of these fields of research as a key ergonomics application.

2.2.2 The Body Proportion Study and Representation of the Human Figure in Visual Arts

In the modeling process of the Boeing Man, the bodily proportions became very important, due to their effect on the application and precision of the final design. In fact, the continuous research of bodily proportions developed in the course of civilization was brought to bear in the creation of the Boeing Man. Throughout the history of visual art, the realization of ideal human proportions has fascinated artists. Around 1487, Leonardo da Vinci created one of the world's most renowned illustrations with accompanying notes in his journal: the *Vitruvian Man*. [*Fig 2.3*]

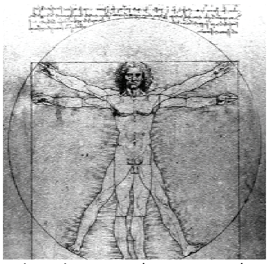

Fig. 2.3: *Vitruvian Man* by *Leonardo da Vinci*.
(Collection of Galleria dell' Accademia, Venice)

Leonardo based this drawing on the correlations between ideal human proportions and geometry suggested in the text of the ancient Roman architect Vitruvius'[88] *De architectura 3.1.3* which in translation reads:

> *The navel is naturally placed in the centre of the human body, and, if in a man lying with his face upward, and his hands and feet extended, from his navel as the centre, a circle be described, it will touch his fingers and toes. It is not alone by a circle, that the human body is thus circumscribed, as may be seen by placing it within a square. For measuring from the feet to the crown of the head, and then across the arms fully extended, we find the latter measure equal to the former; so that lines at right angles to each other, enclosing the figure, will form a square.* [89]

This image both exemplifies the blending of artistic and scientific concepts and disciplines characteristic of the Renaissance and Leonardo's own keen interest in proportion. In addition, this picture is a cornerstone in Leonardo's attempts to relate man to nature.

The drawing itself is often applied as a symbol of the essential symmetry of the human body, and by extension, the universe as a whole.

Renaissance artists became anatomists by necessity, thereby refining their sculptures and paintings into life-like portrayals of the human figure. Leonardo da Vinci and Michelangelo, both undertook detailed anatomical

[88] Marcus Vitruvius Pollio (born c. 80/70 BC; died after c. 15 BC) was a Roman writer, architect and engineer who authored *De architectura*, known today as *The Ten Books on Architecture*. This work is a treatise written in Latin and Greek on architecture. Vitruvius is famous for asserting that a structure must exhibit the three qualities of 'firmitas, utilitas, venustas' which can be translated as strength, utility and beauty. According to Vitruvius, architecture should imitate nature. As birds and bees built their nests, so humans constructed housing from natural materials that gave them shelter against the elements.

[89] Marcus Vitruvius Pollio, *Ten Books on Architecture*, originally written in Latin and Greek around 15 BC, available from: http://www.gutenberg.org/files/20239/20239-h/29239-h.htm#Page_72, accessed 28.02.2011

dissections at various stages in their careers, setting new standards in their portrayals of the human figure. Leonardo da Vinci in particular made precise observational drawings of both the human anatomy and nature.[90]

Between the years 1512 and 1523, the German artist Albrecht Duerer published a text demonstrating five alternative-construction types for both male and female figures where all the body-parts were expressed as fractions of the total height. Duerer based these constructions on both the theory of Vitruvius and the empirical observations of 'two to three hundred living persons'. He wrote altogether four books expounding the principles of bodily proportions and the theory of movement. Nonetheless, Duerer maintained his belief that rules of geometrical body proportioning governed beauty, even though he found it difficult to define their criteria.

Although the discoveries resulting from exploratory voyages, archaeological and anthropological research indicated significant variation in human being's anatomical proportions, there remained many pre-conceived conjectural references to bodily proportions accepted in art, measurement and medicine.

In Western traditional art, the study of body proportions comprised the study of the body parts as related to each other and the human or animal body as a whole. The ratios of these various elements were used in veritable depictions of the figure, and became part of a canon of aesthetic reference within Western culture. For example, for those working without visual reference (or as a means of checking one's work), proportions commonly recommended in figure drawing are:

> *An average person is generally 7-and-a-half heads tall (including the head). This can be illustrated to students in the classroom using paper plates to visually demonstrate the length of their bodies.*
>
> *An ideal figure, used for an impression of nobility or grace, is drawn at 8 heads tall.*
>
> *A heroic figure used in the depiction of gods and superheroes is eight-and-a-half heads tall. Most of the additional length comes from a bigger chest and longer legs.* [91]

Although when placed in its historical context, the figure of the Boeing Man pilot personified the strong heroic qualities associated with the age of the 'Space Race', when humanity's space odyssey expanded further into outer space, astronauts and pilots became heroes of the era. In this era, heroes were to be recreated in a more accurate way than those described in the above canons used in visual art.

[90] Carmen Bambach, Anatomy in the Renaissance, available from: http://www.metmuseum.org/toah/hd/anat/hd_anat.htm. Accessed 28.02. 2011

[91] Wikipedia, s.v. 'Figure Drawing', available from: http://en.wikipedia.org/wiki/Figure_drawing, accessed 28.02.2011,

2.2.3 The Anthropometric Human Model

With the aim of simulating the human figure '*which as a description of the human body is accurate*', the Boeing Man was modeled by Fetter as below:

> *Anthropometric data already encoded in the original figure representing the average-sized American male, was digitized and mathematically-transformed to smaller or larger figures.*[92]

The measurement method and quantity of collected data directly affected the applicability and precision of the body modeling and relation to ergonomic applications.

For example, in his text *Identification anthropométrique*, published in 1893, Bertillon applied a system of measuring body parts to a human identification system. Today, besides the hand-measurement method, a laser-based, overall-body measuring system has been developed to collect data quickly and methodically.

Throughout early 20th-century history, anthropologists in the United States and Europe applied anthropometry to differentiate between races of man. Anthropometry was used to advocate policies of eugenics, and in the 2nd World War, to distinguish between Aryans and Jews. In post-war years, anthropometric approaches to issues of this nature were abandoned.

Today, the study and application of anthropometry plays a leading role in industrial design, clothing design, ergonomics and architecture where statistical data relating to the distribution of body dimensions in the population is used to optimize products. (Furthermore, changes in lifestyles, nutrition and ethnic composition of populations has lead to changes in the distribution of body dimensions e.g., the obesity epidemic). Anthropometric data collections require regular updating as the human body modeling technology alters with changing societies is applied to new concepts, designs and situations.

The demonstration popularized the findings of an ongoing survey known as CAESAR (The Civilian American and European Surface Anthropometry Resource).[93] Administered by the Society of Automotive Engineers (SAE), CAESAR was the first international anthropometric survey to use a whole body scanner for data collection. As a result, the project revised current human measurement databases with detailed, high-resolution measurements of the body's surface.

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[92] William A. Fetter, A Progression of Human Figures Simulated by Computer Graphics, in *IEEE Computer Graphics and Applications*, Vol. 2, No. 9 (1982), p. 9

[93] David J. Bak, Beyond Animation, in *Automotive Industries* March 2000, available from: http://findarticles.com/p/articles/mi_m3012/is_3_180/ai_61361680, accessed 15.07.2010.

These aims designated the future evolution of the algorithmic human. In fact, successors of the Boeing Man became active not only in the design of aeroplane cockpits, but across a range of design realms, including product design, architectural design, furniture design and human-computer interaction design.

Indeed, the present-day adoption of anthropometric human modeling in automotive design, allows the simulation of occupant-motion associated with tasks such as foot-pedal operation, gear-shifting and control-panel access, improvements in driver-positioning and safety, as well as interior layouts. This concept promises both to shorten vehicle design cycles and lower development costs, and will have an impact on the vehicle design process.

For the 1960s' Boeing Man, the movement generated was limited. However, the current capability of whole-body-scan systems facilitated the input of the anthropometric human model data into special software designed to generate algorithmic human models. Hence, the successors of the Boeing Man are progressively becoming part of sophisticated CAD software and systems.

Using specific software, these algorithmic humans are inserted into digital environments, in order to evaluate the ergonomics of the design before costly prototypes are built. This software further enables industrial designers and engineers to manipulate interactively the algorithmic human. The capabilities include scaling humans using validated population databases, predicting occupant postures based on user-defined tasks, defining the maximum reach capacity for any given person, calculating movements needed for certain tasks and performing real-time visual simulations.

Finally, certain sophisticated software packages have built-in algorithms, designed to analyze occupant comfort, field of vision and safety restraint routing, and to verify the design's adherence to pertinent global standards.[94]

2.3 Crossing from Concept to Image and Data to Line: Visualization

2.3.1 Transformation from Invisible Data to Visible Image

William Fetter tried to use the Boeing Co.'s updated CAAD system not only to represent the silhouette of Boeing Man, but also the block and shadow, like any of the artists working with figure drawing in art .

[94] Ibid.

Fetter described his work as a '12-point silhouette with the lines representing 2D edges only, when viewed from the flight path. However, 30 points connected by straight lines defined the figure in block form, and the lines represented the right-angle block edges.' 'The lines now represented surface traces of the minimum radian illustrator's economical technique of letting a single line represent the likely demarcation of shadow.'[95]

The discipline of figure-drawing comprises drawing the human body in its various shapes and positions. Life-drawing refers to the process of drawing the human figure from observations of a live model. Figure-drawing is one of the most difficult subjects an artist encounters.

In developing the image, some artists focus on the shapes created by the interplay of light and dark values on the surface of the body. Others take an anatomical approach, beginning by approximating the internal skeleton of the figure, overlaying the internal organs and musculature, and covering those shapes with the skin, and finally (if applicable) clothing. The study of the human internal anatomy is usually involved in this technique. Another approach is to loosely construct the body out of geometric shapes, for example, a sphere for the cranium or a cylinder for the torso, then to refine those shapes until they more closely resemble the human form.

For artists, pencil and paper as media to make drawings are easily available, but for such computer graphics pioneers as Fetter, accessing the media to design the computer-aided generation of such images as the Boeing Man was not so simple because of the difficulties in obtaining the necessary technology and algorithms of transformation from invisible data to visible image.

However, as the development of hardware accelerated from the mid-1960s onwards, many algorithms related to computer graphics were developed.

In 1965, Jack Bresenham developed an efficient algorithm to scan convert lines. Bresenham's line algorithm is one of the earliest algorithms in computer graphics and employs a highly-efficient incremental method in the scanning process. It produces mathematically-accurate results using only integer addition, subtraction and multiplication by 2, accomplishable through a simple arithmetic shift operation.

Whilst in the image of the Boeing Man, the lines defining the backside of the three-dimensional structure could not be hidden successfully due to the rudimentary Scan-Line Algorithm, with the advent of the Scan-line HSR (Hidden Surface Removal) algorithm in 1967, developed by Wylie, Romney, Evans, and Erdahl, the lines representing the hidden surfaces behind the three-dimensional image on the computer screen could be effectively removed. When working in three dimensions, the chief concern is whether objects are obscured by other objects. Most objects are opaque, thus obscuring the objects behind them.

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[95] William A. Fetter, A Progression of Human Figures Simulated by Computer Graphics, in *IEEE Computer Graphics and Applications*, Vol. 2, No. 9 (1982), p. 9

1968 saw the first computer graphics implementation of ray tracing, developed by Appel (IBM). Ray tracing can be defined as an algorithm used to render an image in three dimensions by the application of light rays to emphasize areas of shadow and light. Ray tracing technology at its beginning was slow and inaccurate. However, further research into the algorithm throughout the next two decades resulted in increasingly more realistic and widely applicable images.

Finally, in 1969, Warnock developed the area subdivision algorithm. Simultaneously as a rendering algorithm and a HSR (Hidden Surface Removal) algorithm, the area subdivision algorithm facilitated the subdivision of the screen area recursively rendering the visible surface easily determinable.

2.3.2 Pure Academic Research to Multi-disciplinary Experimentation

Another feature in the development of computer graphics was the combination of technology and art. Computer graphics is thus the material basis for the algorithmic figure.

As Fetter postulated, from its inception, computer graphics technology modulated between graphic art and computer methodology, between the development and manipulation of data and pictures. The aim of the discipline was to combine these elements, to convert data into images and images into data. The conditions necessary for this aim to be realized were born firstly of the necessity of military advancement and later of the development of artistic and scientific collaborations. From the beginning onwards, computer graphics moved from pure academic research into multi-disciplinary experimentation and thus towards artistic and technological collaborations.

Bell Labs became a leading research centre for this new technology. They operated under the philosophy that technological innovation could be found through artistic vision. Hence, Max Mathews,[96] one of the fathers of computer-generated music, opened Bell Labs' doors to artists to experiment with new technology. Simultaneously, Billy Klüver[97] led scientists to leave the laboratory and enter the artist's studio. This presented the beginnings of a multi-disciplinary approach especially between computer science and art.

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[96] Max Mathews was born in 1926 to become a pioneer of computer music, and went on to direct the Acoustical and Behavioural Research Center at Bell Laboratories from 1962 to 1985. This laboratory carried out research into speech communication, visual communication, human memory and learning, programmed instruction, analysis of subjective opinions, physical acoustics, and industrial robotics. Mr. Mathews' personal research is concerned with sound and music synthesis with digital computers and with the application of computers to areas in which man-machine interactions are critical. He developed a program (Music V) for direct digital synthesis of sounds and another program (Groove) for computer control of a sound synthesizer. Music V and its successors are now widely used in the United States and Europe. His past research included the development of computer methods for speech processing, studies of human speech production, studies of auditory masking, as well as the invention of techniques for computer drawing of typography. He is currently investigating the effect of resonances on sound quality.

[97] Billy Klüver (1927-2004), a Swede, studied electrical engineering in Stockholm and moved to the United States in 1954. Klüver collaborated with the Swiss sculptor Jean Tinguely in the creation of his self-destructing sculpture *Homage to New York*, which was exhibited in 1960 in the

A direct result of this was the collaboration of a group of artists around Robert Rauschenberg[98] with Bell Labs engineers, led by Billy Klüver. They performed the *9 Evenings of Theatre and Engineering* at Armory Hall in New York in November, 1966. The contributors were John Cage[99], Lucinda Childs, Merce Cunningham, Öyvind Fahlström, Alex Hay, Deborah Hay, Steve Paxton, Robert Rauschenberg, David Tudor, and Robert Whitman. The ninth evening's performances were witnessed by an audience of 10,000 people.[100]

In view of the impact of this festival, *9 Evenings of Theatre and Engineering* ranks among the milestones of media art, and made history as one of the United States' first formal collaborations between artists and engineers to support artistic creation.

In 1967, following the event, artists Billy Klüver and Robert Rauschenberg founded an organization to '*develop an effective collaboration between the artist and the engineer*.' This organization recognized the interrelationship between the artist and the computer. Named E.A.T, or *Experiments in Art and Technology*, it provided an environment encouraging artistic creation, and led to collaborations between Billy Klüver and his engineers and artists such as Andy Warhol, Rauschenberg, John Cage, and Jasper Johns.[101] Support was in part provided by Bell Labs.

William Fetter was also one of the organizers of the Northwest chapters of E.A.T., which were founded in 1968 in Seattle and Portland.

His participation in the E.A.T strengthened William Fetter's belief in the artistic and scientific potential of computer graphics. This inspired him to continue his work combining graphic art with computer methodology. In

gardens of the New York Museum of Modern Art. In 1966, he collaborated with Robert Rauschenberg and took part in the event *9 Evenings of Theatre and Engineering*.Together They founded Experiments in Art and Technology (E.A.T.).

[98] Robert Rauschenberg (b. 1925) is a painter, sculptor, and graphic artist celebrated for redefining American art in the 1950s and 1960s, providing an alternative to the then dominant aesthetic of Abstract Expressionism.

[99] John Milton Cage (1912 –1992) was an experimental music composer and writer, possibly best known for his highly contemporary piece 4'33', in which the performer sits at a piano for four and a half minutes without playing a note. He was an early writer of what he called chance music (and what others have decided to label aleatoric music)—music where some elements in the music are left to be decided by chance; he is also well known for his non-standard use of instruments and his pioneering exploration of electronic music.

[100] See medienkunstnetz.de website, 9 Evenings of Theatre and Engineer, available from: http://www.medienkunstnetz.de/exhibitions/9evenings/, accessed 28.02.2011

[101] Jasper Johns, Jr. (born 1930) is an American artist. He is best known for his painting Flag (1954). His work is often described as 'Neo-Dadaist', as opposed to Pop Art, even though his subject matter often includes images and objects from popular culture. Early works were composed using simple schemas such as flags, maps, targets, letters and numbers. Johns' treatment of the surface is often lush and painterly; he is famous for incorporating such media as encaustic (wax-based paint), and plaster relief in his paintings. The contrast between the graphical symbolic subject matter and the loosely handled surface raises the question of whether a painting can be what it depicts. Johns also produces sculptures and lithographs with similar motifs.

fact, following the creation of the Boeing Man, he also created the Second Man, the Third Man and the Woman.[102]

Although the Boeing Man was the first computer-generated man, he was not the first computer-generated image.

In 1950, Ben Laposky[103] created the first electronic oscilloscope imagery by manipulating electronic beams displayed across the fluorescent face of an oscilloscope's cathode-ray tube and then recorded onto high-speed film. He called his oscillographic artworks 'oscillons' and 'electronic abstractions'. Some pioneers also experimented with the aesthetic potential of computers.

The first three exhibitions of computer art were held in 1965; Georg Nees at Studiengalerie TH Stuttgart in February, A. Michael Noll and Bela Julesz at Howard Wise Gallery, New York in April, and Frieder Nake at Galerie Wendelin Niedlich in Stuttgart with Geoges Nees in November respectively.

Besides the Boeing Man's appearance in 1965, another famous early example of the human face on the computer screen was the *Sine Curve Man*[104] by Charles Csuri [105] and James Shaffer. They successfully represented the human face through the combination of sine curves.

In 1968, the Institute of Contemporary Arts (ICA) in London hosted one of the most influential early exhibitions of computer art, entitled *Cybernetic Serendipity*. Organized by Jasia Reichart, it showcased the technology-art world's key contributors; Nam June Paik, Frieder Nake, Leslie Mezei, Georg Nees, A. Michael Noll, John Whitney, and Charles Csuri. This exhibition heightened interest in computer-art globally and especially computer graphics. Although it was not the first computer art exhibition, it is acknowledged as an important milestone in the recognition of this new medium in the art world.

As the first exhibition of its kind in Britain, the curator Jasia Reichardt wrote that it showed how '*man can use the computer and new technology to extend his creativity and inventiveness*.'

The following year, the Computer Arts Society was founded, also in London.

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[102] William A. Fetter, A Progression of Human Figures Simulated by Computer Graphics, in *IEEE Computer Graphics and Applications*, Vol. 2, No. 9 (1982), p. 13

[103] Ben F. Laposky was born in the USA in 1914 to become a mathematician and artist, one of the earliest computer art innovators.

[104] A digitized line drawing of a man was used as the input figure to a computer program which applied a mathematical function. The X value remained constant and a sine curve function was applied to the Y value. Given the X and Y coordinates for each point, the figure was plotted by the computer from X′ = X, Y′ = C* SIN (X)+Y where C is increased for each successive image. (Charles Csuri and James Shaffer, Art, computers and mathematics. AFIPS Conference Proceedings, Vol.33, Thompson Book Company,1968)

[105] Charles A. Csuri is an artist and computer graphics pioneer and professor of the Ohio State University.

Alongside this advance, early attempts to create computer-generated films took place in several research institutions. The first computer-animated film was entitled *Two-Gyro Gravity-Gradient Attitude Control System* (1961) by Edward Zajak of the Bell Laboratory. Besides the research in Boeing, at Bell Laboratories, Michael Noll[106] and Bela Julesz[107] produced various stereo computer animations on film to aid in the study of stereo perception.

One of the earliest experiments in computer-generated character animation was 'Mr. Computer Image ABC', created in 1962 by Lee Harrison III with the Scanimate system at Computer Image Corporation (CIC).

As Fetter described, the rich combination of artistic and technological interactions and computer hardware had 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 due to several factors.

By the mid-1960s, most individuals involved in the creation of computer art were in fact engineers and scientists, because only these persons had access to the mainframe computers, the only computing resource available at that time, at industrial and university scientific research labs. Although most of them lacked formal and systematic training in fine art,

> *In many cases, the scientists themselves were portrayed as, or at least called themselves artists. Because many of them displayed a strong artistic intention and a significant degree of aesthetic consciousness.*[108]

Likewise, for pioneers with an artistic background, who held a general artistic interest in the potentials for technology, there was no real interactive software; artists either learned to program computers by necessity - or else found a suitable mainframe site and persuaded programmers to implement their ideas. Moreover the artistic community was reluctant to accept the new art form. Throughout the 1960s, the computer remained– in the opinion of most visual artists, critics and spectators – too cold and technical to be utilized in the process of artistic creation.

This attitude can be compared to the prejudices arising in the 19th century with the advent of machine technology utilized on a massive scale in industry. Machines subsequently became commonplace additions to eve-

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[106] A. Michael Noll is a professor at the Annenberg School for Communication at the University of Southern California. He has published over ninety professional papers, has been granted six patents, and is the author of ten books on various aspects of telecommunications. He is one of the earliest pioneers in the use of digital computers in the visual arts.

[107] Bela Julesz (1928 -2003) was a visual neuroscientist and experimental psychologist in the fields of visual and auditory perception. He was the originator of the random-dot stereo-image technique which lead to the creation of the auto-stereogram. He also was the first to study texture discrimination by constraining second-order statistics.

[108] Herbert W. Franke, *Computer Graphics-Computer Art*, 1971, p. 104-105

ryday life and finally necessities. Many turn-of-the century painters feared the new technology until they had learned how to use it as a creative tool. 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-19th 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'.

The difference in mindsets between these two groups presented obstacles. Ken Knowlton described the scientific and artistic mindset as wholly contradictory stating that artists were 'illogical, intuitive and impulsive' whereas scientists were 'constrained , logical and precise.' [109]

Despite these limitations, the flourishing of collaborations between artists and scientists became inevitable. The pioneers made effective use of available technology. Some images were initially created for purely scientific purposes, or presented crude imitations of paintings. However, they set a precedent for the potential of algorithmic aesthetics and hastened the development of its applications. They also increased the 'realism' of computer-generated pictures. Their striking works can be regarded as key developments in the context of computer art.[110]

[109] Ibid.

[110] Frank Dietrich, Visual Intelligence: The First Decade of Computer Art (1965-1975), in *Leonardo* Vol. 19, No.2 (1986): 159-169

3 MAPPING AND SHADING ADAM POWERS: THE REALITY OF PORTRAIT

Fig. 3.1: An image of Adam Powers playing the three basic geometric solids in the 3D computer graphics: cube, sphere and cone. (Source: still image from the Information International, Inc.'s video demo *Adam Powers, the Juggler* in 1981)

We might….wish to model a human body to the extent that a close-up view of the eye shows the patterns of the iris, yet such a fine description of the entire body will indeed require large amounts of storage.

-- James H. Clark,
Hierarchical Geometric Models for Visible Models for Visible Surface Algorithms,
in *Communications of the ACM* Vol. 19, No.10 (1976), p. 4

3.1 1970s: Assembling 3D Computer Graphics Infrastructure

3.1.1 Development of Computer Technology in the 1970s

Although the first algorithmic human figure Boeing Man was already born in the middle of 1960s, the image of Boeing Man was only presented with very limited quantity of lines and without any color or shadow. This image is far away from any realistic figurative image in the history. Just as James Clark complained, '*such a fine description of the entire body will indeed require large amounts of storage*.' [111] In 1970s, many obstacles in computer science, such as the storage, must be solved; otherwise the first step of algorithmic human figure towards 'realism' could not be realized.

Following what became known as the 'swinging' 1960s in the West, the 1970's mood shifted its focus from social activism to social activities, recreation and pleasure. In the developing world, this reflected the rise of a new middle class. Following the 1960's boom, the 1970's economic growth rates decreased. Society's overall ethos became increasingly conservative and pragmatic. The increased value placed on practical applications lead to significant achievements in the field of computer graphics which impacted on a range of disciplines. The 1970's development of computer systems has three key characteristics in line with the overall ethos of the decade.

Firstly, whilst some mainframe computers were still used during the decade, the 1970s saw the birth of modern computing. Computers became smaller and more integrated. The world's first general microprocessor (an integrated circuit semiconductor chip that performs the bulk of the processing and controls the parts of a system)- the Intel 4004, became available in November 1971. The first 8-part frame buffer was built with a color map in 1972 by Richard Shoup, Xerox PARC. Evans and Sutherland started marketing the frame buffers in 1973-74. With large-scale integration possible for integrated circuits (microchips) rudimentary personal computers came into production along with pocket calculators. In 1976, Cray Research Inc. introduced the first supercomputer, the Cray-1, which could perform operations at a rate of 240,000,000 calculations per second. Supercomputers designed by Cray continued to dominate the market throughout the 1970's. The majority of the research and production work achieved during this decade was based on mini-computers.

The notable home computers released in the era were the Apple II, the TRS-80, the Commodore PET, the Atari 400/800 and the NEC PC-8801 in Japan. The availability of affordable personal computers led to the first popular wave of internet working with the first bulletin board systems.

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[111] James H. Clark, Hierarchical Geometric Models for Visible Models for Visible Surface Algorithms, in *Communications of the ACM,* Vol. 19, No.10 (1976), p. 4

The standard configuration of an early 1970s microcomputer included an 8-bit CPU (Central Processing Unit) without any graphics co-processors, less than 100KB of main memory (RAM), a clock speed of 10 MHz, and a limited amount of peripheral storage. Besides this, there was a low-resolution screen with a maximum palette of 8 colors (or slightly higher if dithering was used). Compared with their high-end counterparts today, the 1970's microcomputer's 8-bit computing power, memory capabilities and output solution was insignificant.

These achievements made not only those organizations controlled by the government or the very big manufacture companies, but more researchers, scientist and enterprises, even students could devote themselves into the development of computer science and technology.

Secondly, compared with the development of computer hardware, especially with the invention and marketing of the microcomputer, it is evident that the development of software was delayed.

In the mid-1960s, the appearance of large capacity, high speed computers rapidly expanded the scope of computer applications. Complex, large-scale software components were developed, but, the progress of software development technology could not satisfy requirements. The most notable effects were that projected budgets were often over-stepped, completion times were repeatedly delayed, software did not satisfy user requirements, and maintenance and reliability of software was poor.

The original individual design and the individual form of application no longer satisfied requirements. There was an urgent need to improve software production methods in order to enhance the software productivity. Hence, accumulation of unresolved difficulties exposed in the stages of the software development formed an incisive contradiction and caused the software crisis.

In 1968 the North Atlantic Treaty Organization's computer scientists held an international conference in the Federal Republic of Germany. This became the setting for the first discussion of the software crisis and led to coining of the term '*software engineering*'. Following the conference, software engineering became a recognized discipline, emerging in time to provide the research necessary to confront and conquer the software crisis.

In 1970, the first structured programming language emerged. *Pascal*, came to symbolize the beginning of the structured programming methodology's development. UCSD Pascal was written by a group of programmers led by Kenneth Bowles and provided the first version for micro-computers. It compiled programs in P-code that were portable and interpreted (as Java later). This included a complete development environment, a principle used successfully further by Turbo Pascal. In 1981, a role-playing game written in Pascal, Wizardry, became a great success on the Apple II computer system. When Turbo Pascal (by Anders Hejlsberg) appeared in 1983, its high speed and complete IDE (Intergrated Development Environment) led to the success of the language and its wide application.

Barry Boehm, an American software engineer, believed that software, rather than hardware, was the 'big business' [112] of the future. Illustrations from his 1972 publication, Software and its Impact- A Quantitative Assessment, describe relative costs of software vs. hardware for typical systems from 1965-1985. As soon as this illustration was published, it became popular and wide-spread, inspiring members of the younger generation, including Bill Gates, to invest their energy in the business of supplying programming languages for personal computers. *Microsoft* was founded by Bill Gates and Paul Allen in 1975.

Besides, due to the economy and popular mood throughout the 1970s, collaborations were not as frequent or innovative as those of the 1960s. However, they still existed. Amongst these, the research by Xerox Palo Alto Research Center (*PARC*) into combined software applications occupied a key position and made a deep impression on production history. *Xerox PARC* 'gathered together a team of world-class researchers in both the information and physical sciences and [gave] them the mission to create 'the architecture of information'[113]. This finally lead to important developments including laser printing and the *Ethernet*, especially the modern personal computer graphical user interface (*GUI*), which allowed users to experience a new human-computer relationship; 'What-You-See-Is-What-You-Get' (*WYSIWYG*).

Although much of the work *Xerox Parc* was not directly applicable to commercial projects, many of the ideas which the centre initiated were either directly or indirectly applicable to the subsequent developments in the field of computer graphics, e.g. the birth of the *Apple System* and the birth of the computer graphics software company, *Adobe* etc.

3.1.2 3D Computer Graphics: Key Points

When we move to investigate the development of computer graphics, we could say that computer graphics really emerged in the 1960s but in the 1970s saw a considerable breakthrough. An image *Fig. 3.2* named digital Utopia was placed on the cover of Byte Magazine's January, 1977 edition. Within this image, outside the window is revealed an urban scene of sky scrapers, as well as a polluted atmosphere brought about by heavy industrialization. The 1970s' atmosphere is dull and grey. Inside the window, found on the table is a radio and a computer. On the computer screen, one can see a clear and boundless sky in the midst of the green countryside. The computer has a keyboard but at the same time, this soft-disk as well as the data tape is placed on the desktop. This numerical image of Utopia described the 1970s future vision of computer graphics.

[112] Barry Boehm, Software and its Impact--A Quantitative Assessment, in *Datamation*, Dec 1972.

[113] See Xerox Parc website, Milestones, available from: http://www.parc.com/about/history/, accessed 28.02. 2011

Fig. 3.2: The cover of *Byte* magazine, Vol. 2, No. 1, Jan. 1977.
(Source: Paul C. Ceruzzi, *A History of Modern Computing,* 2000, p. 310)

In the 1970s, researchers worked constantly to develop solutions to the questions raised in the 1960s; how to detect the back surface, how to remove hidden surfaces, and how to make the polygon surface look smoother. At the same time, integrated circuit technology and raster display began to develop and the possibility of realistic representation emerged in the field of computer graphics. Research interests shifted towards the production of very realistic, shaded, color pictures of the visible parts of complex three-dimensional objects. [114]

Although in 1964, William Fetter attempted to represent the block and shadow of the Boeing Man's figure, the results were unsatisfactory; revealing discontinuous, rough, dithering lines. However, the 1970s brought a new wave of computer science expertise. Under financial pressure, experts devoted time to the development of computer graphics infrastructure. These efforts led to breakthroughs of computer graphics in monochrome to color, from plate-shading to shading with light and shadow, and from abstract lines to images. In fact, many basic concepts and methods which are still in use today were established in the 1970s. But the realization of these aims depended on the development of the whole computer system in the 1970s, incorporating software as well as hardware.

The 1960s saw the budding of computer graphics, but the 1970s saw the basic establishment of the development of 3D computer graphics. Several research institutions in the USA, Canada, Europe and Japan became responsible for the subsequent development and cultivation of the talented computer animators of the future.

The University of Utah became the cradle of 3D computer graphics. In 1970, the newly instated leader of the Department of Computer Science, Sutherland, chose to focus on a specific domain of computer science in response to financial pressure. He transformed the budding computer science department into a computer

[114] James H. Clark, Hierarchical Geometric Models for Visible Models for Visible Surface Algorithms, in *Communications of the ACM* Vol. 19, No.10 (1976), p. 553

graphics research institute.[115] Throughout the 1970s, the University of Utah was a primordial force and a centre of innovation in the research of three-dimensional computer graphics. Under the guidance of David Evans, co-founder of *Evans & Sutherland*, the Department of Computer Sciences at *the University of Utah* produced a distinguished roster of Ph.D. students.

Despite limited equipment, students worked arduously to find solutions for problems of shapes and objects. Newell, Catmull, Blinn, Gouraud, Phong, Warnock, and Clark, all of them significant contributors to the development of computer graphics, studied at *the University of Utah* in the 1970s.

> *In the early 1970s, computer animation in university research labs became more widespread. Computer graphics, as well as computer animation, received an important impetus through government funding at the University of Utah. As a result, Utah produced several groundbreaking works in animation: an animated hand and face by Ed Catmull (Hand/Face, 1972); a walking and talking human figure by Barry Wessler (Not Just Reality, 1973); a talking face by Fred Parke (Talking Face, 1974). Although the imagery was extremely primitive by today's standards, the presentations of lip-synched facial animation and linked figure animation were impressive demonstrations well ahead of their time.*[116] [*Fig.3.3*]

Fig. 3.3: (from right to left) the hand animation by Ed Catmull in 1972,
and face animation by Fred Parke in 1974
(Source: Isaac Victor Kerlow, *The Art of 3D Computer Animation and Affects,* 2004, p. 9)

Based on his own computer graphics research work as well as the academic talent that he fostered, Sutherland is now known as the father of computer graphics.

Several research centers invested significant resources in the production of in-house short films. Government-sponsored research centers also developed pioneering simulation techniques.

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[115] Dmitry Shklyar, 3D Rendering History: Humble Beginnings' CGSociety, available from:
http://features.cgsociety.org/story_custom.php?story_id=1647, accessed 28.02.2011

[116] Rick Parent, *Computer animation: algorithms and techniques,* 2002, p. 22

Aside from the afore-mentioned *Xerox Parc* and *Utah*, notable institutions included the New York Institute of Technology (*NYIT*). In 1974, *NYIT* situated 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.

The initial work of *NYIT* was focused on 2D animation, specifically creating tools to assist traditional animators. A scan-and-paint system was developed to scan and then paint pencil-drawn artwork. Next the *NYIT* group branched into 3D computer graphics for motion picture production. A film called the Works became *NYIT*'s major project for over two years. Significant time and money was invested in creating 3D models and rending test animation.

Later in the 1970s, a further laboratory, the Computer Graphics Laboratory, located at *NYIT*, commenced the production of a short high-quality feature with the project name, *The Works*. This was never completed despite the investment of millions of dollars. It was to be the first entirely computer-generated film. Production mainly focused around DEC PDP and VAX machines.

In the mid-1970s, Norman Badler at *the University of Pennsylvania* conducted investigations into posing a human figure. He developed a constraint system to move the figure from one pose to another. Continuing this research, he established *the Center for Human Modeling and Simulation*. Jack is a software package developed at the center that supports the positioning and animation of anthropometrically valid human figures in a virtual world.

Some of the other leading academic centers involved in computer graphics research during this period included:[117]

Name of Institution	Research Focus in 3D Computer Graphics in the1970s
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
The Ohio State University	Hierarchical character animation, and inverse kinematics
The University of Toronto	Procedural techniques
The University of Montreal	Character animation and lip syncing
New York University	Procedural textures
The University of Tokyo	Blobby surfaces modeling techniques
The University of Hiroshima	Radiosity and lighting
New York Institute of Technology	Facial animation

[117] Isaac Victor Kerlow, *The Art of 3D Computer Animation and Effects*, 2004, p. 10

Many of the original computer graphics teams now formed the elite in this field. And the members of these teams went on to Silicon Graphics, Microsoft, Cisco, NVIDIA and others, including Pixar President Ed Catmull, Pixar co-founder and Microsoft Graphics Fellow Alvy Ray Smith, Pixar co-founder Ralph Guggenheim, *Walt Disney Feature Animation* chief scientist Lance Joseph Williams, *Dreamworks* animator Hank Grebe, Netscape and Silicon Graphics founder James H. Clark, Microsoft Graphics fellow Jim Blinn, Thad Beier, Andrew Glassner and Tom Brigham. Systems programmer Bruce Perens went on to co-found the Open Source initiative.

In addition there were several new companies which developed in the 1970s. The commercial work done for advertising agencies at Digital Effects, I.I.I., MAGI, and Robert Abel and Associate is illustrative of computer animation in the later 1970s. These companies were active until the mid-1980s and then spawned other companies that continued their innovation. [118]

3.2 Early Attempts at Realistic Algorithms for CGIs

3.2.1 Background and Technical Conditions to Production of the First Realistic Algorithmic Human Figure

Following the 1960s' Boeing Man, no new integrated algorithmic human figure was presented until the 1980s. Whilst the start of the decade saw significant leaps forward in computer graphics, the infrastructure built up in the 1970s was equally vital to the figure's development as it initiated basic concepts and methods particularly integral to 3D computer graphics. In 1981, the first realistic algorithmic figure was displayed in public for the first time at the Electronic Theatre of SIGGRAPH.

On the computer screen, following a period of blackness, the audience saw a man appear inversely. With a combination of panning, zooming and 180-degree camera rotation, this man wearing a black tuxedo and top hat, standing on a checkerboard grid ground could be clearly seen juggling a three-dimensional cube, cone, and sphere. Finally, this man, named Adam Powers, did a back flip and disappeared mysteriously into his top hat, which fell to the grid ground and gently rocked to a stop.

With the exception of the face, which was stiff and puppet-like, the performance of Adam Powers exceeded the expectation of the audience to the computer generated animation. SIGGRAPH, the host of the first Adam Powers screening, was founded as the Special Interest Group on Computer Graphics in 1967. In 1969, it became the Association for Computer Machinery's S.I.G on C.G. Since 1974, SIGGRAPH has held a regular annual meeting encouraging participants to exchange, explore and push forward Computer Graphics research in

[118] Digital effects was active from 1978 until the mid-1980s, I.I.I. open in 1974 and closed in 1982, MAGI was active between 1972 and 1987, and Robert Abel and Associated started in 1971 and closed in 1986

science, art, trade, education, engineering, entertainment and various other fields. The 1981 SIGGRAPH conference set the precedent for the use of the electronic theatre to show the world's most outstanding contributions to the field of computer animation. This tradition has continued to this day, and the electronic theatre has become one of the most attractive events of the annual SIGGRAPH conference.[119]

The film was produced by a company named *Information International Inc (*I.I.I.*)* or *Triple I*, founded in 1962, in order to create digital scanners and other image-processing equipment, similar to the majority of 1960's companies of the computer industry, which chose to focus on the market for hardware and equipment. Information International established the standard for high-quality graphics recording on microfilm.

However, in 1974, along with the increase in the need for computer software and applications on the market, as well as its relatively low development costs in comparison to hardware, I.I.I adjusted its development orientation. Information International work in graphics was founded as Motion Pictures Product Group by John Whitney Jr. and Demos with Art Durinski, Tom McMahon, and Karol Brandt. The aim of this work was digital scene simulation and the achievement of high-quality, smooth-shaded motion pictures for the scientific and entertainment markets.

Approximately $3 million worth of equipment for the image-processing system for colour-graphics recordings was used by Information International. This included PDP-10s control computer, the famed Foonley F1 (a modified DEC 10), a proprietary 1000-line frame buffer, and a proprietary FR-80 film recorder and PFR-3 programmable film reader. There was also periphery input equipment such as two cursor data tablets and display monitors.

Software included the TRANEW, a film-making program developed by Jim Blinn, Frank Crow, et al, which was written with Fortran and ran on the Foonley. Animation was described using ASAS (Actor/Scriptor Animation System) developed by Craig Reynolds. Modeling was done on the Tektronix 4014 display using software developed by Larry Malone.

An in-house report of I.I.I stated that 'the film making process consists of two steps. Firstly, the artist or programmer defines the objects appearing in the film and their motion. Secondly, this information is relayed to TRANEW, which computes the film-frames and either displays the result or records the output on film. Most of the work involves going through this process repeatedly, and revising the input until the film looks right.'[120] Altogether, the process incorporated three input DATA methods. To describe a regular object, algorithms, or mathematical descriptions, were used. However, the majority of data of the objects was encoded by hand.

[119] Joan Collins, SIGGRAPH Present and Past, in *Animation World Magazine* Issue 2.5, August 1997, p. 13.

[120] Rich Schroeppel, Overview of Film Group Software, an Internal Report of Information International, Inc. on 14.03.1983, available from: http://www.bitsavers.org/pdf/informationInternational/, accessed 28.02.2011

Two precise views, from the front and the side were drawn onto drafting paper. Later, XY and Z cursors were sued to encode the points which represented the three-dimensional space coordinates. Unlike hand encoding and algorithmic description, both three-dimensional, the picture scanning method of data entry created two-dimensional data bases. The scanning method was used for adding texture to the three-dimensional surfaces of data bases.[121]

I.I.I. developed a proprietary interactive Director's Language. All of the characteristics of a scene including the size, colour, and orientation of the objects, as well as the lighting, reflections and textures were requested and later added to the Image Processing System.

Systems became more user-friendly and interactive than the system used to generate the Boeing Man. The manual of the *Tranew* aimed to 'be adequate for a highly motivated person with no previous experience of *Tranew*.' [122] *Tranew*, the prototype of the interactive 3D software currently on the market rendered the package visible.

However, the need for an improved human/computer interface to enhance the director's ability to control the action within the scene was pressing. In the time remaining in the 1980s, new companies developed to assist in the research and development of software industrialization.

With the supporting of the pioneer facilities and in-house system, I.I.I did early film tests and broadcast graphics work for the European market.

In order to present their capabilities in the field of computer graphics and to promote their business, *Adam Powers, the Juggler* was produced by I.I.I. as a demonstration.

Firstly, the producers found a real juggler, Ken Rosenthal, and filmed his motions. He was dressed in a white leotard with black dots painted at 17 bone joints. These dots became the reference points for plotting the human motion involved in juggling - the primal 'ones' and 'zeroes' around which the form of Adam Powers was molded, shaded and coloured. Depth coordinates were calculated through the use of an overhead camera in conjunction with the frontal camera.

Secondly, the film was processed and projected, frame by frame, onto a sheet of paper. The joint points were plotted onto a graph with an x-y-z axis and fed into the computer. [123]

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[121] Ibid.

[122] Ibid.

[123] Ibid.

Even earlier than the short film Adam Powers, Demos and Whitney had attempted to generate human figures using a computer in the film *Futureworld*[124] , the sequel to *Westworld* [125]. The actor Peter Fonda covered his face in white, then a grid was projected onto his face. His face was photographed from two directions. On the base of the intersection of the grids of digitalized pictures, a rough preliminary model of the actor's face was produced. In the latter stages of construction, the face appeared as a number of solid flat polygons as opposed to a wire-frame. At first, these polygons were large and sharply-angled, giving the face a faceted shape and a dull white texture. After that, the polygon model was smoothed, and light was projected onto it. Finally the face became smooth and artificial, but identifiable. I.I.I. hired Robert Abel Corporation's [126] Richard Taylor to control the general artistic effect. Taylor brought the film production methodology to I.I.I which had previously been lacking. The team supervised by Richard Taylor continued to develop this technology in their next film, entitled *Looker*[127] . The leading actress, Susan Dey's, face was also made-up white and projected onto the grid, but this time more pictures were taken from more directions. The database of the intersections was far more complex than the database of Fonda's face. This time, the entire head model was generated including the ears. Director Michael Crichton expressed his hope that, in future, the audience would be able to see even more realistic heads.

Following these three films, the aim for I.I.I, became not only the creation of a realistic human head using a computer, but an entire human body, which could be articulated at the joints. Ultimately, Adam Powers, a juggler with a black top hat was born. The metaphorical connotations of his name revealed the ambitions of I.I.I to create the first three-dimensional human character with an entire figure on the screen just as God had created Adam, the first man. Adam Powers represented the powerful potential of the computer-generated image.

[124] Futureworld (1976), directed by Richard T. Heffron. Two reporters, Tracz and Chuck, get a message from a third one who discovered something about 'Futureworld' and becomes killed before he could tell anyone about it. They visit Futureworld to find out what he knew.

[125] Westworld (1973), directed by Michael Crichton.A amusement park for rich vacationers. The park provides its customers a way to live out their fantasies through the use of robots that provide anything they want. Two of the vacationers choose a wild west adventure. However, after a computer breakdown, they find that they are now being stalked by a rogue robot gun-slinger.

[126] Robert Abel & Associates was founded in 1971 by Bob Abel, with his friend and collaborator Con Pederson. Able had done early film work with Saul Bass and camera work with John Whitney. After touring with several rock bands documenting the concerts, Abel joined Pederson to adapt the camera system used for 2001 to general film effects work. Abel was one of four companies (III, Digital Effects and MAGI) contracted to do graphics for the Disney filmTRON in 1982.The Abel raster software was later developed into the Wavefront Technologies product when Bill Kovacs purchased the rights to it in 1987. Their strength was in the ability to bring the knowledge of traditional effects work, cinematography and film making to the area of CGI.

[127] Looker(1981), directed by Michael Crichton.A plastic surgeon gets suspicious when models he has operated on begin to die in mysterious ways. With the help of Cindy, the next in line to be killed, he traces the deaths to a mysterious corporation which develops new technologies.(Summary from www.imdb.com)

3.2.2 Three Early Attempts at Constructing Algorithms for Realistic Figures: Hiding, Shading and Mapping

When comparing the images of Adam Powers with those of Boeing Man in the context of computer graphics, there are obviously great differences due to significant technological developments:

i) Whilst Boeing Man was depicted by a 'wire-frame', Adam Powers was shaped by smooth solids.

ii) In the short film, Adam Powers, colour was added to the skin, lips, pupils and eyebrows to create natural tones. Most strikingly, the hat on the head and the three props, a cube, a cone and a sphere that Adam Powers was juggling, not only had different colours but also had notable highlights. The audiences could imagine that the three solid objects were made of either metal or plastic and that the hat was made of silk.

iii) Akin to the film of the Boeing Man, the environment around Adam Powers was depicted with a realistic atmosphere rather than an abstract wire frame. The ground was paved with tiled stones and the sky is gradually became dark blue and dusky with the moon and stars. The colours and atmosphere within the film came as a result of choices made in the mapping, shading and rendering.

On the road to 'realism', Adam Powers had advanced much further than the Boeing Man. This can mainly be attributed to the 1970s success in obtaining the following algorithms:

3.2.2.1 Hiding: Chaos vs. Clear-cut

The image of the Boeing Man, as the first figure-drawing in computer graphics, consisted of wire-frame representations of various geometric shapes. He was extremely crude, like a sketch with chaotic lines and whilst he was presented in a perspectival viewpoint, it was difficult to determine what lay in front of and behind the shape.

The problem of visibility, of defining the surfaces and parts of surfaces visible from a certain viewpoint was identified early on as a significant difficulty in 3D computer graphics. Whilst the issue was raised in the 1960s it was not until the 1970s that solutions became available. The process of hidden surface determination (also known as Hidden Surface Removal (HSR), or Visible Surface Determination (VSD))is sometimes called 'hiding', and such an algorithm is sometimes called a 'hider' or HSR algorithm.

Several key hidden surface removal algorithms were presented in this decade including back-face detection, depth-sorting, ray-casting, Z-Buffer and area subdivision algorithms[128].

Depth-sorting [129] was proposed in 1972 by the Newell brothers and Tom Sancha.[130] Newell's Algorithm is a 3D computer graphics procedure for the elimination of polygon cycles in the depth-sorting required in hidden surface removal.

In the depth-sorting phase of hidden surface removal, if two polygons have no overlapping extents or extreme minimum and maximum values in the x, y, and z directions, then they can be easily sorted. If two polygons, Q and P do have overlapping extents in the Z direction then possible cutting is necessary.

In addition, in 1974, Sutherland and Hodgman developed a polygon clipping algorithm. Ivan Sutherland and his colleagues later published a paper entitled *The Characterization of Ten Hidden-Surface Algorithms*, covering all the known algorithms of the time. [131] Jack Bresenham developed an efficient algorithm to scan convert circles in 1977. In 1978, Cyrus and Beck developed a parametric line clipping algorithm.

3.2.2.2 Shading: Flat vs. Smooth

During William Fetter’s research at the Boeing Company, in order to present more realistic visual effects, he directly colourized the output film of the aero-landing. However, with the development of the colour raster CRT, it became possible to output the coloured computer-generated image onto the CRT.

The simplest colourization model for a polygon in 3D computer graphics is either 'constant’ or 'flat’ shading. This approach applies an illumination model once to determine a single intensity value that is then used to shade an entire polygon, and to hold the value across the polygon to reconstruct the polygon's shade.

The disadvantage of flat shading is that it gives low-polygon models a faceted look.

[128] Dmitry Shklyar, 3D Rendering History: Humble Beginnings’ CGSociety, available from: http://features.cgsociety.org/story_custom.php?story_id=1647, accessed 28.02.2011,

[129] Depth sorting for use in 3-dimensional computer shading and texturing systems。 A method and apparatus for automatically sorting translucent object data in a 3-dimensional computer shading texturing system first stores a list of objects to be shaded and textured. For each pixel, for each object in turn, it is determined whether an object in the list is further from an image plane than a current deepest object for that pixel. Data is stored for at least the deepest object in the list. The pixel is then shaded and textured for this object and the stored object is then discarded from the list. This is repeated until pixels have been shaded for all objects in the list.

[130] Martin E.Newell et al., A New Approach to the Shaded Picture Problem, in *Proceeding ACM National Conf*erence 1972: 443-450

[131] Ivan E. Sutherland et al., A Characterization of Ten Hidden-Surface Algorithms, in *Computing Surveys*, Vol. 6, No. 1 (1974): 1-5

This disadvantage was remedied in 1971, when Henry Gouraud developed a shading algorithm, which he named the Gouraud shading model. The basic principle behind the method is as follows: Gouraud finds the normal vector pertaining to each vertex of a polygon surface, calculating the pixel color at the vertex and then linearly interpolating that colour across the surface of the polygon.

Both the advantage and disadvantage of the Gouraud shading lay in its interpolation. After the processing of interpolation without the addition of the numbers of polygons, the result was a fairly smooth surface that took only a slightly larger amount of processing power than the flat shading model. However a serious problem with the Gouraud shading model occurred when specular highlights were found in the middle of a large triangle.

Despite the drawbacks, Gouraud shading was considered a significant step on the road to realistic shading. The improvement may be called more realistic in comparison to flat shading because it takes away the sharp edges, which flat shading is necessarily generating.

Later in 1975, Phong Bui-Tuong improved Henry Gouraud's shading model to provide a more accurate approximation of the shading of a smooth surface. Instead of finding the normal vectors only at the vertices, the Phong shader calculates a 'normal' at each pixel. By interpolating across the surface based on the normals, the Phong shading model resulted in an extremely smooth surface with accurate highlights. However, Phong shading is computationally more expensive than Gouraud shading since the reflection model must be computed at each pixel instead of only at each vertex.[132]

The Gouraud and Phong methods of shading are still in use today in most current readily-available non-specialist 3D software to achieve crude realistic images quickly.

3.2.2.3 Mapping: Textures and Surface Elevations

Real objects not only possess inherent color, but also diverse textures and patterns, both smooth and coarse like wet concrete or brick walls.

In 1974, Ed Catmull pioneered texture mapping on bivariate surface patches. In 1976, James Blinn extented Catmull's subdivision algorithm in the areas of texture and reflection. The developments made use of digital signal processing theory and curved surface mathematics to improve image quality. These generalizations

[132] Dmitry Shklyar, 3D Rendering History: Humble Beginnings, available from: http://features.cgsociety.org/story_custom.php?story_id=1647, accessed 28.02.2011

resulted in improved techniques for generating patterns and texture, and in the new capability for simulating reflections.[133]

Besides these developments, James Blinn also tackled many of the infrastructure problems of computer graphics. In 1976, he introduced environmental mapping. Later in 1978, as research into various methods of shading continued, Blinn discovered that instead of using the perturbed vertices to calculate normals used in shading, by disturbing surface normals, one could simulate the appearance of an increased amount of surface geometry. [134]

This technique became known as 'bump-mapping', the simulation of bumps or wrinkles onto a surface without the need for geometric modifications to the model. Bump-mapping is still widely used in applications ranging from real-time games to feature-length films.

Bump mapping is generally implemented by using a black and white bitmap or procedural texture in order to define which pixel will have a perturbed normal. Whilst this method offers the illusion of highly complex geometry, the simulated wrinkles are unable to extend all the way to silhouette the object.

Bump mapping was later extended to form the 'displacement mapping' technique. This technique was similar to bump mapping except that the actual pixel, as well as the normal were transformed. This remedied the problem of the disappearance of surface details along edges, but also led to a severe increase in processor and memory load.[135]

3.2.3 The Limitations of the Algorithms of the 1970s and the Aims of the 1980s

In the 1970s, computer graphics research made advances in the areas of realistic representation and modeling. On the basis of using certain materials which had never been used before, researchers did their best to discover how to improve picture graphics.

James H. Clark summarized the three basic approaches that the researchers of the 1970s used to improving the picture quality as firstly, the contrivance of 'clever ways to add information value to a scene without significantly increasing the total amount of information in the database for the scene, secondly, the employment of

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[133] James F. Blinn and Martin E. Newell, Texture and Reflection in Computer Generated Images, in *Communications of the ACM* ,Vol. 19, No.10 (1976): 542-547

[134] James F. Blinn, Simulation of Wrinkled Surfaces, in *ACM SIGGRAPH Computer Graphics* Vol. 12, No. 3 (1978): 286-292

[135] Dmitry Shklyar, 3D Rendering History: Humble Beginnings, available from: http://features.cgsociety.org/story_custom.php?story_id=1647, accessed 28.02.2011

'more refined mathematical models for the objects being rendered and to devise algorithms that can find the visible surfaces using these models' and finally the increase of 'the information in the database and employment of more structured methods for handling the increased information.'[136]

Examples of the first approaches are found in the improvements to shading algorithms devised by H .Gouraud and Bui-Tuong Phong, to improve image quality without increasing the overall number of polygons.

Due to the disadvantages of representing smooth surfaces with faceted clusters of polygons, research was devoted to parametric surface algorithms, which allow higher degrees of continuity than just positional continuity. These include 'Coons patches' or 'B-splines' rather than clusters of polygons, and do not increase the size of the database.

In 1974, Edwin Catmull developed an algorithm for rendering continuous tone images of objects modelled with bivariate parametric surface patches.

The research to find better methods of modelling belongs to Clark's second approach. The algorithm functions by recursively subdividing each patch into smaller patches until the image of each fragment covers only one element of the picture. [137]

However, Newell and Clark devoted their research to Clark's third approach; namely, the increase of information in the database and employment of more structured methods for handling the information.

Originally created by Newell as the 3D model representative of his research, the teapot[138] [139]model was developed by Blinn, to become one of four default models of 3D software; the sphere, the cube, the clone and the teapot. This teapot, sometimes referred to as the Utah teapot, is testimony to the success of Sutherland's research period at the University of Utah in the 1970s.

As a commercial promotion film, the film Adam Powers showcased the achievements of 1970s' computer graphics. Adam Powers not only juggles the three basic-shaded solids, but also the mapped and shaded teapots images appear as the transitions of the scenes.

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[136] James H. Clark, Hierarchical Geometric Models for Visible Models for Visible Surface Algorithms, in *Communications of the ACM*, Vol. 19, No.10 (1976), p. 547

[137] Ibid., p. 549

[138] Wikipedia, s.v. 'Utah Teapot', available from: http://en.wikipedia.org/wiki/Utah_teapot, accessed 28.02.2011

[139] Wikipedia, s.v. 'the history of Teapot', available from: http://www.sjbaker.org/wiki/index.php?title=The_History_of_The_Teapot, accessed 28.02.2011

Throughout the 1970s, computers were limited in their capabilities. Researchers sought to balance picture quality with algorithmic performance. This had the effect of increasing the '*complexity of a scene, or [the] information in the database such that its values decreased as it approached the resolution limit of the display. There was little sense in using 500 polygons to describe an object that covered only 20 raster units of the display*.' [140]The selection of the specific portions of the data base that had meaning in the context of the resolution of the viewing device and the accommodation of the increased storage requirements were highlighted as points to discuss.

Clark gave an example:

> *We might….wish to model a human body to the extent that a close-up view of the eye shows the patterns of the iris, yet such a fine description of the entire body will indeed require large amounts of storage. Thirdly, how much information must be presented to convey the information content of the scene? In other words, we would like to present the minimal information needed to convey the meaning of what is being viewed. For example, when we view the human body mentioned above from a very large distance, we might need to present only 'specks' for the eyes, or perhaps just a 'block' for the head, totally eliminating the eyes from consideration. The amount of information 'needed' can be the subject of psychological debate, but it is clear that even coarse decisions will yield more manageable scenes than attempting to use all of the available information.* [141]

So although Adam Powers premiered in 1981, five years after Clarks writing, I.I.I had to face the same problems that Clark had encountered. However, I.I.I used some cinematographic language to draw attention away from the limitations. They gave neither a close shot nor a still shot to Adam Powers to avoiding the audiences focusing on his figure.

The most common algorithm, ray tracing**,** we use now to achieve photo-realistic imaging was first performed by Goldstein and Nagel using Boolean set operations (the basis of Constructive Solid Geometry) in the 1970s. Due to the complexity of the algorithm and the limitations of the computer capability of the time, this did not become the mainstream method for rendering until the 1990s.

Similarly, the first synthesis of rendering transparent surfaces was developed by Kay and Greenberg in 1979. In 1977, Frank Crow had developed a solution to the aliasing problem, which was the problem of projecting onto a 2D raster display the information pertaining to the 3D model. These were widely used up until the next decade.

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[140] James H. Clark, Hierarchical Geometric Models for Visible Models for Visible Surface Algorithms, in *Communications of the ACM* Vol. 19, No.10 (1976), p. 552

[141] Ibid., p. 552

On the road to 'realism', computer graphics became an unusual and challenging field of research. It involved working on subjects whose scope extended far beyond the traditional confines of computing including the laws of perspective, the composition of light and the science of color. Even geometry could now be reinstated into the mainstream of academic research; around 350 years after René Descartes' reductionist theories had linked it up to algebra (in analytic geometry). These fields actually not only related to science and engineering, but also to the visual arts.

The images of this short film were amongst the first computer-generated images (CGIs) to meet the vision of 'realism'. However, in order to represent the image of the realistic figure, many problems were left for the future to solve, for instance, the translucency of materials and the shadows of lighting.

3.3 Budding of the Computer-Generated Portrait

3.3.1 Attempts in Portraiture: Approaching Likeness

The algorithmic human body has made significant progress towards the realistic representation of the human body, evolving from the wire-frame Boeing Man to the solid and flaming Adam Powers. In comparison to the ideal model represented by the Boeing Man, the significance of Adam Powers is that he really does have the significance of a born human. He is not limited to a strong torso and limbs, but more importantly, he is a figure with facial features and a variety of expressions.

The following discussion considers the attempts made in the West to establish a visual tradition based in the philosophy of Plato. Within the framework of the dialectical relationship between pure appearance and true reality, I will investigate the similarities and differences between traditional portraiture and computer-generated portraiture.

3.3.1.1 The Algorithmic Human's Outer Appearance: The Limitations of Expression

Sketches of the human figure emphasize research into the common structure and ideal state. They are universal, abstract and most often highly-generalized. They present the research and summary of general rules regarding the state of the human figure existing in the objective world. However, the portrait is specific. The object which is researched and represented in the portrait is the specific individual human being. One hopes to move beyond common features and to capture the uniqueness of the object's features and expression, to allow the object's character and social status to emerge, and finally the inner world beneath each layer of clothing.

Traditionally, portraiture creates an illusory outline of the faces and voices of people who are not in front of the viewer, allowing descendents after many years to have the opportunity to see a life-like depiction of their ancestors and revisit the stories of their forefathers. These images can even generate some degree of spiritual communication. This generates the aesthetic pleasure of the subject. When admiring the portrait, the viewer and the figure in the portrait form an inherent historical association. In order to attain this aim, the artist works meticulously from life to capture the body, face and clothing of the human figure, and to make the picture attain a close similarity with the real object it seeks to represent.

However, when compared with the realism of the portrait by the master of the Renaissance, such as Da Vinci's *Mona Lisa*, the computer-generated imagery of Adam Powers still lacks authenticity.

His skin was unnaturally smooth. 'Phong shading', the rendering algorithm employed in the short film, was a relatively rudimentary 'ideal illumination model', which worked on the assumption that the surface was smooth and the illumination effect should be constant. However, in reality the skin of the human face is coarse and translucent with a complex play of shadows across its surface, and therefore extremely difficult to recreate. The expression on Adam Power's face appeared stiff. This was due to the difficulty in freely modifying Adam's polygonal 3D face model to recreate the vivacity and animated qualities of a human face.

At one stage, mankind's research and interest in science greatly promoted the development of world civilization. This attitude towards science was also embodied in the expression and research of reality. The writer Flaubert asserted that 'The Age of Beauty has ended', yet currently 'art turns more and more towards the development of science , just as science becomes more like art'. In the early days, science and art were divided, but along with the development of civilization reaching its summit, these two subjects are rejoined. In 17^{th} century Holland, which saw the unprecedented development of portraiture, Rembrandt van Rijn's *The Anatomy Lesson of Dr Tulp* conveys a deep impression of the rigour and practicality of the scientific mind through the representation of an anatomy lesson. The incisions into the layer's of the reclined corpse's skin, as well as the blood and flesh all appear in a life-like state. This seems even more authentic; reflecting the genuine desire of people to reveal the true nature of what has long been hidden.

The influence of the Positivist trend lead to the pursuit of the even greater authenticity, clarity and accuracy characteristic of a scientific approach to expression in portraiture. This is reflected especially in the depictions of the surroundings of human figures in paintings. It was no longer sufficient to add background simply to set off the main subject or to choose a scene which was not from the local area. For example, in the classical depiction of the encounter of three figures in Gustave Courbet's *Bonjour, Monsieur Courbet*, in addition to the accurate grasp of the figures, faces and clothes, the artist also made detailed observations of the outskirts of Montpellier in the south of France, including the local plants and the clear air, which were then meticulously represented in the picture. This painting offers a classical realist depiction, which is close to nature, objective and similar in style to a photographic documentary image.

The setting and scenery surrounding Adam Powers was sparse with little visual interest and lacked both depth of field and the effect of fog in the air. In comparison to the mastery in the portraiture described above, Adam Powers still has a long distance to go in the sensitivity and accuracy of the representation of detail.

3.3.1.2 Portrait Brushwork: The Representation of the Inner World of the Subject

However we can be very clear about how great the possibility of using computer graphics to simulate a real person is. Finally, as Jean Baudrillard said, this process is '*the simulation of something which never really existed*.'

With the exception of portraiture, throughout history there are still no remnants or documents which both directly and accurately recapitulate the objective human world whilst simultaneously in that purely physical world represent the figure's character and convey people's rich inner self.

This claim is further clarified in Hegel's discussion of portraiture. He rejects the idea that the portrait should slavishly resemble its sitter's appearance; instead, it needs to display the subject's inner character through its depiction of external appearance. Hegel's example of the successful portraiture is Raphael's *Madonna*. This shows us not only forms of expression; cheeks, eyes, nose, mouth, which, as forms, are appropriate to the radiance, joy, piety, and also the humanity of a mother's love. Whilst some people maintain that all women are capable of this feeling, not every cast of countenance affords a satisfactory and complete expression of this depth of soul.

Adam Powers, the clown, looks naturally comical and has an interesting name. Considering the two parts of this name, 'Adam' and 'Powers', we can explore its possible connotations.

Adam is a mythological figure often encountered in paintings, but traditionally, the earliest nude Adam was seen in depictions of Adam and Eva. 'One might generalize to say that in Western painting the greatest works were depictions of scenes from history or mythology'[142]. In the religious paintings of the Middle Ages, we see Adam conveyed through even more characters and scenes, presenting the Bible Story of the loss of paradise in picture form. Yet in Michelangelo's *Genesis*, Adam is depicted as the forefather of mankind, symbolizing the early state of mankind, weakly raising his arm, his left hand sagging. He looks frail and timid, awaiting God in His might and wisdom to imbue him with strength. He has a strong symbolic significance, indicating the real nature of the poverty of mankind's plight. Later, Adam became popular subject matter for portrait painters. In these scenes, Adam's posture and expression are not particularly naturalistic; he is seen shamefully using a leaf

[142] John Berger, *Views of Seeing*, 1972, p. 108

to cover himself or hiding behind Eva. He gradually became an abstract symbol, representing the accusation and penalty of mankind's original sin.

Going back to our subject, it seems simple to understand the significance of 'Powers' for computer scientists. Power comes from knowledge, knowledge brings reason and reason is usually the opposite of myth. It is not difficult for us to infer that the first genuine algorithmic human, although obviously weak and immature and comical in his every move and action, will without a shadow of doubt, become stronger and mature with the development of computer technology and the increased knowledge of algorithms. The future of the algorithmic human is bright.

3.3.1.3 The Beginnings of the Moving Portrait

Computer animation had already played a role in the industry's advances throughout the 1960s and 1970s. Although the short film Adam Powers was already very successful, the algorithmic expression for the figure of Adam Powers was almost theatrical. Besides the emergence of Adam Powers at the film's introduction and conclusion, the majority of the middle section of the film was a display of technical capability, to prevent the audience forgetting that the images were computer-generated. This exhibitionism was intentional. Previously, images produced using computer graphics in films, whether screened in *Futureworld (1976); Star Wars (1977);or Looker (1981)* mostly appeared on screens similar to computer monitors, in order to define these images as computer-generated rather than taken from reality.

However, the representation of the portrait of Adam Powers was still insufficient. Attempts to eradicate the monotonous expression and stiff movement propelled the development of the algorithmic human through the 1980s. Moreover his puppet-like movement provided an indication of another important area in the study of computer imaging, namely, the development of the moving portrait; the computer animation.

3.3.2 TRON Leading to the Cave

3.3.2.1 Plato's Cave

The Theory of Forms typically refers to Plato's belief that the material world as it seems to us is not the real world, but only a shadow of the real world. Plato spoke of forms in formulating his solution to the problem of universals. The forms, according to Plato, are roughly speaking archetypes or abstract representations of the many types and properties (that is, of universals) of things we see all around us.

Socrates's idea that reality is unavailable to those who use their senses is what put him at odds with the common man, and with common sense. Socrates said that he who sees with his eyes is blind, and this idea is most famously captured in his allegory of the cave, and more explicitly in his description of the divided line. According to Socrates, physical objects and physical events are 'shadows' of their ideal or perfect forms, and exist only to the extent that they instantiate the perfect versions of themselves. Just as shadows are temporary, inconsequential epiphenomena produced by physical objects, physical objects are themselves fleeting phenomena caused by more substantial causes, the ideals of which they are mere instances. In her book *On Photography,* Susan Sontag indicated, 'people always try to resist their own plight, breaking out of captivity in the cave in order to seek the truth behind the shadow. From photography to film, the great inventions are driven by the desires of mankind each seek to improve the state of mankind's captivity in the cave (our world). '[143]

3.3.2.2 From Star Wars to TRON

Since the deceleration of the development of the animation industry towards the end of the 1970s, animated themes began to appear tired and the industry was in need of reform and innovation. Most importantly, following the popularization of television in 1960's America as well as the increasing popularity of the video tape, the adult-based film audience began to dwindle. Film manufacturers sought new solutions to retain their audiences, especially their younger viewers. The audiences of the era were fascinated by science-fiction. In 1975, ILM [144] was created to develop the visual effects for George Lucas's 1977 production, *Star Wars.* Whilst this film was a landmark in bringing visual effects to the foreground of mainstream culture, the use of computer technology was mostly limited to the computerized motion-control systems used to move cameras and miniature models. The blue-screen composition of the visual elements and plates was achieved optically.

Adam Powers reflected the outstanding achievements of the computer image throughout the 1970s. Furthermore, the film was directed with a view to showcasing technological developments. Simultaneously, this film

[143] Susan Sontag, *On Photograph*, 2001, p. 1

[144] Industrial Light & Magic (ILM) is a motion picture visual effects company, founded in May 1975 by George Lucas and owned by Lucasfilm Ltd. Lucas created the company when he discovered that the special effects department at Twentieth Century Fox was shut down after he was given the green light for his production of Star Wars. It was in the late 1980s when Adobe Photoshop made its first appearance on the world stage. It was used at the Industrial Light and Magic studios as an image processing program.

When making Star Wars Episode V: The Empire Strikes Back, Lucas reformed most of the team into Industrial Light & Magic in Marin County, California. They have since gone on to produce special effects for over two hundred films, including the Indiana Jones films, the Harry Potter films, the Jurassic Park films, many of the Star Trek films, as well as less dramatic effects in films such as Schindler's List, Snow Falling on Cedars, Magnolia, and several Woody Allen films. ILM also frequently collaborates with Steven Spielberg, with Dennis Muren acting as Visual Effects Supervisor.

The development of computer imaging as an academic discipline at this time was a significant factor in creating new possibilities for special effects, as well as producing an overall new visual imagery. In 1979 several members of the NYIT research group joined ILM with the goal of integrating computer graphics into visual effects production.

absorbed the aesthetic codes of film creation and combined them with the technological moving image, previously relegated to the science and technological industries. This brought an artistic aspect to moving image production which is reflected in the visual comedy of the film's closing scenes. Disney's recognition of the potentials of computer animation and the introduction of Adam Powers, as the first image with colour, 3D Shading and motion, that confirmed the capacity of the computer to create moving images of the highest standard. This collaboration, henceforth, formed the basis for a new artistic industry: visual animation. Following the success of the *Star Wars*, and the experience of the production team on the film *Future*, Disney, although originally an animated film company specializing in traditional hand-painted animations, came to believe in the potential for computer graphics and the cinema to be successfully united. Therefore, they decided to invest in *TRON*, the science-fiction film. However, the mass-scale application of digital-imaging technology had yet to be incorporated effectively.

There are two different worlds defined in the film *TRON:* the real world, where a vast computer system in a communications' conglomerate is controlled by a single program; and the electronic world, populated with electric-and-light inhabitants who aim to overthrow the program controlling their lives. Whilst both the sections of the film set in the real and electronic worlds incorporate human actors, the scenery displayed in the transition between the real and 'electronic' worlds could not exist in reality. Hence, both the terrain and the forms of transportation were produced using computer graphics. Although images produced using computer graphics had been used in *Westworld, Star Trek*, and *Looker*, the production of *TRON* marked the first grand-scale application of the computer-generated image in the cinema. This was a milestone in film history.

As the director of Adam Powers, Richard Taylor assumed the role of producer of *TRON*. The *TRON* production team overall comprised a combination of artists, technicians and actors including a cast, a direction and production team, a futurism industry designer, a comedy artist, a specialist visual consultant, and a photography instructor as well as special effects experts. Finally the film includes computer-generated imagery totalling 15 minutes in length. In addition, it has over 200 computer-generated background scenes. To complete this formidable project, the film-producers divided the workload between four specialist computer graphics companies.

The animation company Digital Effects Incorporated was responsible for the animation of the 'Bit' character and the creation of the *TRON* character in the opening title sequence.

Robert Abel & Associates provided the remaining animation for the opening sequence and for Flynn's transition into the Electronic World.

Due to their abilities to create complex motion and 3D-shaded graphics, the bulk of the computer animation was handled by the animation companies, MAGI and Triple-I: MAGI's computer imagery is displayed mainly in the first half of *TRON* in the Game Grid area, where they created vehicles including Light-cycles, Recognizors and Tanks. MAGI also employed a unique process of computer simulation call SynthaVision. This process utilized basic geometric shapes that the computer recognized as solid objects with density. By varying the size and quantity of these shapes, MAGI could construct a limited range of 3D designs and animate them efficiently. The SynthaVision process was limited in its ability to create complex objects. It was, however, very easy to create fluid motion (choreography) for these objects.

The computer images seen in the second half of the film, including the MCP and the Solar Sailer, are the work of Triple-I. These images are among the most complex designs in the film. Unlike MAGI's SynthaVision process, most computer graphics companies today employ a method similar to that used by Triple-I. Using a schematic drawing or blueprint, Triple-I engineers recorded the visual images by tracing the lines of a drawing onto a digitizing tablet. This information was translated to the computer as an image whose surface is composed of a multitude of polygons.

Although Disney's *TRON* received a poor turn-out at the box office, the significance of *TRON* should not be under-played. The production companies responsible for *TRON* learned from their earlier errors and continued to work on video-animation projects through the 1980s, providing platforms for young computer animators to learn and develop their skills. In particular, Triple-I was one of the 1970's key pioneers of computer imaging technology, not only due to their technology but also due to several concepts and their predicted vision of the development of computer graphics, described as follows;

i) Firstly, the use of a primitive form of motion capture to create computer animation.

ii) Secondly, the hire of an art director to supervise computer animation, and to ensure the image was produced with cinematographic principles in mind.

iii) Thirdly, the production of a short film as a demonstration of the company's capabilities. This method is still used widely by a range of companies.

In conclusion, Adam the Juggler, through his unprecedented realistic representation of the human being, led audience to believe in a bright future for computer graphics, and led researchers to continue to work on solutions to improve the effectiveness of computer imaging technology. Furthermore, creating a realistic human character became the ultimate challenge in the application of computer graphics to entertainment. The realization of this human character was impossible through cartoon or computer-aided cartoon, but possible through computer-generated animation.

4 DOZO'S FACIAL EXPRESSION AND BODY MOTION: MOVING TO THE BEAT OF 3D ANIMATION

Fig. 4.1: Algorithmic Human Figure Dozo.
(Source: Diana Walczak, Synthespianism and anthropomorphization of computer graphics, available from: *http://www.kurzweilai.net/synthespianism-anthropomorphization-of-computer-graphics*, accessed 28.02.2011)

The elusive goal of creating a photorealistic synthespian indistinguishable from a live actor has intrigued, taunted and tormented programmers for 30 years.

-- Diana Walczak,
Synthespianism and Anthropomorphization of Computer Graphics

4.1 1980s: The Boom of 3D Computer Graphics

4.1.1 Computer Graphics Hardware Development in the 1980s

The 1980s are generally considered to mark the transition between the industrial and information ages in computer graphics hardware development, as exemplified by the increasing popularity of the Bulletin Board System (BBS), a computer system running software that allows users to access general information and to leave messages using a network. During this decade, technological developments in computer graphics included the incorporation of extensive peripheral storage and display facilities in computer hardware systems, as well as the significant advancement of computing capability.

These developments began with the uneven coexistence of powerful minicomputers and microcomputers with 8-bit Central Processing Units (CPU). On 12th August 1981, IBM announced their entry into the microcomputer market with the Model 5150. This announcement shook the industry to its foundations. Although the term 'personal computer' was already in use, at the time it was synonymous with 'microcomputer'. IBM wanted to differentiate this microcomputer from their larger products and thus began to use the term 'IBM Personal Computer' in their advertising. Besides, in order to distinguish this product from the Apple Macintosh, IBM developed a new strategy. The distinction was both technical and cultural. Originally, the IBM PC had the architecture of an Intel microprocessor and an operating system such as DOS or Windows, which was written to use that microprocessor. In contrast, the Apple Macintosh used Motorola microprocessor architecture and a proprietary operating system. Compatibility became one of the most important characteristics of the IBM personal computer. In the market, the IBM-compatible PC was associated with a wide range of businesses and research, whilst the Mac, known for its more intuitive user interface, was associated with graphic design and desktop publishing. Rapidly the IBM PC became the standard in micro-computing. Although the distinctions have become less clear-cut in recent years, people often still categorize a personal computer as either a PC or a Mac.

The advent of the era of the personal computer was quickly captured by *Time* magazine in 1982, when they broke with tradition by choosing the PC ,the first object ever, as their 'Man of the Year'.[145] In 1982, the computer began to receive the distinction. By the end of the decade, the computing capability had significantly improved, but for 3D computer graphics, it was still not good enough, especially for realistic computer motion picture rendering, which produced a series of pictures rather than a single one, thus the display and storage facility became essential.

[145] Since 1927, TIME Magazine has chosen a man, woman, or idea that 'for better or worse, has most influenced events in the preceding year.' Though TIME's list is not an academic or objective study of the past, the list gives a contemporary viewpoint of what was important during each year.

In the 1960s, the displays in use were primarily refresh vector displays, which used a display list of line-and-arc drawing instructions. An internal processor repeatedly drew the image that would otherwise quickly fade on the screen. Despite this unstable display, vector displays enabled moving images to be drawn by carefully changing the display list between refreshing drawings. These were used creatively in Ivan Sutherland's Sketchpad, the earliest interactive design system, by adding an interactive constraint satisfaction system on a vector refresh display. This method was applied to create figures using simplistic computer graphics.

In the 1970s and 1980s, CRT (Cathode Ray Tube) mainly used monochrome. They were able to retain an image due to internal circuitry that continuously refreshed the display, but the image could not be easily modified. At the beginning of the 1980s, under this limitation, static images were frequently recorded onto film by placing a camera in front of the display and photographing the screen. For computer-generated animation, there were few production companies capable of first-generation output to videotape. Much of the high-end work was output firstly to film and then transferred to videotape. During the latter half of the decade, however, video output became the most common output method.

By the mid-1980s, technological advances made it feasible to build a small computer that an individual could own and use, but there were still no business-oriented graphical computers. At the end of the decade, workstations were designed to meet the special requests for small engineering companies, architects, graphic designers, and any organization, department, or individual that required a faster microprocessor, a large amount of random access memory (RAM), and special features such as high-speed graphics adapters. The combination of powerful 32-bit CPU microcomputers and 64-bit RISC (Reduced Instruction Set Computer) graphics workstations reached the forefront of computer technology, and minicomputers were relegated to the background.

4.1.2 Computer Graphics Software Development in the 1980s

After the infrastructural research in computer graphics of the 1970s, the 1980s saw the blossoming of 3D computer graphics. The bulk of software research and development in 3D computer graphics during this decade was spent in refining the modeling and shading techniques inherited from the 1970s. Rendering approaches such as radiosity and procedural textures broke fresh ground with the development of the first generation of solid user-friendly computer-human interfaces for 3D computer animation and imaging software. The most important algorithms relevant to this were developed in the earlier half of the 1980s;

-In 1980, Turner Whitted created a general algorithm incorporating reflection, refraction, anti-aliasing and shadows.

-In 1982, octrees introduced a mechanism for geometric modelling by Meager.

-In 1983, particle systems introduced by William Reeves.

-In 1984, radiosity was introduced by Goral, Torrance, Greenberg, and Battaile.
-In 1984, Liang and Barsky developed an efficient clipping algorithm for rectilinear clipping regions.

Turner Whitted's methods in particular, made a significant contribution to the photo-realistic rendering algorithm of ray-tracing. The Whitted Illumination Model was the first implementation of ray-tracing in computer graphics. In comparison with other rendering methods such as the scan-line rendering or ray-casting methods developed by Appel in 1968, the ray-tracing method held the advantage of the ability to simulate lighting realistically. Effects including reflections and shadows, which were difficult to simulate through the use of other algorithms, came as a natural result of the ray-tracing algorithm. Whilst this technique was capable of producing realistic images to a high degree, this came at a greater computational cost. This made ray-tracing best suited for applications where the image could be rendered slowly ahead of time, such as in still images and film and television special effects. Ray-tracing was poorly suited for real-time applications like computer games where speed was critical.

Generally, during the first half of this decade, the 3D software products commercially available lagged behind the innovative developments made in research institutions. This was due to the lack of capital investors who fully believed in the commercial potential of the technology. It was also due to the difficulty of implementing computer-intensive techniques with 'off-the-shelf' hardware systems that were slow and overpriced. However, by the latter half of the decade, hardware developments finally made the theoretical research achievements of the 1970s both possible to implement and widely applicable. Cost-effective computer software production and computer applications caught the attention of venture capitalists.

4.1.3 The emerging artistic and commercial potential of 3D animation in the 1980s

The 1980s saw rapid developments in numerous technological sectors which have defined the modern consumer world. Electronics such as personal computers, gaming systems, the first commercially available hand-held mobile phones, and new audio and data storage technologies including the compact disc, all remained prominent well into the 21st century. The applications of 3D computer graphics spread rapidly in entertainment. If we consider the most important issue for computer graphics in the 1970s as modeling and the basic clarity of color, then the optimized algorithms and higher quality hardware as well as commercial software lead to the manufacture of CGIs, especially the reduction of the cost of large-scale animations and more realistic visual effects so a large quantity of applications became possible. The 1980s saw a more serious move by entrepreneurs into commercial animation.

After the research into the infrastructure of computer graphics throughout the 1970s, the 1980s also became the decade to see the growing up of both the technological and artistic aspects of computer graphics. In the

1980s, the computer technology began to enter the mainstream culture. CGI appeared not only in films such as *TRON*, produced in the year 1982, but also spread widely by mass media. In particular, the growing popularity of the 1980s music video led to significant stylistic and technical experimentation in the area of special effects production. This included the development of the 3D CGI and animation.

The 1984 music video entitled *Adventure in Success of Will Powers* is a parody of the 'positive thinking' self-help programs of the US President Reagan's era. In this video, an impressive rotating mask comes to life as a computer–generated human character acting the role of the singer *Will Powers*. The members of NYIT, Rebecca Allen and Paul Heckbert created these masks. As the masks rotate, an optical illusion occurs in which the rotation seems to reverse direction when the inside of the mask appears. Later, in 1986, Rebecca Allen produced the music video *Musique Non Stop* for *Kraftwerk*. The computer-generated rotating 3D heads and subtle facial expressions of *Kraftwerk* became the best known characteristics of Allen's work. Today, this video is considered as one of the icons of the technoculture of the 1980s.[146]

Another music video entitled *Money for Nothing* by the British pop-band Dire Straits, which was released on their 1985 album *Brothers in Arms* and subsequently became an international hit when later released as a single, featured early computer animation in order to illustrate the lyrics. Whilst the characters seemed box-like and the animation was slightly crude, the video showed one of the first uses of computer-animated human characters and was considered groundbreaking at the time of its release. Ian Pearson and Gavin Blair created the animation, using a Bosch FGS-4000 CGI system. The animators went on to found computer animation studio Mainframe Entertainment (today known as Rainmaker Animation), and referenced *Money for Nothing's* video in an episode of their *ReBoot* series[147]. The video was also the first to be shown on MTV Europe, when the network opened in August 1987.

Inverting this idea, in 1985, the British network, Channel 4, introduced *Max Headroom*, a supposedly computer-generated talk show host. In fact, this was a real man, Matt Frewer, disguised as a computer–generated figure with the help of heavy make-up, although this information was not initially publicized. Max Headroom appeared as a stylized head on the television against harsh primary color rotating-line backgrounds, and he became well known for his jerky techno-stuttering speech, wisecracks and malapropisms. The Max Headroom TV series aired during 1987 and 1988. Max Headroom's performance brought out the irony of a human being mimicking the form of an algorithmic human.

[146] Rebecca Allen, From Technology to Virtual Art, available from: http://rebeccaallen.com/v2/bio/frank.popper.php, accessed 28.02. 2011,

[147] ReBoot is a Canadian CGI-animated action-adventure television series that originally aired from 1994 to 2001. It was produced by Vancouver-based production company, Mainframe Entertainment, and created by Gavin Blair, Ian Pearson, Phil Mitchell and John Grace, with the visuals designed by Brendan McCarthy after an initial attempt by Ian Gibson.It is the first full-length, completely computer-animated TV series.

In the 1980s, television advertisers became the primary purchasers of computer animation, using it to grab the viewer's attention and to make commercials memorable. Television commercials, initially in the form of flying logos, provided a profitable area where companies could hone their skills. The first wave of computer graphics companies included Information International Inc. (I.I.I or Triple-I), Digital Effects, MAGI, Robert Abel and Associates, and Real-time Design, Co. The first four of these companies combined to produce *TRON* (1982), and appeared towards the end of the 1970s.

Following the bankruptcy of several computer graphics companies in the 1970s, many new and influential companies emerged during 1980s. They began to produce sophisticated software tools making advanced rendering and animation available 'off-the-shelf' for the first time. Some of these companies still dominate the production industry for high-end tools for 3D computer animation and visual effects up until the present day. These include:

-The Wavefront Corporation, formed in Santa Barbara, California in 1981.

-Silicon Graphics Inc., the company responsible for pioneering the visual workstation with its Geometry Engine, which was established by James Clark in 1982.

-Alias, established in Toronto, Canada in 1982.

-1984 Steven Jobs purchased the computer graphics division of Lucasfilm, Ltd. and established it as an independent company christened 'Pixar'. Pixar is leading to the release of their RenderMan shading language in 1988.

-Softimage established in Montreal, Canada in 1986.

-Mental Images established in Berlin, Germany in 1986.

-Side Effects Software, established in Toronto, Canada in 1987.

In the majority of cases, despite the greater computational cost, more advanced hardware and computer graphics techniques, particularly those developed up until the end of the decade, offered the potential to produce an image incorporating a high degree of realism compared with that of the 1970s'.

However, it became clear that the visual effects of CGI or animation in music videos was still rough due to the limited investment, but this marketing led to the establishment of many animation companies or studios specializing in 3D computer animation.

Pixar is one of representative studio of the 1980s.The preexistence of Pixar is Dr. Edwin Catmull's group at NYIT joining to the Computer Division of Lucasfilm. In 1979, the group worked on creating the precursor to *RenderMan*, called *Motion Doctor*, which allowed traditional cell animators to use computer animation with minimal training. The team began working on film sequences produced by Lucasfilm or worked collectively with Industrial Light and Magic on special effects of some films, such as *Star Trek II: The Wrath of Khan* and *Young Sherlock Holmes*. In 1986, the group was purchased by Steve Jobs and renamed Pixar.

Initially, Pixar was a high-end computer hardware company whose core product was the Pixar Image Computer, a system primarily sold to government agencies and the medical community. One of the leading buyers of Pixar Image Computers was Disney Studios, who used the device as part of their secretive CAPS (Computer Animation Production System) project, using the machine and custom software to avoid the laborious Ink-and-Paint 2D animation technique in favour of an automated and more efficient method.

In a bid to drive sales of the system, the director of Pixar, John Lasseter, and a close friend, Ed Catmull, developed an idea that lead to a landmark in Pixar's development and furthermore fused and regenerated art and technology. John Lasseter's initial idea, based on Disney's traditional hand-drawn animation method, was to draw and animate the figures manually but to use computer-generated animation to complete the background. Ed Catmull developed the concept further proposing the use of computer-generated animation to create both the figures and the background in their entirety.

In the same year, the 3D short film animation entitled *Luxo Jr.*, a short film to show off the device's capabilities and for the participation at SIGGRAPH, was produced, providing a significant milestone in the history of 3D computer animation. The character in Luxo Jr. also became the icon for Pixar and could be seen on their logo.

However, in reality, when Pixar was first established, they had little financial support, equipment, personnel or even time to develop as a company. They had little alternative but to simply fix the camera in a position, with hardly any background or stage properties. Perhaps due to this, the chief focus of the audience's attention became the story and the characters. This was extremely effective. The entire animation was completely manual. This short film was the clear manifestation of the basic principles of the computer-generated Disney animation. Moreover, it had excellent visual effects. Pixar branded themselves as a low-tech company with a philosophy of excellent narration with simple methods.

This short film obtained recognition not only in the field of computer graphics, but also around the world, as the first Oscar-nominated, entirely computer-generated 3D short film.

Perhaps, when Pixar was established, it inherited Disney's unique computer-generated creation principles and continued to walk the path connecting technology and art.

At the end of the 1980's, whilst Pixar produced their two highly successful short films', they struggled to survive through commercial advertisement obtained funding , however, the Pixar team had the opportunity to flex their creative muscles and refine their style. They developed a strong collaborative relationship with Disney, and made preparations for the development of Toy Story, a full-length 3D animated film, in the next decade.

Pixar believed that their own copyrighted technology had the unique potential to assist animators to precisely control the animated character in key frames. The resulting high quality, vivid images have brought new visual forms and expressions of emotion. Pixar made significant investments in these software systems, in the belief that through the continued development of these software systems they could bring better quality computer-generated animation effects to films and other works manufactures. The technology developed by Pixar has also improved the system control processes including the editing and the copying of the animated image to different frames, thus reducing the time and the cost of film manufacture. In 1988, Pixar released Renderman, a rendering software system for photo-realistic image synthesis that enabled computer graphics artists to apply textures and colors to the surface of 3D images onscreen.

If Disney were renowned for traditional hand-made animation, then Pixar were equally renowned for computer animation. Pixar's defined themselves as '*a computer animation studio with the technical, creative and production capabilities to create a new generation of animated feature films, merchandise and other related products*'. Their objective was '*to combine proprietary technology and world-class creative talent to develop computer-animated feature films with memorable characters and heartwarming stories that appeal to audiences of all ages*.'[148]

These early animations paved the way for the acceptance of 3D computer animation as an art form. They were among the first fully computer-generated 3D animations to be taken seriously as animations, irrespective of the techniques involved.

The Abyss, a film released in 1989, presented the astonishingly realistic visual effects of computer-generated imagery on the big screen., This was produced by the computer-graphics team of ILM (Industrial Light & Magic), the special effects division of Lucasfilm. In *The Abyss*, the Pseudopod was the strange, gentle creature that undulated, snakelike, through the labyrinth of the underwater drilling complex. In a key scene, the Pseudopod encountered the characters Lindsey (played by Mary Elizabeth Mastrantonio) and Bud (played by Ed Harris), reconfiguring its face in a 3D mirror image of their own. Enchanted, Lindsey dipped her finger into the creature's face, only to discover that it was made entirely of sea water. The film director, James Cameron, wanted the pod to appear completely realistic. He felt that computer graphics presented the only way to achieve this effect and to effectively create something completely original. [149] Pixar's Renderman was used by ILM to render the computer-generated creatures. *The Abyss* was initially greeted with a lukewarm critical response. Its use of computer-generated special effects, however, was praised almost universally, paving the way for Cameron's future projects, which included *Terminator 2: Judgment Day* (1991), *True Lies* (1994), *Titanic* (1997), and *Avatar* (2009). Since the release of *The Abyss*'s director's cut, the film has garnered a strong cult following.

[148] See Pixar's website, about us: Corporate Overview, available from: http://www.pixar.com/companyinfo/about_us/overview.htm, accessed 28.02.2011,

[149] Prix Ars Electronic 1990, Computer Animation Unit Honorary Mention, The Abyss: Pseudopod Sequence by the Senior Visual Effects Supervisor Dennis Muren.

During the 1980s, computer-graphics technology leaped from being a curiosity into becoming an area of proven artistic and commercial potential. *The Abyss* paved the way for the realistic effects-lead films of the 1990s.

4.2 Dozo and Her Contemporaries: Diversity in 3D Animated Figures

4.2.1 The Pianist Tony de Peltrie, 1985

After the first colored and animated algorithmic human figure, Adam Powers, Tony de Peltrie became the first algorithmic human figure taking the role of the main character, expressing his emotion in the short film *Tony de Peltrie*. [*Fig. 4.2*]

Fig. 4.2: Tony is playing the piano.
(Source: screenshots from short film *Tony de Petrlie*, 1985)

The film presents the story of a pianist recollecting his glory days, when he was popular and in-demand. Whilst in appearance, Tony is not particularly life-like, the animation is so realistic that by the end of the short film, he has won the audience's genuine empathy. When the eight-minute short film, *Tony de Peltrie*, was presented to the world at SIGGRAPH in 1985, the eponymous character was widely considered the first computer-animated character to express true emotion through his face and body language. Ironically, whilst Tony spends much of the short film sadly reminiscing about his lost glory-days, his influence on the world of computer animation was just becoming apparent when the short film was released in 1985.

Tony de Peltrie was the brainchild of Pierre Lachapelle, Philippe Bergeron, Pierre Robidoux and Daniel Langlois at the University of Montreal. The animation was created on a 3D interactive graphics system called TAARNA. It had been designed for users with no previous experience of animation. Two major steps were necessary in order to animate the character. Firstly, the facial expressions needed definition and secondly, the body motions needed to be choreographed and laid out. The successful completion of these steps was among Canada's most important achievements in the field of computer graphics. The 1980s presented a period of significant development and achievement in Canada's computer graphics industry, allowing Canada to take the lead on the world stage in the fields of computer graphics, animation and visual effects.

4.2.2 Virtual Marilyn Monroe, 1987

Following the birth of *Tony de Petrie* in l987, a major event was planned for the celebration of the Engineering Society of Canada's 100th anniversary in the Place des Arts in Montreal. The main sponsors, Bell Canada and Northern Telecom were primarily interested in simulating Alexander Graham Bell in a sequence that would showcase both advanced technology and art in Canada. Instead, the couple and cooperator Nadia Magnenat-Thalmann and Daniel Thalmann proposed depicting figures with a wider appeal. Eventually, the idea of the film *Rendez-vous à Montreal* emerged with the concept of simulating a meeting between *Marilyn Monroe* and *Humphrey Bogart* in a cafe in Montreal's old town. [*Fig. 4.3*]

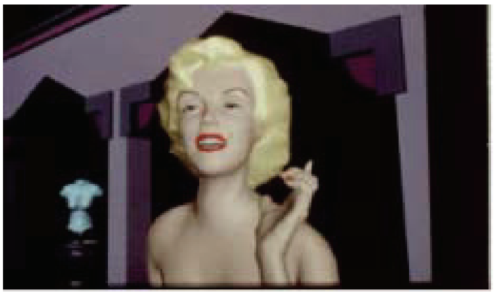

Fig. 4.3: The *virtual Marilyn* Monroe
generated with JLD (Joint-dependent Local Deformation) operators.
(Source: screenshot from short film *Rendez-vous à Montreal*, 1985)

The film development project, conducted by a six-person team, over the course of a year, included software development and 3D character design. Finally, in March l987, both the actors were revivified as virtual human beings.

In the early 1980s, prior to this project, the couple began to facilitate the animation of virtual worlds and 3D characters. They developed MIRA, one of the first abstract data-type languages for graphics and a forerunner of modern object-oriented languages. In 1982, in collaboration with Philippe Bergeron, they produced *Dream*

Flight. This film depicted a person (in the form of an articulated stick figure) transporting across the Atlantic Ocean from Paris to New York. [150]

4.2.3 Mike the Talking Head, 1988

Tony de Peltrie showed that computers were capable of generating realistic animated characters. More people were becoming interested in computer animation, however the majority did not have the opportunity to use computers, due to the expensive hardware and complicated operating systems. With a similar idea to the scientists at the University of Montreal who designed TAARNA, the two animation companies Silicon Graphics[151] and deGraf-Wahrman Inc.[152] planned a collaboration to produce a new type of animation tool which allowed animators to work with their characters in the same way that puppeteers work with puppets. The two companies aimed to produce a real-time, full rendering system with the ability to take input from different sources. This input would enable the expression of the character to be altered as well as its colour and its construction materials. The image could be re-scaled, rotated and distorted and allowed to mouth words. Simultaneously, Michael Wahrman, of deGraf-Wahrman, hoped that research of this nature would help to reduce the cost and complexity of the animation, and thus increase the commercial use of character animation. The result of this cooperation research project was *Mike the Talking Head.*[*Fig. 4.4*] At that time, real-time computer characters were considered to be 'great stunts' but with 'no practical value.' *Mike The Talking Head* was a step towards animator's attaining control of their characters through typing commands rather than drawing their actions. Ken Cope, responsible for modeling Mike Normal, worked as actor, director and animator. *Mike The Talking Head* was a precursor of *Robocop 2*[153]. *Robocop 2* exemplified the 3D animated characters which began infiltrating the film and broadcasting industries. Whilst prior to this, computers were used simply to create set scenes and logos in films and broadcasts.[154]

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[150] Nadia Magnenat-Thalmann and Daniel Thalmann, The Virtual Humans Story, available from: http://www.miralab.unige.ch/repository/papers/101.pdf, accessed 28.02.2011

[151] Silicon Graphics, Inc., also known as SGI, was founded by Jim Clark and Abbey Silverstone in 1982. The initial products were based on Jim Clark's work with geometry pipelines, specializes software or hardware that accelerates the display of three-dimensional images.

[152] DeGraf-Wahrman,Inc.,has been established in 1987, by Michael Wahrman of Abel & Associates and Brad deGraf, pre-instructor of Digital Productions, Symbolics McMahon has provided the fund, the equipment and the software, including a Symbolics 3,600 equipment and a set of S-software softwares.

[153] RoboCop 2 is a science fiction film, released in 1990 and set in the near future in a dystopian metropolitan Detroit, Michigan. It is the sequel to the 1987 film RoboCop, Robocop 1(1987), Robocop 2 (1990), Robocop 3 (1993)

[154] Barbara Robertson, Mike, the Talking Head, in *Computer Graphics*, Vol. 11, No.7 (July 1988):15-17.

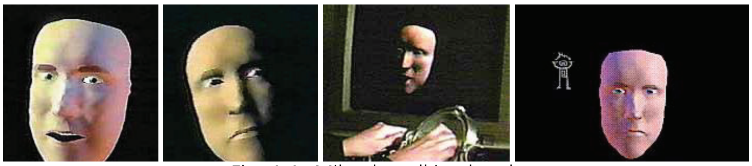

Fig. 4.4: Mike the talking head.
(Source: screenshots from *Mike the Talking Head, deGraf-Wahrman Inc*)

4.2.4 Nestor Sextone for President, 1988

The film *Nestor Sextone for President* premiered at SIGGRAPH '88. [*Fig. 4.5*] It was created by the digital film company Kleiser–Walczak, Inc.(KWCC) [155]. This thirty-second short film centered on a man named Nestor Sextone's presidential nomination campaign for the Synthetic Actors Guild. In the narrative, the muscle-bound Sextone complains that live actors have been masquerading as synthetics and stealing the synthetic actors roles. Sextone declares, 'Some people have been putting on rubber masks and parading around, pretending to be synthetic. When I'm elected, synthetic parts will go to synthetic actors!' The founders of Kleiser–Walczak, Diana Walczak and Jeff Kleiser are known for their early experimental films featuring solo performances by digital human characters. Diana Walczak and Jeff Kleiser coined the term synthespian, a synthetic thespian, to name the simulated character who 'acts' in 3D animations and games. *Nestor Sextone for President* featuring Kleiser-Walczak's first digital human, is the forerunner of the next more popular short film *Dozo* in 1989. [156]

Fig. 4.5: Nestor Sextone
(Source: screenshot of short film *Sextone for President*
produced by Kleiser- Walczak in 1989)

[155] Kleiser – Walczak, Inc., was founded by Jeff Kleiser and Diana Walczak in 1987. Official Website: http://www.kwcc.com/

[156] Diana Walczak, Synthespianism and Anthropomorphization of Computer Graphics, available from: http://www.kurzweilai.net/synthespianism-anthropomorphization-of-computer-graphics, accessed 28.02.2011.

4.2.5 Baby Billy of Tin Toy, 1988

Tin Toy, a five-minute short film, produced by Pixar, tells the story of Tinny, a brave little musical tin man, and Billy, a baby who is learning how to walk. In the film, Tinny has just jumped out of his packing box to freedom when he sees little Billy crawl into the room. [*Fig. 4.6*] At first Tinny is extremely happy to see Billy, but when he sees Billy destroy a string wooden necklace, he decides to avoid him. However, as he is a musical toy, when he prepares to leave, Billy hears the music, and pursues Tinny. Finally, Tinny rushes under the sofa to safety. However, as he begins to calm down, he discovers he is being watched by several other tin toys hiding under the sofa. Billy throws himself down and cries. Whilst the other toys turn away, unwilling to play with Billy, Tinny courageously decides to do his job as a toy; to play with children. Tinny leaves the sofa and bravely circles around Billy, playing marching music. Suddenly, Billy grasps Tinny, sways and throws him.

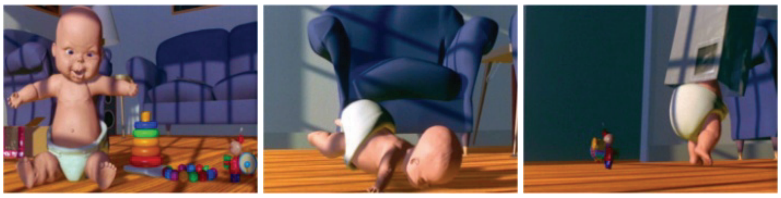

Fig. 4.6: Baby *Billy.* (Source: screenshots of *Tin Toy* produced by Pixar in 1989)

Billy in *Tin Toy* is the first algorithmic baby. He simulates the behaviour of a human infant. He is similar to a real baby of the same age. Billy is therefore significant as a product of the first stages of computer-animation to simulate human behavior, a process from crawling to standing, from walking to running. Tin Toy marked 'the first time a character with life-like bendable arms and knees, surfaces, and facial components, was digitally-animated'. Written and directed by John Lasseter[157], the film premiered at SIGGRAPH in 1988 and went on to win the Academy Award for Best Animated Short Film.

4.2.6 Dozo's Music Video: Don't Touch Me, 1989

The following year, after the successful release of masculine synthespian Nestor Sextone, Kleiser-Walczak released their first feminine synthespian, Dozo, in a music video entitled: *Don't Touch Me*. She has a bonny face, bronze-colored skin, and a symmetrical and charming body in skintight clothing, like a Gauguinian girl. She stands on a huge stage before a microphone, swinging to the rhythm of the music, singing raucously, and

[157] John Lasseter is the founder and creative front man of Pixar, the computer animation pioneers behind *Toy Story*, *A Bug's Life* and *Monsters, Inc.*, win Academy Award for special achievement for *Toy Story* (1995)

repeating the lyric; 'Don't touch me with your love.' She is the first algorithmic human figure singing on-screen. She is so attractive and realistic, not only in her figure and gesture, but also in her sound. Computer-generated Dozo presents the first attempt to personify the ideal of feminine beauty, an attempt which was not realized for another ten years.

One might suggest that the 1980s began with the creation of 'Adam' and concluded with the 'Eva' of algorithmic human figure development, Dozo. Whilst they both stand within a vast background area, not only can Dozo's face be seen clearly, but she can open her mouth to sing, and her figure embodies the beauty of the female swinging her hips.

4.3 Realistic Representation of Facial Expressions

4.3.1 Problems with Modeling and Animation of Realistic Facial Expression

Comparing the algorithmic human figures produced in the latter half of the 1980s with Adam Powers, produced at the beginning of the decade, an improvement in the degree of realism is clearly visible. Adam Powers made a positive contribution to the realistic representation of the human figure. The three basic solids which he juggles, the cone, the sphere and the cube, henceforth constructed the entire computer world visually. However, his face could not maintain its appearance of verity upon close investigation, and his body movement was unsophisticated. The necessity for realistic facial expression and body movement became the most urgent point to be addressed. Different theoretical approaches and practical techniques were involved in the modeling and animation of algorithmic human figures in the cases outlined above.

The complexity of human facial expression and the extreme difficulty in recreating human expressions can be described thus:

> *The human face is interesting and challenging due to its familiarity. Essentially, the face is the part of the body we use to recognize individuals. In the vast universe of similar faces, we are able to recognize a single face and to detect very subtle changes in facial expression. These skills are learned early in life, and they rapidly develop into a major channel of communication.* [158]

Human facial expression has been the subject of scientific investigation for more than one hundred years. The study of facial movements and expressions started from a biological point of view. After some older investigations, for example, those conducted by John Bulwer in the late 1640s, Charles Darwin's book *The Expression of the Emotions in Men and Animals* can be considered a major departure for modern research in behavioral

[158] Frederick I. Parke and Keith Waters, *Computer Facial Animation*, 1996, p. 1

biology. One of the most important attempts to describe facial activities was the Facial Action Coding System (FACS). Introduced by Ekman and Friesen in 1978, FACS defines 64 basic facial Action Units (AUs). A major group of these Action Units represent primitive movements of the facial muscles in actions such as the raising of the eyebrows, winking, and talking. Eight AUs are for rigid three-dimensional head movements, for example, turning and tilting left and right and going up, down, forward and backward.

Besides these complicated facial activities, lip and mouth shapes do not correspond to expression but also to individual sounds. Furthermore, these are dependent on context and further affected by the emotions of the speaker and by the language in use.

As Nadia Magnenat-Thalmann and Daniel Thalmann have summarized in their book *Computer Animation: Theory and Practice* published in 1985, the animation of the human face is extremely difficult to model by computer. There were two problems: one is '*The representation of the face itself. It is difficult to make a realistic image with natural-looking skin…*', the other is '*The modeling of motion. This is very complex, because of the interdependence of different parts….*'[159]

However, in the early 1970's, researchers such as Frederick I.Parke at the University of Utah accomplished significant advances in their pioneering early work with computer-based facial representation. Parke created the first 3D facial animation in 1972. In 1974, Parke developed a parameterized 3D model of a human face, discussed in his 1974 dissertation.[160]

Parke worked on both the surface shape of the face and the underlying muscles. Initially, neither system was effective on its own, but the judicious combination of the two parameterized graphical models worked together to form realistic facial expressions. In principle, Parke's system allowed for fifty independent facial actions, which might occur separately or in any combination. It was worth quoting at length from Parke's research paper, published in August 1982, on the subject to show the painstaking detail that realistic rendering of human faces involved:

> *The expression parameters found useful for the eyes include: eye pupil dilation, eyelid opening, the position and shape of the eyebrows and where the eyes are looking. Useful expression parameters for the mouth include: the rotation of the jaw (which controls the opening and closing of the mouth), the width of the mouth, the expression of the mouth (smiling, frowning and other expressions), the position of the upper lip and the position of the mouth's corners. Other useful expression parameters could include: the size of the nostrils and the orientation of the face (head) with respect to the neck and the rest of the body. The ability to orient and tilt the face was not included in the earliest models and its ab-*

[159] Nadia Magnenat-Thalmann and Daniel Thalmann, *Computer animation--Theory and Practice*, 1985, p. 146

[160] Frederic Parke, *A Parametric Model for Human Faces*, 1974

sence was obvious. With 15 or so parameters, it became possible to develop a model which allowed interesting expression animation and the ability to animate to a spoken sound track.

To allow changes in the conformation of faces (those aspects which vary from individual to individual and make each individual unique) requires a different set of parameters, which have not, as yet, been fully determined. Some conformation parameters apply globally to the face. These are the aspect ratio of the face (height to width ratio), skin colour and a transformation which attempts to model facial growth. The color (and texture in more elaborate models) of the various facial features such as eyebrows, eyelashes, lips and iris of the eye are also controlled by conformation parameters. Other conformation parameters consist of relative size, shape and positioning information. These include parameters which control: the length and shape of the neck; the shape of the cheek and the cheekbone regions; the shape of the chin; the position and separation of the eyes; the size of the eyeball; the size of the iris, the shape of the forehead; the width of the jaw; the length of the nose; the width of the end of the nose; the width of the bridge of the nose; the scale of the chin; the size of the eyelids; the scale of the forehead and the scale of the mouth to eye portion of the face relative to the rest of the face.[161]

Since the pioneering work of Frederic I. Parke, many research efforts have attempted to generate realistic facial modeling and animation. Using the updated research theory, the Facial Action Coding System (FACS), Platt and Badler, in their 1981 SIGGRAPH paper[162], describe how to construct expressions using a muscle-based facial model and how to determine which muscles to activate in the underlying model. Afterwards in the latter half of the 1980s, more solutions were developed and proposed aiming not only to animate realistically, but also to operate in real-time and to automate the process as fully as possible.

4.3.2 Facial Modeling Based on Photography and Sculpture

The short animated film *Tony de Peltrie* in 1985 was regarded as a landmark in the art of facial animation. In this film for the first time computer facial expression and speech animation became fundamental to the narrative.

The animation was done on a 3D interactive graphics system, entitled TAARNA, which had been designed for use by people with no background in computer technology. To get the required realism in the facial expres-

[161] Frederic Parke, Parameterized Model for Facial Animation, in *IEEE Computer Graphics and Applications*, Vol. 2, No. 9 (1982): 61-68

[162] Stephen M. Platt and Norman I. Badler, Animating Facial Expressions, in *ACM SIGGRAPH Computer Graphics*, Vol. 15, No. 3, (1981): 245-252

sions, photography and clay models were used. This method was similar to the one used in the modeling of Adam Powers.

> *Animators photographed a real person doing 28 different facial expressions pronouncing 28 alphabetic letters. The live model of Tony de Peltrie had a grid of dark lines drawn on his face to correspond with the control points which would be mapped onto the animated figure. Only 20 of the photographs were digitized as the difference between some expressions was too small to be distinguished. An example provided was the similarity between the facial positions for 'm' and for 'b'. Simultaneously, a clay model was made of Tony and a control grid was drawn onto this. The model was then photographed and digitized. The animators manually checked and matched up corresponding control points. Since the points on Tony's face were considerably greater than those on the real human model, this was a complex process. The matching process from the single point on the real human model to the proliferation of points caused a few problems for the animation and had to be ironed out later on.*
>
> *For the other parts of the face, a similar approach was taken although there weren't as many key positions to record. For the eyebrows there were three positions, and for the eyelids, four positions. Through the assembly process, hundreds of facial expressions were produced.*[163]

While the improvement in this case was due to an algorithm used by Kochanek for interpolating between key frames.

> *This gives the freedom to choose and combine expressions and reduce or exaggerate them for added effect. The speech sequence was recorded onto tape, and then the timing for the speech was noted. The timings for the speech were copied onto dope sheets and then the synchronizing of speech was done using techniques very similar to traditional cell animation.*[164]

4.3.3 Facial Simulation Based on Scanning

For *Mike the Talking Head* a real person acted as the model in order to obtain the primitive data for Mike's facial model. A 3D scanner scanned his face obtaining 256,000 spots of data. These points were transformed into polygons, were connected to form multi-surfaces, and the concentration of these polygons was controlled. Moreover, Mike's lip shape was scanned whilst each syllable was sent out, as the word was composed by the

[163] Pierre Bergeron and Philippe Lachapelle, Controlling Facial Expressions and Body Movements in the Computer-generated Animated short 'Tony de Peltrie', in *Siggraph '85 Tutorial Notes, Advanced Computer Animation Course*.

[164] Ibid.

syllables. In order to match these syllables to the correct word, the programmer specially developed the code to complete the syllable interpolation.

4.3.4 Facial Simulation Based on Muscle Systems

For the film *Tin Toy*, Pixar made considerable effort to create a realistic baby Billy. However, in 1986, before *Tin Toy*, Pixar had already created a very successful 3D short animated film, entitled *Luxo Jr*.

In the majority of Pixar's projects, they applied techniques developed by Disney.[165] As such, complex anatomical models were not always necessary for facial animation. The key attribute of Pixar's style of animation was vivid motion of the body and head and the eye and mouth. In many cases, animators approximated the movements of the face in order to offer an indication of reality without applying too much detail. It is the animation of the figure as a whole, rather than simply the facial movements, which creates an image with convincing expressions. Simplistic facial shapes accompany this simplistic facial animation. These can be stark, for example, a sphere, yet they offer a convincing effect. A bonus of simple facial animation is that the expressions can be exaggerated to give a funnier and more vivid effect.

Nevertheless, the facial animation in the short film, *Tin Toy*, was more complex. For Tinny, the toy, they used simple techniques as described earlier, however Billy, the baby, required a more realistic image. To animate Billy, they had to create software which could handle complex facial animation. In order to avoid the lengthy procedure of sculpting and digitizing each facial expression in turn, they created a muscle model to work on a set of 3D points which represented Billy's skin.

The first step was to create a clay model of one half of Billy's face with a neutral expression and to digitize this. This was then copied and reversed to create a whole symmetrical face.

Billy's face was animated using a Water's-style model, a general muscle-based model developed by Keith Water in 1987. Water also used FACS theory to relate expressions to muscle activation.

In the case of Billy's facial model, three types of muscles; including 43 linear muscles, 4 sphincter muscles and rotational muscles in order to animate areas where the muscles were in contact with bone were incorporated

[165] Traditional character animation was developed from an art form into an industry at Walt Disney Studio between 1925 and the late 1930s. At the beginning, animation entailed little more than drawing a sequence of cartoon panels—a collection of static images that, taken together, made an animated image. As the techniques of animation developed, certain basic principles evolved that became the fundamental rules for character animation, The Twelve Principles of Animation were originally developed at the Walt Disney Studios in the 1930s but are still in use today by animators all throughout the world to bring drawings to life and create the illusion of life.

into Billy's face. The placement of these muscles was based on the illustrations in Ekman and Friesen's FACS manual[166].

In the majority of situations, Pixar only used polygons in order to represent flat things, however, in this case, their ordinary technique of breaking the face up into triangles was not an option. Instead, they used a series of bi-cubic, Catmull-Rom spline[167] patches in order to construct Billy, and Triangular Bezier patches were also attempted, however severe wrinkling problems precluded their use. Wrinkling remained problematic, although less so after the switch from triangular patches. Billy still had a north pole problem at the top of his head as well as major problems with his neck. At last a formulation was developed by DeRose / Barsky in order to smooth out the resulting surface. The animators at Pixar created their own software to ease the process of animation. A system was developed to give a higher level of control to the animation system. The result was a highly successful short film.

4.4 Realistic Modeling of Body Movements of 3D Character

4.4.1 Body Movement Based on Skeletal Movement and Key-frame Animation

In comparison with the animation of the facial expression, human body motion is neither complex nor subtle, as the body movement is constrained primarily to the rigid skeletal system. However this system has a different range of difficulties to confront in order to create an effective simulation.

This research and experimentation could be applied retrospectively to 1970's computer-aided traditional animation. In the 1970s, many stages of conventional animation appeared ideally suited to computer assistance, especially in betweening and colouring. For example, in 1974, the National Research Council of Canada released *Hunger/La Faim* directed by Peter Foldes, which featured Burtnyk and Wein's interactive key-framing techniques. Similarly, in 1976, M. Wein and N. Burtnyk, developed the computer-generated human figure walking technique with the use of a skeleton to define interpolated shapes.[168]

[166] Facial Action Coding System (Ekman, P. & Friesen, W., 1978; The Facial Action Coding System (FACS) Manual is a detailed, technical guide that explains how to categorize facial behaviours based on the muscles that produce them, i.e., how muscular action is related to facial appearances.

[167] The curve is named after Edwin Catmull and Raphie Rom. In computer graphics, Catmull–Rom splines are frequently used to get smooth interpolated motion between key frames. For example, most camera path animations generated from discrete key-frames are handled using Catmull–Rom splines. They are popular mainly for being relatively easy to compute, guaranteeing that each key frame position will be hit exactly, and also guaranteeing that the tangents of the generated curve are continuous over multiple segments.

[168] Nestor Burtnyk and Marceli Wein, Interactive Skeleton Techniques for Enhancing Motion Dynamics in Key Frame Animation, in *Communications of the ACM*, Vol. 19, No.10 (1976): 564-569

But when the computer animation emphasis developed from 2D to 3D shapes in the 1980s, many of the techniques of traditional 2D character animation no longer applied directly.

Both these techniques were devised to interpolate line drawings, however the same problems arise in interpolating 3D objects. The most important difference is that, in most cases of computer-based animation, the 3D objects are likely to be modeled explicitly, rather than drawn in outlines. Thus the modeling and placement information is available for using interpolation, and the animator does not, in general, need to indicate which points on the objects correspond to different key frames. Nonetheless, interposition between key frames is a difficult issue to address.

> *For the time being, let us restrict our analysis to the interpolation of the position and orientation of a rigid body. Position can be interpolated by the techniques used in 2D animation: The position of the centre of the body is specified at certain key frames, and the intermediate positions are interpolated by some spline path. In addition, the rate at which the spline path is traversed may be specified as well (e.g., by marking equal-time intervals on the trajectory, or by specifying the speed along the interpolating path as a function of time)…*
>
> *Interpolating the orientation of the rigid body is more difficult. In fact, even specifying the orientation is not easy. If we specify orientations by amounts of rotation about the three principal axes (called Euler angles) then the order of specification is important…* [169]

Tony's body was modeled with clay and then digitized in the same way as his head. The skeletal data, the hierarchy of body parts and where they bend, was done through TAARNA. TAARNA has five commands for skeletal manipulation: the bend, twist, pivot, stretch and rotation. For each of these commands, the limb, the point of movement, and the degree of movement need to be given. The animator has to check that the movements are valid as TAARNA does not check for impossible movements.

To animate the body, there were three stages to be worked through. These stages were: [170]

-the specification of the key positions;
-the interpolation between the key positions;
-the correspondence and fitting of the 3D model to each interpolated skeleton.

Unlike the body movement technology used to animate Billy's body in *Tony de Peltrie*, an articulated, hierarchical skeleton was modeled from simple cylinders. A key-frame animation system was used by Pixar to achieve the realistic action of the boy.

[169] James Foley et al., *Computer Graphics: Principles and practice* ,1990, p. 1063

[170] Valarie Hall, Bergeron, available from: http://mambo.ucsc.edu/psl/bergeron.html, accessed 28.02.2011

4.4.2 Body Movement Based on Motion Capture

In the 1980's, with the exception of manual system key frames, computers progressed beyond the central frame interpolating form of body movements, the capture of movement and began to reach applications. Dozo provides an example of this.

Dozo is both symmetrical and seductive, with such a successful music video that many viewers become distracted at the sight of her. However, she is also merely a computer-generated female, who lives on the screen. Her realistic attributes may be attributed to the technology of motion capture.

Motion capture is used to record the movements of human figures and other objects and to analyze and playback the movements later, in real-time. The data, which is captured may be simplified to offer special position information relating to the body. It could also be complex distortion data of the face and muscle group. The application of motion capture in computer character animation includes the correspondence of human movement to the animation of the computer-generated character. The nature of this correspondence may be a direct correspondence; for example the control of the computer-generated character's arm movement through the movement of the real human arm, or an indirect correspondence, in the same way that the design of a human's hand and finger control the character's skin colour and emotional condition.

By the end of the 1980's, the technology of motion capture was still relatively new in the field of character animation. Usually, new technology was expensive and few people had the opportunity to use it. However, motion capture was already being used as a tool in character animation from the late 1970's onwards.

The idea of mimicking real human movements in order to animate convincingly a human figure is not new. In order to make the animation role obtain the persuasive movement in *Snow White*, Disney drew the animation according to the bottom of the film strip of the real human preferment. This method named roto-scoping, has been extremely successful in the character animation role, up until the late 1970's, when the methodology was available to mold animated characters. Animators have now absorbed the roto-scoping method creating traditional animation, Rebecca Allen who is in New York Technology University's computer graphics laboratory uses a kind of half silver-plating glass to take the real human's video to append fold shade to the computer screen as a reference for the computer-generated character's movement. However, despite continuing to develop the roto-scoping method, 2D animations still could not produce a truly dynamic character.

In fact, besides computer-generated character animation, motion capture technology had already been used extensively in medicinal and military applications. The earliest use of motion capture technology in the computer graphics domain began in the late 1970's however, the main research in the early years of the 1980's was limited to the institutes, like MIT, The Simon Fraser University and The New York Institute of Technology. It was not until the mid-1980's that this technology was actively used.

The first of the 3D computer-generated human figures was by Robert Abel who applied motion capture to an attractive metal robot in a film entitled *Superbowl,* released in 1985. In order to create convincing movements, the animators placed 18 black mark points on a dancer's body, then simultaneously took several photographs from different angles as she moved as a reference to build a 3D model.

In 1988, PDI manufactured Waldo C for Jim Henson Hour Graphic. They used input equipment with 8 degrees of freedom to control the character's position and mouth movement with a low resolution rate. They also captured the movement of a live puppet concert. The synthesis of the computer image and the puppet's photographs were screened by camera. Thus in the last section of the concert, when everyone performed together, Waldo was exaggerated again after joining in with the movement.

In 1989, Kleiser-Walczak produced Dozo. In order to capture a sense of realistic human motion, they decided to use motion capture techniques. Based on experiments in motion capture from Kleiser's work at Digital Productions and Omnibus, two now-defunct computer animation production houses, the two companies chose an optically-based solution from Motion Analysis that used multiple cameras to triangulate images of small pieces of reflective tape which were placed on the body. The resulting output was the three-dimensional trajectory of each reflector in the space. As previously suggested, one of the problems with this system was the tracking of points as they were occluded from the cameras. For Dozo, this was a time-consuming but necessary process. Luckily, some newer systems were beginning to do this in software, significantly speeding up the motion capture process. At the end of the 1980's, the utilization of motion capture in 3D animation may have been a recent development, however this lead to the revelation of a range of further possibilities.

4.4.3 Simulating Deformation of the Body Surface

However, the 1980's era witnessed an encounter with the most challenging aspect of physical motion simulation, which presented 3D computer graphics' greatest difficulty. This aspect of physical motion was the need to introduce flexible and soft surfaces whilst retaining rigid skeletal frames. In the cases previously referenced, different cases applied different methods to solve this problem. The conflict was between the desire to articulate motion effectively and the resulting deformation of the body surface.

To take Dozo as an example, when Dozo moved her shoulders, a fracture could be seen between the skin of her shoulders and arms. Simultaneously, in Billy's case, the skin was not soft enough.

However, in the case of the algorithmic human Marilyn Monroe, Thalmann and Thalmann used a polygonal surface model for the animation, whilst simultaneously introduced the concept of Joint-dependent Local Deformation (JLD) operators to allow the skin surface more potential to transform and thus attained a more realistic appearance. These operators were specific local deformations that depended on the nature of joints. Forsey extended the hierarchical B-spline technique to 3D character animation. A hierarchical surface was attached to an underlying skeleton in such a way that the figure designer had control over the location and scope of the surface deformation. Douros et al. used B-spline patches for reconstructing the surface of the scanned human body.

In reality, the anatomy of the human body is comprised of not only the skeleton and skin, but also elements including the muscles, fat and blood. In 1989, Chadwick and his collaborators proposed a layering technique based on Free-Form Deformation to apply muscle efforts to a skeleton. This prototype human body model was not practical until 1996 when Thalmann and his collaborators proposed an effective multi-layered approach for constructing and animating realistic human bodies.[171]

Besides the skin of the cases above, the clothing of all algorithmic figures by the end of 1980s was very similar, but this increased differentiation became the main focus of realistic human figure algorithms in the 1990s.

[171] Paul Siebert and Xiangyang Ju, Realistic Human Animation Using Scanned Data, in *Proceeding 5th Numerisation 3D/Scanning 2000 Congress* (2000): 24-25

5 GERI, DAVE AND AKI'S SKIN, CLOTHING AND HAIR : PHOTOREALISTIC ILLUSIONS

  

Fig. 5.1: (left) Geri in Pixar's short film *Geri's Game*, 1998.
(Source: www.pixar.com/shorts/gg/index.html)
Fig. 5.2: (middle) Dave in short film *Bingo* (Source: screenshot of *Bingo*, 1998)
Fig. 5.3: (right) Aki, as the leading actress of the feature film *Final Fantasy: The Spirits Within.* (Source: Jon 'Hannibal' Stokes and Jonathan Ragan-Kelley, Final Fantasy: The Technology Within, available from: http://arstechnica.com/wankerdesk/01q3/ff-interview/ff-interview-1.html, accessed 28.02.2011,)

Enter a new dimension,
beyond anything you can imagine,
where fantasy becomes reality.

--Tagline of *Final Fantasy: The Spirits Within*

5.1 1990s: The prevalence of 3D Computer Graphics

5.1.1 The Photo-realistic CGI's Achievements in Entertainment in the1990s.

In comparison with the 1980s, the last decade of the 20th century was a time of great change. From a political and economic perspective, following the collapse of the Soviet Union, the reunion of East Germany and West Germany and the end of the Cold War, the 1990s were marked by the rapid progress of globalization and global capitalism. Along with this, technologies first invented and used during the 1980s were being mainstreamed and improved and were becoming more sophisticated. Key forces shaping the decade included the recession and the popularization of personal computers in the early 1990s and the dot-com boom and rise of the Internet in the late 1990s.

The whole decade could be described by the book *Being Digital by* Nicholas Negroponte (1995), which presented a strong belief that humanity is inevitably headed towards a future where everything from newspapers, to entertainment even to sex will be digitalized. The world's becoming a village is no longer one of McLuhan's predictions but by the end of 1990s had become reality.

With regard to the quality and realism of computer-generated images, the 1990s also showed a significant leap forward from the 1980s. This was mainly attributable to the rapid development of hardware and software in the field of computer graphics technology.

Firstly, the computer operation speed has increased. Intel developed a processor with a vastly improved operational speed named the 'Pentium' processor which drastically reduced the time taken to generate an image by computer. At the same time, the processors of the early years of the 1990s in comparison to the 1980s, could generate even more images or images with greater detail and precision. In addition, aside from the central processors improved speed, storage equipment capacity also made a great leap forward. IBM introduced the 1-inch wide hard drive in 170 MB and 340 MB capacities and CD burner drives were introduced. This lead to the capability of even personal computers to process images and graphics, yet prior to this, it was necessary to have a specialist external storage device, such as a tape machine recorder, which afterwards could export and store images.

Alongside research into the effects of computer hardware, price and potential applications, the majority of time and effort was used developing optimum software. Firstly, the computer operating system providing the basic platform for all software function exceeded the development of applications. Microsoft put a graphical operating system called Windows 95 on the market, as well as the updated edition Windows 98. The graphical operating system's distribution and use made computers which could genuinely be used by ordinary users. Windows operating system changed the operating system interface and model of the past based upon language-based text commands which only specially-trained professionals could use. The Windows operating system quickly became popular and recognizable.

This development took place in the early to mid-1990s, leading to the popularization of personal computers. Computer graphics began to enter the vision and lives of ordinary people. At the end of the 1990s, Windows NT and Linux operating systems became prevalent. This trend evolved to a point that even SGI, the computer formerly known as Silicon Graphics Inc. and a traditional stalwart of the UNIX operating system began to offer NT-based computers in 1999.

The increased capabilities of computers developed in the 1990s, the greater convenience and affordability lead to the possibility of CGIs with not only the bigger file size but also more representation of detail. Thus, this significantly altered the entertainment industry. Two aspects were keys to this; namely film special-effects and video games.

In the 1990s, people became inspired by the significant achievements in the film industry, particularly in the special effects brought about by computer graphics imaging techniques. In 1991, after the following film, the Abyss's development of a realistic water-based life form called the *'Pseudopod'*, *'Terminator 2: Judgment Day'*, introduced the first computer graphic-generated main character: the lethal, liquid-metal, chrome T-1000 cyborg terminator. Especially in 1993, *Jurassic Park* thoroughly triumphed over viewers' exacting eyes. Whilst in the past, people could only see dinosaur fossils in a natural history museum, imagining scenes of dinosaurs running in the Jurassic period. Yet now, since the advent of prehistoric archaeological discoveries, the stuff of our imaginations can now be faithfully reproduced on the screen. Special effects continued to become more sophisticated as the decade continued. Later in 1995, Pixar released the first entirely CG feature-length film *Toy Story* after four years making. Later in 1997, film *Titanic* realistically represented the famous historic scene and shocked the audience. The decade was ended by the science fiction-adventure film *Matrix*, which is known for developing and popularizing the use of a visual effect known as "bullet time". But also triggered the wide discussion in culture and philosophy for its containing numerous references to the cyberpunk and hacker subcultures; philosophical and religious ideas; and homage to *Alice's Adventures in Wonderland*, Hong Kong action movies, Spaghetti Westerns and Japanese animation.

In comparison with visual special effects in film, at the beginning of the 1990s the computers games industry maintained a heavy reliance on hardware technology in order to keep up with the required speed. Following the 1990s, further changes occurred, yet this change also lead to long-term alterations of the original intentions to develop realistic effects. Due to the clear differences between computer-generated real-time images and non-realtime images, I have detailed the history and development in the following chapter.

5.1.2 Computer Graphics Photorealism in the 1990s; Creating the Illusion of Reality

In the 1970s and 1980s, research and technological developments lead to increasingly realistic CGIs. With the arrival of the 1990s, rendering technology had also advanced in leaps and bounds.

Rendering became the key challenge for the researchers, who continued to investigate the field of realistic imaging and animation-generation in computer graphics. Much of the research documented at SIGGRAPH throughout the 1990s was concerned with this. The quality and realism of the CGIs of the 1990s were a significant improvement over the previous decade. It became evident that CGIs had the potential to become as realistic as photographs.

Consequently, the day when people believed that computer graphics had the capability to render any life-like image would quickly arrive. In order to differentiate the 1990's CGIs visual results and 1980s CGIs in the pursuit of realism, the field of computer graphics borrowed a word from the history of visual art; 'photorealism' and applied it to the trend for the pursuit of the development of photograph-like realistic effects.

In addition, in the 1990s, with the development of the computer graphics systems, the hardware and rendering techniques as well as the continuous new releases of 3D software, not only large-scale production companies but anyone with some basic skills could render extremely realistic images, for example placing an indoor table with glasses in a corner etc. Images of this kind only needed to set up a limited range of objects and a small quantity of lights, simple materials etc. which were not as complicated as outdoor scenes. After this, if creators had a definite basic knowledge of photography or fine-art, they could make detailed adjustments to lighting; choose colors and textures for mapping images, and finally generate more realistic images.

Once completed, the creator would often ask the viewer: Is this photograph or a computer-generated image? They would feel a sense of accomplishment when given answers such as: 'This is a photograph, this is definitely a photograph.' Originally, there were a few websites established by experts as an arena to debate this question, where computer-generated images and photographs were placed alongside each other and viewers were invited to take part in a test: If this is a photograph, please choose 'Yes' and if not, please choose 'No'. This kind of interactive game boosted the morale of computer-generated image creators and was enjoyable. Viewers began to take an active interest in the realism of computer-generated images through website games questioning their realism. This active interest inspired the creators of the images to make greater leaps forward in the pursuit of 'photorealism'.

However, this exciting development has lead to very few people's genuine engagement with the origins of photorealism, but rather more towards direct simplistic comparisons.

Photorealist art developed in the USA at the end of 1960s, almost at the same time that computer graphics began to develop. However at that time, these two elements with regard to 'realism' were worlds apart. The algorithmic human figure still had only attained the simple line image like the Boeing Man. Through the 70s and 80s the constant research and technological advances, computer generated images became more and more realistic. With the advancement by leaps and bounds of the dramatization technology with the arrival of the 1990s, this made everyone realize that computer graphics had the capability to create the same realism as photographs. In order to divide this from the levels of 'realism' attained in the 70s and 80s, as well as the above mentioned game where rendered images deceived viewers into believing them to be photographers, made 'photo-realism' lead to a vast range of applications. Although of relevance among these, for example the two elements must tackle detailed problems like surface reflection, however there is still a fundamental difference in the aims and motives of computer graphics and photo-realism respectively.

In media, photorealism strictly defines paintings in the style of photographs. Photorealist painting cannot exist without photography. Photorealists gather their imagery and information with the camera and photograph. Once the photograph is developed (usually onto a photographic slide) the artist will systematically transfer the image from the photographic slide onto canvases. This is done by either projecting the slide or grid techniques. This results in the photorealist style becoming tight and precise, often with an emphasis on imagery that requires a high level of technical prowess and virtuosity to simulate, such as reflections in specula surfaces and the geometric rigor of man-made environments.[172] The resulting images are often direct copies of the original photograph but are usually larger than the original photograph or slide. However, when observing a photorealist painting, the viewer is always aware that they are looking at a painting.

3D Computer Graphics images were also modeled according to photographs. Then, a camera was built into the computer graphics software in order to keep the location of same point of view of the photograph. This situation needs to be used in particular 3D rendering of objects synthesis with real environmental images or videos. However, in most cases, CGI is used as a reference rather than directly copying photographs. On this point, it is even closer to the concepts applied by realist painters.

In addition, the photorealist movement moved beyond illusions of reality to tackle deeper issues of spatial representation (e.g. urban landscapes) and took on increasingly varied and dynamic subject matter. In photorealism, change and movement must be frozen in time which must then be accurately represented by the artist. But the main aim and difficulty of computer graphics is not merely to generate a still image, but through the alterations and movement within a series of images, to model, to render and to achieve a display of animation, activity and movement.

[172] Wikipedia, s.v. 'Photorealism', available from: http://en.wikipedia.org/photorealism, accessed 28.02.2011.

The most effective media to record real activity is the camera. The present-day high-speed cameras can easily record realistically the whole process of an activity. But at the beginning of the development of camera, the tradition of photographic artists, such as Eadweard Muybridge used multiple cameras to capture human figure movement and helped people to see images which they could not see in the flesh. [*Fig.5.4*]

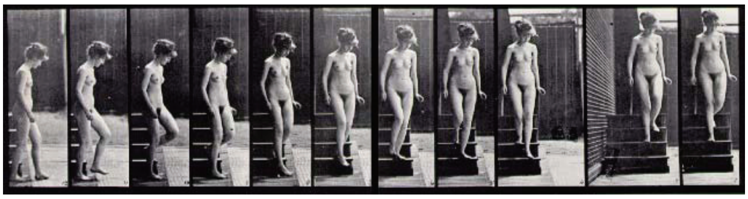

Fig. 5.4: Eadweard Muybridge used multiple cameras to capture human figure' movement, and helped people to see images which they could not see in the flesh before. (Source: Eadweard Muybridge, *The Male and Female Figure in Motion*, 1984)

So, are computer-generated images capable of the same level of realism as camera shots and can they help people to see images which we could not see before?

In fact, the stir caused by the film *Jurassic Park* was already sufficient to make people believe in the CGI's potential for realism. Whilst CGI images could attain the veracity of photographs, photographic images could not capture the images of extinct dinosaurs. CGIs had also achieved what previous artists of hand-painted animations were unable to display: scenes conveying a sense of reality.

Yet in the silent film era, research and examination of dinosaur bones in museums lead to Winsor McCay's hand-painted animation *Gertie the Dinosaur*. [*Fig. 5.5*] He not only recreated the images of dinosaurs from research into the biological and physical posture of the dinosaurs in motion, but also compiled a story about dinosaurs. Although McCay's hand-painted dinosaurs once caused a stir, there was no way for hand-painted images to compete with the realism of the dinosaurs of *Jurassic Park*. [*Fig. 5.6*]

Fig. 5.5: (left) Din*osaur in McCay*'s hand-making short animation *Gertie the Dinosaur*
Fig. 5.6: (right) 3D computer-generated Dinosaur in *Jurassic Park*

However, the film also inherited McCay's method of telling the story of dinosaurs. Yet, what most surprised viewers of the film was the representation of the relationship between dinosaurs and humans which had reached new levels of complexity. In the same picture, dinosaurs pursue humans; humans flee in all directions, making a new soul-stirring reality possible. Here, the art of the computer generated images has emerged. It is different to photographs, videos, films, different to hand-painted images and also different to the special effects of the past. It is the computer generated image.

Computer graphics had attained the capacity to recreate a dinosaur on-screen, but could it also be used to recreate more complex human figures? In theory, this must be the case, however in practice the road held many obstacles which had yet to be overcome. Although in the 1980s, Baby Billy could already totter forward, and Dozo could already sway her body from side-to-side, and open her mouth and sing, these movements were only posture animation. Viewers were able to see the difference between real people and algorithmic humans. The problems discovered by each viewer were different. The main problem was in the detail, for example, the skin's lack of elasticity, the clothes' lack of texture and the hair's lack of movement. Whilst viewers were unaware of the texture of a dinosaur's skin, the color of its eyes, the way it moved and its running posture, we are all instinctively capable of discovering problems with recreation and simulation of human figures.

In fact, for algorithmic figures, the level of realism is especially important. The skin, clothes and hair are important elements of the appearance of algorithmic human figures, not only physical, but also as reflections of social, personal and environmental factors. In comparison to the algorithmic humans figures of the 1980s, research into realism had developed and focused upon these details.

Geri and Dave, the two representatives of the algorithmic human in the late -1990s era are important milestones on the road to resolving these difficulties. They present typical cases with common points; the trialing of the latest techniques, the attempts to create the most up-to-date artistic representations, along with the aim to move towards the optimum techniques. However, differences include greater emphasis placed upon a specific software version for the algorithmic figure, internal tests, and greater emphasis placed upon the integration of technological processes of 3D animation and commercial software. Yet Aki Ross, the other representative of the algorithmic human in the post-1990s era performed in a completely 3D CG film production which used the latest achievements of the computer graphics system's comprehensive integration to achieve the dream of creating a realistic algorithmic human figures.

5.2 Photorealistic Simulation and Representation of Movement in Skin, Clothing and Hair

5.2.1 Limitations of the Representation of the Detail of Algorithmic Human Figure

This section explores the complexity of the human physique and its surroundings as well as the development of attempts to render a realistic depiction of human skin, clothing and hair from the media of painting to computer graphics. It also analyses the computer graphics techniques used to facilitate this process and the extent of their success.

5.2.1.1 Difficulties in the Representation of Photo-Realistic Skin

i) The Real Human Skin: Physique and surroundings.

When viewing the algorithmic human figures of the 1980s, such as virtual Monroe or Baby Billy, we can see that they are not real, and with closer observation, we would feel their similarity to plastic models. This is mainly due to the skin's rigidity.

In a real human figure, skin covers the entire human body. The nature of our skin not only confirms our hereditary and biological diversity, but is also influenced by environmental, social and personal factors. If we were to explore skin from the anatomical viewpoint, we would find complicated structures with specific functions.

Our skin comprises layers of epithelial tissues. As the barrier between the human body and its environment, skin plays a key role in protecting our underlying muscles, bones, ligaments and internal organs as well as against pathogens and excessive water loss. When compared with the pelts of other mammals, human skin looks smoother and less hairy. However, almost all types of human skin are covered with hair follicles. The colour of skin varies according to the habits of various cultures and lifestyles and skin types range from dry to oily. Another prominent feature of our skin is the way it wrinkles. Skin wrinkles typically appear with age, and various other factors such as habitual facial expressions, sun damage, smoking and poor hydration. For an algorithmic human figure, computer graphics' specialists hoped to simulate the skin's composition and its organization, from modeling to rendering. Using the computer graphics technology of the 1990s, this hope was unattainable.

ii) The Human Skin in Visual Art.

Computer graphics also turned to the visual arts in order to explore methods of representing the human body. In the history of visual art, the representation of skin had specific characteristics and forms, and was an important indicator of social status. Prior to the Renaissance, the key subjects of artworks were spiritual beings, and members of the royal family and nobility. In order to represent the spirituality and beauty of these subjects, artists often omitted details of their rough skin texture and hair. Yet with the arrival of the Renaissance, ordinary people and everyday life became suitable subjects. With the birth of realism, artists spared no effort to represent the details of skin.

Realistic representations of skin were a critical element in the art of China in the 1980s. To take an example, the young Chinese photorealist painter Luo Zhongli's oil-on-canvas work, entitled Fu Qin,[173] caught the nation's attention. [*Fig. 5.7*] The bronzed face of an old peasant, marked with the wrinkles of years of toil in the sun, dominates the canvas. In the bottom right-hand corner, his leathery hands are represented holding an old broken bowl. The realism of this artistic representation of such a typical Chinese peasant's face not only impressed the audience but also made the audience associate this face with hundreds and thousands of real Chinese peasants. Eventually, this imagery sparked discussion about the future of China as one of the largest agricultural countries in the world after the disastrous Great Proletarian Cultural Revolution.[174]

Fig. 5.7: Luo Zhongli, *Fu Qin*, oil-on-canvas, 1980, size:216cmx152cm

iii) Depictions of the Human Skin in Computer Graphics

When compared with representations of skin painted with brushes, using computer graphics to represent real skin is wrought with difficulty. Whilst in an image artists represent a figure from a specific angle, in computer graphics, it is necessary to create a realistic representation both from each specific angle and also of the figure in motion, from many different angles. Although with the arrival of the 1990s, techniques to render and paste were already available to generate realistic static human figure images, difficulties emerged with attempts to simulate the skin of figures in movement. Due to the complexity of the structure of human skin, in close-up shots, the appearance of softness and elasticity was often imperfect. The expression was also flawed. Skin is sprinkled with freckles and translucent at certain levels, however, despite research attempts it was not until the

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[173] Fu Qing means father in Chinese

[174] Great Proletarian Cultural Revolution was a period of between 1966 and 1976 in China. It began as a widespread social and political upheaval and led to the nation-wide chaos , economic disarray and eventually changed much of Chinese society.

1990s that rendering and mapping techniques could create realistic representations of human skin in still images. Finally, a computer-generated 'Fu Qin' became possible when photo realistic rendering became a mainstream CGI technique.

But, when people are moving, subtle changes in the skin's surface tones take place, however these still cannot be refined. The greatest difficulty is the skin's elastic movement. It transforms at contact points with bone joints, and wrinkles around the eyes, the mouth and the forehead. To illustrate this difficulty, we might imagine what alterations would take place in Fu Qin's wrinkles were he to raise the bowl to his lips to drink. Actually, as the human body is constantly in motion, the surface of the human body moves in subtle but visually-significant ways: bending, bulging and stretching. Since the human figure is complex and we are so sensitive to human appearance, researchers must investigate techniques for the realistic representation and simulation of the motion of the human body. Skin transformation has become one of the most difficult and interesting computer graphics research areas in 1990s.

With regard to the accurately simulation of skin, the model of the body should refer directly to anatomical principles, that is to model algorithmic human figure with several layers based on anatomy, such as the skeleton, musculature, fatty tissue and skin. The logic of this approach is that the skin shape is derived from its underlying structures; its protruding bones and muscles. The skin stretches across these composite structures to take the body's overall shape. Theoretically this method, could allows strong visual realism, and in 1990s, the computation ability could already support such kind of modeling approach. Unfortunately either for computer scientist or common users, it requires professional knowledge of anatomy and is a tedious rather than intuitive process. In 1990s, this method is used to a limited extent in medical and scientific research and very seldom in the animation industry.

Then how to improve the current existed method of skin simulation becomes the key topic of 1990s computer graphics. The former cases of algorithmic human figures in the thesis, either Adam Power, Dozo used a reductive skin model comparing to the above very scientific method. It is often referred to as the process of 'smoothing the skin' or 'deforming the skin surface'. This approach does not relate to the body's anatomy specifically. The skin's shape is controlled by the transformations associated with the joints of the skeleton. And the detail of the skin, such as wrinkles, is additional through the mapping techniques. This method applied artistic modeling techniques, which is better inclined towards the visual representation of the skin surface. It was based on replicating the eye's experience of skin. But this technique is simple and fast to compute. It is the most popular in animation production and has been incorporated into many animation packages.[175]

Until the 1990s, there were three common skin surface representation methods, each with their own advantages and disadvantages both in modeling and animation.

[175] Xiaosong Yang and Jian Zhang, Realistic Skeleton Driven Skin Deformation, in *Lecture Notes in Computer Science,* 2005: 1109-1118

The simplest and most popular method was polygonal representation. The earliest algorithmic human figures, such as Adam Powers, were modeled using this method. This held the advantage that polygons could be used to describe complex shapes with arbitrary topology and could be rendered quickly. In 1990s, in applications such as video or online games, when time was prioritized above the realism of visual effects, polygonal representation remained the first choice. However, regarding the realistic visual representing, since polygons are planar, the disadvantage was that thousands of polygons would be necessary to model the details of complex surfaces, such as wrinkles. Furthermore, in order to animate the complex surface, it was difficult to maintain a smooth and continuous surface.

Later, parametric surfaces, such as B-spline surfaces or Bezier surfaces, were developed to represent smooth surfaces with a relatively small number of control points. By moving control points, the deformation of a parametric surface is easier and always stays smooth. The immunity of this technique in contrast to the degradation occurring in polygonal representations techniques was its key advantage. However, the disadvantage of the parametric surfaces was that it could not easily represent objects with branch topology such as the human body. Normally this method was used in the deformation of a rectangular object.

From the mid-1980s onwards, a new method called Soft Objects or Metaballs was introduced. It was based on the theory of distributed density, giving shape to realistic, organic-looking creations such as human figures.[*Fig.5.8*] The limitation of this model was that it required a great deal of skill to construct complex objects and in order to finally visualize the soft object, polygonalization or ray-tracing was required. Hence, this process was expensive to compute.[176]

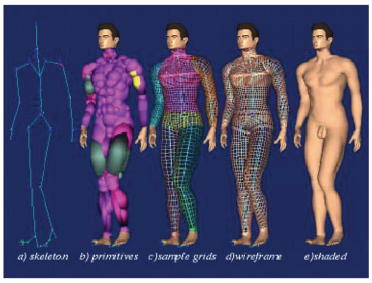

Fig. 5.8: layered human body
(Source: Jianhua Shen, "Human body surface and deformation," PhD thesis, école Polytechnique Fédérale de Lausanne, 1996, chapter3-4)

[176] Jianhua Shen et al., Human Skin Deformation from Cross-Sections, in *Proceeding Computer Graphics International '94, Melbourne, Australia* (1994): 612-619

None of the approaches indicated above were categorically superior to the others. And researchers are also try to find out some hybrid method to represent more realistic skin. Moreover, different applications of algorithmic human figures would require different approaches to the representation of skin.

5.2.1.2 Difficulties in the Representation of Dynamic Clothing

Examining closely the algorithmic human figures of the 1980s, such as Dozo or the baby, we find that the treatment of clothing and skin in the computer graphics of the 1980s is similar.

For example, the black tuxedo of Adam Powers, baby Billy's white nappy and Dozo's dress were tightly affixed to their bodies. When 3D computer graphics were used to make the body swing, climb and jump, the clothing of these figures was dealt with in the same way as the skin surface. The only difference was that the clothing was given different material attributes during the rendering process.

i) Clothing in the Real World

In the real world, clothing is often referred to as man's second skin due to its protective function, providing a barrier between the skin and its environment. Throughout history, clothes have been made of a wide variety of materials, ranging from natural grasses and furs to elaborate and exotic synthetic compounds. However alongside its practical purpose, clothing is an expression of social status and quality. Most societies develop standards in modesty, religious practices, appropriate behaviour, social status, and even political affiliations in which clothes play an important role. Finally, clothing functions as a form of adornment and an expression of personal taste.

ii) Clothing in Visual Art

In western art through the ages, we can see a number of portraits that the artist has put considerable effort into the depiction of the figure's clothing in order to represent the figure's position in society and individual taste. To take Velasquez's painting of *Pope Innocent X* [*Fig. 5.9*] as an example, the pope's clothing covers more than half of the picture's total area. The shape and colour of his cap and cloak and the prominent ring on his finger indicate his identity.

Fig. 5.9: Diego Velázquez, *Papa Innocenzo X,* oil-on-canvas,1650, size:114 cm × 119 cm collection of Galleria Doria-Pampili, Roma

iii) Clothing in Computer Graphics

Following this emphasis on clothing in the depictions of the human being in visual art，with regard to the algorithmic human figure, unless the figure is nude, the clothing also form an important element. In the steps leading towards a realistic algorithmic human figure, the simulation and animation of realistic clothing was critical. From the 1980s onwards, research groups confronted the problem of the representation of a garment in 3D computer graphics. However this was even more difficult than the representation of the skin surface.

Firstly, the motion of the clothes must follow the motion of the body. What makes clothing look natural and dynamic is how they flow and fold with the body as the figure sits, stands and moves. Yet in 3D computer graphics, the mathematical model used to describe the principle of how fabric flows with the body and naturally folds in a variety of different situations must first be defined. In Western portraiture, the folds in clothing must appear vivid and animated and reflect the figure's pose.

The texture of the clothing is also affected by various natural factors, including weight and wind. In portraiture, the life-like depiction of the drapery of clothing thus reflects the figure's posture. In ancient Chinese art, artists developed a method to describe the posture of the human figure effectively through the depiction of clothing with a full sense of movement, although the representation of figures seemed simplistic. [*Fig. 5.10*]

Fig. 5.10: A figure in *Nymph of the Luo River*
painted by GU Kaizhi (ca. 344-406),
collection of the Palace Museum of Beijing

Another difference between clothing and the skin surface is that while the skin can be regarded as a whole, cloth is normally sewn in sections. When it moves subtly with the body, the sewn edge is relatively still and constrained to both sides patches. In the process of the photo-realistic simulation and animation of clothing, the formulas describing the relationship between clothing and the body and different articles of clothing require further explanation.

In early work, cloth simulation was treated as a problem of deformable surfaces, and techniques were borrowed from mechanical engineering and finite element communities to tackle the problem. Later, more specific details were considered in the research, such as collision detection and constraint methods. Equations were formulated to simulate cloth. The cloth's internal energy, damping and air-drag, contact and constraint forces acting on cloth will affect the results of the equation, thus affecting the appearance of the clothing.[177]

Actually clothing simulation developed slowly due to technical difficulties: creating more realistic results, achieving faster running-times, and developing methods capable of constructing and simulating more complex garments.

So, the capacity of the representation of the algorithmic human figure in the 1980s was extremely limited. The human figure was always represented in skin-tight clothing. With the capacity to simulate different clothing, algorithmic figures gained individual identity.

5.2.1.3 Difficulties in the Representation of Casual Hair

A close examination of the 1980's algorithmic figure revealed figures wearing hats like Adam Powers, with bald heads like Baby Billy, or with hair pasted closely to the head, like Dozo and virtual Marilyn Monroe.

[177] David Baraff and Andrew Witkin, Large Steps in Cloth Simulation, in *Proceedings of SIGGRAPH'98* (1998): 43-54

Whether the figures were walking or crawling, the individual strands of hair did not move. These algorithmic figures more closely represent people of Asian origin, with typically straight, black hair, however they were still far from faithful representations of real hair.

i) Human Hair in the Real World

Real human hair not only has an enormous quantity of strands, but also a vast range of shapes. A grown man's head normally has several tens of thousands of individual strands of hair. The shape, color and thickness of hair varies according to heredity and region. People of African origin have tightly coiled black hair and those of Asian origin have straight black hair. Hair style and condition also holds social significance. Modem hair styling techniques easily change colour and style artificially. Hair style, like clothing, expresses personal taste.

ii) Depictions of Hair in Visual Art

The representation of hair in paintings does not require the same clear structure as that of the face or the detailed characteristics of the eyes, nose and mouth. However, depicting hair is still extremely difficult. People often forget that it is an important element in the overall depiction. Hair occupies a large area on the top of the head and has a significant effect on the overall appearance of the figure. The hair's reflection of the figure's disposition is an important element, as in the figure representation, the artist also pays significant attention to the representation of the hair. In the painting entitled *The Birth of Venus* by Sandro Botticell [*Fig.5.11*], Venus' hair floats in the wind providing a visual balance with the figure's posture, as well as covering her private parts, thus expressing the modest nature of the goddess. Here, the hair becomes an important aspect of the artist's expression.

Fig. 5.11: section of *The Birth of Ven*us
painted by Sandro Botticell, circa 1486, tempera on canvas,
size: 172.5x278.5cm, collection of Uffizi Gallery, Florence

iii) Depictions of Human Hair in Computer Graphics

Due to its complexity, research into the modeling, rendering and animation of hair only began in the 1990s. Modeling, rendering and animating hair remains a slow, tedious and often painful process for animators.

If one were to model each hair realistically, the model itself would be enormous. If one progresses on this basis to carry out realistic rendering, supposing one applies the ray-tracing method, one must deal with the reflection between each strand of hair, as well as how the shadows relate to each other. This would significantly challenge the computer's performance. When the hair moves, the hair's shape may alter significantly, the hair's arrangement and construction might also alter significantly. In this case, the treatment of the hair, the relationships between the hair and the body and the hair and the clothes respectively depend on the style. It is also difficult to achieve stable and robust simulation of moving hair as well as interactions between hairs and between the hair and the body for different types of hairstyle. The quantity of calculation necessary for these interactions was too much even for the highest performance computers of the 1990s. [178]

There were various approaches to hair modeling, dynamics and rendering such as the explicit models, particle systems, volumetric textures, cluster models and hair as a fluid.

So, research was directed towards finding an effective and quick mathematics for the modeling and simulation of hair. Simultaneously, hopes were pinned on the advancement of high-speed hardware. In fact, it was not until the end of 1990s that research into the representation of hair made progress.

5.2.2 Magic Subdivision Algorithms: Photo-realistic Skin and Clothing Representation Using Geri as a Case Study

5.2.2.1 Geri, an Old Man with Cotton Jacket

The algorithmic human figures of the 1980s were improved in many areas, however in order to make skin, clothing and hair more realisticly. In CG animation and 3D computer graphics, animators and artists had yet to attain the capability to resolve certain difficulties. In the above-mentioned description, the vast majority of work needed was scientific research. Therefore, this only dealt with specific details of research which were not always of assistance to animators and artists in order to improve the level of realistic representation, as well as how to move forward the development of creative tools.

[178] Kelly Ward, et al., A Survey on Hair Modeling: Styling, Simulation and Rendering, in *IEEE Transactions on Visualization and Computer Graphics, vol. 13, no. 2* (2007): 213-234

But, '*in the history of computer graphics, there are numerous beautiful examples of this creativity*' to realize '*the marriage of technology and art*.' '*Some of the most brilliant have been produced at Pixar Animation Studios*.'[179]

In 1997, Pixar released *Geri's Game*. This was the first short film produced by Pixar since the studio shifted its focus towards commercials in 1989, and finally to feature films with *Toy Story* in 1995.

Pixar aimed to bring the company's technical expertise to bear fruit. *Geri's Game* was a project which tested Pixar's proprietary animation and rendering systems, Marionette and RenderMan, and incorporated a variant of Catmull-Clark subdivision surfaces. Simultaneously, Pixar hoped for a breakthrough in the area of figure modeling. Realistic wrinkles, movement and clothing appearance were all lacking in the algorithmic figures of the 1980s. Furthermore, Pixar aimed to improve its human skin, hair and clothing models, as these were specific areas of weakness.

Geri's Game opens with an aging man named Geri setting up a chess board on a small table in a park on a bright autumnal morning. The colors, Geri's appearance and the cut of his jacket all have a European flavor. When all the pieces are in place, he makes his first move. As he has no opponent, he slowly gets up and ambles across to the other side of the board. As *Geri* sits down, he becomes very competitive. After killing one of his gentler opponent's men, competitive Geri moves back across the table and becomes gentle again. Competitive Geri is laughing the entire time as he captures piece after piece. This continues until Gentle Geri has only one piece left.

As Gentle Geri looks helplessly at his single piece, he has an idea. He fakes a heart attack and falls to the ground. Competitive Geri stops laughing and looks under the table to see whether his partner is all right. As his head is down, Geri peeks up and spins the board around so that he is winning. Competitive Geri makes sure that Gentle Geri is alright and then begins to laugh again. Gentle Geri moves a piece, and competitive Geri realizes that he has lost. As a token of his defeat, competitive Geri takes a pair of dentures out of his pocket and places them on the table. Gentle Geri scoops them up into his mouth and begins to smirk and laugh through his newly-won teeth. However, Geri is laughing at no one. He is alone in an empty park.

Geri's Game, directed by Pixar's Jan Pinkava, was without dialogue, like a mime. The director stated that '*when Pixar set out to do short films, it usually did so with research and development in mind.*'[180] *Geri's Game* was given the same purpose to develop new skills, but in this case, '*the challenge was to take human and clothing animation to new heights*.'[181] At the beginning, Jan Pinkava came up with the idea of creating an old man,

[179] Barbara Robertson, Meet Geri: The New Face of Animation, in *Computer Graphics World*, Vol. 21, No 2 (February 1998), p. 20

[180] See Pixar website, Geri's Game: Behind the Scenes, available from: http://www.pixar.com/shorts/gg/behind.html, accessed 28.02.2011

[181] Ibid.

similar to his own grandfather. [182]However, this old man would be an algorithmic human figure. It would be great challenge to create such kind of algorithmic human figure even at the end of 1990s. An old man would need wrinkles, especially facial wrinkles as this was a key feature of the aging process. Old people mainly wear baggy clothing, unlike the tightly-fitting clothing of Adam Powers. Only this would mark out the old person's specificity and identity.

To achieve this, Pixar developed proprietary software to generate realistic skin motion simulation and clothing dynamics. Eventually, the film became successful due to its vivid depiction of lovely old man who appeared almost real enough to touch. Pixar won the Academy Award for Best Animated Short Film again and once again, following the success of *Tin Toy,* won the Oscar for Best Short Film in 1988. [183]

5.2.2.2 Magic Subdivision Algorithm

In the final film, the most impressive element was the animation and realism of Geri's face, which came as a direct result of the surface modeling algorithm used by Pixar, named the 'subdivision surface model'. [*Fig. 5.12*]

A subdivision surface, in the field of 3D computer graphics, is a method of representing a smooth surface via the specification of a coarse piecewise linear polygonal mesh. The smooth surface is calculated from the coarse mesh as the limit of a recursive process of subdividing each polygonal face into smaller faces better approximating the smooth surface.[184]

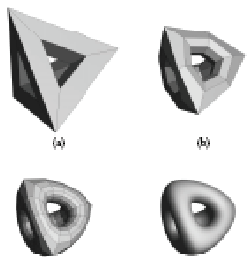

Fig. 5.12: Recursive subdivision of a topologically complicated mesh
(Source: Tony DeRose et al.Subdivision Surfaces in Character Animation,
Computer Graphics SIGGRAPH 1998 Proceedings, 1998)

[182] See Pixar website, An Interview with Jan, available from: http://www.pixar.com/artistscorner/jan/interview.html, accessed 28.02.2011

[183] Barbara Robertson, Meet Geri: The New Face of Animation, in *Computer Graphics World*, Vol. 21, No 2 (February 1998): 20-24+28

[184] Wikipedia, s.v. 'Subdivision Surface', available from: http://en.wikipedia.org/wiki/Subdivision_surface, accessed 28.02.2011

In 1978, subdivision surfaces were discovered simultaneously by Edwin Catmull and Jim Clark[185] as the generalization of bi-cubic uniform B-spline surfaces to arbitrary topology (named as Catmull–Clark subdivision surfaces)[186], and by Daniel Doo and Malcolm Sabin as a generalization of bi-quadratic uniform B-spline surfaces (named as Doo–Sabin subdivision surfaces)[187] [188]. Relatively, the Doo–Sabin subdivision surfaces are not as efficient as the Catmull-Clark surfaces because their matrices are not in general diagonalizable.

But the subdivision surface method did not make great progress and was not widely available until 1995, when Ulrich Reif invented the algorithm for subdivision surface behavior near extraordinary vertices[189].

Until then, the most common method to model complex smooth surfaces was to use a patchwork of trimmed Non-uniform rational B-spline (NURBS). NURBS are a mathematical model commonly used in computer graphics for generating and representing curves and surfaces. This model offered significant flexibility and precision for handling both analytical and free-form shapes. NURBS were developed in the 1950s by engineers who aimed to develop a mathematically-precise representation of freeform surfaces like those used for ship hulls, aerospace exterior surfaces and car bodies, which could be exactly reproduced when required. At first, NURBS were only used in proprietary CAD packages of car companies. Later, they became part of standard computer graphics packages.

In 1985, the first NURBS algorithm for PCs was developed. In 1989, real-time, interactive rendering of NURBS curves and surfaces was first made available on SGI workstations. In the first half of the 1990s, NURBS was used primarily because it was readily available in existing commercial systems such as Alias-Wavefront and SoftImage. NURBS modeling method could model smoother surfaces than polygonal modelers, however, as Pixar's Tony DeRose, who had worked on subdivision surfaces during ten years as a professor of computer science at the University of Washington. In his 1998 paper, DeRose pointed out that '*they held at least two difficulties*,' one is '*trimming is expensive and prone to numerical error,'* the other is *'it is difficult to maintain smoothness, or even approximate smoothness, at the seams of the patchwork as the model is animated. As a case in point, considerable manual effort was required to hide the seams in the face of Woody, a principal character in Toy Story.'*[190]

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[185] They created this method when they were students together at the University of Utah.

[186] Edwin Catmull and James Clark, Recursively Generated B-spline Surfaces on Arbitrary Topological Surfaces, *Computer-Aided Design* Vol.10,No.6 (November 1978): 350-355

[187] Daniel Doo, A Subdivision Algorithm for Smoothing Down Irregularly Shaped Polyhedrons, in *Proceedings on Interactive Techniques in Computer Aided Design 1978*: 157-165

[188] Daniel Doo and Malcolm Sabin, Behavior of Recursive Division Surfaces near Extraordinary Points, *Computer-Aided Design*, Vol. 10, No. 6 (1978): 356–360

[189] Ulrich Reif, A Unified Approach to Subdivision Algorithms near Extraordinary Vertices, *Computer Aided Geometric Design,* Vol. 12, No. 2 (1995):153–174

[190] Tony DeRose, Michael Kass and Tien Truong. Subdivision Surfaces in Character Animation. In *Proceedings Siggraph'98* (1998), p. 85-86

Subdivision surfaces held the potential to overcome all of the problems faced by previous surface modeling techniques, including problems related to the model's animation. The advantages of subdivision surfaces also especially helped to model objects with complex topology such as the human figure.

In fact, in the project of Geri's Game, DeRose stated , '*subdivision surfaces were used to model the skin of Geri's head, his hands and his clothing, including his jacket, pants, shirt, tie, and shoes*,' and '*the use of subdivision surfaces posed new challenges throughout the production process, from modeling and animation to rendering*.'[191]

> *In modeling, subdivision surfaces free the designer from worrying about the topological restrictions that haunt NURBS modelers, but they simultaneously prevent the use of special tools that have been developed over the years to add features such as variable radius fillets to NURBS models.* [192]

Then, '*once models have been constructed with subdivision surfaces, the problems of animation are generally easier [to deal with] than with corresponding NURBS surfaces because subdivision surface models are seamless, so the surface is guaranteed to remain smooth, although the model is animated.* '[193]

However the main problem remained applying mathematical equations to simulate real-life clothing.

In *Geri's Game*, when subdivision surfaces were used for the physically-based animation of clothing, specific problems needed to be solved, including computational problems to make the cloth look and act like cotton, and to keep it from intersecting with itself and with other objects. There were thousands of vertices in the subdivision surface that made up the jacket, each of which could have millions of interactions. The goal was to create a cotton jacket that was neither too rubbery nor too silky. The interactions of the vertices determined its material properties; the stretchiness and stiffness of the cloth. '*As soon as the cotton was stretched to its maximum length, it could not stretch further. Thus, the equation describing its stretch became unreliable. Moreover, the material had to be stiffened in the places where jackets were reinforced in real-life. The invention of 'virtual starch' was also necessary*.'[194]

> *A second computational problem they needed to solve was to make the cloth move like cotton. It was easy to create the feeling of rubbery or silky cloth, but it took longer to develop energy functions which would make the cloth move like cotton material. The energy functions in the model described the resistance to various kinds of deformation. For example, energy functions described stretching on*

[191] Ibid. p. 86

[192] Ibid.

[193] Ibid.

[194] Barbara Robertson, Meet Geri: The New Face of Animation, in *Computer Graphics World*, Vol. 21, No 2 (February 1998), p. 20

the warp and the weft of a piece of cloth. The energy functions in the cloth simulator are now so sophisticated that the cloth moves differently depending on whether a garment is cut on the bias or not.[195]

DeRose found that '*having modeled and animated subdivision surfaces, formidable challenges still remain before they could be rendered. The topological freedom that made subdivision surfaces so attractive for modeling and animation meant that generally they did not admit parameterizations suitable for texture mapping.* '[196] In 1998, this difficulty was partially solved. Jos Stam[197] contributed a method for the exact evaluation of Catmull-Clark and Loop subdivision surfaces under arbitrary parameter values.[198]

In fact, the success of Pixar is an example of the integration of simulation and artistic appearance. To take *Geri's Game* as an example, they had not only applied their technical expertise, although to achieve this film, the studio developed proprietary software to calculate skin motion simulation and cloth dynamics. Whilst the film was created by more than 80 people, it is unlikely that all researchers produced research to transform artistic expression. It is also unlikely that all animators understood how to apply the codes to compile remarkable results; therefore, these two groups took the opportunity to collaborate. As a result, Pixar's simulations were both inimitable and non-promotional. Yet, after the mid-1990s, along with the relative declining in the price of hardware and increasing individual creations in 3D, it required an open stage. This stage would allow developers to integrate the newest research findings very easily as well as being intuitive for animators to understand and use. Computer 3D animation software of this kind became a pressing requirement. In the history of the algorithmic human figure, Bingo was representative of these historical conditions. The production of this film was in order to test a new generation of 3D software which would soon be available, Maya's techniques and artistic capabilities.

5.3 Development of New Generation 3D software: The Illusion of Reality

5.3.1 The Illusions Created Using Maya

[195] Ibid.

[196] Tony DeRose, Michael Kass and Tien Truong. Subdivision Surfaces in Character Animation. In *Proceedings Siggraph'98* (1998), p86

[197] is a leading researcher in the field of computer graphics, focusing on subdivision surfaces, rendering algorithms and the simulation of natural physical phenomena.

[198] Jos Stam, Exact Evaluation of Catmull–Clark Subdivision Surfaces at Arbitrary Parameter Values, in *Proceedings of SIGGRAPH'98* (July 1998): 395–404

In the 1990s, large-scale applications of visual special effects and games on computers and the 1990's growing acceptance of the development of 3D production software is indivisible. These two elements supplement one another. On the one hand, a large market promoted the development of 3D production software. With the exception of a small number of companies such as PIXAR, who had their own software development program and technical department, the majority of production companies did not have the capacity to create films on the scale of Toy Story. Therefore, good value for money was necessary, standing astride the platform as well as aimed at animation-design software. However, on the other hand, the development of software encouraged even more companies to enter into computer-generated image production. Even traditional hand-painted animation companies like Disney prepared to transform into computer production CGI companies.

In fact, with regard to the 3D software market, the 1990s represented the period of a heroic struggle with a divided market. The table below [*Tab. 5.1*] presents the condition of three of the key 3D software packages in the first-half of the 1990s, Softimage, Cinema 4D and 3dsMAX.

Each software package outlined in *Tab. 5.1* had particular strengths and weaknesses. They were each suited for specific applications. Hence, in other areas they were unsatisfactory to requirements. In order to get the best results in all aspects of work, it was usually necessary to use more than one software package.

3D Software	Company or Founder	Precursor	the First Version	Features	1990s Development
Softimage	Softimage was founded in 1986 by a National Film Board of Canada filmmaker, Daniel Langlois	The original 3D modeling and animation package was called the Softimage Creative Environment, later renamed to Softimage|3D	1986, Softimage|3D for SGI.	It was a fast, simple-to-use animation package, the first commercial package to feature Inverse kinematics for character animation. However, the modeling and rendering capabilities were somewhat limited.	1994 bought by Microsoft 1998, bought by Avid Technology Inc.
Cinema 4D	MAXON Computer GmbHf founded by Christian and Philip Losch in Friedrichsdorf, Germany	Christian and Philip Losch enter their ray-tracer into Kick-start magazine's monthly programming contest and win the competition. FastRay is released for the Amiga.	1993, FastRay was renamed as CINEMA 4D 1.0 for Amiga.	CINEMA 4D is a commercial cross platform high-end 3D graphics application. It is capable of procedural and polygonal/subd modeling, animating, lighting, texturing and rendering, and is noted for being very easy to use and artist friendly among high end 3D applications and having a very flexible interface.	1993,Cinema 4D V1 released for Amiga 1994, Cinema 4D V2 for Amiga 1995,Cinema 4D V3 for Amiga 1996, Cinema 4D V4 for Windows, Alpha NT and Macintosh is released 1997,Cinema 4D XL V5 1998,Cinema 4D SE V5 1999,Cinema 4D GO V5 and Cinema 4D NET released
3ds MAX	Autodesk	The original 3D Studio product was created for the DOS platform by the Yost Group and published by Autodesk. After 3D Studio Release 4, the product was rewritten for the Windows NT platform, and originally named '3D Studio MAX.'	3D Studio MAX was officially announced at SIGGRAPH 1995 and shipped to users in April 1996.	It has strong modeling capabilities, a flexible plug-in architecture and a long heritage on the Microsoft Windows platform. It is used mainly by video game developers, TV commercial studios and architectural visualization studios. It is also used for film effects and film pre-visualization.	1996, 3D Studio MAX 1.0 for windows. 1997, 3D Studio MAX R2 for windows. 1999, 3D Studio MAX R3 for windows.

Tab. 5.1: the rapid development of various software packages of the 1990s and their competitive strength.

Thus, '*in the mid-1990s, the most popular pipeline in Hollywood films was a combination of tools: Alias Studio for modeling, Softimage for animation, and PhotoRealistic RenderMan for rendering. This combination was used for numerous films, such as Jurassic Park, The Abyss and Terminator 2: Judgement Day.'* [199] This means at that time there was not a single existing integrated package in the 3D computer graphics market which performed well throughout the modeling, rendering and animation stages. Companies needed to transfer data from one package to another, which was not only inconvenient, but also lead to the loss of information. This affected the efficiency of the work and, to a greater extent, people's requirements. The frequent application of a range of software packages made error-reduction and the need for reworking a pressing priority. Every industry hoped to be able to use the best integrated software, allowing effective movement of data. Towards

[199] See Mayabooks Org website, History, available from: http://www.mayabooks.org/, accessed 28.02.2011

the end of the 1990s, it became necessary to develop a software package to fulfill the market's new requirements. Maya is the software comes out on time.

> *Maya is the culmination of three 3D software lines: Wavefront's The Advanced Visualizer (in California), Thomson Digital Image (TDI) Explore (in France) and Alias' Power Animator (in Canada). In 1993 Wavefront purchased TDI, and in 1995 Silicon Graphics Incorporated (SGI) purchased both Alias and Wavefront (due to pressure from Microsoft's purchase of Softimage earlier that year) and combined them into one working company, producing a single package from their collective source code. The combined company was referred to as Alias|Wavefront.*[200]

The aim of the merger was to produce a single package from their collective source code. It was two years later that Alias|Wavefront released the highly anticipated Maya. They claimed they would release new artist-oriented 3D software which would provide fully for the needs of animators and designers. People were attracted to a more intuitive user-friendly interface which 3D production computer software packages were beginning to provide. This user interface dispensed with the necessity to input code to change images, allowing the user wider parameters within which to create images.

Maya followed a merger of several companies and combined all the advantages of their collective efforts. At the time of the merger, '*Both Alias and Wavefront were working on their next generation of software at the time of the merger. Alias had taken a Macintosh product, "Alias Sketch!", moved it to the SGI platform and added many features to it. The code name for this project was "Maya", the Sanskrit term for "illusion." Maya was developed in close collaboration with Walt Disney Feature Animation, during the production of Dinosaur, and the GUI was all customizable as a requirement from Disney so they could set up their own GUI and workflow based on decades of animation experience. This had a large impact on the openness of Maya and later also helped the software become an industry standard, since many facilities implement extensive proprietary customization of the software to gain competitive advantage.'*[201]

Alias|Wavefront maintained their position at the upper end of the animation market through designing their production paradigm in accordance with client's needs. At first glance, Maya seems to be an amalgamation of TDI's Explore, Wavefront's Kinemation and Dynamation, and Alias' Power Animator, which were all integrated software packages with a range of applications. Maya incorporated many of the familiar features but Maya's salient point was the ability to remap relationships spontaneously. The system architecture was written from the ground up for maximum performance. There was no longer 1980s' legacy code to hamper development or overly simplistic features such as a universal undo, which had resulted in the loss of good work and time wastage.

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[200] Ibid.

[201] Ibid.

Three main architectural components of Maya were the Dependency Graph, MEL scripting and a C++ API. The Dependency Graph could be distilled to nodes with connected attributes. The benefit of this was the artist's ability to reconnect or remap relationships spontaneously. The next most accessible feature was MEL scripting. MEL stood for Maya Embedded Language. It was the command and scripting language that could be utilized for creating a custom user-interface or repetitive set of commands. Users coming from an artistic background could appreciate the utility of this program but without the same technical depth as a Technical Director. The Maya C++ API permitted Plug-in or custom development for proprietary tools.

Maya provided development tools and platforms for technical guidance, allowing successful development of applications.

The most important feature of Maya was its openness to third-party software, which could strip Maya completely of its standard appearance and, using only the Maya kernel, could transform it into a highly customized, proprietary version of the software. Apart from its intrinsic power and flexibility, this feature in itself made Maya extremely appealing to large studios which tended to write a lot of proprietary code for their productions.

Apart from the openness to custom code, Maya also featured a powerful concept resembling C, a program language. This allowed users to tweak almost everything, from simple interface changes/helpers to complex animation effects. This feature was intended for small-medium studios which did not have huge budgets but still needed a certain level of customization.

MAYA allowed animators to quickly and intuitively interact with the characters as digital puppets. Furthermore, MAYA focused on furthering the quest for realistic hair and clothing, two elements notorious for their artificial appearance in the past.

Inverse kinematics were incorporated leading to more realistic human motion, for example limb movement. Maya also included the particle system, which simulated certain natural phenomena including fire, explosions, smoke, moving water, sparks, falling leaves, clouds, fog, snow, dust, meteor tails, hair, fur, grass, and abstract visual effects like glowing trails and magic spells. Without Maya, these would have been very hard to reproduce.

An advanced model of the software permitted both 2D and 3D integration. This allowed 3D objects to be added into live-action scenes and the placing of real objects into the 3D world.

On 1st February 1998, Alias|Wavefront began to ship their latest 3D flagship product, animation software Maya and Maya Artisan. Maya ran on Silicon Graphics hardware with a R4000 or higher processor, 24-bit graphics and OpenGL native preferred. Alias|Wavefront claimed that later it would run on Windows/NT.

5.3.2 The 3D Photo-realistic Animation Based on Live Performance Taking the Case of Bingo

Bingo was the product of an internal project run in order to test the Maya software. Directed by Chris Landreth, *Bingo* became a five-minute animated short designed to demonstrate the new features of the software. The project began in November 1996 and finished 18 months later. As a senior animator at Alias|Wavefront, Landreth developed *Bingo* to push Maya to its limits and to ensuring its capability to satisfy the most innovative of creative endeavours.

On 21st July 1998, a year following the release of the acclaimed algorithmic human figure, Geri, an Bingo, another impressive algorithmic human figure, appeared on the big screen of the Electronic Theater at SIGGRAPH *'98* in Orlando, Florida.

The plot features an innocent young man sitting on a bench. He is approached by a clown puffing on a cigarette, who says 'Hi.' After the man on the bench, named Dave, returns the greeting, the clown says 'Hi, Bingo.' Dave becomes confused, and says that his name is not Bingo. The clown begins to shout at him, and to scream that Dave is Bingo. His head swells in size, distorting his face and giving him a frightening appearance. Suddenly, a woman dressed as a circus ringmaster, who is also quite realistic in appearance, swoops in and asks for music. In a circle around Dave, computer screens rise, filled with images of Timothy Leary, a man shouting into a megaphone, tanks in Tiananmen Square, the words 'Hi Bingo,' and other flashing snippets of video. After a series of similarly weird and visually stunning encounters, Dave is so flummoxed that he believes that he is Bingo after all. 'I am Bingo. Bingo the clown-o, that's me!' he says enthusiastically, jumping up and hopping around. 'Thank you,' says a bored voice over an intercom. 'Next.' The audition is over. This marks the end of the short film.

Both the subject-matter of this five-minute computer animation and the realism of the characters were so extraordinary that they challenged the public's image of 3D computer animation. Its cast of animated alternately human-like and freakish characters was original and disturbing. The film demonstrated how Maya could provide both a stronger degree of realism than traditional animation, and also an element of caricature that live action could not. This allowed the inclusion of a psychological element to the characters which previously would have been impossible.[202]

As a short film with a clear plot progression, characters and sustained theme, *Bingo* was recognized at film festivals around the world. Later, showings of *Bingo* accompanied the promotion of the newly-released Maya v1.0.

[202] Cynthia Amsden, Chris Landreth, in *Take One* (Jun 1999).

In the design and production of Bingo, Landreth was certain of the need to complete an extremely realistic short film. However, the nature of the film's subject-matter and how it could best demonstrate Maya's capacity to integrate were still to be decided. Coincidentally, Landreth saw a performance which he thought would be well-suited to the film's specifications, and which held a challenge. *Bingo* was based on Greg Kotis' three-minute play, *Disregard This Play*, produced in 1993 by the Neo-Futurist Theater Company in Chicago.[203]

'*I happened to see a Neo-Futurist performance and was excited by their concept of doing 30 short plays in 60 minutes*,' stated Landreth. '*Their timing and some of their dark humour and absurdist concepts seemed ideal to adapt as a CGI short. Later, I read [more of] their plays and, finally, settled on one that became Bingo*.' [204] Thus, computer graphics was used to adapt existing art-forms.

This work explored the nature of reality on three different levels. The content itself was about reality and fabrication, 3D animation and real human performance, visual reality and psychological reality.

The word 'Bingo' holds connotations of warmth. It both refers to a gambling game favoured by the elderly, and to a farmer's dog in a famous children's song. However, through placing the name 'Bingo' in the evil clown's mouth in a highly realistic computer animation, Landreth gave the name a more sinister meaning. Here, Bingo explored the darker side of reality and the nature of belief and self-suspicion. People associated the film with the 1990s' game where one had to identify an image as either a photograph or a CGI. People became increasingly uncertain about the verity of the photograph. Following *Forrest Gump*, the uncertainty of viewers when looking at images, was due to uncertainty about whether this was a documentary or a computer-synthesized image. The confusion that Dave experienced when defining his sense of identity offered a metaphor for the confusion viewers experienced when defining the boundaries of the real-world and the virtual world brought about by the development of the realism of computer graphics imaging techniques. From the visual perspective, Landreth referred to actors' performances, as well as directly appropriating the sounds of live sound performances. He hoped to achieve an effect of the verisimilitude of real people.

Landreth also explored the nature of photo-realism. Initially, *Bingo* was performed on stage with real actors. Later, the computer-animated short film attempted to create the visual effect of a hyper-real performance. This was the psychological realism that Landreth was searching for. In the version of *Bingo* performed on stage, due to the performance's time limits, actors would wear ordinary clothing and use the minimum in properties and scenery. However, in the 3D computer animated version of *Bingo*, without the limitations of a stage or the

[203] The Neo Futurists are an internationally acclaimed performance group known for works with intensely social, political and personal edge. Founder and director Greg Allen envisioned a show that emphasized speed, brevity, audience interaction and social consciousness. Neo-Futurism began in 1988 with the first production of Too Much Light. The title came from a medical study about an autistic child who uttered the words of the play's name while smashing light bulbs. Available Online: http://www.neofuturists.org/

[204] See Autodesk website, Conversation Maya Master: Chris Landreth, available from: http://www.autodesk.com/eng//mayamasters/masters/chris_landreth.shtml, accessed 01.07.2008

time limits on interludes between scenes, the director had far greater scope for creativity. Landreth and his team decided to use a sound recording of the live performance of Bingo as the beginning of the CGI film. They arranged wireless microphones on actors, recorded the sound when they performed, and made a video recording of the live performance. They used the video as a reference tool whilst designing the animation. At the beginning of the 3D film, Dave wears a baseball cap backwards, sits on a chair and looks much like the Dave of the theatre edition. However, throughout the animation, Dave is the only character to maintain this human appearance. The characters change drastically as the film continues and they attempt to hurt Dave. The first of these is the evil clown of the opening. The clown's head is suddenly inflated to ten times its normal size, providing a metaphor for Dave's growing fears.

Secondly, a shy little girl demolishes a balloon and says to Dave, mystically: 'You know, he is coming to inspect your progress.' Finally, a person with seventeen arms, waves fistfuls of dollar bills in Dave's face, knocking Dave's self-awareness further. The director manipulated the CGI media to create metaphorical images in order both to arouse the audience's sympathy and encourage them to question the media. This short film met with conflicting responses and raised the time-honoured question; as a rumour is repeated over time does it become the truth?

Although Dave retained a cartoon-like appearance, *Bingo* was not a cartoon, but a unique 3D computer animation which could not be recreated as a real performance or as a traditional cartoon animation. Landreth believed that *Bingo* embodied every aspect of the animation scale, from synthetic character animation to a wilder cartoon style. Pinhead the clown, the villain of the piece, is realistic as a synthetic character, until his head expands, and Dave, the young boy, is portrayed in a cartoon-like style. Bingo's thematic exploration of the frightening darkness of reality is mirrored formally in the richness of shadow, colour and texture. Bingo was an animation that stretched the boundaries of realistic representation whilst pushing the limits of technology. The Alias|Wavefront creative team that brought *Bingo* to life included the 3D conceptual designer, Ian Hayden, character animator, David Baas, and CGI texture and lighting wizard, Owen Demers. *Bingo* pushed the limits on the use of symbolism in design, as well as offering an exacting demonstration of the power of Maya as an animation tool. Furthermore, *Bingo* provided a key example of how art could drive the development of tools rather than tools defining art.

Bingo was shown all over the world with the promotion of Maya Software v1.0 by Alias | Wavefront. The artistic achievements of the short film reflected the creative potential of the newly-released Software and inspired animators. Ultimately, the development of computer software of this nature along with the falling prices of computer technology brought greater freedom to animators.

Landreth stated that '*the direction in which I am particularly interested, is one in which CG technology becomes cheaper and 'democratized'. The result will be that individuals, not just large studios, will soon be able to develop huge works of art, such as CG feature films, on their own. In non-CG animation you see this al-*

ready with people such as Bill Plympton producing one-person film projects. I look forward to seeing similar projects from inspired individuals using tools such as Maya, over the next few years.'[205]

In 2003, the following year, Landreth's predictions were realized in the CGI short film *Eternal Gaze*, produced by a single individual, which was shown at SIGGRAPH. In comparison with a team effort or a small studio, an individual must put in much more time and effort. The creator of *Eternal Gaze* spent two years producing the film.

In the 1990s, sophisticated 3D software connected artists with programmers, musicians and engineers. Landreth commented: '*This is what I call a renaissance field, meaning that it brings people together ….people who use both sides of their brains. The result is a kind of artistry which has enormous potential to move people through new imagery, new storytelling.*'[206]

Both Geri and Bingo have highly realistic skin, facial expressions and behavior than the algorithmic human figures of 1980s. From the Juggler onwards, one of the dreams of 3D CGI scientists and artists was to simulate the virtual world with photo-realistic effect. Photo-realistic rendering is the 1990s' key research area. Most of SIGGRAPH's papers are related to this area. Yet, with the release of more sophisticated 3D software, photo-realistic rendering was no longer limited to a small field, but spread widely. Everyone became capable of generating their own realistic human figures with the aid of a computer.

Bingo was seen as the short film which brought Maya to the attention of the world, making people believe that Maya could definitely advance computer art. The promotion of *Bingo* as a technical test contributed to its success as it played to the key interest of contemporary audience's on the technical background of short films. The film went on to win prizes at the SIGGRAPH Electronic Theatre and Maya gained the support and recognition of the industry. 1999, Alias| Wavefront announced a different kind of production suit to satisfy different specifications at a reasonable price with a good quality of performance, such as Maya Complete[207], Maya Unlimited[208] and Maya Builder[209.] Upon its release in 1998, Alias|Wavefront discontinued all previous anima-

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205 Ibid.

206 Ibild.

210 1999 - Maya Complete Announced Maya Complete incorporates all of the tools and features for world class animation on both IRIX and NT platforms. Maya Complete has been developed to provide state-of-the-art 3D solutions for a broader, more professional market. Maya Complete includes Alias|Wavefront's award-winning 3D modeling, rendering, and animation technology. (Alias|Wavefront, History, available from: http://www.aliaswavefront.com/en/companyinfo/history.shtml, accessed 28.07.2001)

208 1999 - Maya Unlimited Unveiled: Maya Unlimited, the new graphics production suite for high-end film and video industry is introduced. Maya Unlimited incorporates all of Maya Complete elements plus Maya Cloth, Maya Fur, Maya Live, and Maya Power Modeling. Maya Unlimited addresses the unique needs of high-end production houses, by providing them with tools that will help solve complex problems. Maya Unlimited extends the realm of possibility for digital artists who want to shape the frontier of advanced 3D technology. At SIGGRAPH '99 Alias|Wavefront announces that Maya has been used by Industrial Light & Magic (ILM) in the summer blockbusters Star Wars: Episode I 'The Phantom Menace,'

tion-based software lines including Alias Power Animator, thus encouraging consumers to upgrade to Maya. Maya lead the industry in the following key areas: bringing characters to life, creating explosive visual effects and system architecture. It succeeded in expanding its product line to take over a greater share of the market, with leading visual effects companies such as Industrial Light and Magic and Tippett Studio switching from Softimage to Maya for the animation software. Representatives from Blue Sky/VIFX, Cinesite, Dream Pictures Studio, Dream Quest Images, GLC Productions, Kleiser-Walczak, Rhonda Graphics, Square, Santa Barbara Studios and Imagination Plantation were among many of the BETA customers to support Maya.[210]

The 'realism' of the algorithmic figure of the 1990s took a decisive step forward, solving many long-term difficulties, for example the realistic simulation of skin and clothing. However, although Geri's skin has an extremely realistic texture, his clothing moves realistically, and his sparse balding hair does not apply the same algorithms as those used on previous human figures, with immovable features on the head, Geri's quantity of hair does not provide a representative quantity. As computer graphics developed better techniques, it became an independent art form and began to affect our perception of reality and art. In certain circumstances, virtual reality began to replace reality. The development of technical software packages like Maya allowed even more people to create ideal images to their specification. However, the question of what is truth and what is virtual reality, much like the clown's head confronting Bingo began to expand further.

These provide a bridge between realistic simulation and artistic representation, a bridge between commercialism and creativity. Software developers see the final application of technology. This leads to artists/ animators confirming the tool's capabilities and the compatibility of the tool's operational modes with their needs. Yet, designers, artists and animators also begin to explore the potential reliability of this tool through viewing the possibilities of new artistic representations.

5.3.3 The Performance of the Final Fantastic Realistic Algorithmic Human Aki Ross

Were we to say that Dave and Geri, produced in the latter half of the 1990s, represent the intermediate stage in the development of 3D computer imaging software and hardware, then algorithmic human figure Aki Ross,

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The Mummy, and Wild, Wild West. All three films continue to set new standards for creating compelling visual effects and realistic character animation. (Alias|Wavefront, History, available from: http://www.aliaswavefront.com/en/companyinfo/history.shtml, accessed 28.07.2001)

[209] 1999 - Maya Builder Introduced: A subset of Maya Complete, Maya Builder has been optimized to address the specific needs of games industry level designers and programmers in the game and interactive title development community. Maya Builder includes the powerful polygonal modeling and texturing tools found in Maya Complete, but for a more cost-effective budget. (Alias|Wavefront, History, available from: http://www.aliaswavefront.com/en/companyinfo/history.shtml, accessed 28.07.2001)

[210] See Alias|Wavefront website, History, available from: http://www.aliaswavefront.com/en/companyinfo/history.shtml, accessed 28.07.2001

who is the main actress in the 2001 American fullly-3D computer-animated science fiction film *Final Fantasy: The Spirits Within* is the fruit of this movement towards authenticity and its most direct beneficiary.

The film follows scientists Aki Ross and Doctor Sid in their efforts to free a future Earth from a mysterious and deadly alien race known as the Phantoms, who have driven surviving humanity into 'barrier cities'. They must compete against General Hein, who wishes to use more violent means to end the conflict. In the beginning, Aki Ross was designed to be as realistically human as possible in order to convince the audience that she is a human. This aim, seen as the most important, has been extended over the algorithmic human figure's long period of development.

However, if we expect Aki Ross in the context of the algorithmic human figure's representation process, to take a step forwards, then in comparison to Geri and Dave, Aki becomes a performer who will receive even greater challenges.

i) Although there were already fully-3D CG feature-length films including *Toy Story* and *A Bug's Life*, there was not a human algorithmic figure as the protagonist in a full-length feature film. The first full-length feature with a cast made up entirely of photo-realistic algorithmic human, must move from starring in 3D short films of a few minutes length to feature films of close to 100 minutes in length and accept the challenges posed by computer hardware, software and production team collaboration.

ii) In the film, Aki Ross took the role of the lead female protagonist. In comparison with Geri, who did not speak a single line, or with Dave who had only a few simple lines, Aki had a large number of lines. So the dimensions and complexity of the figure's expression posed a significant challenge.

iii) In comparison to the male characters Geri and Dave, Aki's figure also had a greater level of detail, allowing the more realistic representation of specifically female characteristics. Her costume and hair were both important elements in the embodiment of the female character and personality. As described in 5.2, this was the most important point in the computer graphics research of the 1990s.

Therefore, directed by Square's Hironobu Sakaguchi, the director of the *Final Fantasy* series of games, the film brings together the artistic and technical talents of a huge team of artists, writers, programmers, managers, system-administrators and others from a variety of backgrounds, nationalities, and languages to meet the hardest challenge in the history of algorithmic human figures. The whole team spent 4 years completing the work. Much of the final film was completed with the latest computer animation technology at the end of 1990s, especially the rendering techniques, and the hair and clothing simulation techniques. [*Fig. 5.13*]

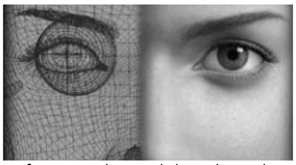

Fig. 5.13: the surface mesh model and rendered image of Aki Ross
(Source: Jon 'Hannibal' Stokes and Jonathan Ragan-Kelley,
Final Fantasy: The Technology Within, available from:
http://arstechnica.com/wankerdesk/01q3/ff-interview/ff-interview-1.html, accessed 28.02.2011)

At first, rendering techniques determined the level of authenticity of the 3D film's lighting and shadows. Although at the end of 1990s, much of the research into computer graphics had centered around increasingly realistic rendering simulation, namely in the form of advanced global illumination and ray-tracing techniques, such advanced rendering techniques were not generally used due to performance and integration limitations. The *Final Fantasy: The Spirits Within* film production applied Pixar's Renderman as its main rendering tool which has developed Direct illumination renderers to the limit of the realism they can produce in terms of lighting, but in order to achieve super realistic effects, many extra programs was written also in Square.[211]

Besides the photo-realistic lighting effects of the film, another breakthrough visual effect of the film was Aki's hair. According to the plot, Aki Ross was designed with short straight hair and natural appearance without make-up in order to appear more intelligent, and to mark her identity as a scientist. Just like the kinds discussed in detail in the above text *5.2*, hair is one of the crucial elements used to represent convincing algorithmic human figures, but simulating and representing human hair is recognized as one of the most difficult tasks in computer animation.

In order to achieve photo-realistic representation, Aki was modeled to a high level of detail. '*Computer software had to deploy to create more than 60,000 hairs in her head*'.[212] Furthermore, Aki's hair in particular used multiple simulation methods. There were many different sorts of dynamics in the film. For example, Aki's hair moves completely differently in a state of zero-gravity from her hair in the courtroom, and the dynamics are likewise different when, for example, she is lying down on a surgical table with her hair pooled around her head. The zero-gravity hair was completed using the same simulation engine as the clothing. Most of the animation of the film was completed with the latest advanced Maya Software. Since the hair was animated

[211] Jon 'Hannibal' Stokes and Jonathan Ragan-Kelley, Final Fantasy: The Technology Within, available from: http://arstechnica.com/wankerdesk/01q3/ff-interview/ff-interview-1.html, accessed 28.02.2011

[212] BBC, Final Fantasy stirs star nightmares, *BBC News*, 11.07. 2001

using Maya Software, the animators could use the custom procedural tools written here, or could animate hair by hand, or could use Maya to connect the hair to constraints, depending upon the demands of the scene.[213]

To achieve photo-realism, expensive and time-consuming advanced techniques and large amounts of the latest hardware were used to guarantee the success of the whole process.

In the interview by Jon 'Hannibal' Stokes and Jonathan Ragan-Kelley with Troy Brooks, the production Systems Supervisor of the film, gives a few more details on exactly how and why the various types of hardware and software are being used, and what their roles are in the production process of the film. [214] Table 5.2 summarized this.

Hardware/software		Function
Hardware	SGI Octane	All the artists have one or two SGI Octanes on their desks, which is the main platform for day-to-day work, which is done with Maya.
	SGI Onyxes	SGI Onyxes used for film compositing, and as a platform for preview system, which lets the artists review full resolution playback of long sequences of the film, spooled on a (very fast) RAID array.
	SGI 16-cpu Origin 2000s	Primarily used for batch-processing MTOR jobs, which is the Maya-To-Renderman conversion. (This generates .rib files, which are rendered on Linux machines; more on that in a moment.)
	SGI Origin 200 server	Disk servers, or to host the backup systems
	NetApp file servers	These provide most of the disk storage (approx. 4TB of primary disk space).
	Render farm consists primarily of ~1000 Linux machines (PIII, custom-built, rack mounted)	These machines do all the Pixar's RenderMan renders, as well as a number of other tasks. running Red Hat 6.2.
Software	MAYA	Maya is the modeling and animation software, and the interface for setting up all the lighting. Some rendering is done w/ the Maya renderer (mostly effects shots, e.g. explosions)
	Pixar's RenderMan.	The majority of the rendering is done with Pixar's RenderMan
	SQB (SQquare Batch processing),	SQB is a Square custom written software for render farm, which controls all access to the Linux machines. SQB also controls access to the Origin 2000s, and makes use of the desktop Octanes when they're not being used by the artists - some 1400-1500 CPUs in all. Artists submit jobs Wavefront | Alias GUI tailored to the particular type of job. The system evaluates the criteria of the job (priority, memory required, CPUs, and schedules the jobs accordingly.

Tab. 5.2: some details on exactly how and why the various types of hardware and software are being used in the production of film *Final Fantasy: The Spirits Within*

[213] Jon 'Hannibal' Stokes and Jonathan Ragan-Kelley, Final Fantasy: The Technology Within, available from: http://arstechnica.com/wankerdesk/01q3/ff-interview/ff-interview-1.html, accessed 28.02.2011

[214] Ibid.

After the long waiting not only by fans of the Final Fantasy Game, but also by computer graphics and film developers, the film was released in the summer of 2001. But alongside the film showing, the audience immediately realized the 'realism' of those computer generated actors is not enough. Time magazine published a critical essay to point out, '*Sakaguchi is a first-time director on the big screen--although it was his beginner's enthusiasm that led him down the road Spielberg would not tread. If the ambitious mix of East-West, movie-game and anime-action doesn't pay off, we may still remember this as the moment true CG actors were born.*' [215]After the film, people's expectation regarding the simulation of real people was cooled down. They recognized that there is still a very long way towards realism. Nevertheless, Aki Ross could still be regarded as the climax in the last century of the attempt to simulate real person objectively and accurately in the history of algorithmic human figures.

[215] Chris Taylor/ Honolulu, Cinema: A Painstaking Fantasy, *Time Magazine*, Monday, 31.07. 2000

6 MOVING TOWARDS REAL-TIME INTERACTIVE LARA CROFT AND RAMONA: IMMERSION IN THE GAMES WORLD

Fig. 6.1: (left) active Lara Croft appeared on the cover of British magazine *The Face* in June 1997.
(Source: http://www.laracroft.name/col-magazines.php)
Fig. 6.2: (right) Chatterbot Ramona is performing on TED 2001.
(Source: http://www.kurzweilai.net/ramona-debuts-to-music-industry)

When we play Lara Croft, who are we?
The connection between us and this figure
happens on many levels.

-- Dave Morris and Leo Hartas,
Game Art: The Graphic Art of Computer Games, 2003, p47

6.1 Millennium: The Triumph of Real-time 3D Computer Graphics

6.1.1 The Breakthrough of Real-time Computer Graphics Technology

Through case studies in previous chapters, we see that the majority of algorithmic figures from the 1960s-1990s have been performers. They take on a range of roles according to the director's instructions. The lead characters in animated short films, such as Tony, Geri and Dave, Adam Powers in a commercial promotion, the singer Dozo in the MV, as well as the resurrected Monroe, can all be rehearsed repeatedly, until the director is satisfied.

In these cases, the director is in complete control, and determines what is to be drawn. For an entire film involving a number of people, this typically involves weeks or even years of decision-making. Finally, the audience will go to the cinema, look at the screen, and experience the story of the film from the beginning to the end. There is no interaction between these human algorithmic figures taking the roles of actors and the film viewers. The relationship between the audience and these algorithmic figures is passive. This is the same relationship as that established when we watch a film with human actors.

However, the relationship between real people and algorithmic human figures of a similar area of scientific research to *Mike the Talking Head*, raised in Chapter Four, or the video games which I begin to discuss in this chapter, are completely different.

While in these cases, usually a user is in control of what is about to be drawn on the display screen; the user typically uses an input device to provide feedback to the system - for example, the decision to move an on-screen character- and the system decides what to display based on this particular action. Thus, the audience is no longer passively viewing, but instead, actively participating. Yet, the computer is on constant alert, instantaneously responding to the viewer's reactions. An application of this nature is usually entitled real-time computer imaging or interactive computer graphics.

Most video-games and simulators fall into this category of real-time computer graphics.

In order to evince the significance of real-time with regard to the development of the algorithmic human figure, we must firstly introduce real-time and non real-time computer graphics.

Firstly, no matter whether we are considering real-time or non real-time, the basic theoretical principle behind all 3D computer graphics requires a final minimum speed of 1/30 second per frame for images to be transmitted onto the screen. At this speed, the human eye will see a continuous stream of images. The difference between the computer-generated image and the film image, shot with a camera onto a film, is that in computer graphics, each picture must be individually computer-generated. Each picture becomes a 'frame'.

With regard to non real-time in the 3D computer graphics of films and commercial applications, the time taken to generate every frame is, in principle, unlimited. The only requirement is that ultimately it can be transmitted at a speed of 1/30 second per frame. Hence, these graphics systems are defined as the non-real-time graphics systems or off-line rendering systems. In non real-time computer graphics, the visual effect of each framed image would define the final film's effect in a great part. Therefore, applications of this kind, to the greatest possible extent, pursue the perfection of every frame. The more authentic each frame appears, the better the final effect. Therefore, in the previous case studies, in order to pursue the authenticity of the algorithmic figure, the details of the human figure, such as skin, clothes and hair, are represented to the greatest possible extent. And when surfaces are shiny and reflect the light close to ideal specularity, the rendering algorithm ray-tracing is a good choice. Yet, these steps mean that the time taken to computer-generate a single frame can stretch from a few minutes to numerous hours depending on the performance of the computer system.

Yet, the biggest difference between real-time computer graphics and non-real-time computer graphics is the necessity of a minimum transmission speed of 1/30 second per frame. Thus, if the time taken to generate every frame cannot be guaranteed at equal to or less than 1/30 second per frame, the fluency of the visual effect will be impaired. However, this is an important factor in deciding whether the user will continue to interact. Yet, the interaction is another difference between real-time and non-real-time graphics. Real-time computer graphics is therefore also known as real-time interactive computer graphics. The most common interactive computer graphics system work process is firstly to input a command through input equipment, secondly, the computer generates a picture, and finally the display equipment displays an image. Based on the display image, the user makes a response, and inputs a further command into the input equipment.

Games where the user manipulates an algorithmic figure to leap over obstacles in its path offer an example of this process. Firstly, through pushing down keys on the keyboard, the user gives the command to move forwards or backwards. According to the direction of the keypad, the computer will calculate the speed and movement by which the algorithmic figure can surmount the obstacle. Then, the computer composes a series of images to illustrate this movement and simultaneously displays this on the computer screen. Following this process, the user sees the final result of the figure jumping over the obstacle. The figure may pass the obstacle smoothly, or fall down or show a mixed reaction. Delayed time, following this, the user according to this, continues to make responses to command this algorithmic figure's behaviour. Here, if we use TT (Total Time) to express the overall time taken to enact this process, use FT (Feedback Time) to express the time necessary for the computer to receive the user's feedback through the user pressing keys on the keyboard and similar equipment, use CT (Calculation Time) to express the time necessary for the computer to create a frame and DT (Display Time) to express the time necessary for the monitor to display the single frame, then we can briefly describe the time necessary to complete this process using the formula below:

$$TT=FT+CT+DT$$

It is certainly not easy to guarantee that the TT is less than 1/30 second per frame. In the field of real-time computer graphics, the two key areas are computer games and virtual reality; therefore it is necessary to contrast these two areas in order to understand their differences.

Speed is a key factor in determining the existence and development of computer games. Computer games are games, where the aim is to participate actively and to compete successfully. Usually, however, the display is far slower to respond than the input device. From the technological aspect, the quality of video game is measured by the speed at which images or frames are generated by computer graphics in a given second. This determines not only the visual quality of video games but also the experience of the players.

In the equation above, FT is far smaller in value than CT + DT. So the primary aim in computer games manufacture is to reduce the value of CT + DT. The image quality is usually not the most important area of consideration, merely hoping to satisfy the basic visual requirement. Supposing it were possible to determine the condition of the hardware, FT and DT are defined, then in order to satisfy the condition that TT is less than 1/30 second per frame, the only possibility is to reduce CT as far as possible. To take the algorithmic figure as an example, we can apply experience from non real-time computer graphics, thus reducing the figure's detail; the detail of the hair and clothes, the folds of skin, and even reducing the figure's range of multilateral forms, although this can lead to a figure with an outer shape without smooth edges. Also, we can use the least time-consuming illumination method when shading, although ultimately this leads to inauthentic lighting and shading in the image.

Simultaneously, scientific research into another area with numerous applications in the field of real-time computer graphics, namely virtual reality, has only just begun. Virtual reality (VR) is a technology which allows a user to interact with a computer-simulated environment, whether that environment is a simulation of the real world or an imaginary world. Although research into virtual reality was initiated in the 1960s by Sutherland, seemingly budding at the same time as computer graphics, in fact, virtual reality not only required the development of computer graphics but also the invention of specific hardware including the keyboard, virtual goggles and gloves. Within the requirements of 1/30 second per frame transmission speed, it became necessary to increase this specific equipment's feedback time, as well as its feedback precision and similar issues. In other words with the exception of improving the speed of CT and DT, it was also necessary to improve the efficiency of FT. From the 1960s onwards, although this research was continuous, the breakthroughs were extremely slow. The visual effect displayed in the 1990s was little different to that of the 1960s. Yet, this area of research was typically the main motivation for pushing real-time graphics to its future. Virtual reality was not merely confined to scientific research, the study of medicine, and education areas but also blurred the distinction between games and virtual reality.

Therefore, real-time computer graphics development is a process where these three dynamic parameters must be balanced. At the beginning of the development process, real-time was reliant on graphics and thus the DT and FT were very large. Sacrificing image quality and reducing the CT was therefore unavoidable. Yet with technical developments, hours became sufficient for the DT and FT, therefore the CT could be guaranteed. Real-time computer graphics images' authenticity became more and more important as technology developed.

So, when algorithmic human figures are not simply actors in short films, but must interact with humans in real-time, how do the parameters of real-time computer graphics affect their appearance and behaviour?

Below there is a detailed analysis of two cases of algorithmic human figures. In the history of the realistic human algorithmic figure, different problems arise, method as well as background technology and also cultural are different. Consequently, the final appearance greatly differs from each other, yet all belong to the field of computer graphics, and relate in some way to computer games. These examples raise direct questions about the meaning of the algorithmic figure's authenticity and try to resolve these. When the algorithmic figure is no longer simply controlled by the director, and instead can become the embodiment of anyone in the virtual world, how do we control it? When these human algorithmic figures development reaches a small climax, yet simultaneously reaches a turning point. They, like the Boeing Man, point the path of development for the algorithmic figure in the new century.

6.1.2 The Realism of Real-time Video Game

6.1.2.1 The Rise of the Japanese Electronic Game Industry in 1980s

The earliest electronic games were produced in 1950s' America, however due to the enormous volume and high price of computer games, most early computer games were developed in laboratories. A notable example is *Tennis For Two* which was created in 1958 by the scientist William Higinbotham, as an electrical experiment to cure the boredom of visitors to Brookhaven National Laboratory, where he worked. *Spacewar,* designed by Steve Russell in 1961 with the intent of implementing it on a mainframe computer to test the ability of this huge DEC PDP-1 at the Massachusetts Institute of Technology, provides a further example.

However, Nolan Bushnell and Ted Dabney saw the immense commercial potential and prospects for these inventions of research or individual hobbies. They founded *Atari Computers* in 1972, and in the same year, began marketing their coin-operated arcade game *Pong*. *Pong* was a 2D sports game created by 'point' and 'line' to simulate table tennis. The player could control an in-game paddle by moving it vertically across the left side of the screen, and could compete against either a computer-controlled opponent or another player controlling a second paddle on the opposing side. Players used the paddles to hit a ball back-and-forth. The aim was for a player to earn more points than his opponent. Points were earned when one opponent failed to return the ball to the other. Pong quickly became a success and was the first commercially successful video game, which led to the start of the video game industry. Several years later, in 1976, Bushnell produced a flexible video game console that was capable of playing all four of Atari's then current games. The result became known as *Atari 2600*, sometimes called VCS for Video Computer System. The computer game brought a new form of game and way of interacting, beyond the limits of time and space. A single person could play alone on a computer or two people or more could all play together.[216]

ATARI VCS mainframe was developed with the wave of computer games sweeping America and Europe. Therefore, *Atari* defined arcade games and contemporary computer games production. *Atari Inc*. was primarily responsible for the formation of the video arcade and modern video game industries, however due to the long-term constraints of Atari's lack of commercial applications, major games manufacturers competitively produced low-cost poor-quality games. The proliferation of poor-quality games on the market led to player's dislike, leading to the 1983 Christmas time when the computer games industry created by ATARI suddenly crashed. As a direct result of the crash, in 1984, *Atari* was closed and its assets split. [217]

One could suggest that at the end of the 1970s and the beginning of the 1980s, America mastered a large number of the core computer technologies, staying at the leading edge of the industry. Up until the crash of 1983, the first generation of computer games mainframe ATARI's total sales exceeded millions units, creating computer games industry one million dollars earliest scale/ magnitude. America initiated a high-technology, high profit computer games industry.

While on the opposite face of the globe, the Japanese games industry was in a state of chaos throughout the late 1970s. Japanese games manufacturers including Nintendo consistently took second place in the games world. However, towards the end of the 1970s, the companies *Hundson Namco, Nintendo, Sega, Epoch* turned around the Japanese computer games industry, making it competitive. The fall of the North American industry inversely led to the development of the Japanese industry, particularly the games company Nintendo. In 1983，at the same time that *Atari* closed, *Nintendo* also developed the hugely influential Family Computer (FC) game machine making it quickly become the world's biggest visual games company. In Japan, the game was so popular that it was being sold at a rate of one game machine per family. The same year, Sega SG-1000 game went on sale. Thus, the computer games stronghold switched from America to Japan. Japan ushered in games industry development opportunities. Japanese games began to influence the whole world.

6.1.2.2 Final Fantasy Game Series: A Role-playing Game with a Realistic Cinematic Approach

[216] Wikipedia, s.v. 'ATARI', available from: http://en.wikipedia.org/wiki/Atari, accessed 10.07. 2010

[217] Ibid.

If one suggests that the 1960s and 1970s were mankind's era of space exploration, then popular games directly embodying this zeitgeist included *Spacewar, Computer Space, Odyssey.* Due to the limitations of contemporary computer graphics software and hardware, these games were all in a simple point, line and visual form. Hence, the development of the Japanese computer games industry at the beginning of the 1980s, not only in hardware, but also due to the different cultural background, in games content and visual style, possessed very different characteristics to American games. This places the realistic algorithmic figure not only on the big screen, but also on the small screen (television and computer screens) with the development of their objective requirements and a grand plan exhibition space.

Final Fantasy series was developed against this background. The production of the *Final Fantasy* video game series and the Japanese games industry as a whole are heavily inter-related. The first version of *Final Fantasy* was released by *Square Co.* in Japan in 1987.

The developer of the *Final Fantasy* games series, *Square Company*, is also a product of this era. The video games industry in Japan, driven by the Nintendo Family Computer (FC) began to develop rapidly, in order to meet the era of opportunity, Square started as a computer game software division of Den-Yu-Sha, a power line construction company. As in the late seventies film special effects company Lucas set up a 3D production department to meet the 3D computer graphics applications in the film era, this sector has become a forerunner of later *Pixar.* In the case of Square, history repeated itself. In September of 1986, Square spun off from Den-Yu-Sha and became an independent company officially named Square Co., Ltd. It was officially established in the central district of Tokyo, main members are Miyamoto Masahumi and Hironobu Sakaguchi. After releasing several unsuccessful games, SQUARE was facing a serious financial crisis. They had wanted to develop a new role-playing game (RPG) named *Final Fantasy* in a final desperate bid to save the company from bankruptcy. In fact, *Final Fantasy* spawned multiple sequels over the years and became Square's main franchise reversing their fortunes.

A role-playing game (RPG) is a game in which the users assume the roles of fictional characters. Users determine the actions of their characters based on their characterization, and the actions succeed or fail according to a formal system of rules and guidelines. Within the rules, players have the freedom to improvise; their choices shape the direction and outcome of the game.

The differences between the figures that players can take in role-playing games and their real selves, can satisfy players' most magnificent desires; to become the world's (of course in the context of the game world) strongest people. Yet, the first-hand experience of the twisting-and-turning ups-and-downs of the story can make players feel as if they are watching the story of a novel unfold, empathizing with the joy and pain of the game's characters. This is also the role-playing game's most attractive feature.

The RPG game is an ancient game. Before computers were invented in Europe, games were played by hand with everybody sitting around a table. European-style RPG usually allows greater freedom to select figures to achieve the tasks set in the game. However, European-style RPG mainly do not have a main story-line but are composed of hundreds of unrelated tasks.

However *Dragon Quest* by *Enix* developed by the Japanese-style version of RPG, became the originator of the Japanese-style RPG game. The design of the Japanese-style RPG game even more strongly relies on a storyline in its development. The game's framework is also more closed off in comparison. The player can only progress according to the system's levels. If they do not obtain certain items from one level, then they are unable to move onto the next level.

From the perspective of the laws of history, Japanese RPG games' rise and development was adapted to the technical and cultural history background. In the 1980s, from the perspective of the conditions of the contemporary computer graphics techniques, from the perspective of equations, computers at first must satisfy the requirements of basic interaction so in the resulting visual pictures and the developing complexity of games, Europe, America and Japan chose different directions.

The Western RGP due to more people participating, the open structure, therefore the program needed even more computer capacity and time to decide the game's next step of development. The Western RPG could only lessen the requirements for visual images, so over a long period of time, Western RPG games developed through a text-only interface. Yet in the same way, Japanese RPG games decreased the openness of the game's level system. Users could only progress according to the systems default options, yet retained stronger visual images, as if the players could interact with visual images similar to film images. Hence, in comparison to Western games, Japanese RPG were aimed more towards the adult market, with a wider age range of players and a larger market. However, the Western RPG games becoming familiar with online and 3D technology, could simultaneously offer satisfactory interaction, an open level structure and the requirements of visual effects. The space needed for this development was not obtained until the end of the 1990s and the beginning of the 21st century.

Square's decision to launch *Final Fantasy* was inspired by Enix's success with the first Japanese game of the role-play game genre, *Dragon Quest* which sold 400,000 copies.[218] In addition, Sakaguchi saw the potential connection between RPG games and films; an abundance of story-plots and distinctive characters were at the heart of RPG games. Thus, from the beginning, applying a cinematic approach to electronic games was confirmed as the main concept behind *Final Fantasy*. Hironobu Sakaguchi was a pioneer who believed that for *Final Fantasy*, the most important thing to attract the game players was not extremely violent scenes, but precise images and impressive background music. Square marketed its products to adults rather than youths.

[218] Daiji Fujii, *Entrepreneurial Choices of Strategic Options in Japan's RPG Development*, 2006

Adult players made higher demands for storylines and visual effects than youths. However, Square also had no idea of how *Final Fantasy* would develop. In fact, in the 1980s' most of the studios developing games were small and hand-made. It was almost impossible for them to even realize games which felt realistic let alone films with film-like images, with such limited hardware and software resources. Consequently during that period, game development was usually conducted by only one programmer. Miyamoto believed that it would be more efficient to have graphic designers, programmers and professional scriptwriters working together on common projects. So during the production of the first version *Final Fantasy*, *Square* comprised only three programmers, four plotters, and five artists and designers in its entirety. However, just such a small team had produced a game with extremely significant images and music at the same time. In 1986, despite working in two different areas of computer graphics; real-time and non-real-time, *Pixar* and *Square* both firmly believed that technology and art could develop a perfect collaboration, and become the pioneers of rewarding efforts and attempts.

The concept of the *Final Fantasy* game originated with these words;

The world is veiled in
darkness. The wind stops,
the sea is wild,
and the earth begins to rot.
The people wait,
their only hope, a prophecy----
'When the world is in darkness
Four Warriors will come----'
After a long journey, four
young warriors arrive,
each holding an ORB.

Thus, users were set on the road to save the world. If *Final Fantasy I*, released in 1987 was the first step, *Final Fantasy* II caught the players' attention in the next year. *Final Fantasy III*, released in 1990, then propelled *Final Fantasy* into the top games tier. From 1991 to 1992, *Final Fantasy* IV and *Final Fantasy* V made *Final Fantasy* even more sophisticated, advancing further in all aspects; game plot, role and characterization. By 1994, *Final Fantasy* VI, which was released that year, had become the best of the 2D video games, no matter on scene or sound effect. SQUARE had been ranked on the top naming of game industry. However, due to the limitations of real-time graphics, up until *Final Fantasy* VI, each character required limited pixels and less than 11 colours and 40 frames for animation in order to represent movements including walking, lying down and reacting to shots. Characters also only appear from a side-view perspective. Thus, the graphical effect is far away from the realistic visual effects of film or the contemporary CGI such as Pixar's Toy Story in 1989.

Three years later in 1997, the *Final Fantasy* Series reached a clear turning point. The 1997 version of the game, entitled *Final Fantasy* VII, moved beyond the two-dimensional graphics used in the first six games to 3D computer graphics; the game introduced 3D graphics with polygonal characters composited on pre-rendered backgrounds. Benefiting from the 1990s' advances in game-related technology, such as the widespread adoption of CD-based storage and software distribution, which met the requirements for the high quantity of storage to implement the motion data. Finally, this format was chosen over a cartridge format, which was used in all of the former *Final Fantasy* series, due to its larger game data storage capacity.

Simultaneously, this transition was accompanied by a focus on a more realistic presentation. While the extra storage capacity and latest 3D computer graphics technology gave the team the means to implement more than forty minutes of pre-rendered full 3D CG animations in the form of 'cut scenes' and introductory sequences in order to create a cinematic atmosphere. These were typical of non-real-time computer graphics applications.

However, this innovation brought with it the added difficulty of ensuring that the inferiority of the in-game graphics in comparison to the full motion video sequences was not overly obvious. All the motion videos used as introductory sequences or cut scenes were pre-rendered, but the in-game graphics needed the real-time rendering. So the game was still not like the 3D animated short films, with a free viewpoint and angle. In order to reduce the computer processing necessary, the angle of the lens in the game and the viewpoint were mostly fixed, and objects were generally shown from one viewpoint, at most three viewpoints. The number of polygons composing the characters was also still very limited. Most details were ignored or were shown using flat images. The gap between the full motion video sequences and the in-game graphics within such a short time could not be leveled。However, the players were so inspired (or even obsessed) by the realistic atmosphere in the CGI films, that they were keen to see the same kind of visual effects throughout the whole computer game.

Against the background of the previous era and *Final Fantasy*'s consistent position as a game produced in a cinematic style, and following the success of *Final Fantasy* VI, Square made two key decisions aimed to develop further the realistic visual effects of the game.

One of these decisions was based on *Final Fantasy VII*. Starting with *Final Fantasy VIII*, the series adopted a photo-realistic look. *Final Fantasy VIII* would also include a cast of realistically-proportioned characters who would appear as real people. This design marked a departure from the super-deformed designs used in the previous version. Additionally, the development team attempted to enhance the realism of the in-game world through brighter lighting effects with appropriate shadow distribution and motion capture technology. The latter was used to give the game's characters life-like movements throughout the CG animation.[219]

[219] Famitsu Weekly, Final Fantasy VIII Kitase, Nojima, Naora and Nomura Interview, 2001

The second of Square's decisions was to invest in a completely 3D computer animation film along the same lines as *Final Fantasy* VIII. Square hoped that this film, entitled *Final Fantasy: The Spirits Within*, would be highly realistic, with a cast of realistic algorithmic figures.

Of course, the development of these two decisions also had inevitable consequences outlined as follows:

> i) In order to change *Final Fantasy* from 2D to 3D, in 1997, Square established a professional studio. Consequently, *Final Fantasy* VII built the standard for the next generation of 3D RPGs and marked the end of the era of small game studios. Simultaneously, it opened the era of the massive-scale production game industry. This switch also led to increased production costs and a greater subdivision of the creative staff for *Final Fantasy VII* and subsequent 3D titles in the series. This was in order to provide experience, human resources and basic technical capacity for *Final Fantasy VIII* and *Final Fantasy: The Spirits Within*. Thus, *Square* made a huge investment in a studio in Hawaii, to be responsible for production of 3D computer animation parts.
>
> ii) From the mid-1990s onwards, just as we saw in the examples in Chapter 5, the advancing performance and sophistication of computer graphics led to a fever for photorealistic 3D animated images. Although the vast majority of the main roles were played by animals and cartoon characters, they were able to achieve an extremely life-like standard, bringing mankind's imagination and reality close together for the first time. Viewers looked forward to when they might see a film story wholly performed by 3D algorithmic performers. At the same time, inspired by the completely 3D CG full-length feature films such as *Toy Story* and *A Bug's Life*, *Square* decided to invest in the film *Final Fantasy: The Spirits Within*, a photo-realistic computer-generated film, unique for its cast of photo-realistic CG algorithmic actors. They hoped to realize *Final Fantasy* enthusiasts' ultimate fantasy.

Consequently, in 1999, *Final Fantasy VIII* was formally released, followed by *Final Fantasy: The Spirits Within*. With exquisite computer generated imagery, emotional music, a romantic story and realistic characters, *Final Fantasy VIII* pushed forward the *Final Fantasy* games series to the top of the market. The promotional CG film, a ballroom dancing scene from *Final Fantasy VIII* featuring the melody theme *Eyes On Me*[220], sung by the distinguished Chinese female vocalist Faye Wong, in particular attracted global attention. The realistic fantasy world which *Square* brought to its players was indicated in the words of the song as follows:

Darling, so share with me
your love, if you have enough,
your tears, if you're holding back,
or pain, if that's what it is.
How can I let you know

[220] theme 'Eyes On Me' of <Final Fantasy VIII>, lyrics: kako someya, music: nobuo uematsu, arranger: shirou hamaguchi

I'm more than the dress and the voice?
Just reach me out then
you will know that you're not dreaming.

In comparison to computer games enthusiasts, people who had never been exposed to the game became interested in the game and tried to enter the world of the characters through watching the promotional film. The number of *Final Fantasy* players gradually expanded and strengthened their expectation and belief in the possibility of a film featuring realistic algorithmic figures where they would know that they were not dreaming.

The photo-realistic algorithmic human figure *Aki Ross* acted as the overall film's advocate and focal point and prior to the film's official release, she stole the show. In June 2001, prior to the release of the film version, Maxim magazine[221] released its 2nd annual HOT 100[222] supplement, placing *Dr. Aki Ross* on its front cover. Aki was standing in a bikini swimsuit, like any real beauty chosen for the Maxim magazine. However, this image was created after months of work by several CGI artists employed by Square. Inside the issue, Maxim magazine also conducted a short interview with Aki through Aki's 'agent', the director of Square. In the interview, *Aki* emphasized that virtual actors were the dream of every director, because they did not eat, speak too much or complain.[223] One might suggest that at the end of the 1980s, Sexton predicted the threat to real actors from the competition from computer animated characters. However, through *Aki Ross* the algorithmic figure turned actress became a reality and one to be compared with real actors for beauty.

The film was finally released in 2001. Although the final box office performance was unsatisfactory, the landmark status of this film is indisputable. It manifests RPG games' unremitting pursuit of realism and satisfies the games' expectations for real-time interaction. Its visual effects and sound experience were good enough for comparison with film. Users could genuinely become one with the characters, and genuinely experience the essence of the RPG game. Yet creating a realistic algorithmic figure was the most challenging element for the game's animators. One might say that the algorithmic actress Aki joined the two different worlds of non-real-time films and real-time games.

Sakaguchi intended to make Aki the 'star' of Square Picture's. He intended to use her in later games and films by Square and the flexibility of being able to modify aspects of her such as her age for said appearances. [224] [225]

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[221] Maxim is an international men's magazine based in the United Kingdom and known for its revealing pictorials featuring popular actresses, singers, and female models. Official websie: www.maxim.com

[222] The definitive list of the world's most beautiful women.

[223] Ruth La Ferla, Perfect Model: Gorgeous, No Complaints, Made of Pixels, in *The New York Times*, 06.05.2001

[224] Lori Reese, Fantasy' Female, *Entertainment Weekly*, 21.07.2001

[225] Jon Hannibal Stokes and Jonathan Ragan-Kelley, Final Fantasy: The Technology Within, available from: http://arstechnica.com/wankerdesk/01q3/ff-interview/ff-interview-1.html, accessed 28.02.2011

The algorithmic human figure Aki represents the development of the algorithmic human figure at the turn of the century and also marks a high point in the pursuit of the realistic appearance over the last sixty years.

6.2 3D Tomb Raider Series and the Active Algorithmic Heroine Lara Croft

6.2.1 Reveling in the 3D Action-Adventure Game

In 2001, Aki Ross became well-known as the female lead of a totally 3D-animated film and game of the same name. However in the games-world, another female lead had developed even earlier than Aki Ross with even greater fame and influence. This was the star of the *Tomb Raider* game; *Lara Croft*. In the mid-1990s when the *Final Fantasy* series became successful in Japan, on mainland Europe, the *Tomb Raider* game was also becoming popular.

Whilst Lara, like Aki, was a well-known figure who presented the beginning of a new era for the algorithmic figure, the difference between Lara and Aki was that Lara did not carry a heavy historical burden on her shoulders. *Tomb Raider* did not have such a long history as *Final Fantasy* and also did not require transformation from 2D to 3D. The birth of *Lara Croft* benefited from the breakthroughs in real-time 3D computer graphics techniques of the 1990s. She represented the adventurous Western spirit and the utmost requirement for high-speed, however the players experienced more realistic and fluent real-time interaction due to 3D technology in contrast to those available with 2D technology.

With regard to video games, in its impact on Western culture, 3D computer imaging technology must be considered equal to the invention of photography, as well as the abundance of subsequent archaeological discoveries in its wake. 3D computer imaging technology caused a great leap forward in the world of video games' virtual reality, offering a completely new appearance.

Firstly, this sudden transformation presented a unique opportunity for computer games. Although the earliest computer games were generated by computer, after the 1970s, in comparison with game consoles for home-use, computers were more expensive and less universal. Thus, the main games development was in connection with game consoles. Only a small quantity of people chose to play games on computers. However, this state of affairs was altered at the beginning of the 1990s.

i) Firstly, the speed and sophistication of CPU increased, advancing from 16-bit up to 32-bit. This allowed the users to play games at 500 times the performance speed.

ii) Secondly, another critical factor leading to the development of realism in video games in the 1990s was the introduction of 3D graphics cards for the PC. With its ability to create 3D spaces on the computer screen which could be explored, the PC was an ideal platform for games with advanced graphics. It became a real contender on the video games' market.

In 3D real-time rendering, an important element was the need to compute a vast quantity of polygonal vertices as well as dynamic light and shadow data. In computer graphics, this is described as transformation, clipping and lighting (T&L or TCL). In the majority of PCs, most T&L operation is processed by the CPU. However, in the computer system, CPU acts as the overall computer processor. Aside from handling T&L, this must also handle all other details, including system and software management, input response and non-3D image-processing work. Hence, when models became complicated, if using only CPU to make calculations, due to CPU's range of tasks, the calculation speed could influence the display speed, and the display card would often have to wait for the CPU data. This operation speed failed to keep pace with the requirements of 3D games. However, even though the work frequency of CPU continued to increase, this was not particularly useful for T&L. This problem arises from the PC's basic design, and isn't especially related to the CPU's speed. However, a graphics processing unit (GPU or VPU) is a specialized processor that offloads 3D graphics rendering from the microprocessor. GPU can integrate on the motherboard and also on special video-cards, however the latter result was more significant. Thus, real-time 3D computer imaging display was made possible.

Based upon this technological development, in 1993 *id Software* developed a shooting computer game with a first-person perspective entitled Doom. They pioneered immersive 3D Graphics as well as realistic 3D spatiality. The story of Doom was very simple. The main theme was based on science-fiction and horror stories but the background stories could only be found in the games' manual. In the game itself, the main explanations were given as simple details at the end of chapters. Even if they were not familiar with the plot, anyone, at any time or place, could start to play the game. Known as the first shooting game, the game was played through the eyes of the characters. Each checkpoint goal was to find the key leading to the next room (using the red Exit sign as the sample mark) as well as surviving the fatal obstacles on the road. When discovering the way to Exit, the player must clear away the obstacles; perhaps monsters, harmful radioactive contaminants, falling ceilings to crush players as well as find a range of key cards and power switches.

3D image technology helped Doom to change the face of computer gaming forever. From the point of view of the players, its excellent 3D images and (on personal computers) unmatched instant processing created a game with a quality of realism and interactivity which no previous games had attained. The first time, video games had extremely realistic 3D spatiality. This was reflected in the texture and decoration of the surfaces, floors, ceilings, walls dispensing with the monochrome flat paint effect of previous games. Aside from the appearance of the material covering walls and surfaces, the space in Doom also had gradations of light, dispensing with the same lighting in every room found in previous games. The changes in lighting strongly enhanced the space and gave the players even more fear and confusion. In the game world, the lighting and the texture can be described as the most important alteration.

The bloody violence of the game's realism and animation could be identified as the catalyst and inspiration of what we know now as 3D action gaming. The release of *Doom* became the prelude to the 1990s realistic 3D computer game fever. This also marks the moment when computer games became popular in Europe. Although before the mid-1990s, the European game industry developed rapidly, in comparison with the Japanese game industry, video games were still very unpopular in Europe.

While from 1993 onwards, the situation changed due to the rise of 3D graphics as well as 'multimedia' capabilities; using sound cards and CD-ROMs. The European game industry also started to enter the 3D game era. In comparison with the strong love of RGP games in Asia, in Europe, players preferred adventure and fighting games, but this kind of game often required better interaction and more complicated structures. The success of Doom offered proof that games incorporating 3D technology brought new possibilities. *The Tomb Raider* series is a great example; its success came with the release of a graphics card, offering mutual benefits in one package.

Tomb Raider is a video game developed by Core Design, set up in 1988 and based in Derby, a city in the United Kingdom. Inspired by the wide popularity of *Doom*， they believed that the development of 3D graphics technology made the creation of bigger and better games possible. After a brief history of producing titles for the Sega consoles, Core Design wanted to develop a new 3D action game to catch up with the latest technological developments of video games and thus fully unleash the potential that 3D graphics technology brought to games.

However, in 1993, there were few developers who had attempted to create a 3D game environment. Ambitiously, Core Design set the target of making their hero visible on-screen at all times throughout the game. This required the successful creation of a 3D game offering a third-person perspective, as opposed to the first-person perspective offered by the game *Doom*. Game designers and developers had struggled to crack this formula for years.

On December 10th 2006, the British Museum of Science held an exhibition 'Game On'. Within this exhibition, some of the earliest design files of the *Tomb Raider* game were displayed. A file from 20th March 1995 showed Tomb Raider's earliest design outline sketch including the following description:

> *It is basically a 3D action-maze game, with the twist that the action is not first-person but third. This means that you control a character moving and interacting with a real-time generated 3D environment. The action will be viewed from an intelligent dynamic camera which follows your character, and chooses the best angle from which to view any given situation. With careful control of this camera, Tomb*

Raider will offer the dramatic impact of an FMV game like Creature Shock but without any of its limitations.

This is not a game solely about guns, war and explosions. Its significance lies in the alteration from the first-person perspective to the third-person perspective. This allows the player to see figures and their actions. The third-person perspective game most clearly derives from the theatre, film and television forms, where the figures are displayed from the perspective of the lead role.' Yet, unlike the first-person game, both the lead role and the viewer are outside the screen. 'This created suspense; sometimes, firstly we can see the danger from the perspective of the lead role. It also can lead to even more mature feelings of response, because we are not the lead role, but bystanders. The first-person perspective game makes people feel emotional but after quitting the game, what we finally stand to gain from it becomes an issue. With regard to getting to the next stage, in the end how interested are we? With the third-person perspective, we have a consistently firm angle of vision, similar to those of television performances or old films made for large audiences. Within the third-person perspective game, we can revisit it with the desire to understand more because we are more concerned.

In the early 1990s, most action game players were young men. The game characters available normally had strong masculine physiques. Especially in action-adventure games produced in the USA and Europe, the use of male characters was standard. But Toby Gard, a Core Design designer specializing in character design, considered designing a beautiful and daring woman as the game's leading character. At the time female games characters were mainly presented as victims or hostages. Nobody had ever considered asking male game players to take the role of a woman. In 1994, soon afterwards, Tank Girl, Jamie Hewlett's cartoon character, became widely known in the UK. The Tank Girl heroine strengthened the team's resolve to design the first heroine in the history of the video game.

Actually, the original concept for the character of Lara is not entirely similar to the figure we now know. The earliest version of the character wore a motley tunic, a baseball hat and tied her hair in a ponytail. However, Toby Gard decided this style was both too common and held connotations of Nazism. Thus, he decided to design a fashionable British noble for the lead role. In the beginning, this actress was called Laura Cruise. In order to appeal to the American market, the first name's spelling was altered to Lara, and the surname refined from 'Cruise' to 'Croft' forging a clearer link to the nomenclature of the British nobility. So *'in many aspects, Lara Croft has a global presence from the beginning*.'[226]

Despite the use of highly advanced 3D graphics technology, a totally realistic appearance was not possible due to the limitations of the character's detail. For example, the detail of Lara's ponytail was left out of the game because the ponytail used too much memory, slowing down the game. Instead, the hair was fixed at the back

[226] Astrid Deuber-Mankowsky, *Lara Croft: Cyber Heroine*, 2005, p. 20

of the head. The 3D model of Lara had approximately 500 polygons in total. A higher quantity of polygons allowed a smoother figure model, but 500 polygons also guaranteed the ability to work smoothly on the available hardware despite its limitations. This meant that Lara's figure was less smooth.

The Lara Croft phenomenon was caused by a human factor as well as technical limitations. Gard intended Lara to have somewhat exaggerated dimensions from the beginning. While making test adjustments to her girlish figure, a slip of his mouse turned an intended 50% increase to her breast size into a 150% gain. This met with instant approval from his team before he could correct it. Lara's large bosom became so exaggerated that everybody remembered her.

Finally, Tomb Raider was a third person 3D Action-Adventure game which followed the exploits of Lara Croft, a British female archaeologist in search of ancient treasures, like Indiana Jones. The players took the role of Lara Croft, jumping ,climbing, fighting, exploring, solving puzzles and avoiding traps. At the E3 exhibition in May 1996, Tomb Raider came as a big surprise to games players. When it was released, Tomb Raider was widely praised by gaming magazines for its visual effects and storyline. On October 31st 1996, Tomb Raider's PC and PS versions were distributed simultaneously. The SS version later became available for sale on 18th November.

In a short time, Core Design developed an edition of the same game for a different game platform. Previously, this would have been inconceivable. Initially, games were generally designed for specific game platforms and would not work on other platforms. Therefore, electronic games platforms could be divided into home-use games machines which connected with video games played on television screens; arcade games machines (ARCs); portable games machines (POKET Games); as well as computer games (PC Games).

Due to the difference in hardware equipment, the user's operations and experience of the game was not always the same. The screen belonging to the games machine for home-use was directly connected to the television. Although the TV's image resolution was lower than that of the computer screen, it was more widespread and the larger size made it suitable for the user to operate at a greater distance. This allowed more people to play together. At the same time, competition in the hardware market and self-interest resulted in fundamental differences between the products of different manufacturers. For games development, the issue was that the same game's content needed to be targeted to different games' platforms and different manufacturers, and it became necessary to develop different editions. In a period of financial and material limitations, it was only possible to target certain hardware developers, and the enormous risk of this was that the hardware would not become lucrative or would drop out of the market too quickly. This meant that games manufacturers might suffer heavy financial blows.

Particularly in the early stages of the game's development, the majority of stages within the game's development process required difficult decisions with regard to the choice of hardware. Especially when the games were issued, the choice of a particular platform made a direct impact on the game's market. If for once, the market for this platform was on the decline, then this would directly influence the game's sales. Prior to the release of Tomb Raider, Core Design had once developed a game for Sega's newest platform, Maga CD. But, very quickly, Maga CD dropped out of the market, leading to the game's failure.

The breakthrough of 32-bit platforms and 3D graphics cards， not only lead to accelerated operations, but furthermore lead to the possibility of straddling platforms. Thus, on the basis of the latest technology as well as the lessons of previous experience, when designing the Tomb Raider game, Core Design decided to use a form which could be used on multiple platforms allowing Core Design to simultaneously release PC, PS and SS editions. Sony PS developed the first game to use the 32-bit platform, but it is clear that Play Station received powerful promotion from the fact that Tomb Raider became the first game available on Play Station. Along with SONY, 3dfx also benefited. The 3D accelerator Voodoo, a graphics card which accelerated the motion of the play and the display of visual data, was vigorously promoted due to its connection with Tomb Raider, while a number of players upgraded their computers simply in order to play Tomb Raider better. Thus, Tomb Raider made a marked contribution to the promotion of the PC's 3D era.

The magazine PC Gamer described *Tomb Raider 2* as the best 3D adventure game in the history of electronic games. Tomb Raider 3 was released at the end of 1998. Tomb Raider was undoubtedly the most important electronic game in Europe at that time.

6.2.2 Lara Croft: the Algorithmic Heroine of Tomb Raider Becoming the Icon

The algorithmic figure Lara Croft was strong, independent and far more realistic than previous video games characters. Lara became the symbol of real-time 3D computer graphics. Either Tomb Raider, or Lara directly, received enormous media coverage. The game's influence had already developed beyond anything Core Design could have imagined.

Soon after Lara's release in June 1997, immediately a trendy British music, fashion and culture monthly magazine *the Face* [*Fig 6.1*] in the June issue featured an 8-page article on the most fashionable character in computer games: Lara. The most notable fact is the exclusive photo of Lara appeared on the cover, where Lara was wearing a black bikini by Gucci, a red and black print dress by Jean Colonna and a black jacket and trousers by Alexander McQueen, complemented by a 9mm sub-machine-gun by Walter, a gun by Kalashnikov, a 9mm gun by Uzi and Lara's own hand grenade. [227]

[227] Miranda Sawyer, Lara hit in The Face, available from: http://www.laracroft.name/archive/97-01.php, accessed 28.02.2011

Shortly afterwards, the *Financial Times*, the most famous financial newspaper in the UK, released a report about Eidos's financial situation, and used a photograph of Lara Croft as the title. The Financial Times' report suddenly became highly topical in the games industry. Reacting to this, the *Sunday Dispatch* also released a subject article. The image of Lara driving a motorcycle attracted readers' attention. The public became increasingly interested in the game industry. Lara began to make frequent appearances on a range of different media platforms.

As the icon of Tomb Raider, Lara began her new superstar career in entertainment. In terms of realism, Lara's figure is not perfect, but she is as famous as any real superstar, and she has detailed personal information: [228]

Title: Countess of Abbingdon
Relations: Richard Croft, 10th Earl of Abbingdon (father); Amelia Croft, Countess of Abbingdon (mother)
Nationality: English
Birth: February 14, 1968 in Wimbledon, London
Astrological Sign: Aquarius
Current Residence: Croft Manor, Buckinghamshire
Marital Status: Single (once engaged to the, now deceased, Earl of Farringdon)
Blood Type: AB-
Height: 5' 9' (175 cm)
Weight: 8 st 3 lb (115 lb, 52 kg)
Hair Color: Brunette
Eye Color: Brown
Dress Size: 8
Shoe Size: 7 (UK) / 9.5 (US) / 41 (EUR)
Favorite food: Beans on Toast
Distinguishing Features: Dual 9 mm pistols/ .357 Desert Eagles/ .45 Heckler & Koch USPs
Hobbies: Any challenging sports. /Interested in various vehicles.
Education:
Private Tutoring: 3-11 years
Wimbledon Girls High School: 11-16 years
Gesidun-Boarding School: 16-18 years
Swiss Woman's Finishing School: 18-21 years

EIDOS selected Rhona Mitra as Lara's official model from a quantity of candidates, and Mitra took part in the E3 exhibition in May. Whilst the most identifiable character of Lara's figure was her exaggerated bosom, a bosom of this size would put a real woman at risk of serious illness. However, in order to meet the requirements of Lara's figure, Rhona underwent a breast-enhancing operation shortly afterwards. A famous Britain magazine *For Him* released a related report for Lara and the model, even adding 9 image pages to compare, and the interview report about Rhona. EIDOS also released a music special and a single song, named Lara Croft: living and Lara Croft: naked, sung by Rhona. The famous adult magazine Playboy also displayed Lara's

[228] Information released on the official website of Tomb Raider, www.tombraider.com, accessed 10.07. 2008, Lara Croft's biography has been significantly changed; it is now almost completely different from the original biography which was relevant for the first six Tomb Raider games.

official model and another Lara model named Nell McAndrew in the nude. In addition, Lara also possesses her official magazines such as Lara Croft in Germany, and LARA in Britain.

Furthermore, Core and EIDOS promoted their virtual idol widely. Firstly, they took back the accredit contract of Timberland. Later, they produced TV performances, modeling shoots and films. Images of Lara extended to autocars, drinks and clothing. Her image also appeared on a huge MV screen at a concert on U2's world tour. Lara became a popular social and economical phenomenon. According to the American magazine, *Time*, Lara emerged as the only virtual idol within the top 50 most influential figures in the world. Her influence followed Bill Gates and George Lucas.

Vast media coverage and representation by Lara Croft, ultimately lead to the electronic game attaining a far larger audience, as well as cultural and social status. Many people therefore began to enter the games world. In addition, at the end of the 1990s, along with the technical developments, arcade games began gradually to disappear. The discrepancy between computer, television and hand-held machines gradually faded. The term 'video-game' became a general designation for an electronic game available on different platforms.

From the economic and social perspective, the development and sales of electronic games became an industry. From the beginning up until today, this lead to a rich variety of games, better and better interaction with games, increasingly realistic visual effects and even more participation.

In the present moment, we can no longer look upon these increasingly realistic algorithmic figures from the perspective of outside the picture. As real humans, operating and interacting with these figures, our mutual relationship must alter. Just as Molis described in his book, *Game Art: The Graphic Art of Computer Games: 'When we play Lara Croft, who are we? The connection between us and this figure happens on many levels.'*

We do not only play with the same purpose as Lara, although this is one element of the game; she is our 'pet' trained for our benefit. She is our plaything, created for our amusement and fighting, collisions. In the midst of many difficult challenges, breathing heavily, she makes the utmost effort to move forward. We, then, are her unseen friend, and when she meets danger, we become an angel guarding her. Simultaneously, we also lose ourselves in admiration for this self-reliant Lara. She is a guide, a lead role, a star. So, with this significance, some players aspire to become her and others aspire to possess her just like in school, young classmates hope to become the most popular child. So Lara becomes the player's alter-ego, the ideal self, the playmate of the fantasy world.

In the history of the algorithmic human figure, just like William Fetter's earliest definition, the ultimate aim is to simulate a real person. In this process, the direction of the algorithmic figure is towards the study of realism, the study of how movement occurs, the study of the construction of the human figure. Another direction of the algorithmic figure is towards the study of classical art; painting, film, theatre, performance, scenery and texture. Algorithmic figures hope to become like the beautiful women to be found in portraits or film stars. Yet, along with the development of computer technology, especially the development of real-time interaction, the study of the traditional media of films begins to decline in favour of the study of the story of the game, the study of the construction of the narrative etc.

For example, a German filmed released in 1998 entitled *Run Lola Run* is a non-conventional, non-linear film. It covers the same twenty-minute span of time three times in succession, each incorporating slight differences in detail thus leading to radically different plot outcomes. This film not only uses the plot of the game, but also inserts 2D animation in the cut-scene of the three sections. Furthermore, in 2001, Lara was brought to life by the actress Angelina Jolie for the film *Tomb Raider* (2001) and Tomb Raider: the Cradle of Life (2003). It became another very successful example of genuine film adaptation of a game. Angelina Jolie had previously performed in a few films, but because she performed the role of the algorithmic figure, Lara Croft, she became more famous. Many real actors expressed opposition to the argument that algorithmic figures might lead to their unemployment. However, later with the popularity of the icon, Lara Croft, more and more real films reflected the influence of electronic games. Quentin Tarantino's *Kill Bill* in 2003 and 2004 presented extreme cases of experimentation with the game style and spirit in film.

In 2001, the films *Final Fantasy: The Spirits Within* [*Fig. 6.3*] and *Lara Croft: Tomb Raider* [*Fig. 6.4*], took the same names as the electronic games, and were released simultaneously. Just as Angelina Jolie was successfully imitating Lara Croft's distinctive appearance, Aki's film appearance revealed that there were still elements of her figure which were not authentically human. Aside from difficulties facing the scriptwriter and director, this was the first time that a genuine algorithmic human had taken the lead role in a film, an enormous challenge. However, people had come to expect this

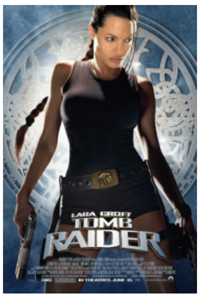

Fig. 6.3: (left) movie post of *Final Fantasy: The Spirits Within*
Fig. 6.4: (right) movie post of and *Lara Croft: Tomb Raider*

Final Fantasy also represented the realization of the kind of RPG which Square had hoped for. With not only the realistic background of a film version but also a photo-realistic algorithmic human, the player could become immersed in the games world even to the extent of becoming one with the game character. Yet the world of 2D fiction was difficult to realize. In addition, at the end of the 1990s, the desire to have one's own realistic incarnation within a game was difficult to realize. Many games characters' designers and graphic artists quickly discovered that through using graphics workstations (which was no longer too costly), as well as increasingly mature 3D software and graphics processing software, one could complete a static image of their own ideal algorithmic figure. The ability to create their own woman, their own 'Mona Lisa', was for the majority of people, not far away.

One could say that the experiment of Aki reflected the vast potential of 1990s computer graphics, but encountered challenges when faced with the intuitive and subtle understanding of human emotion and intellect of which humans are capable. Objectively, the film *Final Fantasy: The Spirits Within* dampened the world's passion for photo-realistic computer graphics. With regard to the expectations for the realism of the algorithmic figure beginning from outside even more has now transferred to behaviour and emotions, as well as realistic interaction.

One might say that with regard to the development of the algorithmic figure, Lara Croft provided a new direction of development. The realistic algorithmic figure not only conformed to William Fetter's definition; with the ultimate aim of simulating real people, but also in turn began to influence the tastes and behaviour of real people. Following the film, the games industry became the next mass media. The games industry has influenced our films, culture and industry in their entirety and initiated a new era for the algorithmic human figure.

6.3 The Intelligent Algorithmic Chatter-bot Ramona and Her Virtual World

6.3.1 The Live Performance of Photo-realistic Algorithmic Human Ramona and Her Creator

A consideration of the development of the algorithmic human figure up to the stage of Aki Ross, shows that the figure already possessed a photo-realistic appearance, not only in form, but also in the details of the skin, hair and clothes. But no matter how realistic Aki became, the audience could still at a glance see the difference between this algorithmic figure and a real person, and of course, there were numerous reasons for this discrepancy. Aside from reasons such as the quantity of details, a very important reason was mankind's possession of not only senses and perceptions but also rationale. This expression and behaviour reflects the psychological activity and mental response of mankind. However, another algorithmic human figure in this transitional period, named Ramona, although far less famous than Aki Ross or Lara Croft, possessed the characteristics described above which the others lacked; intelligence, the ability to learn and the ability to interact with people. Of course, she still represents a completely new area of development, but with regard to the overall development of the algorithmic figure, the dimensions of visual realism expanded in somewhere differently.

In 2001, the algorithmic figure Ramona caught the public's attention. In the same year that Aki starred in the full 3D film *Final Fantasy: The Spirits Within* and the live-action incarnation of algorithmic Lara Croft appeared in a live-action version of *Lara Croft: Tomb Raider*, at the TED (Technology Entertainment Design) conference, Ramona and her inventor, the scientist Raymond Kurzweil (1948-), carried out an eye-catching live performance. Ray Kurzweil recalled the performance in an interview with *Wired* Magazine:

> *I turned myself into a computer avatar named Ramona. I had magnetic sensors in my clothing, picking up all my motions and sending the data to Ramona, who followed my movements in real-time. My voice was turned into Ramona's voice, so it looked like she was giving the presentation. I was standing next to the screen, so people could see what was happening. A band came onstage, and I sang two songs: 'White Rabbit,' and a song I wrote called 'Come Out and Play.' Then my daughter came out, who was 14 at the time, and she was turned into a male backup dancer. Her avatar was in the form of Richard Saul Wurman, the impresario of the conference. He's kind of a heavyset gentleman, not known for his hip-hop kicks, so it was quite a show.* [229]

To be precise, there were altogether four performers; the 3D computer-generated singer Ramona and her backup dancer, and her producer Ray Kurzweil and his daughter. On the site, they entertained the audience with live music, a dance performance, and music videos via state-of-the-art motion-capture equipment, real-time photo-realistic animation, and sound-altering software. To accomplish this challenging feat, Kurzweil assembled a team of engineers, sound and video technicians, and dancers and musicians as well as an array of sophisticated computer graphics, video and sound systems.

Ramona is a hybrid figure. On the site, she was the female alter ego of Ray Kurzweil, controlled by the behavior of Ray Kurzweil. But her face and body were actually inherited from Kurzweil's daughter. Weeks prior to the performance, the face and body of Kurzweil's daughter Amy were scanned with 3D laser scanners. The point cloud data roughly represented her basic shape and points were joined to form polygons, or faceted surfaces and missing data was filled in. Thus, the incarnation of Ramona was created. For the face scan, mouth and facial movements were defined for each phoneme and a set of facial expressions were developed. Both models (body and face) were then integrated into a rough 3D model. This model was then enhanced for realistic movement (using rigging and weighting) and for realistic skin and clothing (using texturing and deformation curves). The final model was loaded onto computers for real-time image rendering during the performance. [*Fig. 6.5*]

[229] Eliza Strickland, Coming Soon to a Theater Near You: The Singularity, in *Wired*, 13.11.2007.

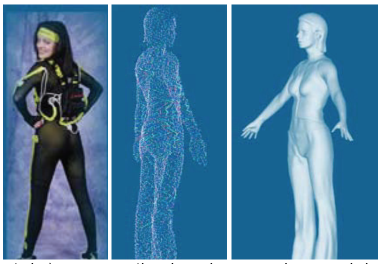

Fig. 6.5: (left to right) Kurzweil's daughter as the model of Ramona;
Ramona started out her incarnation as 3D laser scans of her face and body, the "point cloud" of color dots representing her basic shape; the model of Ramona was shaded after that. (Source: Ray Kurzweil , The Technology of Ramona, 2001, available from: *www.kurzweilai.net*)

In performance, Kurzweil and the dancer (his daughter Amy in the TED11 performance) were wired up with motion-capture sensors which transmitted movements to a motion-capture system. This motion-capture data was sent to an array of computers which generated 3D moving images of Ramona and the dancers (including TED producer Richard Saul Wurman in the TED11 performance) in real-time. Meanwhile, Kurzweil's voice was computer-processed to change gender. Reverberation was added and his voice was combined with sound from the musicians and sent to speakers. At the same time, phonemes (basic speech sounds) were extracted and used to control Ramona's lip and facial expressions. Ramona's final image was then rendered and converted to video, and combined with video backgrounds to create a music-video effect, and displayed to the audience on a video projector.[230]

According to her developer and inventor Raymond Kurzweil, Ramona is, '*the world's first live virtual performance and music-recording artist*', Her music and videos are also free for downloads on KurzweilAI.net. She has her virtual life story same as the superstar Lara Croft has, and some detailed pertinent facts about Ramona are as following: [231]

Zodiac sign: Aquarius
Favorite clothes: tight
Favorite color: red
Favorite car: Ferrari
Favorite food: Canolli
Favorite candy: pop rocks
Favorite pet: Australian Sheepdog ('because they're loyal')
Favorite songs: Runaway train, White Rabbit

[230] Ray Kurzweil ,The Technology of Ramona, in *KurzweilAI.net*, 21.02.2001

[231] Ray Kurzweil, Ramona's Story, in *KurzweilAI.net*, 21.02.2001

Inspirations: Marilyn Monroe, Audrey Hepburn, Janis Joplin, Alanis Morissette, Cat, Tori Amos, Ani Di-Franco, Holly McNarland

If comparing Ramona's music video with that of Dozo in the 1980s, we would find a startling resemblance in their appearance and their wiggly motion whilst singing, as well as the stage background. Whilst it is certain that Ramona looks more realistic than Dozo in her skin, clothing, and the lack of breakage at the shoulder, yet she is still far behind Aki's photo-realistic appearance and movement. Ramona, Kurzweil's newest invention, is different from Dozo, Lara Croft or Aki. While in these instances, the voice and the expression were not synchronous. In the case of the algorithmic figure Dave in Bingo, for example, the voice was inherited from video recordings of live performances, in advance of the 3D CG film technology. In the case of the algorithmic figure Aki, the performance was first recorded in the studio, and finally the director, Sakaguchi, chose the actress Ming-Na Wen to provide Aki's voice due to her similarity to Aki in personality. However, Ramona represented the first case of the transformation of 'a singer and dancer into a virtual person in real-time.[232]

Ray Kurzweil, his daughter and Ramona's performance not only showcased the newest motion capture, sound discernment and realistic animation technology but also presented an ethical and logical challenge to the relationship between algorithmic figures and people. The algorithmic figure Ramona was endowed with an individual appearance (that of Kurzweil's daughter, Amy) and another person's sound and movement (that of Kurzweil himself.) During this live performance, the particularities of gender distinction, age and sound were all subverted and obscured. Ramona as seen by the audience was a combination of ages and genders extracted from different people. At the TED conference, Ramona caused people to consider the future development of the realistic algorithmic figure. [*Fig.6.6*]

Fig. 6.6: Ramona and Kurzweil performed together in TED
(Source: www.kurzweilai.net)

[232] Barbara Robertson, Pioneers and Performers, in *Computer Graphics World*, Vol. 20, No. 10 (Nov,1997): 46-48+50+52

Yet, this performance also presented the result of Ramona's inventor, Ray Kurzweil's, continuous experiments and exploration. Ray Kurzweil, an American inventor and futurist, is involved in fields as diverse as optical character recognition (OCR), text-to-speech synthesis, speech recognition technology, and electronic keyboard instruments. He is the author of several books on health, artificial intelligence, transhumanism, the technological singularity, and futurism. Ray might be described as a technological optimist, who maybe believes that '*the rate of improvement of technology is going to accelerate and that we are going to become robots or fuse with robots or something like that*.' [233] Ramona is one of his inventions and the live performance on TED promoted Ramona's status as a chatterbot.

6.3.2 The Emergence of the Intelligent Chatter-bot with a Realistic Algorithmic Figure

6.3.2.1 The Emergence of Artificial Intelligence

Ramona's true significance was not simply that she was 'a pretty face and figure' but that 'she became the tech-savvy interactive e-hostess for KurzweilAI.net.' She was a 'chatterbot', a conversational robot. On the website, she was a photo-realistic, life-like talking head, whom any visitor could converse with by typing questions or comments. She conducted conversations with visitors, responded to typed questions or comments with a life-like face and lip-synchronized speech with facial expressions. [*Fig 6.7*]

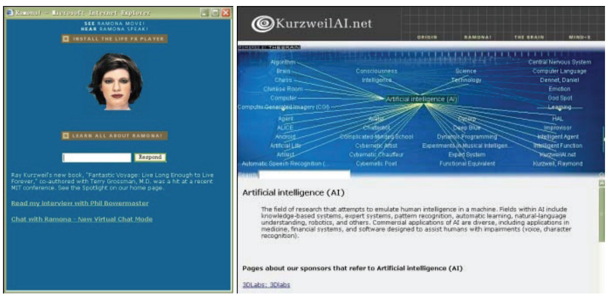

Fig. 6.7: (left to right) Ramona as a chatterbot of Kurzweil.net, and brainmap of Ramona (Source: www.kurzweilai.net)

Ramona was a chatter-bot, the product of artificial intelligence research. Artificial intelligence became the next stage of development for the human algorithmic figures of the early 2000s. Artificial intelligence, as a consideration of whether computers might attain the ability to think, was raised when computers were first invented. Whether computers could think like people and attain the same outer appearance of people has been the

[233] Bill Joy, Why the Future Doesn't Need Us, in *Wired*, 08.04.2000

consistent subject of literature and film. The most famous example is Mary Shelley's novel, *Frankenstein*, within which Frankenstein used a chemical method to create his monster in a vat, as well as the robot developed by the scientist Rotwang in Fritz Lang's *Metropolis*.

Frankenstein's monster and Rotwang's machine-man hybrid, named Maria, have deeply influenced scientific research and popular culture. This work has inspired numerous films, television programs, video games and derivative works. When computers were invented, scientists also tried to make this new invention simulate human thinking.

One of the most famous ideas proposed by the British mathematician Alan Turing at the beginning of his 1950's paper, 'Computing Machinery and Intelligence' [234], was raised by the question: 'Can machines think?' He constructed the simple proposition that if human beings are intelligent, and if a machine can imitate a human, then the machine, too, should be considered intelligent.

During the Turing Test, the machine and the tester were divided. A human interrogator sat in a room opposite a teletype or computer terminal. Hidden from the interrogator were a computer and another human being. The interrogator interviewed both the teletype or computer terminal asking a range of questions, and tried to determine whether the answers were derived from a person or a computer. Turing proposed that the testers should be limited to interaction with the machine through soundless keyboards, but would be allowed to ask the machine any question. After asking a few questions, if the tester could correctly discriminate between a person and the machine, then the machine would not pass Turing's test. If the tester could not discriminate between a person and the machine, then this machine was said to possess artificial intelligence.

Aside from Turing's outstanding work, further research into the development of artificial intelligence solved several key problems. For example in the 1950's, Norbert Wiener[235] research into the feedback theory finally lead to the conclusion that the result of people's intelligence is the result of a kind of feedback, which was keeping feedback to organize economy for movement. In 1955, Claude E.Shannon[236] had developed The Logic Theorist, which is a program which introduces a tree structure to the questions and answers. During the process, the computer seeks out the answer in the tree which is on the 'closest' branch in order to obtain the

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[234] Alan Turing, Computing Machinery and Intelligence, Mind: A Quarterly Review of Psychology and Philosophy, 1950, in *New Media Reader* (2003): 50-64

[235] Norbert Wiener (1894 -1964) was an American theoretical and applied mathematician. He was a pioneer in the study of stochastic and noise processes, contributing work relevant to electronic engineering, electronic communication and control systems. Wiener is perhaps best known as the founder of cybernetics, a field that formalizes the notion of feedback and has implications for engineering, systems control, computer science, biology, philosophy, and the organization of society.

[236] Claude Elwood Shannon (1916 -2001), an American electrical engineer and mathematician, has been called 'the father of information theory', and was the founder of practical digital circuit design theory.

correct answer. In the history of artificial intelligence, this procedure is important due to its huge influence on current academic thought and methodology.

In 1956, the term used to refer to artificial intelligence (AI), defined as 'the science and engineering of making intelligent machines',[237] was set down officially at a conference, held by John McCarthy[238]. This conference gave the pioneers of AI a chance to communicate with each other and prepared for the development of artificial intelligence in the future. Later, these pioneers and their students wrote programs that astonished many people at the time. And LISP, a list-processing language for artificial intelligence programming, was invented by John McCarthy about 1958. Computers were gradually becoming able to solve problems in algebra, to understand simple English sentences, and this lead to the emergence of a new discipline: Natural Language Processing. In the 1970s and 1980s, the expert system, a form of AI program that simulated the knowledge and analytical skills of one or more human experts appeared, making huge progress. This marked the first time when people became aware that computers might replace human beings as experts in certain jobs. Artificial intelligence could deal with series of statistical and analytical data, and could participate in activities such as medical diagnosis.

In the 1990s and early 21st century, AI achieved its greatest successes in logistics, data mining, medical diagnosis and many other areas throughout the technological industries. This success was due to several factors; the incredible power of computers today, a greater emphasis on solving specific sub-problems, the creation of new ties between AI and other fields working on similar problems, and above all, a new commitment by researchers to solid mathematical methods and rigorous scientific standards.

Although Turing's Test looks very simple, in the 1950s, there were only basic computers, and computers without the means to pass this test. Yet, despite the current status of the development of computers, if the interrogators could ask any question today, the machines would still be unable to pass Turing's test. Thus, we can ascertain that the difference between the intelligence of computers and mankind is still very large. What then is the deep secret of the human brain? Is it comparable to the simultaneous work of several million central processing units (CPUs)?

Would the alteration of this quantity lead to a difference in quality? Creating a computer which could pass the Turing Test became the goal of many scientists and researchers. There are many scientists like Kurzweil with the technological optimism to pursue this life-long aim. At the beginning of the 1990s, the American scientist and philanthropist Hugh Loebner established an annual artificial intelligence competition. The com-

[237] See John McCarthy, What is Artificial Intelligence? http://www-formal.stanford.edu/jmc/whatisai/whatisai.html

[238] John McCarthy (1927-), is an American computer scientist and cognitive scientist who received the Turing Award in 1971 for his major contributions to the field of Artificial Intelligence (AI). He was responsible for the coining of the term "Artificial Intelligence" in his 1955 proposal for the 1956 Dartmouth Conference and is the inventor of the Lisp programming language.

petitors were divided into gold, silver and bronze award winners, encouraging researchers to put Turing's assumptions into practice.

Turing believed that it was possible to build a learning machine, which simulated a human's mental activities. Along with this prophecy, he also predicted that, with the increase in the capacity of computers, at the end of the 20th century computers would certainly be capable of passing Turing's Test. He further indicated that 'if, under certain conditions, computers could model people's answers extremely well, so as to raise the questioners doubts over a comparable length of time as to whether or not they were in dialogue with a machine, then the machine could be considered capable of thought.' The questions which then followed was by how much the time of Turing Test should be extended for a machine with a constantly evolving operational capability, in order to reach a suitable time. This became the most important question for scientific researchers.

In fact, within specific areas and under defined conditions, computers have already begun to pass Turing's Test. For example, on May 11th, 1997, IBM developed Deep Blue, a chess-playing computer to play games against the human chess world champion, Garry Kasparov. The machine won a six-game match by two wins to one with three draws. Deep Blue's challenge to the World Chess Champion sought to clarify whether the computer could beat mankind through the application of logical processes in this specific area. Following the case studies we discussed in the previous chapter, the development of realistic computer graphics at the end of the 1990s allowed the life-like simulation of human hair, skin, the drapery of clothes and other details, making realistic stationary images of algorithmic figures. It is already difficult to discriminate between photographs and computer-generated images leading to people's doubts about authenticity. In addition, chatter-bots like Ramona can realistically understand people's language and enter into dialogue with people.

6.3.2.2 Real-Time Text-only Chatter-bots Converged with Realistic Algorithmic Human Figures From the Late 1990s Onwards

At the time when Turing's test was underway, computers were merely calculators without any imaging capabilities. Computers didn't have the countenance of Aki or Ramona and also could not realize Ray Kurzweil's creation; endowing the female figure with the male voice. The Turing Test also asserted that testers could only communicate with the computer through a soundless keyboard. So the earliest chatter-bot was a computer program, which simulated people and the dialogue between people through the use of script only.

Of course Ramona was not the first chatterbot. The first one was developed by German-American author and professor Joseph Weizenbaum[239] in 1966.

[239] Joseph Weizenbaum (1923 – 2008) was professor emeritus of computer science at MIT, the author Computer Power and Human Reason: From Judgment To Calculation , one of the leading critics of Artificial Intelligence and Weizenbaum was the creator of the SLIP programming language..

Weizenbaum named his program ELIZA[240] after the character Eliza Doolittle in the renowned play Pygmalion by George Bernard Shaw.[241] It tells the story of a common London girl working at the Covent Garden market who is 'sold' to Professor Higgins, a theoretical scientist. He is challenged to prove his theory that class and position in life can be taught. He takes young Elisa and teaches her to speak 'correctly' using elocution techniques, dresses her, teaches her manners and launches her into high society where she became an exotic mystery, and a love interest to a young dandy. Professor Higgins creates a new Eliza, but he does not regard her as a real human, but as a mere puppet. Finally, she finds out the truth that wealthy society cannot accept her, and it impossible for her to return her original life.

Like the Eliza of Pygmalion fame, Joseph Weizenbaum named the program 'Eliza' to emphasize that it may be incrementally improved by its users, since its language abilities may be continually improved by a 'teacher'. Eliza was a comparatively simple program which modeled its conversational style on the influential American psychologist Carl Rogers[242], who introduced the use of open-ended questions to encourage patients to communicate more effectively with therapists. When using the program, a human being would input sentences using a keyboard, sentences were then broken down into words and analyzed by the program to recognize the key words which appeared in the input text. Then, responses were generated by reassembling the selected keywords.

Weizenbaum gave an example in his paper 'ELIZA--A Computer Program For the Study of Natural Language Communication Between Man and Machine' with the sentence 'It seems that you hate me'. Suppose a foreigner with only a limited knowledge of English but a very good ear heard that sentence spoken but understood only the words 'you' and 'me'; i.e., he applied a template that decomposed the sentence into the four parts: (1) It seems that (2) you(3) hate (4) me. Of these four parts only the second and fourth parts were understood. The reassembly rule might then be: 'What makes you think that I hate you'; i.e., it might throw away the first component, translate the two known words ('you' to 'I' and 'me' to 'you') and tack on a stock phrase (What makes you think) to the front of the reconstruction. Finally, inheriting the third part of Hate directly, although according to the supposition, this foreigner might not know the word's meaning.[243]

ELIZA makes certain kinds of natural language conversation between man and computer possible by try to solve some fundamental technical problems with which ELIZA was concerned: '*(1) the identification of key*

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[240] Eliza's chatter-bot is available at http://www-ai.ijs.si/eliza/eliza.html

[241] The play was written in 1913. In 1938, a film with the same name Pygmalion issued, also adaptation by Shaw. In 1956, My Fair Lady, a Broadway musical by Lerner and Loewe was played, which was based on the 1938 film .In 1964,there was a film version My Fair Lady of the musical starring Audrey Hepburn and Rex Harrison. In 1999, modern film She's All That take on Pygmalion

[242] Carl Ransom Rogers (1902 –1987) was an influential American psychologist and among the founders of the humanistic approach to psychology.

[243] Joseph Weizenbaum, ELIZA--A Computer Program For the Study of Natural Language Communication Between Man and Machine, in *Communications of the ACM*, Vol.9, No.1 (January 1966), p. 36

words, (2) the discovery of minimal context, (3) the choice of appropriate transformations, (4) generation of responses in the absence of key words, and (5) the provision of an editing capability for ELIZA "scripts".'[244]

In the paper Weizenbaum also has given a classical dialogue in the following; the capitalized lines are the Eliza's responses:

> *Men are all alike.*
> *IN WHAT WAY?*
> *They're always bugging us about something or other.*
> *CAN YOU THINK OF A SPECIFIC EXAMPLE?*
> *Well, my boyfriend made me come here.*
> *YOUR BOYFRIEND MADE YOU COME HERE*
> *He says I'm depressed much of the time.*
> *I AM SORRY TO HEAR YOU ARE DEPRESSED*
> *It's true. I am unhappy*
> *.....*[245]

Weizenbaum was shocked to find that his program was taken seriously by many users, who would open their hearts to it. In 1966, many people only had basic knowledge of computers, seeing them as calculators, without emotion and intelligence. So when they began to interact with the computer program Eliza, they opened their hearts to it, and afterwards felt offended, invaded and angry. This made Weizenbaum start to think philosophically about the implications of Artificial Intelligence and later release his influential 1976 book *Computer Power and Human Reason: From Judgment to Calculation*[246]. The book displays his ambivalence towards computer technology and lays out his case: whilst Artificial Intelligence may be possible, we should never allow computers to make important decisions because computers will always lack human qualities such as compassion and wisdom. Weizenbaum makes the crucial distinction between deciding and choosing. Deciding is a computational activity, something that can be programmed. It is the capacity to choose that makes us human. Choice is the product of judgment, not calculation. Comprehensive human judgment includes non-mathematical factors including emotions. Judgment can compare apples and oranges, and can do so without quantifying each type of fruit and then reductively quantifying each to factors necessary for comparison.

Eliza, maybe could be called a fake thinking machines, because it did nothing except very simple repetition like a parrot, but it still offered the illusion of human-human interaction. Eliza has inspired many later chatterbots

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[244] Ibid., p. 36

[245] Ibid., p. 36-37

[246] Joseph Weizenbaum, Computer Power and Human Reason: From Judgment to Calculation, 1976

and computer games, for example, the chatterbot Julia was a descendant of Eliza. Julia was designed by Michael Mauldin[247] in 1989 and appeared on TinyMUD, a multi-user adventure game on the Internet.

The first MUDs (Multi-User Dungeon, Multi-User Dimension or Multi-User Domain) appeared in 1977 as a multi-user real-time virtual world described entirely in text. It combines elements of role-playing games, hack and slash, interactive fiction, and online chat. Players can read descriptions of rooms, objects, events, characters, computer-controlled creatures or non-player characters and actions performed in a virtual world. Players interact with each other and the world by typing commands that resemble a natural language, usually English.

These MUDs' popularity increased in the USA during the 1980s, against a background of popular, relatively cheap home personal computers with modems. In Europe, at a similar time, the MUDs development was centered around academic networks, as students devoted free-time to MUDs. It could be said that MUDs, text-based virtual realities on the internet, were conceived as interactive adventure games and were the earliest ancestors of multiplayer online role-playing games, such as Second Life, when the limitation of band-width is exceeded, realistic algorithmic avatar replaced the text-based creatures in virtual world.

In this context, TinyMud, where Julia is resident, was introduced in 1989 with the ability for the players to easily participate in creating the online environment, as well as playing in it. As a conversational agent of TinyMUD, Julia contributed through conversing in natural language with other players, answering players' questions about other players, rooms and objects.

In comparison with Eliza, Julia incorporated a significantly greater number of tricks than Eliza and appeared far more human than ELIZA, for example, the following story of Julia on TinyMUD was spread widely: A young man named Barry met Julia in the virtual environment and decided to flirt with her, attempting to talk her into entering his virtual apartment. Julia continued to resist his advances for several days until, at last, Barry learned that he had not been flirting with a real person. One snatch of typed conversation went like this[248]:

> Barry says, 'Hello, how are you?'
> Julia says, 'Hello, Barry.'
> Barry says, 'Are you a virgin?'
> Julia says, 'As far as you are concerned, Barry, I always will be.'
> …..

[247] Michael Mauldin : a programmer best known for creating the Lycos spider, a Search Engine while working on the Informedia Digital Library project at Carnegie Mellon University. And when Mauldin created Julia in 1989, he was also a computer science graduate student at Carnegie Mellon University, and later he devotes in the field of chatterbot for his life, and now chairman of Virtual Personalities, a software company based in Los Angeles

[248] Michael L Mauldin, ChatterBots, TinyMuds, and the Turing Test Entering the Loebner Prize Competition, presented at AAAI 1994, available from: http://robot-club.com/lti/pub/aaai94-slides.html, accessed 28.02.2011

This case is discussed widely not only in the field of computer science but also in cultural and sociological research circles.

If we describe Eliza as parrot-like, with the ability to imitate speech, then Julia had developed a sense of empathy between artificially intelligent chatter-bots and real people. However, unwittingly Barry developed a dialogue with Julia. A few days later, he discovered that Julia was not a real person, but a chatter-bot controlled by processes. We can assume that if participants conducting Turing's Test found out this same information, then one would quickly discover the truth, rather than a few days later. Therefore, this example still doesn't satisfactorily clarify whether in the 1980s, chatter-bots could pass Turing's Test.

In the mid-1990s, more and more increasingly capable chatter-bots emerged. The chatter-bot A.L.I.C.E. (Artificial Linguistic Internet Computer Entity), also inspired by Joseph Weizenbaum's classical ELIZA program, was developed by Richard Wallace[249] in 1995, as a natural language processing chatter-bot.[250] ALICE could support conversation in a range of languages including English, German and French. Theoretically, it could support any language, even Chinese. But due to the large difference between Chinese and Western languages, there were shortcomings when ALICE was used for Chinese processing. Hence, it became necessary to explore solutions relating to Chinese word segmentation, tagging, synonymous sentence processing and the basis of knowledge construction. [251]

At the end of the 1990s, people discovered that chatter-bots were not only inexhaustible 24-hours per day, with no time limits on their ability to work, but could also patiently listen to you like Eliza, carefully judge how to answer questions like Julia, and serve as a translator or digital secretary and companion like Alice. Thus, the general interest in chatter-bots and the quantity of chatter-bots clearly increased. Further research was not only concerned with the speech recognition capabilities of the chatter-bot, but also the aspiration to create a chatter-bot capable of non-text-based interaction who would be agile and vivid, and possess a similar expression, sound and body language to that of real people.

'This will become one of the major computer interfaces of the near future,' stated Dr. Mauldin. After creating the first chatterbot Julia, he continued his work to put an animated face onto the chatterbot technology, thus integrating the chatter-bot into consumer electronics.[252] This would allow the chatterbot not only to write out answers, but also to say answers and move its lips. The chatter-bot also had built in speech recognition allow-

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[249] Richard Wallace(1960-), is the Chairman of the Board and co-founder of the A.L.I.C.E. Artificial Intelligence Foundation. He is the author of Artificial Intelligence Markup Language (AIML) and Botmaster of A.L.I.C.E. (Artificial Linguistic Internet Computer Entity).

[250] ALICE is living in www.alicebot.org

[251] Xia Tian, Fan Xiao-zhong, Liu Lin, ALICE Mechanism Analysis and Application Study, Computer Applications, Vol. 23, No.9 (2003)

[252] David Pescovitz, Look What's Talking: Software Robots With Chatter-bots on the Web, Conversation Can Be Surprising, or Surprisingly Limited, in *New York Times*, 18.03.1999

ing the user to speak to the chatter-bot instead of typing. What was once an illusion became a reality when the user became able to talk to chatter-bot in the same way as to an assistant, to represent something we want to appear on a central computer screen, to arrange a schedule and to alert us when we have not closed a window as we leave the house.

Dr. Wallace predicted that 'in the future, lots of people [would] have their own chatter-bots based on their own personalities,' and that 'even while you're asleep, your chatter-bot will talk to other chatter-bots online and find people that share your interests so you can link up with them.' [253]

Ramona has the personality of her creator Kurzweil. As such, she is the agent of the AI knowledge-based KurzweilAI.net. She could interact with visitors not only through text, but also use visual expressions, including eye-blinks, lip-motion when speaking and body rotation. Although her facial expression was far less animated than other contemporary algorithmic figures and her expression, less life-like, unlike Geri, Ramona was not subject to meticulous and repeated adjustments by animators in studios, leading to the consistency between her expressions, behaviour and actions. However, the wisdom of Ramona's answers to a certain extent made up for these deficiencies.

Chatter-bots like Ramona were not only realistic in appearance, but could also answer questions fluently. This has become the present realistic algorithmic figure's key area of development. From the intellectual perspective, Ramona's knowledge configuration is still not perfect. Ramona 'likes' to direct conversations in certain predictable ways. She will ask the user's name, discuss a book she has read, a dream she has had, her pet frog and finally her burgeoning career as a virtual rock star. In addition, she prefers to be asked questions relating to artificial intelligence. She also has a 'brain', a visual net map showing how each 'thought' (word or phrase) relates to other thoughts on the site. Visitors use this to intuitively navigate through the site's knowledge base or to click on any bold blue words to get to articles or other sites. Ramona has mastered thousands of 'thoughts' (for example, nanotechnology and virtual reality) gleaned from site content and explains them with an attitude born of her own virtual life experiences. She also provides a wealth of information about each thought, including glossary definitions and links. [254]In addition, during conversations, Ramona has a tendency to confuse pronouns, the inability to distinguish between the 'I' and the 'you', and the inability to remember previous conversations.

Under these conditions, we can assume that Ramona's range of expressions is adequate; however Ramona's potential to make low level mistakes, and to give mismatched expressions and answers when confronted with any open question means that her realism comes at a price. At present lacking a facial expression, Ramona is not sufficiently realistic, yet she is still the only case of a problem-solving chatter-bot.

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[253] Ibid.

[254] Ray Kurzweil , The Technology of Ramona, in *KurzweilAI.net*, 21.02.2001

At present Ramona, as a representative the intelligent algorithmic human, is not yet ready for Turing's Test. However, this represents the direction of the development of the algorithmic human over a long period in the future.

7 CONCLUSION

Fig. 7.1: (left) *China Tracy,* the avatar of Chinese artist *Cao Fei* in *Second Life*
Fig. 7.2: (right) Poster of the film *Avatar*

We can only see a short distance ahead,
but we can see plenty there that needs to be done.

--Alan Turing,
Computing Machinery and Intelligence,
in *The New Reader,* 2003, p. 6

From the beginning of the thesis, I wanted to answer the following question about the algorithmic human figure in the context of computer graphics:

i) Where do they come from?

ii) How were they done?

iii) What may their future become?

Realism has become one of the central theoretical issues in computer graphics since about 1980, while realism itself, in history, is a term widely discussed in visual art, but not limited to philosophy, politics, culture, or social science. So more questions were raised:

iv) How have traditional theories of visual realism been applied in computer graphics?

v) How is computer-mediated 'realism' related to realism in general?

I have made a start on answering the above questions by developing two main strands of research which run through the selection of examples and their interpretation:

i) A forty years panorama of the algorithmic human figure was given in the context of computer graphics. In particular, while this thesis documents the development of the creation of the naturalistic appearance of images, it reviews the impact of key algorithmic achievements in the course of the journey of the algorithmic human figure towards more 'realism'.

ii) An analysis of computer graphics in relation to the concept of realism was provided by this thesis taking a historical perspective. A comparison of realistic images of human figures throughout history with their algorithmically-generated counterparts allows us to see that computer graphics has both learned from previous and contemporary art movements such as photorealism but also taken out-of-context elements, symbols and properties from these art movements with a questionable naivety. Therefore, this work also offers a critique of the justification of the use of their typical conceptualization in computer graphics.

Two important observations were formulated by the thesis in the history of algorithmic human figure:

i) The year '2001' was defined in this thesis as an important turning in the development of algorithmic human figures since the beginning in 1964. This point is marked mostly by the release of the full 3D feature film *Final Fantasy: the Spirits Within*. The realistic still image of Aki Ross makes expectations fly high of large parts of the public; but, the motion pictures are totally different. The aim of computer graphics seems to shift from a representation of reality as in photography, to the creation of reality itself.

ii) I still used the borrowed term 'realism' but in quotation marks only to describe the aim of computer graphics; to describe reality objectively and accurately. This is countered by the observation that the realism of computer generated images, especially at the beginning, has certainly near to nothing to do with the historic movement and philosophy of realism. It has to do with the simulation of light as it plays a role in photography. It is algorithmic simulation of photographic imaging. The quotation marks are used to make the reader aware of this realism during second half of 20th century not being the same as the realism in the traditional visual art.

A decade has passed since the year 2001, and the 'realism' of algorithmic human figures is now confronted by new challenges. Research should be done in the future under the following three aspects:

i) Alan Turing wrote, *'We can only see a short distance ahead'*, immediately, withdrew himself and continued to write *'but we can see plenty there that needs to be done.'* This is may be a very pragmatic position. Most of the examples I have selected are dealing with the whole figure. But much of research of computer graphics focuses only on some special parts and details, e.g., the simulation of lighting, material, or some natural phenomenon like snow, rain, fire, and simulation of skin, hair, facial expression etc. Experience shows that the overall appearance and the detail of a human figure support each other in the quest for realism (or believability). The realism of figures in *Second Life* [*Fig. 7.1*] is still far away from the world the film *Avatar* [*Fig. 7.2*] has presented.

ii) From the beginning on, research of algorithmic human figure has borrowed concepts from other traditional fields, e.g. visual art, film, animation, theater. Currently, conversely, theories of traditional realism have to be extended to include new problems that active algorithmic human figures present.

iii) Quite likely, a two-way tendency will prevail. Traditions will be studied, but also the most up-to-date research in fields, such as biotechnology, nanotechnology, communication technology will be taken up. In 1970, roboticist Masahiro Mori formulated a hypothesis of the uncanny valley. A robot, too close in appearance and behavior to a human being, is refuted by people in revulsion. Could such an observation become a factor in the attempt by computer graphics researchers to improve the 'realism' of the algorithmic human figure? If so, where could the uncanny valley on the realism of algorithmic human figures be located?

Given the results of this thesis work, my research in the future may be about the next turning point in the 'realism' of algorithmic human figures. Against the background of globalization, the meeting of Western traditions and the rise of China may become an important aspect of such research. What could be the Chinese contribution be to the ‘realism’ of algorithmic human figures, not only in computer graphics, but also in culture? The question has been touched only very little in this thesis, but will be left for my further research.

Finally I want to quote Thomas Stearns Eliot to end the thesis for the moment, but the end will be another new start:

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.
....[255]

[255] Thomas Stearn Eliot, Little Gidding (No. 4 of 'Four Quartets'), in *The Complete Poems and Plays,* 1971, p.138

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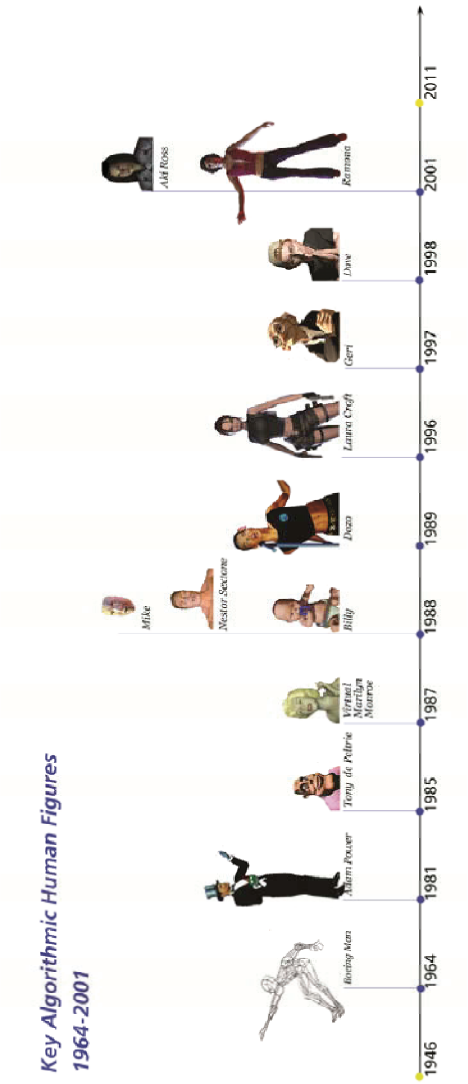
APPENDIX:


Key Algorithmic Human Figures
1964-2001
1946
1964
Boeing Man
1981
Adam Power
1985
Tony de Peltrie
1987
Virtual Marilyn Monroe
1988
Billy
Nestor Sextone
Mike
1989
Dozo
1996
Laura Croft
1997
Geri
1998
Dave
2001
Ramona
Aki Ross
2011

The Chronology of Key Algorithmic Human Figures 1964-2001

Boeing Man

Description: The first algorithmic human figure, a pilot figure, in the ergonomic research in order to maximize the efficiency of the layout inside Boeing's airplane cockpits.
Producers: William Fetter *of Boeing Aircraft Co.*
Related Technique: early computer-aided design and manufacturing (CADAM) system
Year: 1964.

Adam Powers

Description: The first 3D algorithmic human figure, a colored juggler, with a solid volume and body motion, who juggles three preliminary objects of computer graphics, the cone, the cube and the sphere, in the company I.I.I's promotional film
Producers: John Whitney and Gray Demos of I.I.I (Information International Inc.) with Art Durinski, Tom McMahon, and Karol Brandt
Related Technique: early image-processing system for colour-graphics recording, hardware included Foonley F1 etc, software included TRANEW developed by Jim Blinn, Fran Crow et al.
Year: the company promotional film released at the Electronic Theatre of SIGGRAPH in 1981

Tony de Peltrie

Description: The first real fleshy computer-animated character, a pianist, with emotional expressions , who plays piano while in the short-film *Tony de Peltrie*
Producers: Pierre Lachapelle, Philippe Bergeron, Pierre Robidoux and Daniel Langlois at the University of Montréal.
Related Technique: 3D Interactive Graphics system, TAARNA.
Year: premier released at the SIGGRAPH 1985.

Virtual Marilyn Monroe

Description: The first algorithmic human representation of a past celebrity, who met Humphrey Bogart in a café in the short-film *Rendez-vous à Montreal*
Producers: Nadia Magnenat-Thalmann and Daniel Thalmann et al.
Related Technique: the concept of Joint-dependent Local Deformation (JDL) operators and MIRA , a forerunner of modern objected-oriented language
Year: showed to public in 1987 for the celebration of Engineering Society of Canada's 100th anniversary in the Place des Arts in Montreal.

Mike

Description: The algorithmic human talking head with speech and facial expressions capable of communication with humans in real-time. *Mike the Talking Head* (Real-time computer program).
Producers: A joint research by Silicon Graphics and deGraf-Wahrman Inc., Ken Cope has modeled the head.
Related Technique: real-time and full rendering computer system
Year: 1988

Nestor Sextone

Description: The first muscular algorithmic bust to deliver a speech in the short-film *Nestor Sextone for President* and was named as the first synthespian by Jeff Kleiser and Diana Walczak.
Producers: Kleiser - Walczak Inc. (KWCC)
Related Technique: Facial expression simulation
Year: 1988

Billy

Description: The life-like algorithmic human baby with realistic baby behavior in short-film *Tin Toy*
Producers: produced by Pixar Animation Studios, and John Lasseter as both director, screenwriter, and animator
Related technique: a key-frame animation was used to body movement; photography, sculpture and a muscle model were used to model the head of Billy
Year: premiere at SIGGRAPH in 1988.

Dozo

Description: The first realistic algorithmic human singer, in the music video *Don't Touch Me*
Producers: Kleiser-Walczak Inc.
Related technique: the early motion capture method was used to animate the seductive body movement
Year: 1989

Lara Croft

Description: the most outstanding algorithmic human figure and the icon of cyberculture, an archaeologist heroin, adventuring in video game *Tomb Raider*
Producers: developed by Core Design, produced by Eidos Interactive.
Related technique: 3D graphics cards and 32-bit platforms
Year: 1996.

Geri

Description: The algorithmic human figure with realistic skin and moving clothes, an old man, playing chess with himself in the short-film *Geri's Game*
Producers: Written and directed by Jan Pinkava, produced by Pixar Animation Studios.
Related technique: Subdivision surfaces algorithm was used in modeling of skin, clothing and hair
Year: 1997

Dave

Description: The algorithmic human with both realistic appearance and emotions in short-film *Bingo,* which based on the short play 'Disregard This Play' by Chicago's Neo-Futurist Theatre Company
Producers: Directed by Chris Landreth, animated by Chris Landreth, David Baas, Joan Staveley,
Related technique: Maya Software
Year: 1998.

Aki Ross

Description: The most photo-realistic algorithmic human figure in the last century, a leading actress in feature film *Final Fantasy: The Spirits Within* (Feature-film).
Producers: Directed by Hironobu Sakaguchi, written by Al Reinert, animation directed by Andy Jones, produced by Columbia Pictures Corp
Related technique: state-of-art system and program, motion capture
Year: 13.07. 2001.

Ramona

Description: Real-time on-stage performance and intelligent chatter-bot Chatter-bot hosted website www.kurzweilAI.net
Producers: Ray Kurzweil
Related technique: state-of-art system and program, motion capture
Year: performing at Technology Entertainment Design (TED) conference in 02.2001.